SHADE TOLERANCE, NITROGEN NUTRITION, AND HARVEST MANAGEMENT IN HYBRID NAPIER UNDER RAINFED CONDITION

by

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(2012-21-102)

THESIS

Submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR-680 656
KERALA, INDIA

2016

DECLARATION

I, hereby declare that the thesis entitled **"SHADE TOLERANCE, NITROGEN NUTRITION, AND HARVEST MANAGEMENT IN HYBRID NAPIER UNDER RAINFED CONDITION"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date: 6-4-2016

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Certified that the thesis, entitled **"SHADE TOLERANCE, NITROGEN NUTRITION, AND HARVEST MANAGEMENT IN HYBRID NAPIER UNDER RAINFED CONDITION"** is a record of research work done independently by Ms. Savitha Antony (2012-21-102) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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ACKNOWLEDGEMENT

It is with great respect and devotion, I place on record my deep sense of gratitude and indebtedness to my chairman, Dr. **C. George Thomas**, Professor and Head, Department of Agronomy, for his sustained and valuable guidance, constructive suggestions, friendly approach, and encouragement during the conduct of the research work and preparation of the thesis. I gratefully remember his knowledge and wisdom, which nurtured this research project in the right direction without which fulfillment of this endeavor would not have been possible.

No words can truly represent my profound gratitude and indebtedness to Dr. **P. Sreedevi,** former Professor and Head, Department of Agronomy and member of my Advisory Committee for her unstinted support and guidance during the course of my PhD work.

I am deeply obliged to Dr. **S. Krishnan**, Associate Professor and Head, Department of Agricultural Statistics and member of my Advisory Committee for his valuable suggestions and timely help he has always accorded to me during the course of this study.

I am extremely delighted to place on record my profound sense of gratitude to Dr. **T. Girija,** Professor (Plant Physiology) and PI, AICRP on Weed Control and member of my Advisory Committee for her support and valuable advice during the preparation of this manuscript.

I express my gratitude to Dr. **T. N. Jagadeeshkumar**, Retired professor (Agronomy) and Director of Students Welfare, who was a member of my Advisory Committee until his retirement for his valuable advice during the course of investigation.

I would like to express my thanks to Dr. **P. Prameela,** Asst. Professor (Agronomy) and Dr. **Sindhu P. V.**, Asst. Professor (Agronomy), AICRP on MAP & B, who willingly agreed to be members of my advisory committee after the retirement of Dr. P. Sreedevi and Dr. T. N. Jagadeeshkumar.

I am profoundly thankful to Dr. **C. T. Abraham**, emeritus Professor and Head, Department of Agronomy, for his guidance in the conduct of field experiment and critical scrutiny of the manuscript.

I sincerely thank Dr. **Pathiyur Gopinath,** Dr. **P. A. Joseph,** Dr. **K. E. Savithri,** Dr. **P. S. John,** Dr. **Lalitha Bai,** Dr. **K. E. Usha,** Dr. **Meera V. Menon**, Dr. **Latha A.,** Dr. **Mercy George,** and Dr. **T. K. Bridgit**, Professors in the Department of Agronomy for encouragements and advice rendered during the course of my study.

I am thankful to Dr. **Sushama P. K**., Mr. **Vishveshvaran**, and Dr. **Jayasree Sankar,** Professors in Soil Science and Agricultural Chemistry for providing facilities to conduct part of my chemical analysis in soil science lab. I am deeply grateful to Dr. **S. Beena** Professor of Plant Pathology for her valuable suggestions during the course of investigation.

My sincere thanks are also due to Dr. **Nirmala Devi S.,** Dr. **Diji Bastin**, Dr. **A. T. Francis,** and library staff for their co-operation and academic assistance during the course of investigation.

I wish to express my sincere gratitude to Ms. **Vandana**, Farm officer, Ms. **Sreela,** Ms. **Saritha,** Ms. **Deepika,** Ms. **Sofia,** Ms. **Valsala,** Ms. **Elsy,** Ms. **Shyamala,** Mr. **Aravind,** Mr. **Arun,** Ms. **Mayadevi,** Ms. **Asna,** and Ms. **Sheena** for the support , friendship, and help given to me during the field and lab work.

I am extremely thankful to the labourers attached to the Department of Agronomy for their cooperation and support during the conduct of field experiments.

I am happy to place on record my sincere thanks to my senior and junior students of Dept. of Agronomy for their innumerable help and support during the course of this study.

I also thank the **Associate Dean**, College of Horticulture, Vellanikkara for providing me all the facilities for the successful completion of my PhD programme.

I am at a loss of words to express my heartfelt gratitude to my family for their constant encouragement and silent prayers throughout the course of study.

The award of **Maulana Azad National Fellowship by UGC** is thankfully acknowledged.

Finally I bow my head before **THE ALMIGHTY** whose blessings enabled me to undertake this venture successfully.

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Introduction

1. INTRODUCTION

Shortage of feed resources has often been cited as a major reason behind the drastic decline in cattle population during the last two decades in Kerala. There is an alarming gap between demand and supply of fodder, and the latest area under fodder cultivation in Kerala is just 5572 ha only (GOI, 2016). Under the prevailing socio-economic situations, it is very difficult to set apart more open areas for fodder cultivation. In Kerala, the most viable option to make available fodder materials would be to grow high yielding fodder crops that fit well with existing homestead or tree based farming systems under limited supply of water by adopting the best management practices. The best management practices involve good harvest management practices along with judicious application of fertilizers, especially nitrogen fertilizers. In Kerala, coconut is grown in 7.94 lakh ha (2014-15), and it offers an excellent opportunity to expand fodder area.

Hybrid napier is a popular fodder grass among small farmers of Kerala because of its heavy yielding potential and high nutritive quality. It can readily establish itself, has high growth rate, and quick regeneration capacity with good response to applied fertilizers providing year round supply of fodder both in quantity and quality. Some cultivars have the potential to produce about 400 Mg/ha of fodder annually. Hybrid napier is relatively free from most of the pests and diseases and the issue of plant protection normally does not arise. However, most cultivars of hybrid napier express high yield potential when grown under open conditions with irrigation. This limitation hinders its cultivation among resource poor farmers who lacks irrigation facilities and do not have much open spaces to spare for fodder cultivation.

Hybrid napier is the F1 hybrid between bajra (*Pennisetum glaucum* (L.) R.Br.) and napier grass (*Pennisetum purpureum* Schum.). Although hybrid napier performs well in irrigated conditions, the suitability of this grass under rainfed conditions, persistency under severe defoliation, response towards higher doses of applied fertilizers, and shade tolerance are not studied fully. An understanding of the shade tolerance of hybrid napier cultivars helps the farmers to grow this crop under and near the tree crops that provides an excellent opportunity for increasing fodder production. Antony and Thomas (2014) reported that cultivars such as CO-3, CO-4, Suguna, and PTH can be grown in rainfed conditions as they survive summer drought periods. CO-3 and CO-4 are cultivars released from Tamil Nadu Agricultural University and Suguna from Kerala Agricultural University. PTH (*Pennisetum* trispecific hybrid), a cross between three species (*Pennisetum glaucum* X *P. purpureum* X *P. squamulatum*), is generally recommended for rainfed conditions (Biradar *et al.*, 2008). It acquired softness from bajra, high yield potential from napier grass, and drought tolerance from *P. squamulatum.* IGFRI-3 is a superior shade tolerant hybrid napier cultivar exhibiting high fodder yield (IGFRI, 2000). The AICRP trials conducted at IGFRI regional station Dharwad revealed that the cultivar DHN-6 is superior in terms of yield (IGFRI, 2002); however, its adaptation to shade is not known. It was decided to test all the above six cultivars for shade tolerance when grown under rainfed conditions.

Similarly, knowledge on the plant's morpho-physiological response to cutting management is essential for maintaining optimum fodder production. The cutting management practices include alteration in cutting intervals and cutting heights .The intensive cutting management practices and frequent harvesting very close to the ground affect fodder production through their adverse effect on plant growth and growth attributes.

The response of hybrid napier cultivars to higher doses of nitrogen was another point of investigation as the fertilizer use efficiency of the crop varies under limited supply of water. The present recommendation of nitrogen at 200kg/ha has been fixed when the yield potential of prevailing hybrid napier cultivars were comparatively low. Therefore, it was thought worthwhile to probe the need for higher nitrogen requirement under rainfed conditions. This helps in judicious use of fertilizers for sustainable fodder cultivation.

Considering the above mentioned factors, a study was planned to have information about the cultivars suited for shaded situations grown under rainfed conditions and to develop sustainable management practices. This project was formulated with the following specific objectives:

- To assess shade tolerance of selected hybrid napier cultivars so as to introduce them in tree based farming systems
- To find out optimum nitrogen levels and harvesting frequency
- To study the influence of different cutting heights on regrowth and mortality of major cultivars

Review of Literature

2. REVIEW OF LITERATURE

Successful fodder cultivation in tropical environment is accomplished through intelligent selection of species well adapted to the environment and adoption of good management practices. The cultivars adapted for the humid tropics must readily establish themselves, have high growth rate and quick regeneration capacity, and persist well under severe defoliation with good competitive ability and good response for the applied fertilizers. In addition, the cultivars must be high yielding and provide year round supply of quality fodder (Humphreys, 1978). The best pasture management practices, among other things, involve suitable harvest management practices (Onyeonagu and Asiegbu, 2012) along with judicious application of fertilizers, especially nitrogen fertilizers (Crowder and Chheda, 1982).

Limited land availability is a major constraint for the cultivation of fodder grasses in the humid tropics. However, fodder cultivation under and near the tree crops provides an excellent opportunity for increasing fodder production. Small farmers in the humid tropics prefer high yielding cultivars of fodder grasses that are well suited to be grown under tree shades (Reynolds, 1995).

Hybrid napier or bajra-napier hybrid (2n=21) is a major tropical fodder crop, which could effectively convert solar energy into plant biomass and animal nutrients. This fodder grass is very popular among dairy farmers because of its high yield potential, quick growth, ease of establishment, palatability, and high nutritive quality. It is the F1 hybrid between bajra (*Pennisetum glaucum* (L.) R.Br.) (2n=14) and napier grass (*Pennisetum purpureum* Schum.). Bajra or pearl millet is a coarse annual bunch grass grown for grain, feed and forage. Napier grass (2n=28) is a heavy yielding fodder grass which could give high dry fodder yield exceeding most tropical grasses (Skerman and Riveros, 1990). It is a native of Rhodesia (now Zimbabwe) in South Africa, widely grown in the tropics and sub-tropics. Napier grass is a tall clumped grass with copious growth, receiving the name 'elephant grass' (Humpherys, 1994). The name 'napier grass' was given in honour of Col.

Napier, who first portrayed the consideration of the Rhodesian Department of Agriculture in 1909 to the fodder potential of this grass (Thomas, 2008). It was introduced to India in 1912 from South Africa.

Napier grass is being successfully used in developing new multicut, high forage yielding hybrids by crossing it with pearl millet. The perennial and heavy tillering characteristics along with deep root system and multicut habit of napier grass have been combined with quicker growth habit, leafiness and high quality of bajra, and the napier x bajra hybrid was developed. The first hybrid was produced in South Africa, and released under the name 'Babala Napier hybrid' or 'Bana Grass.' In India, 'Cumbu Napier Hybrid' was the first hybrid, which was produced at Coimbatore during 1953, followed by 'Pusa Gaint Napier' at New Delhi in 1961 (Chatterjee and Das, 1989; Thomas, 2008; Faruqui *et al.*, 2009).

Besides producing high fodder yield, hybrid napier has other beneficial uses too. For example, this can be used as wind breaks and is considered as a climate resilient crop, which can sequester huge amount of carbon from the atmosphere (Nishanth *et al.* 2013). It is a soil restoring crop which improves soil structure, water retention capacity, resistance to erosion and productivity (Pahuja and Joshi, 2007; Gangaiah, 2008).

Hybrid napier grass grows throughout the tropics and provide year round supply of fodder (Dwivedi *et al.*, 2007). This crop is well adapted to wide range of soils but do not thrive in waterlogged soils. Light showers alternated with bright sunshine, optimum temperature of 31^0 C and pH ranging from 5-8, are very congenial for the crop. Total water requirement of crop is 800 mm-1000 mm (Pandey and Roy, 2011). It is widely distributed in subtropical regions of Asia, Africa, Southern Europe and America. In India, it is mainly grown as irrigated crop in almost all states especially in southern states (Vijayakumar *et al.*, 2009).

Bajra and napier species readily inter cross and the hybrids are sterile triploids which are more vigorous than the parent species. The sterile nature prevents the grass from becoming a weedy menace (Gupta and Mhere, 1997; Burton, 1944). They behave as high yielding perennial fodder grasses that give good quality fodder for the livestock (Powell and Burton, 1966). The hybrids are robust perennials forming large clumps, branched upwards; culms grow to 2 m-3.5 m high with about 3 cm diameter near the base. It has extensive root system penetrating to 4.5 m deep. Leaf blades are glabrous or hairy, 30-120 cm long and 1-5 cm wide. Leaf sheaths are glabrous or with stiff hairs. It spreads by short rhizomes, rooting from lower nodes or falling stems rooting at nodes creating a stolon (Cook *et al.*, 2005). Inflorescence is a bristly false spike, 10-30 cm long, 1.5 cm -3 cm wide (excluding bristles), dense, usually yellow-brown in colour, in some cultivars greenish or purplish. Compared to the parents, hybrids are heavy tillering, more succulent, leafy, fine textured, with less persistent hairs of leaf blade and leaf sheath and less sharp leaf edges, palatable with high sugar content, high leaf-stem ratio, fast growing, drought resistant (Bogdan, 1977; Thomas, 2008) and resistant to major pests and diseases.

As the hybrids are sterile they are planted by rooted slips or stem cuttings at 60 cm X 60 cm spacing (Pahuja and Joshi, 2007). Cuttings are taken from three month old stems preferably from the lower two-third portion of stem. Since these hybrids are heavy feeders and yielders they need considerable heavy dose of nitrogen which is more than 100 kg/ha and farmyard manure to the tune of 25 Mg/ha (Bogdan, 1977).

Hybrids grow fast and yield heavily in the range of 300- 400 Mg/ha of fresh fodder annually under irrigated condition (Thomas, 2008) and 100-200 Mg/ha under rainfed condition (Antony and Thomas, 2014). It is mostly cultivated for cut and carry system and not for grazing. They have high leaf –stem ratio, highly palatable, with high crude protein content and low fibre content. Besides its use as fresh fodder, it is used for hay and silage making (Pritchard, 1971). The stems are hard and less persistent and the crop survive for three years. This is a highly remunerative fodder crop where the cost of production is half compared to single cut crops (Pandey and Roy, 2011).

The amount of foliage confined to plant canopy is an elementary ecological characteristic as it is the outcome of the interactions between microclimate, nutrient dynamics, herbivore activities or defoliation and many other factors. These factors will affect the physical, biochemical, functional and structural attributes pertinent to plant canopy parameters (Asner *et al.*, 2003). This review chapter gives a basic awareness of these changes which are relevant in the scenario of plant adaptations to various stresses including light stress, defoliation and nutrient dynamics and the subsequent changes in fodder production potential and the quality of the commonly used fodder grass in tropics- the hybrid napier.

2.1. IMPORTANT CULTIVARS OF HYBRID NAPIER

Production potential, physiognomies and quality characteristics are primarily determined by the plant genotype (Schank *et al.*, 1993; Cuomo *et al.*, 1996). A brief review of characters of cultivars included in the present study is provided in this section.

Among the various cultivars so far released in India, 'CO-3' is the most popular cultivar because of its superiority in fodder production potential and quality in terms of leafiness, broader and soft leaves, and high leaf – stem ratio, which were inherited from its parents, bajra 1697 and napier grass. 'CO-3' is recommended for cultivation under irrigated conditions in South India. It is highly preferred for cattle, sheep and goat feeding, as it flowers late in the season and could produce high proportion of dark green leaves (Pandey and Roy, 2011). From the station trials conducted at Tamil Nadu during 1991-92 and Adaptive Research trials conducted at Pudupalayam in Salem district, 'CO-3' could produce fresh fodder yield of 393.60 Mg/ha and 514.00 Mg/ha per year respectively. (Fazlullahkhan *et al.*, 1996). According to Chellamuthu *et al.* (2011), 'CO-3' is the best suitable hybrid napier cultivar for cultivation in coastal lowlands of Karaikal as compared to 'IGFRI-3', 'IGFRI-7', 'IGFRI-10', 'CO-4', 'KKM-1' and 'PBN-23' in terms of growth, green fodder yield and economics.

Considering the morphological characters of 'CO-3', at flowering it can attain 300- 360 cm of plant height and 5.0 cm of stem diameter. Leaf margins are serrated with average leaf length of 80- 95 cm and leaf width of 3.0-4.2 cm. Tiller number per plant vary from 25-30 and that of leaves from 300 – 400 numbers per plant (Vijayakumar *et al.*, 2009).

This cultivar is superior in terms of other good characters also, such as higher tillering capacity, regeneration capacity, leaf – stem ratio, crude protein, resistance to pest and diseases and free from adverse factors. It contains 18-20 per cent dry matter, 15 -16 percent crude protein, 9.8 – 12.8 per cent ash, 34 - 37 per cent crude fibre and 74 – 78 per cent neutral detergent fibre on dry matter basis (Premaratne and Premalal, 2006).

Regarding the fodder production potential, 'CO-3' can facilitate for an year round supply of quality fodder as it can produce 5 -8 kg/plant of fresh fodder from a single cutting or 250- 350 Mg/ha annually (Premaratne and Premalal, 2006). On an average, this cultivar could produce 65 Mg/ha per year of dry fodder and 5.4 Mg/ha per year of crude protein. In addition, it is having low content of antinutritional factors such as oxalic acid (Fazlullahkhan *et al.*, 1996). Vijayakumar *et al.* (2009) reported annual fresh and dry fodder yield of 'CO-3' as 325.50 Mg/ha and 62.10 Mg/ha respectively with dry matter percentage content of 19.10.

The cultivar 'CO (CN) 4' or 'CO-4' is an interspecific cross between fodder bajra- Co-8 and napier grass- FD-461 developed and released for cultivation in 2008 by the Department of Forage Crops, Center for Plant Breeding and Genetics, TNAU, Coimbatore. It is a well-adapted, high yielding nutritious fodder for soil and climatic conditions of Tamil Nadu. It is highly preferred by cattle, goat and sheep as it is highly palatable with high leaf – stem ratio, and soft stem (Velayudham *et al.*, 2011).

'CO-4' is a high yielding cultivar that can give seven cutting per year with mean yield of 368 Mg/ha which was 33 per cent higher yield than 'CO-3'. It gave fresh fodder yield of 396.75 Mg/ha and dry matter yield of 81.40 Mg/ha in a year with dry matter percentage of 21.3 during the station trials conducted at TNAU. This cultivar is also rich in protein (Vijayakumar *et al.*, 2009).

This cultivar is non lodging and erect growing, which can grow up to 400-500 cm at flowering. It is a profuse tillering cultivar that can produce 30-40 tillers per clump. Stems can attain 5.6 cm of girth which are soft and juicy with a brix value of 3.4. Stems have a uniform and visible white powdery coating. Leaves are dark green with bright white mid rib and serrated leaf margins; they have an average leaf length of 110-115 cm and 4-5 cm of leaf width. The cultivar can produce 400-450 no. of leaves per clump with leaf stem ratio of 0.71. The quick regeneration capacity of this cultivar is mainly because of its green, conspicuous aerial roots encircling each node.

'Suguna' is a hybrid derivative of the cross between Composite 9 and FD 431 developed at College of Agriculture, Vellayani, under the AICRP on Forage Crops and released for cultivation during 2006 which is recommended for southern districts of Kerala (Pandey and Roy, 2011). It differs from other cultivars in having pale green leaf sheath with purplish pigmentation. It can yield fresh fodder of 283.70 Mg/ha per year with high quality (KAU, 2007).

'IGFRI-3' (Swetika) is a superior shade tolerant cultivar developed at Indian Grassland and Fodder Research Institute, Jhansi by crossing napier and bajra (PSB-2). It is recommended for cultivation in north and central zones of the country. This grass can tolerate frost and low temperature, and is well adapted to low pH soils. In addition, it has field resistance to *Helminthosporium* blight (Pandey and Roy, 2011).

It tillers profusely, has erect posture with narrow upright leaves with thin stems like guinea grass. It is also characterized with quick regeneration capacity and persistence (IGFRI, 2000). These characters makes it highly suitable for inter cropping in central, north east and north hill region. 'IGFRI-3' can yield fresh fodder to the tune of 90 - 160 Mg/ha (Faruqui *et al.*, 2009).

'DHN – 6', also known as 'Sampoorna,' is another high yielding cultivar recommended for cultivation under irrigated condition in Karnataka. It was developed at the IGFRI Regional Research Station, Dharwad, through interspecific hybridization of IPM 14188 (Bajra line) and FD 184 (napier line) followed by clonal selection (IGFRI, 2002). It can yield 120 - 150 Mg/ha of fresh fodder from 6

– 8 cuts. Superiority in fodder yield, low oxalic content of 1.9 per cent and resistance to diseases such as Helminthosporium leaf spot and rust makes this cultivar popular among dairy farmers (Pandey and Roy, 2011). Sridhar *et al.* (2008) opined that 'DHN-6' could yield fresh and dry fodder to the tune of 182.40 Mg/ha and 73.10 Mg/ha respectively.

'PTH' (*Pennisetum* trispecific hybrid) is a perennial, which is morphologically intermediate of the three species developed as a result of crossing between *Pennisetum glaucum, P. purpureum* and *P. squamulatum* (Dujardin and Hanna, 1985). This is recommended for cultivation under rainfed conditions (Biradar *et al.*, 2008). It has the softness of bajra, high yielding nature of napier grass and drought tolerance of *P. squamulatum.* The cultivars 'PTH' and 'IGFRI-3' are suitable for planting on the bunds for soil conservation and fodder production. It is reported that 'PTH' could give fresh fodder of 4 – 6 kg from a single cut from 1 m length bund (IGFRI, 1999).

2.2. EFFECT OF SHADE ON HYBRID NAPIER

Solar energy is not a key limiting factor in tropical pastures (Humpherys, 1978), however, purposeful establishment of tree crops, invasion of trees and shrubs, establishment of fodder crops in plantations, and the cloud cover reduce the amount of light reaching above the forage canopy. The forages adapt to light limited environment through morpho- physiological changes (Bernardino, 2002).

2.2.1. Growth and growth attributes

Shading affect growth of forages, and severe reduction in light will reduce photosynthetic productivity and growth of plants (Monteith *et al.*, 1991).The extent of growth reduction depends on the amount of shade and degree of shade adaptation (Terashima and Hikosaka, 1995).

Morphological characters

Plants acclimatize photosynthetically to reduced light through phenotypic plasticity and the extent varies for each of the morphological characters (Pierson *et al.*, 1990). Under reduced light, plants have increased plant height, leaf length, and leaf width but reduced number of tillers and leaves in order to attain better access to sunlight (Singh *et al.*, 1995).

The forages grown under shade show an increased inter nodal length compared to that grown under full sunlight (Blanche, 1999 and Lin *et al.*, 2001), and therefore, stem length is often greater for forage plants adapted to shade (Buxton, 2001). This is true with tropical grasses, where they attain maximum plant height under 50 per cent light intensity compared to 100 per cent light intensity in full sunlight (Bhatt *et al.*, 2002).

The various reasons favouring the etiolated growth of leaves and stems are well documented by many workers. Gobbi *et al.* (2009) are of the opinion that under reduced light, plants distribute most of their resources for increasing the canopy height aiming at better accessibility to PAR for balancing photosynthesis and respiration.

Endogenous factors are also involved in plant adaptations to shade (Assuero and Tognetti, 2010). Shading activates many genes which stimulate the synthesis of many growth promoting hormones such as auxin and gibberellins, thereby initiating a sequence of shade avoidance syndrome in low light stressed plants. Auxin will induce apical dominance, whereas gibberellins will promote stem elongation (Keuskamp *et al.*, 2010). The accelerated stem and leaf elongation (Ballare *et al.*, 1994) is the result of stimulating effect of gibberellins (Chandler and Robertson, 1999).

In addition to the above reported causes, plant meristematic activity is also involved in the etiolated growth of plants under shade. The enhanced growth is more regulated by functional meristem than by difference in carbohydrates pool (Pierson *et al.*, 1990). As hydraulic resistance is much less in the internodal region compared to nodes, increase in internodal length in napier is an adaptive mechanism to cop up with the water loss through transpiration due to increased leaf area under shade (Nagasuga and Kubota, 2008).

Tillering and leaf production mainly decide the fodder production of fodder grasses. The basal bud gives rise to new leaves and tillers, and in fodder grasses, tillering occurs from tiller buds at the base of each leaf whereas the development of tiller buds is highly sensitive to defoliation and light intensity. The basal bud development is extremely reduced under low light intensity (Wong and Sturr, 1995). Consequently, reduced light will delay phyllochron and also the rate of development of the bud into tiller (Gautier *et al.*, 1999).

Under reduced light, nutrients are diverted to the existing tillers and these tillers have maximum plant height with elongated leaves and stems at the expense of axillary buds (Bahmani *et al.*, 2000; Difante *et al.*, 2011). Because these axillary buds can give rise to new tillers, reduced light suppress tillering in plants (Sulthan, 2000).

According to Assuero and Tognetti (2010) and Keuskamp *et al.* (2010), cytokinins initiates axillary growth, however shading stimulates auxins which induce apical dominance and suppress the activity of cytokinins and lateral meristems, which also adversely affect axillary tiller bud development.

Gobbi *et al.* (2009) commented that, shading will significantly affect leaf production and tillering by retarding their initiation and development because plants distribute most of their resources for increasing the canopy height aiming at better accessibility to PAR for balancing photosynthesis and respiration.

As Wong and Sturr (1995) commented, shading depresses the shoot, stubble- cum crown, and root production, in turn, reduces the dry matter accumulation and the persistence of the tropical forages.

Physiological characters

Tropical pastures are efficient in converting solar energy to biomass since they acquired their adaptability to high light intensity during their long history of adaptation to tropical conditions. Majority of the tropical grasses belongs to panicoid group which has special adaptation of the leaf to high light intensity known as 'Kranz anatomy' with large chloroplast. This facilitates in carbon assimilation and its passage to the conductive tissues (Johnson and Brown, 1973). However, because of these adaptation, high efficiency of the tropical grasses can only be achieved under high temperature and high light intensity. Hence, anything which limit these factors will affect the pasture productivity and consecutively the animal production (Bogdan, 1977).

Shading increase leaf area of fodder grasses (Lin *et al.*, 2001) and consequently the leaf area index. For example, guinea grass attained maximum leaf area under 75 per cent shade compared to open and low levels of shade (Mullakoya, 1982). Increasing leaf area is an adaptive mechanism of plants to maximize light interception for efficient utilization of photosynthates (Evans and Seemann, 1996).

The reasons for increase in leaf area under shaded situation are well elucidated by many researchers. Under reduced light, plants allocate most of their resources for shoot growth and invest less for specific leaf weight. Leaves are much longer and thinner under reduced light (Kephart and Buxton, 1996 and Lin *et al.*, 2001), and therefore, specific leaf area would be much higher which results in overall increase in leaf area under shaded situations (Pierson *et al.*, 1990). Senevirathana *et al.* (2003) observed that increasing shade had a facilitating effect on specific leaf area but had a negative effect on leaf weight ratio and relative growth rate of plant.

Another reason for increase in leaf area is based on endogenous factors. Shading induces auxins and gibberellins. Auxins activate leaf meristem activity whereas gibberellins induce leaf elongation, which altogether result in increased leaf area (Bultynck *et al.*, 2004).

Increased leaf area, specific leaf area, leaf area ratio and reduced leaf weight ratio in plants grown under shade are indications of plant adaptation to reduced light (Valio, 2001). Increased specific leaf area and leaf area ratio are the means for amelioration of stress developed due to reduced light. Changes in LAR in response to light treatments are used in assessments of plant morphological plasticity. Higher LAR in shade compared to full sunlight are plant adaptations to improve light capture under reduced light and to prevent photo inhibition in full sunlight (Ray *et al.*, 2004). These plants, which are less stressed, have faster growth with lower LAR as a result of reduced SLA (Semchenko *et al.*, 2012).

In tropical grasses, reduction in light intensity result in elongated plant growth, increased leaf area ratio and reduced specific leaf weight (Ludlow *et al.*, 1974). As thinner leaves use limited light more efficiently, plants adapt to reduced light by developing increased specific leaf area and reduced specific leaf weight ratio (Terashima and Hikosaka, 1995). In napier grass, specific leaf area increases with increasing shade levels (Eriksen and Whitney, 1981). Napier grass when grown under shade, allocate more to the leaves, hence it could attain maximum leaf area and leaf area ratio under reduced light (Nagasuga, 2005).

Leaf -stem ratio of fodder grasses also increase when grown under coconut shade (Pillai, 1986) as the proportion of green leaves increase under tree shades compared with that grown under open pastures (Wilson *et al.*, 1990). Increasing the proportion of green leaves is an adaptive mechanism of plants grown under shade to maximize radiation absorption (Ramus, 1995). Forages when grown under shade maintain a higher leaf – stem ratio by reducing the stem growth (Singh, 1994) as shading reduce biomass allocation to stems (Cruz, 1997). The above findings were well confirmed by Lin *et al.* (2001). They reported that significant difference in leaf –stem ratio could be much evident when forages are grown under 50 per cent or more shade.

2.2.2. Light intensity, PAR availability, and light harvesting pigments

Potential for year round growth and production of herbage in perennial forages is primarily determined by the energy supply or light availability through its relationship to photosynthesis (Crowder and Chheda, 1982), where the carbondioxide, nutrients and water in the herbage is transformed into animal food products such as protein and fatty substances. This is assisted by well-developed plant canopy which is the locus of physical and biochemical processes in an ecosystem (Asner *et al.*, 2003).

On yearly basis, a lush growing tropical pasture can fix about 1-5 per cent of solar energy (Humphreys, 1978) and 3-10 per cent during peak growth (Cooper, 1970). Tropical grasses can fix about one- sixteenth of the incoming radiation available for photosynthesis during the production of 1g of dry matter (Butterworth, 1964).

Light intensity is an important parameter which determines the photosynthetic rate of leaves (Cooper and Tainton, 1968). In normal case, for the initiation of photosynthesis, an assured quantity of light intensity is essential and the photosynthetic productivity increase with increasing light intensity up to 15,000 – 25,000 lux. Supplementary increase in light intensity do not increase the productivity in temperate grasses. Conversely, in tropical grasses, photosynthetic productivity reaches its maximum at 50,000 – 60,000 lux and sometimes even at higher light intensity (Bogdan, 1977).

According to Pandey *et al.* (2011), the light intensity under coconut gardens of the humid tropics of India ranges between 32 per cent (3294 lux) and 59 per cent (4865 lux) relative to its light intensity in full sunlight. The corresponding light interception by grass canopies depends on grass cultivars, and in full sunlight, it ranges between 77 per cent and 92 per cent (da Silva *et al.*, 2012).

Viability of silvi –pastoral systems depend on the amount of photosynthetically active radiation (PAR) penetrating through the plant canopies. Fodder production potential of hybrid napier is essentially reliant on the PAR availability to the canopy surface. Compared to the yield of hybrid napier in full sunlight, for an increase in relative PAR from 57 per cent during rainy season to 76 per cent during summer, the relative yields increased from 73 per cent to 96 per cent (Chatterjee and Das, 1989).

Light interception and PAR transmission to the lower layers depends on the leaf area index of plant canopy. Maximum light interception occurs at high LAI but it can reduce the PAR transmission to lower leaves (Lunagaria and Shekh, 2006). According to Candido *et al.* (2005a), at the earlier stage of fodder grass development each increment in leaf area is an indication of the substantial increment in PAR interception. The light penetration through the plant canopy of napier reduces asymptotically as a function of LAI (Andrade *et al.*, 2005).

Morpho-physiological changes along with its better investment on light harvesting pigments maximize light interception for efficient carbon assimilation in plants grown under shade. During shading, more quantity of chlorophyll will be associated with antennae molecules for maximum light harvesting (Senevirathana *et al.*, 2003). However, faster rate of destruction of chlorophyll occurs under high light intensity (Eriksen and Whitney, 1981).

In fodder grasses, chlorophyll content increase with decreasing light availability (Mullakoya, 1982) which is an adaptive mechanism of plants to maintain photosynthetic efficiency (Attridge, 1990); therefore shade tolerance in forage species is allied with high content of chlorophyll per chloroplast (Evans and Seemann, 1996). Moreover, shaded plants have more spongy tissues and the chloroplast in spongy tissue have large grana, hence the photosynthetic pigments are more concentrated in chloroplast of spongy tissue, resulting in increased total chlorophyll content (Terashima and Hikosaka, 1995).

As shade induced partitioning of chlorophyll molecules into light harvesting complex takes place under reduced light, chlorophyll b molecules increase causing higher chlorophyll b to chlorophyll a ratio (Misra and Misra, 1997; Evans and Poorter, 2001).

In view of these principles, the selection criteria for shade tolerance in forage species must also include high chlorophyll density, high content of both chlorophyll a and chlorophyll b, and high chlorophyll b to chlorophyll a ratio (Sturr, 1991). Increasing chlorophyll b content helps the plants to harvest more light under shade by facilitating more production of PSII reaction centers, thereby reducing the too (Singh, 1994). However, compared to shaded condition, in full sunlight, plants allocate a great proportion of their total production to roots thereby they could produce more number of tillers, leaves, and ultimately huge biomass. As shading delays plant phenology and regrowth, plant maturity is delayed, which also negatively affects the cutting frequency and harvested produce (Pierson *et al.*, 1990).

Plants grown under shade usually have low dry matter production because of succulent growth (Gordon *et al.*, 1962) and higher proportion of spongy tissues (Anita and Lakshmi, 2014). Moreover, increasing chlorophyll b content, which is an adaptive mechanism of plants to harvest more light under shade by facilitating more production of PSII reaction centers, reduces the synthesis of ATP syntetase causing low rate of photosynthesis (Anderson, 1986). These factors also reduce the dry matter accumulation under reduced light.

The extent of decline in fodder production is influenced by the grass genotype and intensity of light. Compared to commonly cultivated fodder grasses in coconut gardens such as guinea grass, the decline in fodder production is higher in hybrid napier. Hybrid napier shows 20 per cent relative reduction in yield under 65 per cent relative PAR (Chatterjee and Das, 1989). The reduction in yield under reduced light is associated with less nitrogen use efficiency of hybrid napier under reduced light intensity. In normal situation under reduced light, plants have lower shoot to root biomass and the rate of nitrogen mineralization in soil will be higher. These phenomenon facilitates in higher nitrogen uptake by plants, which in turn increases leaf nitrogen concentration. However, this compensatory mechanism is much less pronounced in hybrid napier under shaded situation (Pandey *et al.*, 2011).

Successful cultivation of hybrid napier cultivar under coconut gardens (Subramanian *et al.*, 2007) and black pepper gardens (Thankamani *et al.*, 2011) of Kerala have been well documented. Even though hybrid npier shows yield reduction under reduced light it has better dry matter production in plantations compared to guinea grass (Manjunath *et al.*, 2002).

2.2.4. Nutritive quality

Low light intensity affects forage quality of grasses (Wilson and Wong, 1982) and the changes in forage quality under reduced light occurs due to change in morphological, physiological, anatomical and chemical changes (Lin *et al.*, 2001). There are different reports for the nutrient content under reduced light.

Eriksen and Whitney (1981) stated that nutritive quality of napier increases under tree shades as the content of nitrogen, phosphorous, potassium, calcium and magnesium increases under shade, and under full sunlight, because of dilution of nutrients by higher yields, the percentage content in plants would be lower.

Shading affect the nutritive quality of forages only after the long exposure of more than two months (Wilson, 1996). According to Buxton (1995), shading had a significant effect on forage yield than quality and observed that imposing 63 per cent shade on perennial forage grasses reduced forage yield by 43 per cent; however, only 3 per cent reduction was noticed in fibre content. Shading reduce carbohydrate content of forages.

Baig *et al.*, (2005) reported that there was no change in leaf protein content of tropical fodder grasses at 25 per cent and 50 per cent shade level. Under higher light intensity, increase in leaf concentration of nitrogen is much higher compared to those grown under shade, therefore, the nitrogen use efficiency for carbon dioxide assimilation is much higher under full sunlight (Field, 1983).

Photosynthetically active radiation indirectly affects crude protein content and fibre content of fodder grasses (da Silva *et al.*, 2012).The reduced PAR delay the ontogenic development of fodder grasses (Bos and Neuteboom, 1998), and thereby reduces the fibre content. Lin *et al.* (2001) stated that substantial changes in crude protein and fibre content could be noticed in forages under agroforestry systems when the light availability was reduced below 50 per cent.

According to New *et al.* (2007), light indirectly affects the mineral composition of forages by regulating the biological process of photosynthesis, transpiration, respiration, synthesis of chlorophyll, rubisco and chloroplast. Photosynthesis occurs smoothly in the presence of light, hence the elements associated with those photosynthetic pigments increase, especially the nitrogen content. This also increases the crude protein content in forages and reduces the fibre content (da Silva *et al.*, 2012) and Gutmanis *et al.* (2001), established that increase in crude protein and fibre content were similar to the increments in PAR.

Shading reduces ash content and structural carbohydrates of tropical forages (Gutmanis *et al.*, 2001 and Samarakoon *et al.*, 1990). However, shading has no significant effect on calcium content of forages (Parissi and Koukoura, 2009).

2.3. EFFECT OF CUTTING MANAGEMENT ON HYBRID NAPIER

Among various pasture management practices, the harvesting management alters the fodder production in forage grasses to a great extent (Giacomini *et al.*, 2014). The rapid resumption of shoot growth to maintain the optimum fodder production potential is accomplished through phenotypic and physiological adjustments (Wong and Sturr, 1995). As far as napier grass is concerned, it has quick recuperation ability over the intensive cutting management practices (Bayble *et al.*, 2007).

The cutting management practices include alteration in cutting intervals (Onyeonagu and Asiegbu, 2012) and cutting heights (Dutra *et al.*, 2014). The intensive cutting management practices and frequent harvesting very close to the ground affect the fodder production through their adverse effect on plant growth and growth attributes. Therefore, an understanding of the plant's morpho-physiological response to cutting management is essential for maintaining optimum fodder production (Hume, 1991). The morpho-physiological response to cutting management includes - inherent bud regeneration capacity, rate of regeneration of new and existing tillers, swiftness in restoration of leaf area, dry matter partitioning to plant parts and the utilization of reserved carbohydrates in the stubbles (Wong and Sturr, 1995).

2.3.1. Morphological characters

Plant height and leaf growth are significantly influenced by harvesting interval and delayed harvesting increase plant height, stem diameter, and leaf growth (Shehzad *et al.*, 2012). Extending the cutting interval from 4 weeks to 8 weeks increase plant height in bunch fodder grasses by 74 per cent (Onyeonagu and Asiegbu, 2012). However, cutting height management has no substantial effect on plant height and leaf elongation and expansion of napier grass, but cutting at higher height helps in early elongation of stem (Tessema *et al.*, 2010).

Defoliation rejuvenates plants on removing the apical meristem, which favours new flushes (de Lana Sousa *et al.*, 2012). For viable fodder production and persistence of tropical forages, the threshold level of cutting fluctuates among the plant genotypes and the removal of basal meristem during defoliation affects the persistence of plants (Humpherys 1981).

Tillering and leaf production are substantially influenced by defoliation activities (Assuero and Tognetti, 2010). Defoliation removes a part of leaf area and temporarily limits the trophic movement. This reduces light interception by plant canopy and at the extent of this limitation that is, during frequent cutting, it delays the phyllochron and basal bud development to tillers (Gautier *et al.*, 1999). The reason behind this delayed phyllochron and basal bud development to tillers can be attributed to the emerging leaf which acts as a strong sink thus depriving other sinks such as tiller buds for local carbohydrates reserve (Bos and Neuteboom, 1998). Tiller density in bunch fodder grasses increase with increasing cutting interval and nitrogen nutrition (Onyeonagu and Asiegbu, 2012).

Correspondingly, cutting at higher plant height induces more basal buds and assists in higher tiller production. Persistence of more number of tillers from the previous harvest for higher cutting heights is the source contributor of fodder yield in the later regrowth (Wong, 1993). Defoliation at ground level reduces the nearest carbon source for tiller development, thereby the existing tillers and leaf growth deprive the basal bud for carbohydrates and suppress tillering in grasses (Gautier *et al.*, 1999).

Optimum cutting height and cutting interval favour sunlight reaching the lower part of the plant canopy and activates the dormant bud and promotes tillering in fodder grasses. On delayed harvesting, plant canopy get closed and reduces the solar radiation reaching the lower layers, which delays the leaf and tiller development (Difante *et al.*, 2011).

Delayed harvest reduces the number of tillers but increases the size of grass leaves (Wilman and Asiegbu, 1982). Increasing number of tillers with increasing cutting height correspondingly increase the leaf production in napier grass (Zewdu *et al.*, 2003). Similarly, delayed harvesting maintain the leaf growth and increase plant canopy of fodder plants (Shehzad *et al.*, 2012). Intensive defoliation, especially in summer periods, deprives the emerging tillers and leaf primordia in bunch grasses (Gittins *et al.*, 2010) like napier grass and its hybrids (Manyawu *et al.*, 2003).

In hybrid napier, plant height and number of leaves showed an increasing trend, while number of tillers per clump, crude protein digestibility, and leaf: stem ratio decreased with increase in cutting interval from 5 to 7 weeks (Singh and Joshi, 2002).

2.3.2. Physiological characters

The harvest management practices have significant effect on the physiology of napier grass (Briske, 1991). Frequent defoliation reduces the leaf area index in tropical forages and delaying the harvest assists in restoration of leaf area index (Wong and Sturr, 1995). Plants have lower SLA and LAR under long periods of growth (Milla *et al.*, 2008). At higher cutting heights, there would be supplementary amount of residual leaf area, and hence the recuperation and dry matter production in plants depends on its photosynthetic capacity, rate of emergence of new foliage, and the subsequent carbon assimilation rate (Ryle and Powell, 1975).

Maturity of the crop decides the nutritive quality and palatability of napier grass. The stem and dry matter increase with plant maturity and decrease the leaf – stem ratio and digestibility in napier grass (Wandera, 1997). Accordingly, early harvesting damages the growth of fodder grasses by reducing stem accumulation and simultaneously reduces the stem proportion (da Silva *et al.*, 2012) .

Aging is the main factor, which decides the stem accumulation in fodder grasses (Paciullo *et al.*, 2001). Long cutting interval accelerates leaf senescence and increases the stem portion and thus reduces the proportion of leaves in fodder grasses (Mello and Pedreira, 2004). Increasing cutting interval decreased the leaf – stem ratio of hybrid napier (Singh *et al.*, 2000).Intensive defoliation prevents stem accumulation and adversely affect leaf-stem ratio in fodder grasses (Asiegbu and Onyeonagu, 2008).

Growth of pasture is a succession of regrowth to each defoliation. The cyclic phenomenon of exhaustion and storage of carbohydrates in pasture is associated with regrowth vigour and persistence of sward (Weinmann, 1961). Therefore, the regrowth of fodder grasses are significantly influenced by harvesting managements.

The initial growth rate of napier grass are low for 2-3 weeks, and hence early harvesting adversely affects the stubble regeneration (Snijders *et al.*, 2011). Wijitphan *et al.* (2009) opined that napier grass harvested at 30 cm height has faster regrowth compared to those harvested at 0 cm, because low level cutting removes a large part of photosynthetic tissues, which takes longer time for regrowth than higher levels of harvest (Wadi *et al.*, 2004). Therefore, elevation in cutting height helps to maintain the regrowth vigour of napier grass during summer (de Lana Sousa *et al.*, 2012).

2.3.3. Fodder production

Fodder production in bunch grasses like napier and its hybrids are significantly influenced by cutting management (Manoharan and Paliwal, 1997). The harvest management practices and their subsequent effect on fodder production are well elucidated by many researchers.

Yield, in general, increases when the interval of cutting is increased (Watkins and Lewy-Van Severen, 1951). Accordingly, frequent harvesting decreases green fodder yield (Ramasamy *et al.* 1993). Long cutting interval increases the fibrous material and thereby increases the dry matter production. However, frequent cutting reduces the dry matter reserve, as remaining leaves ensure regrowth and persistence of forage grasses. This is also true with the case of harvesting at lower plant height in bunch fodder grasses (Mello and Pedreira, 2004 and da Silva *et al.*, 2012).

The yield of herbage increases with decrease in cutting frequency (Aleem and Noor, 1979). The higher fodder production potential on delayed harvesting can be elucidated in stands of the long period of exposure of photosynthesizing tissue to light and allowing for complete interception of PAR (Mitchell and Calder, 1958).

In trials conducted by Tomer *et al.* (1974) with hybrid napier 'Pusa Giant', the highest fresh fodder yield (137.10 Mg/ha) was obtained by cutting at 50 days intervals than by cutting at 30 days intervals (111.00 Mg), 40 days intervals (122.40 Mg) or 60 days intervals (110.90 Mg) and by cutting to a height of 30 and 45 cm (124.00-124.78 Mg) than by cutting at 15 cm (112.37 Mg). The crude protein content decreased with delay in cutting intervals, but crude protein yields were the highest when cut at 50-days intervals. Mani and Kothandaraman (1981) reported the highest yield in *Pennisetum purpureum* with the application of 100 kg N/ha and cutting at every 45 days interval. In hybrid napier cultivar ABPN-1, the green and dry fodder yields increased with increasing cutting interval from 30 to 60 days (Devi *et al.*, 2007). Krishnaveni *et al.* (2007) found that green fodder yields were statistically comparable when cuttings were made at 45, 55, 65 and 75 days interval. Among the treatments, cuttings at 45 days interval could be recommended to farmers as it is advantageous to them in view of frequent intervals (6 cuttings in a year).

In the tropics, cutting of napier at 2 to 4 months interval gives the highest dry matter yield (Wandera, 1997). Manyawu *et al.* (2003), opined that napier and its hybrids should be harvested between 6 and 7 weeks to optimize the nutritive value and herbage production. de la Ribera *et al.* (2008), stated that harvesting in napier should not be delayed beyond 75 days as delayed harvesting results in stunted growth.

In view of the dry matter production and digestibility, the appropriate stage for harvesting napier is 7 to 9 weeks of maturity (Wandera, 1997). Increased nitrogen fertilization and shorter cutting interval could increase the crude protein and fat content of forage grasses (Warner *et al.*, 2015). Increasing the cutting interval will increase the fresh fodder yield in hybrid napier and harvesting at 6 weeks interval is the optimum stage for maximum dry matter production without affecting the fodder quality (Singh *et al.*, 2000).

Considering the effect of cutting height, harvesting at higher plant height increases the biomass accumulation in napier grass (Wijitphan *et al.*, 2009). Increasing tiller and leaf number at higher plant height increased the dry matter yield of napier grass (Zewdu *et al.*, 2003). Napier grass when harvested at lower height has reduced leaf and stem growth rate and the overall growth and forage accumulation is more in plants harvested at higher plant heights (de Lana Sousa *et al.*, 2013).

Cutting at stubble height of 15 cm to 30 cm produce the highest fodder yield in napier grass (Wandera, 1997). Maintaining high sward height in napier grass promotes early stem elongation and dry matter accumulation, which helps in early recuperation of growth and helps in better light interception and higher forage production (Nascimento *et al.*, 2012).

2.3.4. Nutritive quality

Forage age and maturity decides the quality of forage, which can be altered through varied dates of harvesting and harvesting height. Early harvesting delays lignification of cell wall and improve quality (Buxton, 1995). Guenni *et al.* (2005), observed that nitrogen content of grasses declined from 1.9 per cent at the beginning of regrowth to 1 per cent at 45^{th} day. The decrease in nitrogen content and crude protein content with delayed harvesting is the result of accumulation of cell wall constituents which is the severest in leaf blades (Crowder and Chheda, 1982).

In napier grass, the content of crude protein and ash decrease with delayed harvest but the fibre content increases (Wandera, 1997). However, in the case of early stage harvested crop, as the total nonstructural carbohydrates reserve is been utilized after each harvest for the initial regrowth the fibre content is much less than the matured crop (Wong, 1993).

Aging reduces the crude protein content and nutritive value of leaves and stems through dilution effect (Paciullo *et al.*, 2001) because delayed harvesting increases dry matter accumulation by the greater addition of stems and dead material (da Silva *et al.*, 2012). The nitrogen free extract of forages also decrease with plant maturity (Kanak *et al.*, 2012). Onyeonagu and Asiegbu (2012) reported that the fibre content in fodder grasses increased by 19 per cent on increasing the cutting interval from 4 weeks to 8 weeks.

Even though there is significant effect of cutting interval on nutritive quality, cutting height has substantial effect only on fibre content of napier grass. Cutting height has no significant effect on crude protein content of napier grass and its hybrids (Wijitphan *et al.*, 2009). This is also in accordance with the opinion of Tessema *et al.* (2010).

2.4. EFFECT OF NITROGEN FERTILIZATION ON HYBRID NAPIER

Nitrogen fertilization in forages induce morphological, physiological, and chemical changes. Among all nutrients, nitrogen has the utmost influence on growth of forages (Buxton, 1995), and it is the most important nutrient that limits the quality and fodder production of forages (Mohammad, 1981; Amin, 2011).

As far as napier is concerned, it is an aggressive crop, which exhaust the nitrogen in soil through plant uptake (Wandera, 1997). Fertilizer requirement of napier depends on the feeding systems, and if it is cut and carried, it requires N, P, K and Mg whereas only N and P is required for grazing systems.

2.4.1. Morphological characters

The growth of napier is less limiting in the presence of nitrogen (Snijders *et al.*, 2011). Nitrogen facilitate plant growth through increased activity of meristem (Hazary *et al.*, 2015). According to Afzal *et al.* (2012), increasing nitrogen levels could improve all yield attributing factors of fodder grasses such as increased plant height, number of leaves, and number of tillers.

Nitrogen fertilization increases the sward height of napier grass under optimum light intensity (Eriksen and Whitney, 1981) as nitrogen promotes plant growth through internodal elongation (Turkhede and Rajendra, 1978). Plant height in hybrid napier increases for every increment in nitrogen levels. Jayakumar (1997) reported that plant height in hybrid napier could attain a maximum of 174.82 cm on application of 200 kg N/ha. Increase in plant height with nitrogen fertilization is highly correlated with dry matter accumulation in forges (Kanak *et al.*, 2012).

Higher levels of nitrogen stimulate growth of tillers in grasses (Lebedev, 1963). Consequently, increasing nitrogen levels increase tillering in hybrid napier (Jayakumar, 1997) especially in the early stages. Nitrogen stimulates new tillers and leaf development (Snijders *et al.*, 2011). With the increase in plant height along with increase in internodal length and number of nodes, number of leaves also increase (Amin, 2011).

Significant facilitating effect of nitrogen fertilization on tiller production under favourable environment induce leaf development in grasses (Onyeonagu and Asiegbu, 2012). Substantial increase in leaf size increases the plant canopy (Buxton, 1995). Judicious application of nitrogen maintains a continuous supply of nitrogen to the young leaves thereby preventing the internal mobilization of nitrogen from older leaves to the newly emerged leaves thus keeping the plant canopy green for a longer period. This maintain high proportion of photosynthetic tissues in fodder grasses (Dutra *et al.*, 2014)

2.4.2. Physiological characters

Nitrogen fertilization is effective for increasing leaf area in napier grass (Eriksen and Whitney, 1981). Increase in leaf area is achieved through various mechanisms. Increasing nitrogen levels promotes cell division and elongation, which affect leaf expansion and elongation rate in plants. This ultimately increases the leaf area and leaf area index of fodder grasses. The facilitating effect on leaf number results in increase in leaf area with increasing nitrogen levels (El Noeman *et al.*, 1990).

Leaf area index of hybrid napier increases with increased rate of nitrogen fertilization and could reach up to a maximum of 13.94 on application of full dose of nitrogen (200 kg/ha) (Jayakumar, 1997). Higher LAI of forage grasses is the consequence of a higher proportion of nutrient diversion to assimilatory tissues (Guenni *et al.*, 2005)

Partitioning of assimilates to various plant organs for varying nitrogen levels depend on plant genotype (Heggenstaller *et al.*, 2009). Leaf to stem ratio in hybrid napier decrease with increasing nitrogen fertilization and may reach up to 1.94 (Jayakumar, 1997) on application of 200 kg N/ha. Nitrogen fertilization reduced the leaf- stem ratio in napier grass (Zewdu *et al.*, 2003; Singh *et al.*, 2000). Increase in plant height and internodal length increase the proportion of stem which maintain a lower leaf- stem ratio at higher levels of nitrogen (Amin, 2011).

2.4.3. Fodder production

Annual fodder production of grasses is maximum in the humid tropics; however, the major constraint limiting the yield is that most of the tropical soils are deficient in nitrogen. Owing to this constraint and the exhaustive removal of nitrogen to produce such huge yield, heavy application of nitrogen fertilizers is required to compensate nitrogen loss. Napier and its hybrids are heavy yielding fodder grasses which are favorably responsive to nitrogen fertilizers (Crowder and Chheda, 1982).

Nitrogen fertilization mostly affect fresh fodder yield and crude protein yield of fodder grasses (Bumane, 2010). Application of nitrogen increases the biomass yield of fodder grasses especially in their early stage of development by promoting plant growth through increasing plant height, number of leaves, and by increasing the shoot and root weight (Amin, 2011). Wadi *et al.* (2003) observed that plant height, total dry matter weight, stem dry matter weight, root dry matter weight, mean tiller dry matter weight, crop growth rate, and leaf area index increased with time with the increase in the level of fertilization.

Nitrogen boosted forage yield is achieved through increased basal tillering and extended root development (Crowder and Chheda, 1982). According to Terashima and Hikosaka (1995), since the canopy photosynthesis of greater nitrogen fertilized plants is higher, more biomass is allocated to corresponding plots. Plant height (155.80 cm), fresh fodder yield (102.73 Mg/ha), and dry matter yield (17.03 Mg) were increased with nitrogen rate up to 90 kg with high economic returns but tillering was unaffected by fertilizers (Gupta, 1995).

Forage production of all grasses increased with nitrogen fertilizer increments and hybrid napier at 120 kg/ha N yielding 32 Mg/ha dry matter (Pandey *et al.*, 2011). Pathan and Bhilare (2008) reported higher yields of green forage (71.20Mg/ha), dry matter (16.98 Mg/ha), and crude protein (1612 kg/ha) with the application of NPK at 75:60:30 kg/ha. Munegowda *et al.* (1987) reported that application of 120-180 kg N, 80-120 kg P_2O_5 and 40-80 kg K_2O/ha to hybrid napier cv. NB-21 gave total fresh fodder yields of 224.20 to 237.20 Mg/ha in 10 cuts compared with 162.98 Mg without NPK. Prasad and Kumar (1995) obtained dry matter yield of 14.10 Mg/ha from *Pennisetum purpureum* with 60 kg/ha N under rainfed condition at Ranchi, Bihar. Miyagi (1983) recorded remarkable increase in forage yield of napier grass with nitrogen application upto 600 kg/ha. However, increase in napier grass yield diminished as the level of nitrogen increased.

The nitrogen- yield response curve of napier grass increased linearly with annual rates of nitrogen at the rate of 600-800 kg N/ha and the curve being less pronounced beyond 1000-1200 kg N/ha. Conversely, the response curve vary with plant genotype, stage of crop growth, amount and time of nitrogen application, soil moisture and climate (Crowder, 1977). For napier grass to produce high fodder yield in dry zones it has to be top dressed annually with 300 kg N/ha (Wandera, 1997). According to Pieterse and Rethman, eventhough the fodder yield in napier and its hybrids increased with increasing nitrogen levels up to 400 kg/ha, the optimum dose is 150 kg/ha at low pH (< 4) in the tropics.

2.4.4. Nutritive quality

The quality of napier grass depends on the quantity of fertilizer applied (Wandera, 1997). Nitrogen fertilization mostly affect the crude protein content of fodder grasses (Bumane, 2010). Eriksen and Whitney (1981) reported that nitrogen content in napier grass increase with increasing nitrogen fertilization. As nitrogen is the chief constituent of protein, the increased application of nitrogen could increase the crude protein content of fodder grasses (Amin, 2011) such as hybrid napier (Jayakumar, 1997).

Increase in crude protein content of leaves and stems for every additional dose of nitrogen was well documented in forage grasses (Magalhaes *et al.*, 2007). Nitrogen increase leaf protein by enhancing the production of photosynthetic enzymes rubisco and PEP carboxylase (da Silva *et al.*, 2012). Napier grass can have more than 10 per cent of crude protein when fertilized with more than 1000 kg N/ha at 60 days of harvest. This can be attributed to the luxury consumption of nitrogen which can sometimes leads to nitrate accumulation (Vincente- Chandler, 2000).

Hazary *et al.* (2015) reported that increasing nitrogen levels increase the crude protein and crude fat content but decreased the crude fibre content of fodder grass. This is due to the fact that increased application of nitrogen helps in rapid synthesis of carbohydrates into protein and protoplasm leaving low proportion for cell wall synthesis and maintain succulent growth (Johnson *et al.*, 2001).

Crude fibre content of hybrid napier decrease with increasing rate of nitrogen fertilization and may reach to 28.60 per cent on application of 200 kg nitrogen per hectare (Jayakumar, 1997). Amin (2011) reported that higher nitrogen fertilization reduced the fibre content of forages. The highest crude fibre content was obtained from plants not treated with nitrogen and the lowest was recorded from plants fertilized with higher dose of nitrogen.

Increasing nitrogen levels increase the mineral levels in napier grass except in case of P due to the antagonistic effect of nitrogen on P uptake (Doberman and Fairhurst, 2000). Eventhough the napier grass could accumulate more K compared to other tropical grasses there was no substantial effect of N fertilization on K content. Similarly nitrogen fertilization increased the uptake of cations such as Ca and Mg and thereby its concentration in leaves of napier (Tripathi *et al.*, 1979). Top dressing with nitrogen fertilizer has no significant effect on calcium content of forages (Parissi and Koukoura, 2009) but applying 125 per cent of the recommended dose of nitrogen through fertigation in 'CO-4' cultivar of hybrid napier increased the Ca content (Alagudurai and Muthukrishnan, 2014).

Increasing nitrogen levels could not produce substantial changes in ash content of forages (Afzal *et al.*, 2012). Rapid stimulation of growth on application of nitrogen fertilizer reduces soluble carbohydrates and lowers concentration of minerals through dilution effect (Buxton, 1995).

According to Mohammad *et al.* (1988), nitrogen fertilizers increased crude protein and ash percentage, but did not reduce crude fibre. They also reported that dry matter yield and total quantity of crude protein per unit area were higher from moderately fertilized (N 80 kg/ha) plants maintained at 60 days interval than heavily fertilized (N 120 kg/ha) plants subjected to frequent clipping (30-45 days).

2.4.5. Nitrogen utilization

The efficiency of nitrogen fertilizer added to grasses is estimated as kilograms of dry matter produced per kilogram of nitrogen applied and known as nitrogen recovery (Crowder and Chheda, 1982). Nitrogen use efficiency in tropical grasses decrease at higher levels of nitrogen (Hiremath *et al.*, 2002). Eriksen and

Whitney (1981) recorded 41 per cent nitrogen recovery in napier grass but compared to other tropical grasses, the nitrogen recovery in napier grass is much lower because of the very high yield of napier grass under nitrogen minus plots. This is because of its extensive forage area in the soil so that it could capture nitrogen from vast area in the soil.

According to Crowder and Chheda (1982), nitrogen recovery depends on two major factors- the amount of nitrogen applied and cutting interval. Application of 400 kg N/ha and harvesting at 45 days interval could yield 50 to 65 kg of dry matter per kilogram of nitrogen under irrigated condition but can vary under rainfed situations. Commonly obtained value of nitrogen recovery is between 30 per cent and 65 percent in fodder grasses. *Pennisetum purpureum* had nitrogen recovery value of 53.6 when top dressed annually with 220, 480 and 960 kg N/ha.

Grasses have more response for applied nitrogen on delayed harvest and yield more per kilogram of nitrogen. In napier, on an average nitrogen use efficiency increase from 21 kg to 40.1 kg dry matter for each kilogram of nitrogen applied over cutting intervals of 4 weeks to 12 weeks (Snijders *et al.*, 2011) The nitrogen recovery of urea is 40.6 per cent at soil pH of 4.8 (Figarella *et al.*, 1972).

Unfavorable soil conditions such as decreased soil pH, phosphorous fixation due to increased soil acidity, increased exchangeable Al, decreased exchangeable Ca and Mg, inadequate soil moisture, and insufficient soil organic matter are the major constrains which results in declining response to the continued application of nitrogen (Crowder and Chheda, 1982).

2.5. ANTINUTRITIONAL FACTORS

Tropical fodder grasses such as napier and its hybrids contain certain chemical substances, which interfere with animal metabolism, food utilization, or affect the health and production of animals. Most of these compounds are secondary metabolites produced as defense mechanism against herbivory. Occasionally, plants accumulate excessive amounts of these compounds and become toxic to the animals. Hence, these substances are known as antinutritional factors (Patel *et al.*, 2013). Nitrates and oxalates are the common antinutritional factors present in hybrid napier. Their content in plants vary with species, plant parts, season and stage of harvest, and soil conditions (Singh *et al.*, 2000).

2.5.1. Oxalate content

Oxalates are salts of oxalic acid which are common constituents of tropical fodder grasses (Rahman *et al.*, 2006). They bind with ions such as sodium, potassium, ammonium, calcium and magnesium and form soluble oxalate forms with sodium, potassium and ammonium ions, and insoluble oxalate forms with calcium, magnesium, and iron ions (Savage *et al.*, 2000), thereby reduce the absorption and availability of these nutrients to animals.

Oxalate content in plants varies with plant species and parts (Jones and Ford, 1972; Marais *et al.*, 1997). In hybrid napier, oxalate levels in the leaves are higher than in stems compared to napier grass, and napier grass accumulated more oxalate in stem portions. The oxalate levels decreased in both plants with advancing maturity. (Kipnis and Dabush, 1988). Hybrid napier accumulates 3.82 per cent of oxalate in leaves and 1.95 per cent in stems (Kaur *et al.*, 2009). Hence consumption of some tropical grasses, especially, *Pennisetum* spp. (Lal *et al.*, 1966; Mathams and Sutherland, 1952) and *Setaria* spp. (Jones *et al.*, 1970) containing oxalates in higher concentration induce Ca deficiency (Rahman *et al.*, 2013).

The other important factors deciding the oxalate content in plants are the season and stage of harvests, nitrogen fertilization, and light availability. The oxalate content of napier hybrids is higher during June and July due to the peak in growth during rainy season (Singh, 2002). Plants harvested during early summer have more oxalate (3.6 – 4.8 per cent) than those harvested in late summer (Rahman *et al.*, 2006).The content also varies with harvesting management; in napier grass, clipping increase oxalate concentration and oxalate levels decline with delayed harvest (Rahman *et al.*, 2009).

Application of nitrogen and phosphorus have considerable effect on oxalate content of grasses (Rahman and Kawamura, 2011). Oxalate content of hybrid napier grass increases with increasing nitrogen and decreases with delayed harvesting (Mani and Kothandaraman, 1981). Rahman *et al.* (2010) observed that nitrogen application in the form of nitrate caused higher concentrations of soluble and insoluble oxalates in shoot and soluble oxalates in root than nitrogen in the form of ammonium compounds. To prevent excess levels of oxalate accumulation, they suggested avoiding application of nitrate as the sole source of nitrogen and keeping potassium application to a necessary minimum. Phosphorus fertilizer as superphosphate depressed oxalate levels in vegetables (Singh, 1974). Rahman *et al.* (2009) reported that soluble oxalate in napier grass showed decreasing trend but insoluble oxalate content showed an increasing trend with increased rate of calcium application.

Plants grown under shade accumulate insoluble oxalates compared to those grown in full sunlight (Moreau and Savage, 2009). This happens because the oxalate is associated with glycolate cycle and photosynthesis, wherein shade high proportion of Ca, Fe and Zn are being bound to oxalates in leaf tissue as insoluble oxalates (Noonan and Savage, 1999).

The soluble oxalate content which exceeds more than 2 per cent leads to acute toxicities in ruminants whereas the insoluble oxalates seems to pass through the digestive system and cause less harmful effects (Ward *et al.*, 1979). The content in grasses is the highest during periods of rapid growth even more than 6 per cent of plant dry weight (Cheeke, 1995). The level of toxicity vary with cultivar (Chaudhary *et al.*, 2007) and age of plant. Young plants accumulate more oxalate and the content decrease with plant maturity (Davis, 1981). According to Rahman *et al.* (2009), harvesting of napier at 2-8 weeks interval with optimum dose of fertilizers provides high fodder yield with crude protein content of 14 per cent and oxalate content not more than 2.5 per cent, however, the situation varies under unfavourable environment.

2.5.2. Nitrate accumulation

Nitrate is an essential nutrient ion required for plant metabolism, however, accumulation of nitrate ions in plant parts leads to nitrate poisoning in animal during their consumption. The first case of nitrate poisoning was reported in 1895 at Kansas in USA as corn stalk poisoning in cattles. Some of the fodder crops such as maize, bajra, sorghum, sudan grass and oats accumulate nitrate at potentially toxic levels (Andrews and Kumar, 1992). Fodder grasses are more susceptible to nitrate toxicity than other crops (Bose and Fazlullahkhan, 1996). The sole stands of grasses accumulate high amount of nitrates especially in their immature stage (Nikolic and Cmiljanic, 1986).

Nitrate poisoning can also be called nitrite poisoning. Once the nitrate ion is absorbed by plant roots a portion is accumulated in root cells, a portion is reduced, and a significant amount is translocated to leaves. A portion of the translocated nitrates to leaves gets accumulated in the leaf cells and the remaining portions is reduced (Donald *et al.*, 1978). During digestion, nitrate is converted to nitrite, nitrite to ammonia and ammonia to amino acid and then to protein. When plants accumulate nitrate, animals cannot complete the nitrate metabolism and nitrite accumulates. Nitrite is absorbed into the blood and bind with haemoglobin and form methaemoglobin. As a result, haemoglobin cannot bind with oxygen and results in asphyxiation and finally death. The blood turns to chocolate brown colour (Patel *et al.*, 2013).

The highest recommended safe limit of nitrate in forages for livestock is 3000 ppm (Bilal *et al.*, 2011). However, more than 10,000 ppm nitrate is required to produce potential harmful effect and nitrate poisoning in animals (Andrae, 2008).

The various factors contributing to nitrate poisoning depends on plant species, plant parts, stage of growth, drought and high soil nitrogen. The nitrate levels are higher in the leaves and stalks. However, most of the nitrate accumulates in stem than leaves and grains, especially in the lower plant parts.

3. MATERIALS AND METHODS

Three field experiments were conducted over a period of two years during 2013-2014 and 2014-2015 at the Agronomy Research Farm of Kerala Agricultural University, Vellanikkara. The experiments were planned with three main objectives - to assess the shade tolerance potential, to find out the optimum nitrogen levels and harvesting frequency, and to study the effect of different cutting heights on regrowth and mortality of hybrid napier cultivars under rainfed condition. Comparisons were made between six popular cultivars of hybrid napier (CO-3. CO-4, Suguna, IGFRI-3, DHN-6 and PTH). The details of the materials and methods adopted for the study are reported in this chapter. The three experiments included under the study were - Experiment I: Shade tolerance of hybrid napier cultivars; Experiment II: Nitrogen nutrition and cutting frequency in hybrid napier grown under rainfed condition; and Experiment III: Cutting height management in hybrid napier grown under rainfed condition.

3.1. GENERAL DETAILS

Experimental site

The field experiments were conducted at the Agronomy Research Farm of Kerala Agricultural University, Vellanikkara; situated at 10^0 31'N latitude and $76^0$13'E longitude at an altitude of 40.3m above mean sea level.

Soil

The soil of the experimental site is sandy clay loam (Order: Ultisol). The details of pysico- chemical properties of the soil are given in Table 1.

Materials and Methods

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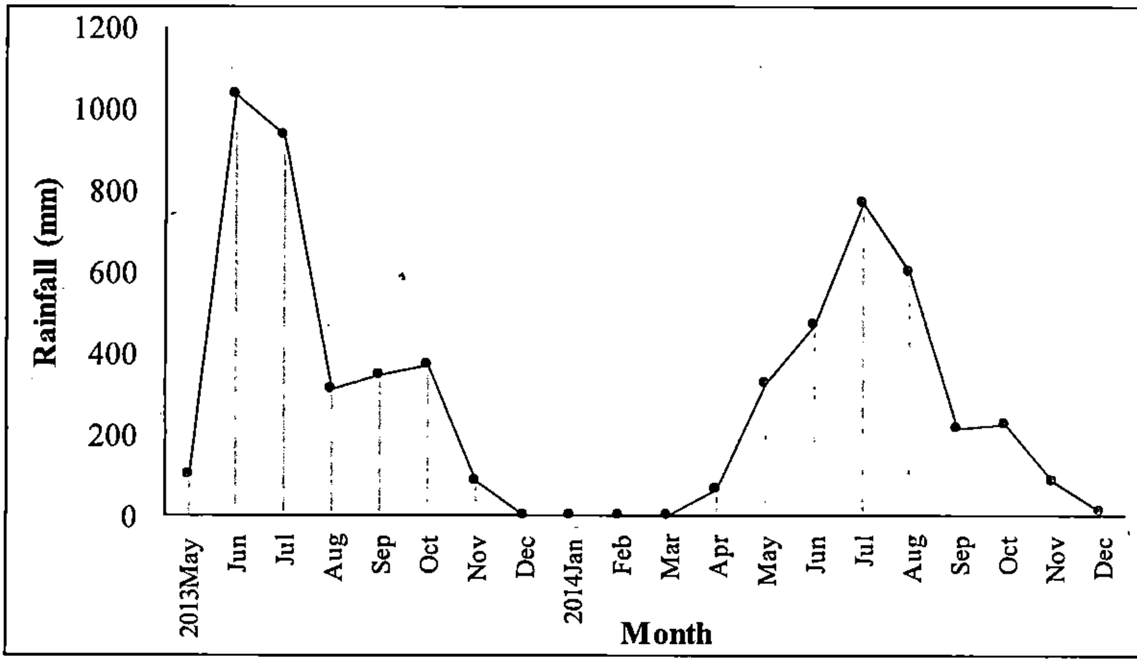

Fig.1 Total monthly rainfall during the crop period at Vellanikkara, Thrissur

Table 1. Physico-chemical properties of soil

Particulars	**Content**			**Methods used**
Particle size composition				
Sand (%)	68.20			Robinson international pipette method (Piper, 1942)
Silt (%)	19.50			
Clay (%)	11.50			
Chemical composition	Experiment			
	I	II	III	
pH	5.80	5.90	5.80	1: 2.5 soil water ratio Beckman glass electrode (Jackson, 1958)
Organic carbon (%)	1.40	1.45	1.40	Walkley and Black method (Jackson, 1958)
Available N (kg/ha)	682	744	713	Alkaline permanganate method (Subbiah and Asijah, 1956)
Available P (kg/ha)	72	76	76	Ascorbic acid reduced molybdophosphoric blue colour method (Watnabe and Olsen, 1965)
Available K (kg/ha)	315	339	328	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1958)

Climate

The weather data recorded during the period of field experiments (June 2013 to June 2015) are given in Appendix II. The amount of rainfall received during the crop growth is graphically presented in Fig.1.

3.2. CROP HUSBANDARY

Field operations

On receipt of summer showers the selected experimental site was divided in to three experimental areas. The entire area was ploughed, stubbles removed, levelled and laid out into plots as per the lay out plans (Fig. 2, Fig. 3, and Fig. 4). The experiments were maintained continuously for two years without any fallow period. The schedule of field operations is given in Appendix I.

Planting

Rooted slips of selected hybrid napier cultivars were collected from fodder germplasm collections maintained at the Agronomy farm, College of Horticulture, Vellanikkara. The slips were planted at one slip each at a spacing of 60 cm X 60 cm with the onset of south west monsoon and the crop was maintained as perennial crop for two years.

Manures and fertilizers

Manures and fertilizers were applied by adopting the package of practices recommendations, Kerala Agricultural University (KAU, 2011). Recommendation followed was: farm yard manure (FYM) at 25Mg and fertilizers at 200:50:50kg N, P_2O_5 and K_2O per hectare per year. N, P_2O_5 and K_2O were applied as Urea (46 % N), Mussorie Rock Phosphate (20 % P_2O_5) and Muriate of Potash (60 % K_2O). The schedule of FYM, P_2O_5 and K_2O were same for all the three experiments. The details of application of nitrogen for experiment II is given in Section 3.3. FYM at 25Mg/ha, P_2O_5 and K_2O at 50 kg/ha each were applied at the time of land preparation. For experiments I and III, nitrogen at 200 kg/ha was applied in three splits as basal and after the first and second harvests in the first year. During the second year, the recommended full dose of farm yard manure, P_2O_5, K_2O and one third dose of nitrogen was applied after the first harvest, and the remaining nitrogen was applied in two splits after the second and third harvests.

After cultivation

Gap filling was done within 10 days after planting to maintain the optimum plant density. Intercultivation and weeding was done at the time of fertilizer application.

Harvesting

The first harvest was taken at 75 days after planting and subsequent harvests at 45 days intervals. There were four harvests during the first year and five in the second year; but no harvestings were done during summer seasons because of non receipt of rainfall. Harvesting was done by leaving one border row from all sides. The harvesting details carried out for experiment II and III are given in Section 3.3

3.3. EXPERIMENTAL DETAILS

Experiment I: Shade tolerance of hybrid napier cultivars

The layout of the experiment is given in Fig.2. The experiment involved full sunlight condition, two levels of shade and six cultivars of hybrid napier. The details of the experiment are as follows:

Design: Split plot

Plot size: 12.96 m^2 (3.6m x 3.6 m)

Replication: 3

Spacing: 60 cm x 60cm

Treatments:

Main plots (3): Levels of shade- 0%, 25% and 50%

Sub plots (6): CO-3, CO-4, Suguna, IGFRI-3, DHN-6, and PTH

Treatment combinations: 18

Shade levels were established using synthetic green shade nets of 25 per cent and 50 per cent by erecting wooden poles at 3.0 m above ground level.

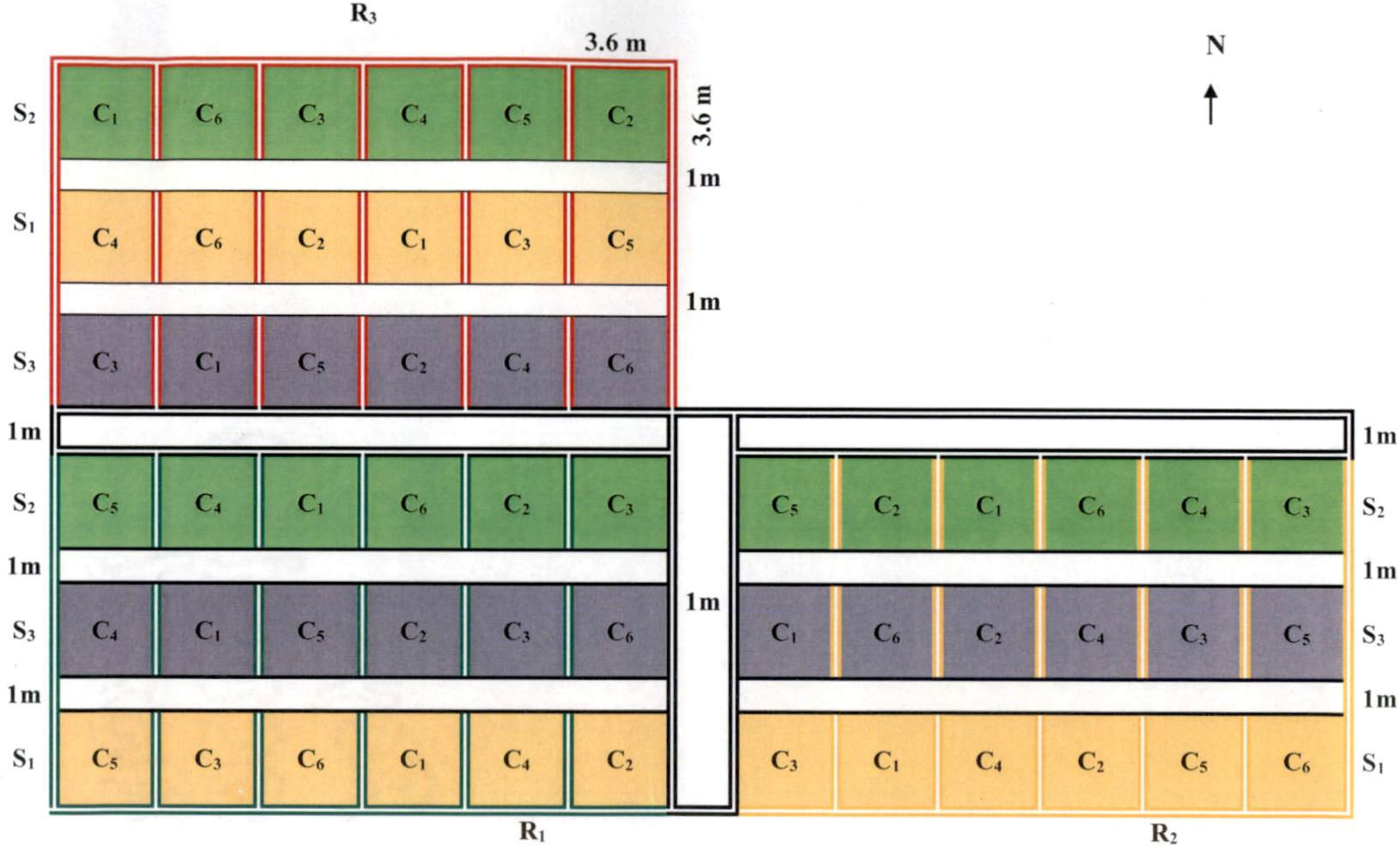

Fig. 2 Layout of field experiment I

R_1, R_2, R_3 - Replications

Main plot treatments	**Sub plot treatments**	
S_1- Open	C_1 – CO-3	C_4 – IGFRI-3
S_2 – 25 % shade	C_2 – CO-4	C_5 – DHN-6
S_3 – 50 % shade	C_3 - Suguna	C_6 - PTH

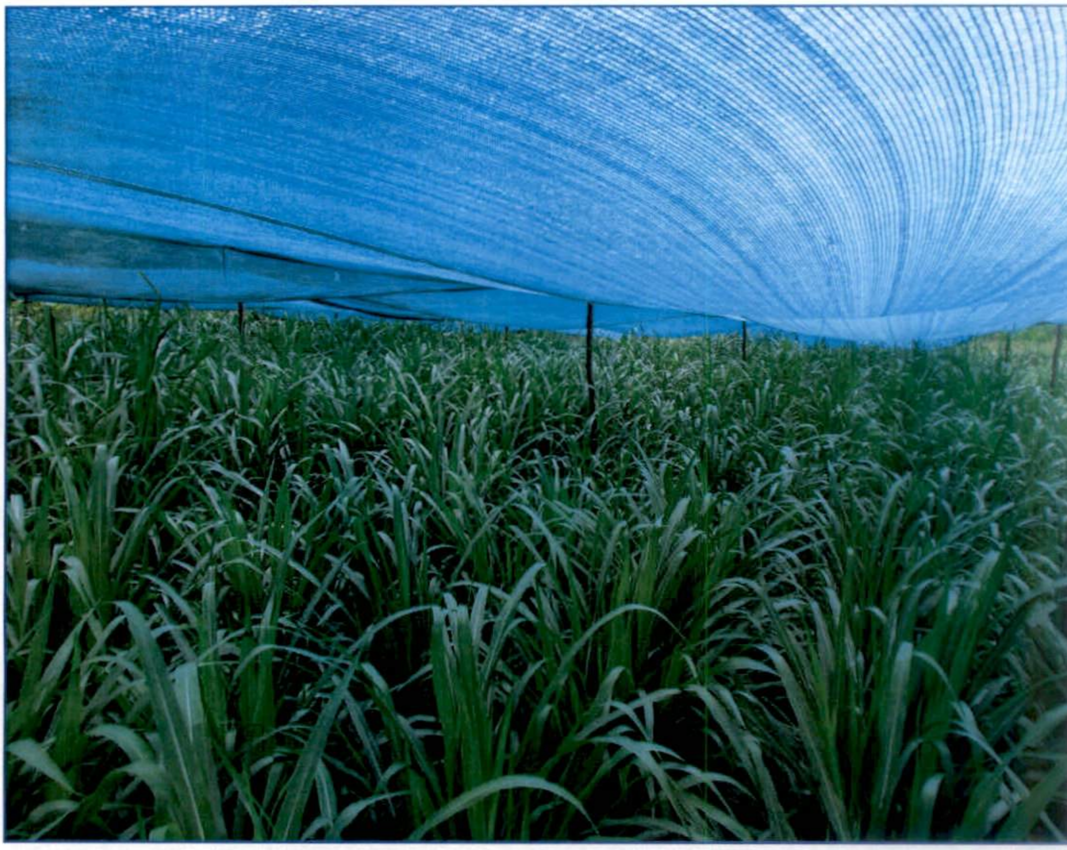

Plate 1. Field view of experiment I

Plate 2. Measuring PAR readings using canopy analyser

Experiment II: Nitrogen nutrition and cutting frequency in hybrid napier grown under rainfed condition

The layout of the experimental field is given in Fig.3. The experiment involved three cutting frequencies at five different levels of nitrogen fertilizer (Urea) under open condition. The details of the experiment are as follows:

Design: RBD

Plot size: 20.16 m^2 (4.8 m x 4.2 m)

Replication: 3

Spacing: 60 cm x 60cm

Treatments:

Factor 1

Cutting frequency/interval (3): 30, 45, and 60 days

Factor 2

N levels (kg/ha) (5): 0, 100, 200, 300, and 400

Treatment combinations : 15

Cultivar : CO-3

The first harvest was taken at 75 days after planting irrespective of the treatments and subsequent harvests at 30, 45 and 60 days intervals. During the first year, there were five, four and three harvests respectively for 30, 45 and 60 days cutting intervals. In the second year, there were seven, five and four harvests for 30, 45 and 60 days cutting intervals. The recommended doses of nitrogen were applied in three splits. During the first year, for 30 days cutting intervals, three nitrogen splits were applied as basal, after the first and third harvests, while for 45 and 60 days cutting frequencies, three nitrogen splits were given as basal, after the first and second harvests. For the second year, three nitrogen splits were given after the first, second and third harvest for 45 and 60 days cutting intervals whereas for 30 days cutting frequency, three nitrogen splits were given after the first, third and fifth harvests.

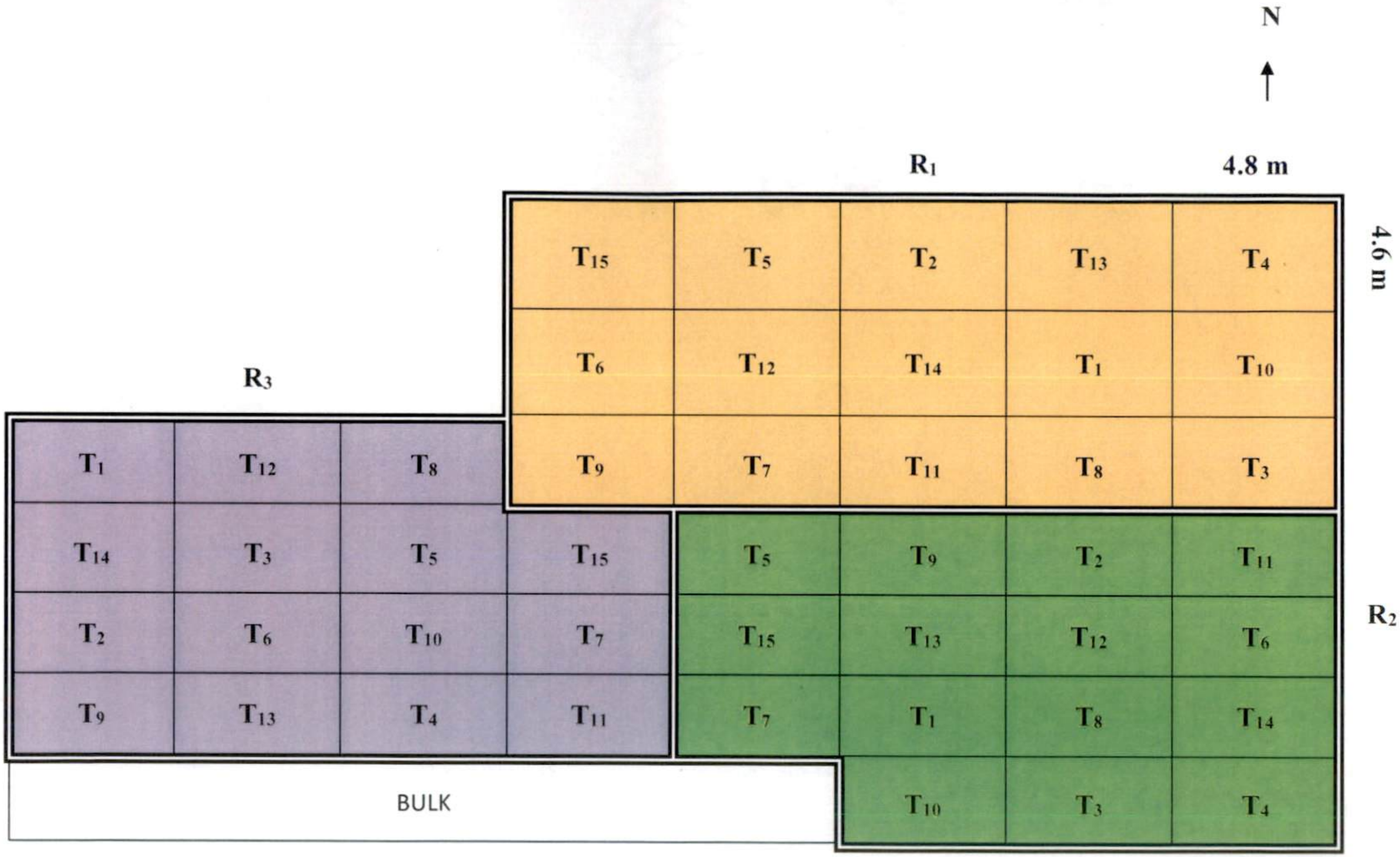

Fig. 3 Layout of field experiment II

R_1, R_2, R_3 – Replications **F- Cutting frequency (days)** **N- Nitrogen levels kg/ha**

Treatments

T_1	F30 N0	T_6	F45 N0	T_{11}	F60 N0
T_2	F30 N100	T_7	F45 N100	T_{12}	F60 N100
T_3	F30 N200	T_8	F45 N200	T_{13}	F60 N200
T_4	F30 N300	T_9	F45 N300	T_{14}	F60 N300
T_5	F30 N400	T_{10}	F45 N400	T_{15}	F60 N400

Experiment III: Cutting height management in hybrid napier grown under rainfed condition.

The layout of the experimental field is given in Fig.4. The experiment was conducted under open condition with six cultivars of hybrid napier at four different cutting heights. The details of the experiment are as follows:

Design: RBD

Plot size: 20.16 m^2 (4.8 m x 4.2 m)

Replication: 3

Spacing: 60 cm x 60 cm

Treatments:

Factor 1

Cutting height (4): 5cm, 10cm, 15cm and 20cm

Factor 2

Cultivars (5): CO-3, CO-4, Suguna, DHN-6, and PTH

Treatment combinations: 20

The different cutting heights were marked on a straight wooden peg and fixed at the base of each plant and cuts were given with a sharp sickle.

3.4. DETAILS OF OBSERVATIONS

Observations were made on morphological characters, physiological parameters, mortality percentage during summer months, fodder yield, nitrogen use efficiency and chemical analysis of plant and soil. Biometric and physiological parameters were recorded just before each harvests by randomly selecting five plants from each plot. Derived growth parameters such as Leaf Area Index (LAI), Leaf Area Ratio (LAR), Leaf Weight Ratio (LAR), Specific Leaf weight (SLW), Regrowth Rate and leaf-stem ratio were worked out as detailed by Hunt(1978) and Gardner *et al*., (1985).

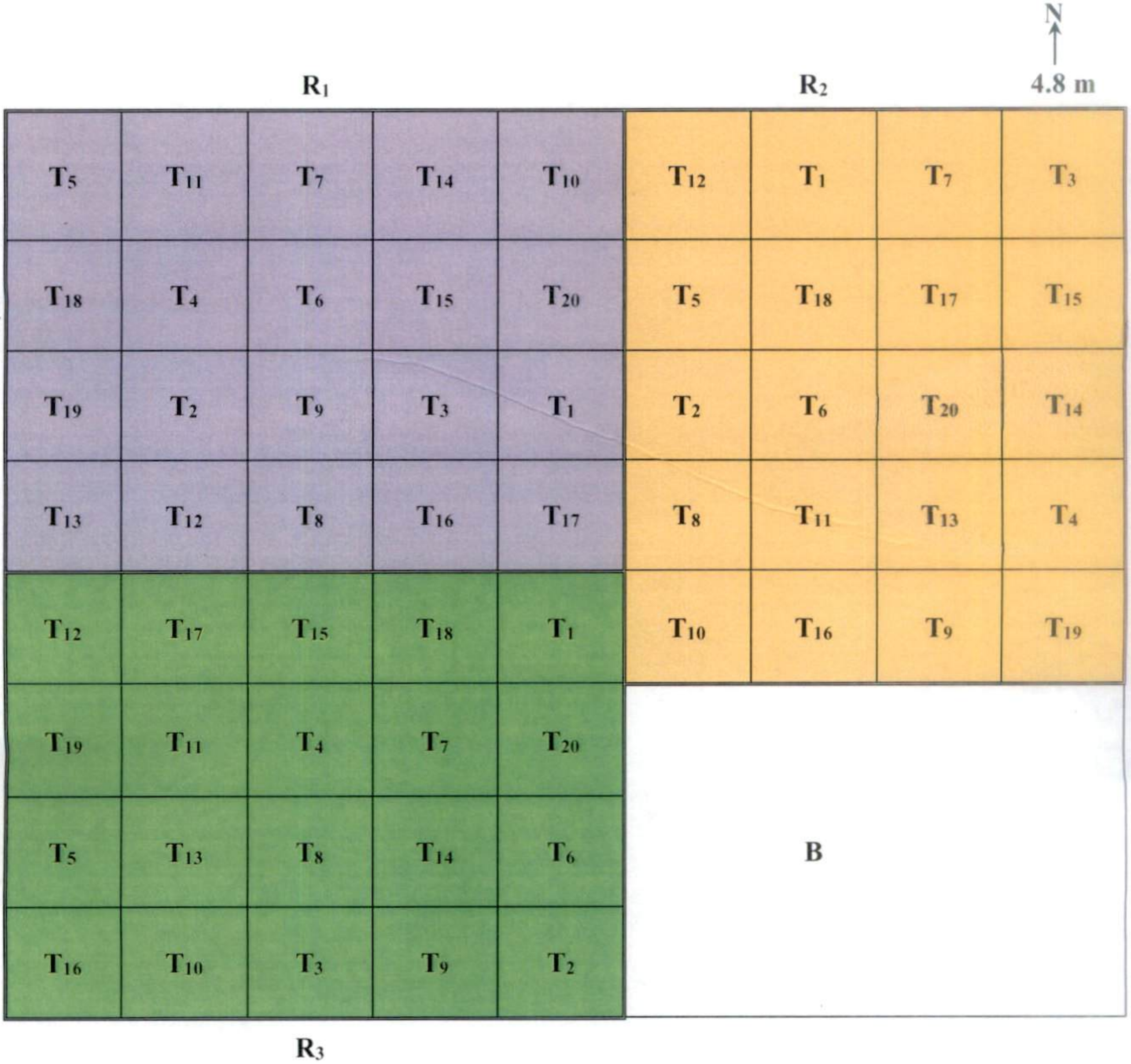

Fig. 4. Layout of field experiment III

R_1, R_2, R_3 – Replications **H- Cutting height (cm)** **B- Bulk**

Treatments

T_1	H_5 CO-3	T_6	H_{10} CO-3	T_{11}	H_{15} CO-3	T_{16}	H_{20} CO-3
T_2	H_5 CO-4	T_7	H_{10} CO-4	T_{12}	H_{15} CO-4	T_{17}	H_{20} CO-4
T_3	H_5 Suguna	T_8	H_{10} Suguna	T_{13}	H_{15} Suguna	T_{18}	H_{20} Suguna
T_4	H_5 DHN-6	T_9	H_{10} DHN-6	T_{14}	H_{15} DHN-6	T_{19}	H_{20} DHN-6
T_5	H_5 PTH	T_{10}	H_{10} PTH	T_{15}	H_{15} PTH	T_{20}	H_{20} PTH

Plate 3. Observing the regrowth pattern of crop after cutting at different plant heights

3.4.1. Morphological characters

Plant height

The plant height in cm was recorded from base of the culm to the tip of the top most leaf just before each harvests by randomly selecting five plants from each replication and the means were worked out.

Number of tillers

Total number of tillers per clump was recorded just before each harvests by randomly selecting five plants from each replication and the means were worked out.

Number of leaves

Total number of green and photosynthetically efficient leaves per clump were recorded just before each harvests by randomly selecting five plants from each replication and the means were worked out.

Leaf length

For taking leaf measurements, fully opened and matured, second pair of leaves from the top were fixed as index leaves. Length of the index leaves in cm were measured from the base of leaf to the leaf tip and their means were worked out.

Leaf width

Width of leaves were measured at the middle portion of the index leaves and their means were worked out in cm.

3.4.2. Growth analysis

Plant growth is affected to a great extent by accessibility to environmental resources and crop management practices. An understanding of the resource limitations and best management practices to be adopted are possible through plant growth analysis which is a measure of photosynthetic efficiency of the plant. Photosynthetic efficiency is associated with leaf area and its weight. Measurements on leaf area, leaf dry weight and plant dry weight made at frequent intervals were used for plant growth analysis. Leaf weight reflects the leaf thickness which is important in the plant adaptations to various environmental stresses. Leaf area measurements reflects the photosynthesizing tissues, whereas the plant dry weight is a measure of the total respiring plant tissues. For computing various growth analysis quantities, measurements on basic parameters were made just before each harvest from each sampling unit from each replication and their averages were worked out.

Leaf area index (LAI)

Leaf area index is the ratio of leaf area to ground area, which is a measure of the photosynthetic area occupied by the plant. Leaf area occupied by the sampling units was worked out using graph paper. For calculation of LAI, the average of the leaf area to ground area ratios of each sampling unit from three replications was worked out.

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Land area}}$$

Leaf area ratio

Leaf area ratio, a measure of the relative leafiness of the plant, is the ratio between the area of leaf lamina or the photosynthesizing tissues and the total respiring plant tissues or total plant biomass. For practical purpose, LAR is defined as the ratio of total leaf area to whole plant dry weight and expressed in dm^2/g.

$$\text{Leaf area ratio (LAR)} = \frac{\text{Leaf area per plant}}{\text{Plant dry weight}}$$

Leaf weight ratio

Leaf weight ratio is an index of the leafiness of the plant on plant dry weight basis. It is a dimensionless index of the leaf dry weight per unit whole plant dry weight.

$$\text{Leaf weight ratio (LWR)} = \frac{\text{Leaf weight per plant}}{\text{Plant dry weight}}$$

Specific leaf weight

Specific leaf weight is the ratio of leaf dry weight to leaf area, expressed in g/dm^2. It measures the leaf thickness.

$$\text{Specific leaf weight (SLW)} = \frac{\text{Leaf weight}}{\text{Leaf area}}$$

Leaf: stem ratio

Leafiness of the species is related to fodder quality which is measured as the ratio of total leaves to stem portions of plant. Stems and leaves were separated from the plant and the dry weights were recorded separately. From this, leaf to stem ratio was worked out. The fodder species with high leaf - stem ratio will show more digestibility and less wastage.

$$\text{Leaf: stem ratio} = \frac{\text{Dry weight of leaves}}{\text{Dry weight of stems}}$$

Regrowth rate

Regrowth rate was measured in experiment III, to have a comparative study between the cutting height treatments. It is a simple measure of increase in dry weight of the top regrown over a given time and expressed in g/day.

$$\text{Regrowth rate (Rgr)} = \frac{\text{RG}}{\text{T}}$$

Where RG is the dry weight of the top regrown over a given time T.

3.4.3. Physiological and biochemical parameters

Chlorophyll content

Chlorophyll content of leaves was estimated colorimetrically using spectrophotometer (Yoshida *et al.*, 1976) and expressed as mg/g of fresh leaf weight. Representative measurements on chlorophyll a and chlorophyll b were taken for experiment I, just before third (first year) and fifth (second year) harvests. The index leaves were used for chlorophyll estimation. The ratio of chlorophyll b to chlorophyll a was also worked out. The formula used for chlorophyll estimation is as follows:

$$\text{Chlorophyll a} = [(12.7 \times A663nm) - (2.69 \times A645nm)] \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll b} = [(22.9 \times A645nm) - (4.68 \times A663nm)] \times \frac{V}{1000 \times W}$$

$$\text{Total chlorophyll} = [(8.02 \times A663nm) + (20.2 \times A645nm)] \times \frac{V}{1000 \times W}$$

Where A is the absorbance, V is the volume of aliquot taken and W is the fresh weight of leaf taken.

Light intensity and Photosynthetically Active Radiation

Representative measurements on light intensity and photosynthetically active radiation (PAR) were taken on clear sky days at 12.00 h and 13.00 h, just before third and fifth harvests, for the first and second year respectively, when the canopy was fully developed. Light penetration through the plant canopy was measured with the help of lux meter. PAR readings were taken using CI-110 digital plant canopy imager. Measurements on light intensity were reported as percentage fraction of light interception by the canopy, and PAR measurements as percentage fraction of transmitted and intercepted PAR. The lux meter readings at the top of canopy are the incident light (I_0) and those below the canopy give the transmitted light (I). The difference between I_0 and I gives the intercepted light by plant canopy. Similarly, PAR measurements at the top of canopy are the incident PAR (PARi) and those below the canopy give the transmitted PAR (PARt). The difference between PARi and PARt gives the intercepted PAR (IPAR).The ratios were worked out from these basic readings as follows:

$$\text{Light interception percentage (LI \%)} = \frac{I_0 - I}{I_0} \times 100$$

$$\text{PAR interception percentage (IPAR \%)} = \frac{PARi - PARt}{PARi} \times 100$$

$$\text{PAR transmission percentage (TPAR \%)} = \frac{PARt}{PARi} \times 100$$

3.4.4. Mortality of clumps

Observations on completely dried clumps were taken after the receipt of a few premonsoon showers, but clump mortality was not noticed.

3.4.5. Fodder yield

Fresh and dry fodder yield

For estimation of fresh fodder yield, the harvested produce from each plot was immediately weighed and weight was expressed in Mg/ha. Dry weight was recorded by randomly selecting five plants from each plot and by drying them at 80 ± 5 °C for 24 hours until constant weight was achieved. From this dry matter per cent was worked out for computing the dry fodder yield from fresh fodder yield. The yield was expressed in Mg/ha.

3.4.6. Plant analysis

Plant samples were collected from each replication, just before third (first year) and fourth (second year) harvests; leaves and stems were separated, chopped, air dried and oven dried at 80 ± 5^0C for 24 hours till constant weight was achieved. The samples after grinding were used to find out the percentage content of nitrogen, phosphorus, potassium, calcium, magnesium and the five fractions of proximate analysis - crude protein, crude fibre, total ash, ether extract, and nitrogen free extract of leaves and stems. Percentage content of antinutritional factors –oxalate and nitrate of both leaves and stems corresponding to Kharif, Rabi and Summer also were analysed in the harvested produce collected from harvests coinciding the respective seasons of both years. The samples collected after the heavy premonsoon showers were used for plant analysis corresponding to summer season. The oxalate content was analyzed for experiment 1 and 2, whereas nitrate content was analysed for experiment 2 only. In the first year, for nutrient and proximate analysis samples were collected at the third harvest, where the harvesting interval was 45 days. For 30 days harvesting interval, samples were collected at the fourth harvest and for 60 days harvesting frequency at the second harvest. Samples for the second year analysis were taken from fourth (45 days cutting interval), sixth (30 days cutting interval) and third (60 days cutting interval) harvests.

Proximate analysis

1. Crude protein

The nitrogen content was estimated by Microkjeldal digestion and distillation method (Jackson, 1958). The nitrogen content thus obtained was multiplied by 6.25 to get the crude protein content of the plant samples.

2. Crude fibre

The crude fibre content was estimated using the acid – alkali digestion method (Sadasivam and Manickam, 1992).

3. Ether extract

The ether extract content, which represents the crude fat fraction of the sample was estimated by extracting the plant fat using the organic solvent, petroleum benzene (AOAC, 1975).

4. Ash

The ash content was determined by igniting a known quantity of plant sample at 600°C for three hours (AOAC, 1975).

5. Nitrogen free extract

Nitrogen free extract was estimated by subtracting the percent crude protein, crude fibre, ether extract and ash content from 100.

Antinutritional factors

1. Oxalate content

The oxalate content in the plant sample was analysed colorimetrically, as suggested by Burrows (1950).

2. Nitrate content

The nitrate content in the plant sample was analysed colorimetrically, as suggested by Bhargava and Raghupathi (1993).

Nutrient content

1. Nitrogen

The nitrogen content was estimated by Microkjeldal digestion and distillation method (Jackson, 1958).

2. Phosphorus

The plant samples were digested using the diacid mixture (HNO_3: $HClO_4$ at 2:1 ratio) and the phosphorus content was determined by vanadomolybdo phosphoric yellow colour method (Jackson, 1958). The intensity of colour was read using Spectrophotometer at 420nm.

3. Potassium

The potassium content in the digested plant sample was estimated by using EEL Flame photometer (Jackson, 1958).

4. Calcium and Magnesium

The Ca and Mg contents were estimated using Atomic Absorption Spectrophotometer (AAS) (Jackson, 1958).

3.4.7. Nitrogen use efficiency

Nitrogen use efficiency was assessed in terms of agronomic efficiency (AE) index, as suggested by Dobermann and Fairhurst (2000). It is the increase in yield or the additional yield produced over unit quantity of applied nitrogen.

$$AE_N = \frac{Y_{+N} - Y_{0N}}{FN}$$

Where AE_N is the agronomic efficiency of applied nitrogen, Y_{+N} is the dry fodder yield in a treatment with nitrogen application, Y_{0N} is the dry fodder yield in a treatment without nitrogen application and FN is the amount of fertilizer N applied, all in Mg/ha.

3.4.8. Soil analysis

Analyses of soil were done before (experiment I, II and III) and after the experiment (experiment II) to find out organic carbon, available nitrogen, available phosphorus and available potassium. Methods adopted for soil analysis are given in Table 1.

3.5. DATA ANALYSES

The data were subjected to statistical analysis using WASP (WEB AGRI STAT PACKAGE Version 2.0), developed by Ashok Kumar Jangam and Pranjali Thali of ICAR Research Complex for Goa, India.

Results

4. RESULTS

Field trials were conducted at the Agronomy Research Farm of Kerala Agricultural University, Vellanikkara (2013 – 2015) to assess the feasibility of introducing hybrid napier cultivars under tree crop based farming system and to find out optimum nitrogen levels and harvesting management practices suitable for rainfed conditions. The experiments were done under three heads; (1) Shade tolerance of hybrid napier cultivars; (2) Nitrogen nutrition and cutting frequency in hybrid napier grown under rainfed condition; and (3) Cutting height management in hybrid napier grown under rainfed condition. Various observations recorded during the course of the experiment were analysed using suitable statistical tools and are presented in this chapter.

4.1. EXPERIMENT I: SHADE TOLERANCE OF HYBRID NAPIER CULTIVARS

Shade levels significantly affected the growth parameters of hybrid napier and as such had an impact on the fodder production. In both years, increasing shade levels had a facilitating effect on plant height, leaf length, leaf width, leaf area index, leaf area ratio, leaf weight ratio, leaf- stem ratio, chlorophyll content and light/PAR interception, and a reducing effect on the number of tillers, number of leaves, specific leaf weight, and fodder yield.

4.1.1. Morphological characters

Plant height

In general, plants showed higher plant height under 50 per cent shade and lower under open condition (Table 2 and Table 3). In the first year; the plants recorded maximum height at the first harvest, and thereafter, a decreasing trend was noticed. The crop had the highest plant height during the first harvest (75 DAP). If the effect of shade alone is considered, the plants showed maximum plant height under 50 per cent shade (192.58 cm) followed by 25 per cent shade (181.58 cm), and the least under open condition (169.16 cm). Among the cultivars, 'PTH' recorded maximum plant height followed by 'Suguna' and the least by 'IGFRI-3'.

Table 2. Effect of shade on plant height (cm) of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	169.16	145.17	106.08	49.71
25	181.58	161.98	124.49	60.83
50	192.58	175.52	132.96	70.35
LSD 5%	1.37	2.34	1.90	2.18
Cultivars				
CO-3	176.81	169.32	127.67	61.39
CO-4	183.16	167.33	124.76	58.87
Suguna	188.42	170.16	131.11	60.47
IGFRI-3	164.79	133.50	100.67	56.73
DHN-6	182.76	171.87	123.34	55.69
PTH	190.72	153.16	119.52	68.63
LSD 5%	1.84	1.95	2.41	1.49
Open				
CO-3	158.47	155.07	108.50	48.67
CO-4	176.30	148.33	105.77	48.77
Suguna	182.10	155.67	111.50	50.40
IGFRI-3	155.67	120.33	88.73	47.43
DHN-6	161.00	158.27	112.20	46.63
PTH	181.43	133.37	109.80	56.33
25 % shade				
CO-3	176.10	169.73	133.83	63.33
CO-4	178.83	169.23	130.50	58.50
Suguna	185.63	168.30	134.83	59.33
IGFRI-3	165.83	134.67	102.00	57.00
DHN-6	191.63	172.00	124.67	56.17
PTH	191.47	157.93	121.13	70.67
50 % shade				
CO-3	195.87	183.17	140.67	72.17
CO-4	194.33	184.43	138.00	69.33
Suguna	197.53	186.50	147.00	71.67
IGFRI-3	172.87	145.50	111.27	65.77
DHN-6	195.63	185.33	133.17	64.27
PTH	199.27	168.17	127.63	78.90
LSD 5%	3.18	3.38	4.17	2.56

Table 3. Effect of shade on plant height (cm) of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	127.53	165.99	119.23	169.79	92.01
25	155.15	176.56	137.88	181.28	111.28
50	168.99	185.02	149.44	191.49	122.54
LSD 5%	1.84	1.00	3.63	1.31	1.19
Cultivars					
CO-3	147.90	180.64	144.32	184.87	115.00
CO-4	150.28	178.16	136.27	186.01	113.58
Suguna	151.92	182.72	148.41	189.83	118.10
IGFRI-3	146.93	152.13	122.47	165.98	93.10
DHN-6	161.83	186.60	135.87	198.11	105.42
PTH	144.48	174.90	125.78	160.31	106.46
LSD 5%	1.93	1.68	2.27	2.27	2.07
Open					
CO-3	118.50	177.20	128.07	174.07	94.67
CO-4	125.43	171.93	125.07	176.60	94.73
Suguna	124.23	179.10	132.17	181.10	103.10
IGFRI-3	121.80	125.17	107.97	154.50	80.23
DHN-6	138.13	180.30	119.33	181.70	83.33
PTH	137.10	162.27	102.77	150.80	96.00
25 % shade					
CO-3	154.40	180.40	151.10	185.05	118.17
CO-4	153.67	178.50	136.90	184.80	113.80
Suguna	157.50	183.60	149.87	189.07	120.17
IGFRI-3	152.43	153.43	124.20	167.40	96.10
DHN-6	168.97	185.60	137.40	200.53	109.50
PTH	143.93	177.83	127.83	160.80	109.93
50 % shade					
CO-3	170.80	184.33	153.80	195.50	132.17
CO-4	171.73	184.03	146.83	196.63	132.20
Suguna	174.03	185.47	163.20	199.33	131.03
IGFRI-3	166.57	177.80	135.23	176.03	102.97
DHN-6	178.40	193.90	150.87	212.10	123.43
PTH	152.40	184.60	146.73	169.33	113.43
LSD 5%	3.35	2.93	3.94	3.94	3.59

Considering the differential effect of shade with respect to cultivars, maximum plant height under 50 per cent shade level was recorded by 'PTH' (199.27 cm) and the height of 'Suguna' (197.53 cm) was on par. 'Suguna' was on par with 'CO-3', 'DHN-6' and 'CO-4'. Under 25 per cent shade; 'DHN-6' (191.63 cm) and 'PTH' (191.47 cm) were at par and recorded maximum plant height, followed by 'Suguna'. When grown in full sunlight, maximum plant height was shown by 'PTH' (181.43 cm) and 'Suguna' (182.10 cm) which were at par. The least plant height was recorded by 'IGFRI-3' under all shade levels. Plant heights of 'IGFRI-3' and 'CO-3' were comparable under open condition.

At the time of second harvest also, maximum plant height recorded was under 50 per cent shade and the least in plants grown in full sunlight. With respect to cultivars, the plant height of 'DHN-6' and 'Suguna' were comparable and attained maximum height. 'Suguna' was on par with 'CO-3'. The least plant height was recorded by 'IGFRI-3'.

Considering interaction effects, under 50 per cent shade, 'Suguna', 'DHN-6', 'CO-4' and 'CO-3' were at par showing maximum height. Under 25 per cent shade, maximum plant height was attained by 'DHN-6' and 'CO-3,' which were on par. In full sunlight, the plant height of 'DHN-6', 'Suguna' and 'CO-3' were comparable with each other and showed maximum plant height. 'IGFRI-3' attained the least plant height at all shade levels.

At the third harvest, considering the main effects alone, under 50 per cent shade cultivars attained more than 130 cm of plant height and the least plant height was attained under full sunlight. Among the cultivars, 'Suguna' attained the first position and the least by 'IGFRI-3'.

The interaction effect was significant and maximum height of 147 cm was attained by 'Suguna' under 50 per cent shade. At 25 per cent shade 'Suguna', 'CO-3' and 'CO-4' were on par attaining the first position. When grown under full sunlight, 'DHN-6', 'Suguna', 'PTH' and 'CO-3' were on par and showed maximum height. The cultivar 'CO-3' was on par with 'CO-4' too. Under all shade levels, 'IGFRI-3' attained the least plant height.

By the time the harvest progressed and reached the fourth stage the growth of crops has reduced. Plants could attain a maximum of 70.35 cm height only under 50 per cent shade and minimum height was 49.71 cm in full sunlight. With respect to cultivars, 'PTH' attained the first position and the lowest position was by 'DHN-6' and 'IGFRI-3'. Considering the effect of shade on cultivars, 'PTH' showed maximum plant height under all shade levels and minimum by 'DHN-6' and 'IGFRI-3'. Whereas, under 25 per cent shade, the cultivar 'CO-4' was on par with 'DHN-6' and 'IGFRI-3'. In full sunlight; 'CO-3' and 'CO-4' were at par with 'IGFRI-3' and 'DHN-6'. Plant heights of 'Suguna', 'CO-3' and 'CO-4' also were comparable.

In the second year, maximum plant height was observed in the fourth harvest followed by the second harvest. When considering the effect of shade alone, throughout the harvests, plant height was maximum under 50 per cent shade and minimum under full sunlight. During the first harvest; among the cultivars, 'DHN-6' attained maximum height and minimum by 'PTH' and 'IGFRI-3'. Interaction was significant under 50 and 25 per cent shades, 'DHN-6' recorded maximum height and 'PTH' had the least. When grown in full sunlight, 'DHN-6' and 'PTH' were at par with each other and showed maximum height, whereas the least were recorded by 'CO-3' and 'IGFRI-3'. 'IGFRI-3' was on par with 'Suguna'. Plant heights of 'Suguna' and 'CO-4' were comparable.

In the second harvest, with respect to cultivars, maximum height was shown by 'DHN-6' and 'IGFRI-3' had the least height. Considering the interaction effect, 'DHN-6' showed maximum plant height under all shade levels and 'IGFRI-3' the least. Under 25 per cent shade and in full sunlight, heights of 'DHN-6' and 'Suguna' were comparable. In full sunlight, 'Suguna' was also at par with 'CO-3'.

In the third harvest, among the cultivars, 'Suguna' reached maximum height and 'IGFRI-3' the least. Regarding the interaction effect; under 50 percent shade, maximum height was recorded by 'Suguna' and the least was recorded by 'IGFRI-

3' and 'CO-3'. When grown under 25 per cent shade; maximum height was observed in 'CO-3' and 'Suguna' which were at par with each other. The heights of 'IGFRI-3' and 'PTH' were the lowest. In full sunlight, 'Suguna' showed maximum height and the least was observed in 'PTH'.

At the fourth harvest, under 50 and 25 per cent shade, 'DHN-6' attained the first position and the lowest was attained by 'PTH'. Under full sunlight, 'DHN-6' and 'Suguna' showed maximum plant height and they were on par. The height of 'PTH' and 'IGFRI-3' were comparable with each other and recorded minimum plant heights.

During the fifth harvest, among the cultivars, 'Suguna' and 'CO-3' recorded the maximum plant height. 'CO-3' was also at par with 'CO-4'. 'IGFRI-3' attained the least plant height at all shade levels. When grown under 50 per cent shade, 'CO-4', 'CO-3' and 'Suguna' were at par showing maximum plant height. At 25 per cent shade, 'Suguna' and 'CO-3' were on par and reached maximum height. When plants were exposed to full sunlight; 'Suguna' recorded maximum plant height. In full sunlight, 'DHN-6 and 'IGFRI-3' were on par with each other.

Leaf length

The leaf length of hybrid napier cultivars at different shade levels are given in Table 4 and Table 5. In the first year, all the cultivars recorded maximum leaf length at the second harvest, and thereafter, started decreasing towards the final harvest. Throughout the experimental period, maximum leaf length was attained under 50 per cent shade and the least on full exposure to sunlight.

During the first harvest, 'DHN-6' attained the first position, and the lowest position was attained by 'PTH'. Interactions were significant at all levels of shade. Under all shade levels, 'DHN-6' had maximum leaf length while 'PTH' had minimum leaf length, but under 50 per cent shade, leaf length of 'DHN-6' and 'IGFRI-3' were comparable with each other.

Table 4. Effect of shade on leaf length (cm) of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	69.29	80.54	59.79	31.68
25	78.87	93.17	71.69	33.92
50	87.08	102.84	78.34	36.43
LSD 5%	0.89	1.64	2.22	1.60
Cultivars				
CO-3	76.90	102.71	84.02	36.68
CO-4	75.84	102.93	77.27	37.14
Suguna	76.67	107.59	86.49	40.66
IGFRI-3	81.78	62.60	57.44	28.76
DHN-6	92.98	97.92	72.60	33.21
PTH	66.33	79.34	41.83	27.62
LSD 5%	2.70	2.95	1.94	1.75
Open				
CO-3	68.67	87.77	73.42	35.33
CO-4	66.00	85.17	69.87	35.50
Suguna	67.00	84.17	73.00	40.50
IGFRI-3	67.33	59.23	47.50	25.50
DHN-6	88.87	94.57	67.37	29.00
PTH	57.90	72.33	27.60	24.27
25 % shade				
CO-3	77.83	102.17	84.80	36.43
CO-4	75.67	104.77	76.93	36.93
Suguna	77.67	111.93	88.60	38.97
IGFRI-3	83.67	62.43	61.30	29.33
DHN-6	92.73	96.67	74.00	33.93
PTH	65.67	81.03	44.50	27.93
50 % shade				
CO-3	84.20	118.20	93.83	38.27
CO-4	85.87	118.87	85.00	39.00
Suguna	85.33	126.67	97.87	42.50
IGFRI-3	94.33	66.13	63.53	31.43
DHN-6	97.33	102.53	76.43	36.70
PTH	75.43	84.67	53.40	30.67
LSD 5%	4.69	5.11	3.37	3.04

Table 5. Effect of shade on leaf length (cm) of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	81.77	99.93	79.35	64.48	55.20
25	99.12	110.37	92.08	78.26	66.51
50	106.37	114.67	98.74	84.32	78.73
LSD 5%	1.84	1.41	7.98	1.62	4.97
Cultivars					
CO-3	103.24	117.22	102.47	82.31	68.71
CO-4	99.01	116.18	94.21	81.29	76.04
Suguna	108.54	116.63	95.49	87.32	73.12
IGFRI-3	90.90	92.62	86.62	61.06	55.00
DHN-6	102.73	111.81	95.04	87.96	77.28
PTH	70.08	95.48	66.50	54.19	50.71
LSD 5%	1.90	2.46	7.68	2.09	4.43
Open					
CO-3	86.00	108.00	94.57	67.37	56.70
CO-4	84.97	108.97	81.17	71.23	66.63
Suguna	86.10	106.57	77.20	74.40	59.53
IGFRI-3	83.70	84.87	83.27	53.07	47.00
DHN-6	87.57	104.53	85.07	73.47	61.57
PTH	62.27	86.63	54.83	47.37	39.77
25 % shade					
CO-3	103.97	120.47	104.87	87.07	63.43
CO-4	103.83	118.50	96.67	82.90	76.30
Suguna	119.03	119.63	101.27	90.03	72.20
IGFRI-3	90.97	94.47	86.43	62.10	56.53
DHN-6	106.10	112.97	95.97	92.33	83.23
PTH	70.83	96.20	67.27	55.10	47.33
50 % shade					
CO-3	119.77	123.20	107.97	92.50	85.99
CO-4	108.23	121.07	104.80	89.73	85.20
Suguna	120.50	123.70	108.00	97.53	87.63
IGFRI-3	98.03	98.53	90.17	68.00	61.47
DHN-6	114.53	117.93	104.10	98.07	87.03
PTH	77.13	103.60	77.40	60.10	65.03
LSD 5%	3.28	4.27	13.32	3.63	7.69

At second harvest, among the cultivars, maximum leaf length was observed in 'Suguna' and minimum in 'IGFRI- 3'. Under 50 and 25 per cent shade, 'Suguna' attained maximum leaf length, however in full sunlight, maximum value was observed in 'DHN-6'. At all shade levels, 'IGFRI-3' showed minimum leaf length.

In the third harvest, with respect to cultivars alone, 'Suguna' recorded maximum value while the least value was recorded in 'PTH'. Considering the interaction effect, under 50 per cent and 25 per cent shade, 'Suguna' recorded maximum leaf length, and 'PTH' recorded the least leaf length under all shade levels. In full sunlight, leaf length of 'CO-3' and 'Suguna' was comparable with each other showing maximum leaf length.

During the fourth harvest, among the cultivars, maximum leaf length was observed in 'Suguna' and minimum in 'PTH' and 'IGFRI-3'. Leaf lengths of 'CO-3', 'CO-4' and 'Suguna' at 25 per cent shade and open condition were comparable. At all shade levels, maximum values were observed for 'Suguna'. Under 25 per cent shade, 'Suguna' was on par with 'CO-4', 'CO-3' and 'DHN-6'. Leaf length of 'PTH' and 'IGFRI-3' were comparable at all shade levels and both cultivars recorded minimum leaf length.

In the second year, maximum leaf length was attained under 50 per cent shade at the time of second harvest and thereafter leaf length gradually got reduced towards the final harvest. In the first harvest, among the cultivars, 'Suguna' recorded maximum leaf length. 'PTH' had the least leaf length at all shade levels. Under 50 per cent shade, 'Suguna' and 'CO-3' were on par and recorded maximum leaf length. At 25 per cent shade, 'Suguna' recorded maximum leaf length. In full sunlight, 'DHN-6', 'Suguna', 'CO-3' and 'CO-4' were at par with each other and attained maximum leaf length, whereas 'IGFRI-3' was on par with 'Suguna', 'CO-3' and 'CO-4'.

During the second harvest, among the cultivars 'CO-3', 'Suguna' and 'CO-4' were at par with each other and had maximum leaf length. 'IGFRI-3' had minimum leaf length. Under 50 per cent shade, the leaf length of Suguna', 'CO-3' and 'CO-4' were comparable. They recorded maximum leaf length. The values of both'CO-4' and 'DHN-6' were comparable with each other. 'IGFRI-3' attained the lowest position. On exposure to 25 per cent shade, 'CO-3', 'Suguna' and 'CO-4' were on par and attained the first position, and the lowest position was attained by 'IGFRI-3' and 'PTH'. In full sunlight, 'CO-4', 'CO-3', 'Suguna' and 'DHN-6' were on par and showed maximum leaf length. 'IGFRI-3' and 'PTH' recorded the lowest leaf length.

In the third harvest, among the cultivars, 'CO-3', 'Suguna' and 'DHN-6' were on par and recorded maximum leaf length. 'Suguna' and 'DHN-6' were on par with 'CO-4'. 'PTH' showed minimum leaf length. When exposed to 50 per cent shade, 'Suguna', 'CO-3', 'CO-4' and 'DHN-6' were on par with each other and recorded maximum leaf length. 'PTH' and 'IGFRI-3' showed minimum leaf length and they were on par. At 25 per cent shade, leaf length of 'CO-3', 'Suguna', 'CO-4' and 'DHN-6' were comparable with each other and recorded maximum leaf length. 'DHN-6' was on par with 'IGFRI-3'. Minimum was observed in 'PTH'. Under open condition, 'CO-3', 'DHN-6', 'IGFRI-3'and 'CO-4' were on par and recorded maximum leaf length , whereas 'Suguna' was on par with 'DHN-6', 'IGFRI-3' and 'CO-4'. 'PTH' recorded the least leaf length.

Maximum leaf length during the experiment was attained in the fourth harvest. Considering the effect of cultivars alone, 'DHN-6' and 'Suguna' were on par and showed maximum leaf length, whereas 'PTH' showed the minimum length. In view of interaction effect; at 50 per cent shade, 'DHN-6' (98.07 cm) and 'Suguna' (97.53 cm) attained first position and they were on par. Similarly at 25 per cent shade 'DHN-6' (92.33 cm) and 'Suguna' (90.03 cm) attained first position. Also, they were on par with each other. 'Suguna' was also on par with 'CO-3'. Under full sunlight, 'Suguna' (74.40 cm), 'DHN-6' (73.47 cm) and 'CO-4' (71.23 cm) were on par and recorded maximum leaf length. At all shade levels, 'PTH' showed minimum leaf length.

During the fifth harvest, with respect to cultivars, leaf length of 'DHN-6', 'CO-4' and 'Suguna' were comparable and recorded maximum value. The minimum leaf length was attained by 'PTH' and 'IGFRI-3' and they were on par with each other. When exposed to 50 per cent shade, 'Suguna', 'DHN-6', 'CO-3' and 'CO-4' were on par and showed maximum leaf length whereas 'IGFRI-3' and 'PTH' showed minimum length also they were at par with each other. At 25 per cent shade, 'DHN-6' and 'CO-4' attained the first position, and 'PTH' the lowest position. In full sunlight, 'CO-4', and 'DHN-6' showed maximum leaf length, and minimum leaf length was observed in 'PTH'.

Leaf width

The data on leaf width are shown in Table 6 and Table 7. In the first year, maximum leaf width was recorded during the first harvest; thereafter, started decreasing towards the final harvest. The crop attained maximum leaf width under 50 per cent shade. During the first harvest, among the cultivars, maximum leaf width was observed in 'DHN-6' (3.31 cm) and minimum was observed in 'PTH' (1.05 cm). Considering the interaction effect, under all shade levels, 'DHN-6' recorded maximum leaf width, and 'PTH' the least.

In the second harvest also, with respect to cultivars, 'DHN-6' attained the first position and 'PTH' the lowest position. In view of interaction effect, at all shade levels, maximum leaf width was observed in 'DHN-6' and minimum was observed in 'PTH'. During the third harvest, among the cultivars, 'CO-4' recorded maximum leaf width and 'PTH' the least width. Similarly, on analysis of interaction effect, 'CO-4' attained first position and 'PTH' the lowest position under all shade levels.

At the fourth harvest, considering, the cultivar effect, maximum leaf width was recorded in 'CO-3' and 'Suguna', which were on par. The minimum was recorded in 'PTH'. On analysis of interaction effect, 'CO-3' and 'Suguna' were on par at all shade levels and recorded maximum leaf width. Under full sunlight, 'DHN-6' recorded maximum leaf width and was on par with 'CO-3', 'Suguna' and 'CO-4'. 'Suguna' was on par with 'CO-4' at all shade levels. 'PTH' recorded minimum leaf width at all shade levels.

Table 6. Effect of shade on leaf width (cm) of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	2.15	1.85	1.30	0.97
25	2.33	2.10	1.56	1.07
50	2.46	2.24	1.75	1.18
LSD 5%	0.04	0.07	0.04	0.03
Cultivars				
CO-3	2.39	2.26	1.81	1.38
CO-4	2.47	2.44	2.11	1.19
Suguna	2.37	2.28	1.83	1.32
IGFRI-3	2.31	1.85	1.03	0.99
DHN-6	3.31	2.73	1.81	1.07
PTH	1.05	0.81	0.63	0.51
LSD 5%	0.06	0.13	0.08	0.07
Open				
CO-3	2.30	1.93	1.43	1.25
CO-4	2.39	2.37	1.93	1.07
Suguna	2.17	1.93	1.55	1.15
IGFRI-3	2.13	1.80	0.90	0.80
DHN-6	3.03	2.50	1.57	1.16
PTH	0.89	0.59	0.42	0.40
25 % shade				
CO-3	2.39	2.39	1.88	1.40
CO-4	2.48	2.46	2.13	1.20
Suguna	2.36	2.33	1.84	1.34
IGFRI-3	2.30	1.85	1.00	0.99
DHN-6	3.39	2.73	1.91	0.97
PTH	1.07	0.83	0.60	0.52
50 % shade				
CO-3	2.49	2.47	2.13	1.50
CO-4	2.53	2.48	2.26	1.30
Suguna	2.57	2.58	2.10	1.46
IGFRI-3	2.50	1.90	1.19	1.17
DHN-6	3.49	2.97	1.97	1.07
PTH	1.19	1.02	0.87	0.60
LSD 5%	0.10	0.24	0.14	0.11

Table 7. Effect of shade on leaf width (cm) of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	2.31	2.67	1.94	1.61	1.25
25	2.55	2.91	2.18	1.91	1.46
50	2.92	3.16	2.44	2.10	1.67
LSD 5%	0.04	0.08	0.08	0.06	0.03
Cultivars					
CO-3	2.77	3.25	2.47	1.98	1.56
CO-4	2.82	3.18	2.47	2.10	1.75
Suguna	2.77	3.19	2.51	2.19	1.71
IGFRI-3	2.78	2.95	2.24	1.71	0.97
DHN-6	3.58	3.69	2.41	2.32	1.90
PTH	0.83	1.22	1.00	0.93	0.88
LSD 5%	0.08	0.10	0.11	0.06	0.11
Open					
CO-3	2.55	3.10	2.13	1.70	1.27
CO-4	2.53	3.00	2.13	1.70	1.62
Suguna	2.47	2.93	2.23	1.87	1.47
IGFRI-3	2.50	2.77	2.07	1.51	0.77
DHN-6	3.13	3.19	2.17	2.03	1.70
PTH	0.70	1.00	0.89	0.82	0.70
25 % shade					
CO-3	2.73	3.24	2.47	2.03	1.53
CO-4	2.83	3.13	2.37	2.17	1.70
Suguna	2.73	3.20	2.53	2.22	1.75
IGFRI-3	2.77	2.97	2.21	1.74	1.00
DHN-6	3.43	3.57	2.47	2.40	1.93
PTH	0.80	1.37	1.02	0.90	0.83
50 % shade					
CO-3	3.03	3.42	2.80	2.21	1.87
CO-4	3.10	3.40	2.90	2.43	1.93
Suguna	3.12	3.43	2.78	2.50	1.90
IGFRI-3	3.07	3.11	2.46	1.90	1.13
DHN-6	4.17	4.30	2.60	2.53	2.07
PTH	1.00	1.30	1.10	1.05	1.10
LSD 5%	0.13	0.17	0.18	0.10	0.17

In the second year, the highest values for leaf width were observed at second harvest at 50 per cent shade. At the first harvest, maximum leaf width was observed in 'DHN-6' and minimum in 'PTH'. Regarding the interaction effect, 'DHN-6' recorded maximum leaf width at all shade levels and 'PTH', minimum leaf width.

The highest value of 4.30 cm leaf width was recorded in 'DHN-6' at 50 per cent shade during the second harvest. Under all shade levels, 'DHN-6' showed maximum leaf width and 'PTH' showed minimum width. In full sunlight, 'CO-3' and 'CO-4' was on par with 'DHN-6' and showed maximum leaf width. Leaf width of 'Suguna' was comparable with 'CO-3', 'CO-4' and 'IGFRI-3'.

In the third harvest, maximum leaf width was recorded in 'Suguna', 'CO-3' and 'CO-4' and they were on par. 'PTH' recorded minimum leaf width. At 50 per cent shade; the leaf width of 'CO-4', 'CO-3' and 'Suguna' were comparable while they recorded maximum leaf width. 'Suguna' was on par with 'DHN-6', whereas 'DHN-6' was on par with 'IGFRI-3'. Similarly at 25 per cent shade, leaf width of 'Suguna', 'CO-3', 'DHN-6' and 'CO-4' were comparable and recorded maximum leaf width. 'CO-4' was on par with 'IGFRI-3'. In full sunlight, leaf width of all cultivars except 'PTH' were on par. Under all shade levels minimum leaf width was observed in 'PTH'.

During the fourth harvest, among the cultivars and interactions, maximum leaf width was recorded in 'DHN-6' and the least width in 'PTH'. At 50 per cent shade, leaf width of 'Suguna' and 'CO-4' were comparable with 'DHN-6' and showed maximum leaf width. At the final harvest, among different cultivars, 'DHN-6' recorded maximum leaf width at all shade levels and 'PTH' the minimum leaf width. At 50 per cent shade and full sunlight, the leaf width of 'PTH' was comparable with 'IGFRI-3'.

Table 8. Effect of shade on no. of tillers/clump of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	13.70	21.19	36.28	53.03
25	11.61	17.67	28.52	46.13
50	10.21	13.94	24.84	43.50
LSD 5%	1.34	1.54	1.66	0.92
Cultivars				
CO-3	11.84	15.96	30.21	44.37
CO-4	8.84	12.49	25.44	42.03
Suguna	13.51	19.59	29.48	43.22
IGFRI-3	14.84	18.41	37.73	61.03
DHN-6	9.03	14.81	19.73	30.44
PTH	12.96	24.37	36.67	64.22
LSD 5%	1.43	1.32	1.83	1.37
Open				
CO-3	13.67	20.56	39.00	47.00
CO-4	9.80	14.83	36.33	48.10
Suguna	15.87	23.67	36.00	49.00
IGFRI-3	16.33	21.67	42.67	67.43
DHN-6	11.10	16.78	20.67	35.67
PTH	15.43	29.67	43.00	71.00
25 % shade				
CO-3	12.00	16.33	26.67	43.77
CO-4	8.87	12.30	22.00	41.00
Suguna	13.00	21.77	27.67	42.00
IGFRI-3	14.33	17.89	36.43	59.00
DHN-6	8.67	15.00	19.67	28.67
PTH	12.77	22.77	38.67	62.33
50 % shade				
CO-3	9.87	11.00	24.97	42.33
CO-4	7.87	10.33	18.00	37.00
Suguna	11.67	13.33	24.77	38.67
IGFRI-3	13.87	15.67	34.10	56.67
DHN-6	7.33	12.67	18.87	27.00
PTH	10.67	20.67	28.33	59.33
LSD 5%	2.46	2.31	3.19	2.37

Table 9. Effect of shade on no. of tillers/clump of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	27.00	34.17	47.67	56.02	60.74
25	23.04	29.81	38.26	52.00	56.83
50	19.40	26.17	34.50	46.72	52.33
LSD 5%	0.39	1.24	1.39	1.90	1.59
Cultivars	19.11	25.18	35.44	48.11	52.00
CO-3	17.29	21.67	33.22	44.78	48.92
CO-4	20.73	25.78	37.33	50.11	52.78
Suguna	24.96	34.67	47.44	64.92	67.00
IGFRI-3	22.40	24.56	28.18	33.89	37.11
DHN-6	34.40	48.44	59.22	67.67	82.00
PTH					
LSD 5%	1.32	1.21	1.04	1.58	1.46
Open					
CO-3	20.67	27.67	44.33	51.00	55.67
CO-4	18.67	26.00	40.67	49.33	52.10
Suguna	23.33	29.67	45.00	54.67	56.33
IGFRI-3	27.67	40.67	57.33	68.77	70.67
DHN-6	24.67	27.33	32.67	38.67	42.33
PTH	47.00	53.67	66.00	73.67	87.33
25 % shade					
CO-3	19.67	26.53	34.33	48.00	51.67
CO-4	17.53	22.00	32.00	46.00	48.67
Suguna	20.67	25.67	34.67	51.00	52.33
IGFRI-3	25.53	32.67	44.33	66.00	67.67
DHN-6	22.53	24.00	26.53	32.00	36.33
PTH	32.33	48.00	57.67	69.00	84.33
50 % shade					
CO-3	17.00	21.33	27.67	45.33	48.67
CO-4	15.67	17.00	27.00	39.00	46.00
Suguna	18.20	22.00	32.33	44.67	49.67
IGFRI-3	21.67	30.67	40.67	60.00	62.67
DHN-6	20.00	22.33	25.33	31.00	32.67
PTH	23.87	43.67	54.00	60.33	74.33
LSD 5%	2.29	2.10	1.80	2.72	2.52

Number of tillers

The data pertaining to number of tiller per clump are given in Table 8 and Table. 9. Maximum tiller production was observed under full sunlight. During both years, tiller numbers showed an increasing trend towards the final harvests, but after the final harvest of the first year, tiller decline was noticed, until the first harvest of the second year.

During the first harvest, among the cultivars, maximum number of tillers was observed in 'IGFRI-3' which was on par with 'Suguna' and 'PTH'; both were on par with 'CO-3'. The lowest number of tillers was observed in 'CO-4' and 'DHN-6', which were on par. In full sunlight, 'IGFRI-3', 'Suguna' and 'PTH' were at par and showed maximum number of tillers. 'Suguna' and 'PTH' were on par with 'CO-3'. The least number of tillers were observed in 'CO-4' and 'DHN-6', both were at par with each other. Under 25 per cent shade, tiller number of 'IGFRI-3', 'Suguna', 'PTH' and 'CO-3' were comparable showing maximum number of tillers. The minimum was observed in 'DHN-6' and 'CO-4', both were at par. At 50 per cent shade, 'IGFRI-3' recorded maximum number of tillers and was on par with 'Suguna'. 'DHN-6' and 'CO-4' were at par and showed the least number of tillers.

During the second harvest, with respect to cultivars, 'Suguna' and 'IGFRI-3' were at par and showed maximum number of tillers. 'CO-4' showed the least number of tillers. Considering the interaction effect, in full sunlight, maximum number of tillers was observed in 'PTH'. 'CO-4' and 'DHN-6' were at par and showed minimum number of tillers. At 25 per cent shade, 'PTH' and 'Suguna' were at par and showed maximum number of tillers. 'CO-4' showed the least number of tillers. In 50 per cent shade too, 'PTH' recorded maximum number of tillers and the minimum was observed in 'CO-4', 'CO-3' and 'DHN-6', which were at par.

During the third harvest, 'IGFRI-3' and 'PTH' were at par and showed maximum number of tillers. 'DHN-6' showed minimum number of tillers. In full sunlight, maximum number of tillers were observed in 'PTH' and 'IGFRI-3' and they were at par. 'IGFRI-3' was on par with 'CO-3' which was on par with 'CO-4' and 'Suguna'. 'DHN-6' recorded minimum number of tillers. At 25 per cent shade, 'PTH' and 'IGFRI-3' were at par and showed maximum while minimum was observed in 'DHN-6' and 'CO-4', they were on par with each other. In 50 per cent shade, 'IGFRI-3' attained the first position and the lowest position was attained by 'DHN-6' and 'CO-4', tiller number in both cultivars were comparable with each other.

At the fourth harvest, among the cultivars, maximum number of tillers were observed in 'PTH' and 'IGFRI-3' while minimum was observed in 'DHN-6'. At all shade levels, 'PTH' attained the first position and 'DHN-6' attained the lowest position. The highest number of tillers of 71 /clump was produced by 'PTH' in full sunlight.

In the second year, during the first harvest, maximum number of tillers was observed in 'PTH' and minimum was observed in 'CO-4'. Under open condition, 'PTH' attained the first position while 'CO-4' and 'CO-3' attained the lowest position which were on par with each other. At 25 per cent shade, maximum number of tillers was recorded in 'PTH' and, 'Co4' recorded minimum number of tillers. 'CO-4' was on par with 'CO-3'. Under 50 per cent shade, 'PTH' recorded maximum number of tillers and was on par with 'IGFRI-3'. Minimum number of tillers was recorded in 'CO-4' which was on par with 'CO-3'.

In the second harvest, with respect to cultivars, 'PTH' showed maximum number of tillers and 'CO-4' showed minimum. Under open condition, maximum number of tillers was observed in 'PTH'. 'CO-4', 'DHN-6'and 'CO-3' were at par and showed minimum number of tillers. At 25 per cent shade, 'PTH' recorded maximum number of tillers and minimum was recorded in 'CO-4' which was on par with 'DHN-6'. 'DHN-6' was on par with 'Suguna' and 'CO-3'. At 50 per cent shade, 'PTH' recorded maximum number of tillers and minimum number of tillers was observed in 'CO-4'.

In the third harvest, 'PTH' recorded maximum number of tillers while 'DHN-6' recorded minimum. At 50 per cent shade, 'CO-4' was at par with 'DHN-6' and 'CO-3' and showed maximum number of tillers. During the fourth and fifth harvests; 'PTH' attained first position and 'DHN-6' attained the lowest position.

Table 10. Effect of shade on no. of leaves/clump of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	97.48	156.06	225.04	240.91
25	84.62	126.94	181.11	209.38
50	72.97	99.44	154.49	193.75
LSD 5%	3.83	7.16	3.76	2.30
Cultivars				
CO-3	87.10	128.82	161.90	197.59
CO-4	66.21	86.39	143.23	189.56
Suguna	95.93	153.05	181.04	195.17
IGFRI-3	115.23	136.60	262.24	274.54
DHN-6	66.60	107.06	114.96	136.33
PTH	79.08	152.98	257.89	294.89
LSD 5%	4.62	6.42	3.30	2.73
Open				
CO-3	97.37	161.12	208.70	212.00
CO-4	75.61	96.20	203.77	219.52
Suguna	112.65	188.90	206.13	222.17
IGFRI-3	120.73	164.83	299.67	305.12
DHN-6	84.37	129.14	137.65	163.83
PTH	94.15	196.17	294.33	322.83
25 % shade				
CO-3	88.53	140.67	144.67	196.95
CO-4	68.15	88.56	118.73	183.33
Suguna	92.30	167.60	180.97	189.33
IGFRI-3	116.80	130.60	255.03	266.17
DHN-6	64.03	102.90	106.23	125.67
PTH	77.94	131.32	281.00	294.83
50 % shade				
CO-3	75.39	84.67	132.32	183.83
CO-4	54.88	74.40	107.20	165.83
Suguna	82.83	102.63	156.03	174.00
IGFRI-3	108.16	114.37	232.03	252.33
DHN-6	51.40	89.13	100.99	119.50
PTH	65.13	131.47	198.33	267.00
LSD 5%	8.00	11.11	5.71	4.73

Table 11. Effect of shade on no. of leaves/clump of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	217.02	244.28	310.94	365.10	392.56
25	188.75	222.21	252.73	339.31	364.75
50	162.21	198.48	229.28	303.92	340.93
LSD 5%	2.64	3.20	2.62	3.06	2.07
Cultivars					
CO-3	164.98	179.60	231.50	316.07	337.83
CO-4	159.81	170.56	216.50	292.08	315.78
Suguna	188.64	195.40	244.07	321.14	341.72
IGFRI-3	239.40	254.81	309.77	418.77	435.14
DHN-6	178.93	189.77	198.89	226.17	241.44
PTH	204.18	339.80	385.19	442.42	524.56
LSD 5%	2.63	2.37	3.04	3.6	2.84
Open					
CO-3	187.27	197.07	288.17	338.20	364.83
CO-4	177.63	188.67	261.00	320.07	335.33
Suguna	206.00	214.33	296.70	342.00	367.17
IGFRI-3	251.70	284.67	376.97	446.98	458.50
DHN-6	192.20	208.60	217.17	264.67	275.17
PTH	287.30	372.33	425.67	478.67	554.33
25 % shade					
CO-3	163.03	185.73	223.17	315.33	332.50
CO-4	159.47	167.33	209.67	302.33	313.00
Suguna	197.60	199.00	225.33	332.17	338.50
IGFRI-3	244.34	255.00	288.17	419.33	439.83
DHN-6	181.27	186.83	194.80	210.67	236.83
PTH	186.77	339.33	375.23	456.00	527.83
50 % shade					
CO-3	144.63	156.00	183.17	294.67	316.17
CO-4	142.33	155.67	178.83	253.83	299.00
Suguna	162.33	172.87	210.17	289.27	319.50
IGFRI-3	222.17	224.77	264.17	390.00	407.10
DHN-6	163.33	173.87	184.70	203.17	212.33
PTH	138.48	307.73	354.67	392.60	491.50
LSD 5%	4.55	4.10	5.26	6.23	4.91

Number of leaves

The number of leaves per plant at each harvest are presented in Table 10 and Table 11. The data on leaf number showed the same trend as that of tiller number. The crop produced maximum number of leaves when grown in full sunlight and with increasing shade levels, inverse relation was noticed in leaf production. During both years, the highest number of leaves was shown in later harvests. After the final harvest in the first year, leaf production was reduced and started increasing after the first harvest, in the second year.

During the first year, 'IGFRI-3' produced maximum number of leaves and the minimum was noticed in 'DHN-6' and 'CO-4', which were on par with each other under 50 per cent and 25 per cent shade. Under open condition, the minimum number of leaves was observed in 'CO-4'. In the second harvest, 'Suguna' and 'PTH' surpassed 'IGFRI-3'and recorded maximum number of leaves, and both were on par. Under full sunlight, 'PTH' and 'Suguna' were on par and recorded maximum number of leaves. Whereas, under 25 per cent shade, 'Suguna' recorded maximum. Under 50 per cent, 'PTH' recorded maximum number of leaves. Under all levels of shade, the minimum number of leaves was noticed in 'CO-4'. At 50 per cent shade, 'Co- 4' was on par with 'CO-3' and 'DHN-6'.

At the third harvest, among the cultivars, 'IGFRI-3' recorded maximum number of leaves while 'DHN-6' the least. Considering the interaction effect, in full sunlight, maximum values was observed in 'IGFRI-3' and 'PTH' which were at par and the least was observed in 'DHN-6' . Under 25 per cent shade, 'PTH', recorded maximum number of leaves and 'DHN-6' the minimum. At 50 per cent shade, 'IGFRI-3', produced maximum number of leaves and 'DHN-6' produced the minimum.

During the fourth harvest, 'PTH' attained the first position at all shade levels and 'DHN-6' attained the lowest position. On an average, 'PTH' could produce 322.83 leaves from a single plant in full sunlight.

In the second year, during the first harvest, 'IGFRI-3' recorded the maximum number of leaves and 'CO-4' recorded minimum. In full sunlight, maximum leaf production was observed in 'PTH' and the least was observed in 'CO-4'. At 25 per cent shade, 'IGFRI-3' showed maximum leaf production and 'CO-4' the minimum. Whereas, under 50 per cent shade, 'IGFRI-3' showed maximum number of leaves and 'PTH' showed the minimum.

During the second harvest, maximum leaf production was noticed in 'PTH and minimum was noticed in 'CO-4' at all shade levels. At 50 per cent shade, 'CC 3' was on par with 'CO-4' and showed the least number of leaves. In the thi harvest, at all shade levels, maximum leaf production was observed in 'PTH' a minimum was observed in 'DHN-6', but under 50 per cent shade, the low position was attained by 'CO-3' and 'CO-4' which were at par with each other.

By the fourth and fifth harvests also, under all levels of shade, 'P attained the first position and 'DHN-6' attained the lowest position. At the fo harvest, under 50 per cent shade, both 'PTH' and 'IGFRI-3' were at par recorded maximum leaf production. By the final harvest, 'PTH' could pro 554.33 leaves per plant in full sunlight.

4.1.2. Growth analysis

Leaf area index (LAI)

The data pertaining to leaf area index are given in Table 12 and Tab LAI showed an increasing trend with increasing shade levels. Througho experiment, maximum LAI was recorded under 50 per cent shade. In both yea highest LAI values was recorded in the second harvest.

During the first year, at the first harvest, 'Suguna' showed maximu while 'PTH' showed the least. Under 50 and 25 per cent shade, 'CO-3' was with 'Suguna' and showed maximum LAI. In the second harvest, amo cultivars, 'CO-3' attained the highest position. Under 50 per cent shade, 'S showed maximum LAI of 12.01. At 25 per cent shade, 'CO-3' and 'Suguna'

Table 12. Effect of shade on leaf area index (LAI) of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	7.16	8.15	6.15	0.89
25	7.66	8.67	6.56	0.97
50	8.26	9.22	7.04	1.09
LSD 5%	0.03	0.13	0.10	0.01
Cultivars				
CO-3	8.89	10.89	9.02	1.12
CO-4	8.57	9.24	7.24	0.95
Suguna	9.38	10.73	9.22	1.36
IGFRI-3	8.25	8.79	6.95	0.74
DHN-6	6.71	7.64	4.03	0.86
PTH	4.37	4.80	3.07	0.85
LSD 5%	0.13	0.10	0.16	0.02
Open				
CO-3	8.14	10.11	8.90	1.09
CO-4	7.98	9.12	6.74	0.89
Suguna	9.17	9.45	8.86	1.22
IGFRI-3	7.92	8.43	6.69	0.58
DHN-6	5.83	7.30	3.00	0.78
PTH	3.94	4.50	2.72	0.76
25 % shade				
CO-3	9.04	10.84	9.03	1.11
CO-4	8.57	9.26	7.26	0.96
Suguna	9.27	10.72	9.24	1.37
IGFRI-3	8.24	8.91	6.96	0.62
DHN-6	6.46	7.50	3.93	0.88
PTH	4.36	4.80	2.96	0.86
50 % shade				
CO-3	9.49	11.72	9.13	1.17
CO-4	9.14	9.34	7.70	1.01
Suguna	9.70	12.01	9.55	1.48
IGFRI-3	8.61	9.03	7.18	1.02
DHN-6	7.83	8.11	5.17	0.93
PTH	4.81	5.10	3.53	0.92
LSD 5%	0.23	0.17	0.26	0.05

Table 13. Effect of shade on leaf area index (LAI) of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	7.75	11.85	7.77	6.86	3.40
25	8.39	12.50	8.71	7.53	3.73
50	8.68	12.85	9.83	7.96	4.05
LSD 5%	0.07	0.18	0.17	0.13	0.04
Cultivars					
CO-3	10.05	15.05	10.07	8.80	4.10
CO-4	9.91	14.49	12.10	9.09	5.72
Suguna	10.62	15.55	10.57	10.04	5.37
IGFRI-3	9.89	11.28	8.32	6.29	2.25
DHN-6	6.22	12.51	7.01	7.45	3.24
PTH	2.96	5.52	4.55	3.02	1.68
LSD 5%	0.10	0.11	0.14	0.20	0.04
Open					
CO-3	9.75	14.10	8.07	8.44	3.70
CO-4	9.38	13.77	11.46	8.45	5.53
Suguna	9.71	15.33	8.77	8.64	4.55
IGFRI-3	9.18	10.51	7.83	5.81	2.18
DHN-6	5.61	12.21	6.42	7.33	2.95
PTH	2.83	5.22	4.10	2.49	1.49
25 % shade					
CO-3	10.10	15.27	9.73	8.70	3.81
CO-4	10.15	14.59	12.12	9.28	5.78
Suguna	10.90	15.62	10.73	10.39	5.69
IGFRI-3	9.93	11.53	8.32	6.32	2.26
DHN-6	6.38	12.53	6.80	7.36	3.23
PTH	2.91	5.46	4.55	3.11	1.61
50 % shade					
CO-3	10.29	15.80	12.42	9.27	4.78
CO-4	10.20	15.11	12.72	9.55	5.86
Suguna	11.24	15.70	12.22	11.10	5.87
IGFRI-3	10.54	11.82	8.81	6.73	2.31
DHN-6	6.66	12.80	7.82	7.65	3.55
PTH	3.15	5.88	4.99	3.47	1.94
LSD 5%	0.17	0.20	0.23	0.35	0.07

par and recorded maximum LAI. 'CO-3' attained the first position under open condition. Under all shade levels, 'PTH' attained the lowest position.

At the third harvest, 'Suguna' had the maximum LAI and 'PTH' the minimum LAI. At 25 per cent shade and open condition, LAI of 'CO-3' was comparable with 'Suguna' with maximum values. During the fourth harvest, among the cultivars 'Suguna' recorded maximum LAI and 'IGFRI-3' the least. Both under open condition and 25 per cent shade, 'IGFRI-3' recorded the least LAI, but under 50 per cent shade, 'PTH' and 'DHN-6' were at par showing the least LAI.

In the second year, at first harvest, maximum LAI was observed in 'Suguna'. In full sunlight, the highest LAI was recorded in 'CO-3' (9.75) which was on par with 'Suguna'. At second harvest too, 'Suguna' showed maximum LAI, and under 50 per cent shade, LAI of 'CO-3' and 'Suguna' were comparable. In the third harvest, the highest LAI was observed in 'CO-4'.

During the fourth harvest, among the cultivars, 'Suguna' showed maximum LAI. However, under open condition, LAI of 'Suguna' was comparable with 'CO-4' and 'CO-3'. At the final harvest, with respect to cultivars, maximum LAI was recorded in 'CO-4' whereas under 50 percent shade the highest LAI was observed in 'Suguna' which was on par with 'CO-4'. Throughout the experiment, at all shade levels the lowest LAI was produced by 'PTH'.

Leaf area ratio (LAR)

Leaf area ratio of hybrid napier cultivars at each harvest are presented in Table 14 and Table 15. The plants showed an increase in LAR, with increasing shade levels and the highest LAR was observed in cultivars grown under 50 per cent shade. In the first year, during the first harvest, 'CO-4' attained the first position and 'PTH' attained the lowest. Under 50 per cent shade, LAR of 'CO-3', 'CO-4' (1.85 dm^2/g) and 'DHN-6' (1.82 dm^2/g) were comparable attaining maximum values. At 25 per cent shade, 'CO-4' and 'DHN-6' had comparable ratios and showed

Table 14. Effect of shade on leaf area ratio (dm^2/g) of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	1.14	1.39	1.52	1.79
25	1.39	1.65	1.62	1.90
50	1.61	1.95	1.73	1.99
LSD 5%	0.03	0.03	0.13	0.10
Cultivars				
CO-3	1.46	1.81	1.69	1.98
CO-4	1.57	1.94	1.76	2.06
Suguna	1.40	1.82	1.68	1.97
IGFRI-3	1.29	1.44	1.63	1.78
DHN-6	1.53	1.79	1.73	2.16
PTH	1.01	1.18	1.25	1.42
LSD 5%	0.03	0.03	0.11	0.07
Open				
CO-3	1.18	1.49	1.55	1.91
CO-4	1.28	1.74	1.61	1.96
Suguna	1.16	1.40	1.56	1.89
IGFRI-3	1.11	1.17	1.71	1.73
DHN-6	1.22	1.53	1.56	1.94
PTH	0.89	0.99	1.13	1.31
25 % shade				
CO-3	1.37	1.81	1.70	1.96
CO-4	1.57	1.87	1.77	2.03
Suguna	1.47	1.85	1.69	1.96
IGFRI-3	1.33	1.45	1.56	1.83
DHN-6	1.55	1.76	1.70	2.21
PTH	1.03	1.15	1.25	1.42
50 % shade				
CO-3	1.85	2.10	1.83	2.08
CO-4	1.85	2.21	1.89	2.19
Suguna	1.59	2.21	1.78	2.05
IGFRI-3	1.44	1.69	1.62	1.79
DHN-6	1.82	2.09	1.91	2.33
PTH	1.12	1.40	1.35	1.53
LSD 5%	0.03	0.05	0.18	0.11

Table 15. Effect of shade on leaf area ratio (dm^2/g) of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	1.62	1.45	1.55	1.14	1.36
25	2.03	1.79	1.87	1.46	1.59
50	2.25	2.02	2.13	1.61	1.84
LSD 5%	0.01	0.08	0.05	0.04	0.03
Cultivars					
CO-3	2.19	1.98	2.10	1.42	1.64
CO-4	2.04	1.91	1.96	1.54	1.72
Suguna	2.19	1.92	2.07	1.59	1.75
IGFRI-3	2.24	1.68	1.82	1.26	1.51
DHN-6	2.29	2.06	2.04	1.84	1.88
PTH	0.83	0.96	1.10	0.77	1.08
LSD 5%	0.04	0.06	0.05	0.03	0.03
Open					
CO-3	1.82	1.69	1.78	1.23	1.34
CO-4	1.69	1.47	1.62	1.12	1.46
Suguna	1.71	1.52	1.68	1.25	1.57
IGFRI-3	1.87	1.41	1.62	1.12	1.43
DHN-6	1.91	1.78	1.70	1.53	1.62
PTH	0.70	0.86	0.92	0.57	0.76
25 % shade					
CO-3	2.23	2.03	2.15	1.42	1.60
CO-4	2.12	2.00	1.97	1.64	1.72
Suguna	2.34	1.96	2.19	1.79	1.73
IGFRI-3	2.35	1.66	1.78	1.25	1.48
DHN-6	2.35	2.07	2.02	1.84	1.87
PTH	0.81	0.97	1.10	0.79	1.12
50 % shade					
CO-3	2.53	2.22	2.36	1.60	1.99
CO-4	2.32	2.27	2.30	1.84	1.99
Suguna	2.52	2.28	2.35	1.73	1.95
IGFRI-3	2.51	1.97	2.06	1.41	1.61
DHN-6	2.62	2.32	2.39	2.13	2.15
PTH	0.98	1.04	1.29	0.95	1.35
LSD 5%	0.06	0.09	0.07	0.04	0.05

maximum LAR. In full sunlight, 'CO-4' showed maximum LAR. At all levels of shade, the minimum was observed in 'PTH'.

During the second harvest, maximum LAR was observed in 'CO-4' and minimum in 'PTH'. At 50 per cent and 25 per cent shade, 'CO-4' and 'Suguna' were at par and attained the first position. In full sunlight, 'CO-4' attained the first position. At all shade levels, 'PTH' attained the lowest position.

In the third harvest, among the cultivars, LAR of 'CO-4', 'DHN-6', 'CO-3'and 'Suguna' were comparable and had the maximum LAR while 'PTH' had the minimum. Considering the interaction effect, at 50 per cent shade, 'DHN-6', 'CO-4', 'CO-3'and 'Suguna' were at par recording the maximum values. At 25 per cent shade, maximum value was attained by 'CO-4', 'CO-3', 'DHN-6' and 'Suguna' which were at par. In full sunlight, all cultivars except 'PTH' were at par with each other and showed the maximum LAR. Under all shade levels 'PTH' showed the minimum.

In the fourth harvest, 'DHN-6' attained the first position and 'PTH' had the lowest. Under both shade levels, 'DHN-6' attained the first position. In open condition, 'CO-4', 'DHN-6', 'CO-3' and 'Suguna' were at par and showed maximum LAR. 'PTH' showed the minimum LAR at all shade levels.

During the second year, at the first harvest, among the cultivars, 'DHN-6' attained the first position while 'PTH' attained the lowest position. In full sunlight, 'DHN-6'and 'IGFRI-3' were on par and attained the first position. 'CO-3' was on par with 'IGFRI-3'. At 25 per cent shade, 'DHN-6', 'IGFRI-3' and 'Suguna' were at par and showed maximum LAR. 'DHN-6' recorded the highest value at 50 per cent shade. 'PTH' recorded the least LAR at all levels of shade.

In the second harvest, maximum LAR was observed in 'DHN-6' and minimum in 'PTH'. At 50 per cent shade, 'DHN-6', 'Suguna' and 'CO-4' were at par and showed maximum LAR. 'CO-3' was at par with 'CO-4'. In 25 per cent shade, values of 'DHN-6', 'CO-3' and 'CO-4' were comparable and showed maximum LAR. In open condition, 'DHN-6' and 'CO-3' recorded maximum LAR which were at par. 'PTH' recorded minimum LAR at all levels of shade.

At third harvest, 'CO-3' and 'Suguna' were at par and recorded maximum LAR and 'PTH' recorded minimum LAR. Under 50 per cent shade, 'DHN-6', 'CO-3' and 'Suguna' were at par and showed maximum LAR. In 25 per cent shade, 'Suguna' and 'CO-3' were at par and showed maximum LAR. Under open condition, 'CO-3' attained the first position. At all levels of shade, minimum LAR was observed in 'PTH'. During the fourth and fifth harvests, 'DHN-6' attained the first position and 'PTH' had the lowest.

Leaf weight ratio (LWR)

The data pertaining to leaf weight ratio of hybrid napier cultivars at different shade levels are presented in Table 16 and Table 17. The LWR increased with increasing shade levels and maximum was obtained under 50 per cent shade. 'PTH' recorded the least LWR at all harvests under various levels of shade.

During the first year, in the first harvest, among the cultivars, 'Suguna' recorded maximum LWR. At 50 per cent shade, 'Suguna', 'CO-3' and 'CO-4' recorded maximum LWR and were at par. At 25 per cent shade, 'Suguna' recorded maximum LWR. In full sunlight, 'Suguna' had the highest ratio, which was on par with 'CO-3'. At all levels of shade, 'PTH' recorded the least.

In the second harvest, considering the effect of shade alone, the LWR values were comparable at both 25 per cent and 50 per cent levels of shade. At all levels of shade, 'Suguna' and 'CO-3' were at par and showed maximum LWR. At 50 per cent shade, 'CO-4' was at par with both cultivars and showed maximum LWR. 'PTH' recorded the lowest LWR values.

Table 16. Effect of shade on leaf weight ratio of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	0.53	0.59	0.72	0.66
25	0.58	0.61	0.74	0.67
50	0.62	0.63	0.74	0.68
LSD 5%	0.01	0.02	0.01	0.003
Cultivars				
CO-3	0.60	0.66	0.78	0.70
CO-4	0.59	0.64	0.77	0.70
Suguna	0.63	0.66	0.78	0.70
IGFRI-3	0.59	0.56	0.73	0.69
DHN-6	0.57	0.58	0.74	0.68
PTH	0.47	0.51	0.61	0.55
LSD 5%	0.01	0.01	0.01	0.01
Open				
CO-3	0.55	0.64	0.77	0.69
CO-4	0.54	0.64	0.76	0.69
Suguna	0.56	0.65	0.77	0.69
IGFRI-3	0.54	0.56	0.74	0.67
DHN-6	0.53	0.54	0.73	0.67
PTH	0.45	0.48	0.58	0.53
25 % shade				
CO-3	0.59	0.67	0.77	0.70
CO-4	0.58	0.64	0.76	0.69
Suguna	0.65	0.66	0.78	0.70
IGFRI-3	0.60	0.56	0.73	0.69
DHN-6	0.58	0.59	0.74	0.68
PTH	0.47	0.52	0.62	0.55
50 % shade				
CO-3	0.66	0.68	0.79	0.71
CO-4	0.65	0.67	0.78	0.71
Suguna	0.66	0.68	0.78	0.72
IGFRI-3	0.63	0.58	0.73	0.69
DHN-6	0.61	0.61	0.75	0.69
PTH	0.51	0.54	0.63	0.57
LSD 5%	0.01	0.01	0.01	0.02

Table 17. Effect of shade on leaf weight ratio of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	0.59	0.57	0.65	0.65	0.61
25	0.60	0.61	0.69	0.69	0.64
50	0.62	0.63	0.72	0.71	0.66
LSD 5%	0.01	0.01	0.003	0.02	0.003
Cultivars					
CO-3	0.68	0.65	0.72	0.71	0.69
CO-4	0.61	0.62	0.71	0.70	0.68
Suguna	0.69	0.65	0.74	0.73	0.70
IGFRI-3	0.65	0.60	0.68	0.74	0.71
DHN-6	0.62	0.60	0.63	0.61	0.60
PTH	0.36	0.48	0.62	0.61	0.42
LSD 5%	0.002	0.01	0.01	0.01	0.01
Open					
CO-3	0.67	0.64	0.69	0.69	0.66
CO-4	0.60	0.58	0.69	0.68	0.66
Suguna	0.69	0.62	0.70	0.69	0.68
IGFRI-3	0.65	0.56	0.65	0.74	0.71
DHN-6	0.57	0.55	0.59	0.57	0.58
PTH	0.33	0.45	0.57	0.55	0.36
25 % shade					
CO-3	0.68	0.65	0.72	0.71	0.69
CO-4	0.60	0.63	0.71	0.70	0.69
Suguna	0.69	0.66	0.76	0.74	0.71
IGFRI-3	0.65	0.61	0.68	0.74	0.69
DHN-6	0.64	0.61	0.63	0.61	0.60
PTH	0.35	0.49	0.61	0.61	0.43
50 % shade					
CO-3	0.69	0.67	0.74	0.73	0.71
CO-4	0.63	0.66	0.74	0.73	0.68
Suguna	0.70	0.68	0.77	0.75	0.72
IGFRI-3	0.66	0.62	0.70	0.74	0.73
DHN-6	0.65	0.63	0.68	0.65	0.63
PTH	0.39	0.50	0.67	0.68	0.46
LSD 5%	0.01	0.02	0.03	0.02	0.02

By the third harvest, with respect to different shade levels, the LWR values were comparable at both 25 per cent and 50 per cent levels of shade. Under all shade levels, maximum was observed in 'CO-3', 'Suguna' and 'CO-4' and minimum was observed in 'PTH'. In the fourth harvest, among the cultivars, all except 'PTH' were at par and 'PTH' recorded the minimum LWR. At 50 per cent shade, 'Suguna', 'CO-4' and 'CO-3' were at par and showed maximum LWR. At 25 per cent shade and open condition, all cultivars except 'PTH' were at par. The lowest values were observed in 'PTH'. The LWR of 'PTH' at 25 per cent shade was on par with LWR at 50 per cent shade and open condition.

During the second year, at first harvest also, LWR under 25 per cent shade and open condition were at par. Among the cultivars, the highest LWR was recorded in 'Suguna' and the lowest was recorded in 'PTH'. At 50 per cent and 25 per cent shade, 'Suguna' and 'CO-3' had comparable ratios and showed maximum LWR. Their LWRs at 25 per cent shade were comparable at 50 per cent shade and full sunlight. In full sunlight, maximum was observed in 'Suguna'. The lowest LWR was recorded in 'PTH'.

In the second harvest, among the cultivars, 'CO-3' and 'Suguna' were at par and showed maximum LWR. At 50 per cent and 25 per cent shade, 'Suguna', 'CO-3' and 'CO-4' were at par and showed maximum LWR. At 25 per cent shade, 'CO-4' was at par with 'IGFRI-3' and 'DHN-6'. Under full sunlight, 'CO-3' had the maximum LWR. At all shade levels, 'PTH' recorded the least values.

By the third harvest, 'Suguna' showed the highest LWR, and the lowest LWR was in 'PTH' and 'DHN-6,' which were at par. At 50 per cent shade, maximum was observed in 'Suguna', 'CO-4' and 'CO-3' which were on par, and the least was observed in 'PTH' and 'DHN-6. 'IGFRI-3' was at par with 'CO-3' and 'CO-4'. At 25 per cent shade, the crop could produce comparable ratios with LWRs of crop grown in open condition and 50 per cent shade. 'Suguna' recorded the highest LWR while 'PTH' and 'DHN-6' recorded the lowest. In full sunlight, 'Suguna', 'CO-4' and 'CO-3' were at par showing maximum LWR. The least LWR was observed in 'PTH' and 'DHN-6' which were at par.

At the fourth harvest, the LWR values at 25 per cent and 50 per cent shade were at par. Among the cultivars; 'IGFRI-3' and 'Suguna' recorded maximum LWR and the least was recorded in 'PTH' and 'DHN-6'. At 50 per cent shade, the highest was observed in 'Suguna' and had comparable values with all cultivars, excepting 'PTH' and 'DHN-6'. Those cultivars, which recorded maximum LWRs at 50 per cent shade had comparable values at 25 per cent shade and in open condition too. At 25 per cent shade, the highest LWR was observed in 'IGFRI-3' and 'Suguna'. In full sunlight also, 'IGFRI-3'recorded maximum. While 'PTH' and 'DHN-6' recorded the least which were at par with each other.

In the fifth harvest, 'IGFRI-3' and 'Suguna' were at par and showed maximum LWR while 'Suguna' was on par with 'CO-3' which was on par with 'CO-4' also. At 50 per cent and 25 per cent shade, all cultivars were at par with each other, except 'DHN-6' and 'PTH'. The highest LWR value was observed in 'IGFRI-3' at 50 per cent and in 'Suguna' at 25 per cent shade. In full sunlight, 'IGFRI-3' showed the maximum LWR. At all levels of shade, 'PTH' attained the lowest position.

Specific leaf weight (SLW)

The specific leaf weight of hybrid napier cultivars at each harvest are shown in Table 18 and Table 19. With increasing shade levels, the SLW showed a decreasing trend. Maximum SLW was recorded in plants when grown in open condition and minimum was recorded under 50 per cent shade.

During the first year, in the first harvest, among the cultivars, 'PTH' showed the maximum SLW while 'CO-4' and 'Suguna' were at par and showed the minimum SLW. Under all levels of shade, 'PTH' recorded the maximum SLW. At 50 per cent and 25 per cent shade, 'DHN-6' showed the least where as in full sunlight, 'CO-4' recorded the least SLW. In the second harvest, among the cultivars, all had comparable SLW.

Table 18. Effect of shade on specific leaf weight (g/dm^2) of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	0.46	0.43	0.48	0.37
25	0.42	0.37	0.46	0.36
50	0.39	0.33	0.43	0.35
LSD 5%	0.02	0.01	0.03	0.03
Cultivars				
CO-3	0.42	0.37	0.46	0.35
CO-4	0.38	0.34	0.44	0.34
Suguna	0.45	0.37	0.46	0.36
IGFRI-3	0.46	0.40	0.46	0.39
DHN-6	0.38	0.33	0.43	0.32
PTH	0.47	0.44	0.49	0.39
LSD 5%	0.004	NS	0.02	0.02
Open				
CO-3	0.47	0.43	0.50	0.37
CO-4	0.42	0.36	0.47	0.35
Suguna	0.48	0.46	0.49	0.37
IGFRI-3	0.49	0.47	0.44	0.39
DHN-6	0.43	0.35	0.47	0.34
PTH	0.51	0.48	0.52	0.41
25 % shade				
CO-3	0.43	0.36	0.45	0.36
CO-4	0.38	0.34	0.44	0.35
Suguna	0.45	0.37	0.45	0.35
IGFRI-3	0.45	0.39	0.47	0.38
DHN-6	0.37	0.34	0.44	0.31
PTH	0.46	0.45	0.49	0.39
50 % shade				
CO-3	0.37	0.32	0.43	0.34
CO-4	0.36	0.31	0.41	0.32
Suguna	0.42	0.30	0.44	0.36
IGFRI-3	0.44	0.34	0.46	0.39
DHN-6	0.33	0.29	0.39	0.29
PTH	0.45	0.39	0.46	0.38
LSD 5%	0.004	0.01	0.05	0.03

Table 19. Effect of shade on specific leaf weight (g/dm^2) of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	0.38	0.40	0.44	0.62	0.45
25	0.31	0.36	0.38	0.51	0.40
50	0.29	0.33	0.35	0.47	0.36
LSD 5%	0.01	0.01	0.003	0.02	0.002
Cultivars					
CO-3	0.31	0.33	0.35	0.50	0.42
CO-4	0.30	0.33	0.37	0.48	0.40
Suguna	0.32	0.35	0.36	0.47	0.40
IGFRI-3	0.29	0.36	0.37	0.59	0.47
DHN-6	0.27	0.29	0.31	0.33	0.32
PTH	0.44	0.50	0.57	0.81	0.40
LSD 5%	0.01	0.001	0.002	0.02	0.004
Open					
CO-3	0.37	0.38	0.39	0.56	0.49
CO-4	0.36	0.39	0.43	0.61	0.45
Suguna	0.40	0.41	0.42	0.56	0.43
IGFRI-3	0.34	0.40	0.40	0.66	0.50
DHN-6	0.29	0.31	0.34	0.37	0.36
PTH	0.48	0.52	0.63	0.97	0.48
25 % shade					
CO-3	0.30	0.32	0.33	0.50	0.43
CO-4	0.29	0.31	0.36	0.43	0.40
Suguna	0.29	0.33	0.35	0.42	0.41
IGFRI-3	0.28	0.37	0.38	0.59	0.47
DHN-6	0.27	0.29	0.31	0.33	0.32
PTH	0.43	0.50	0.55	0.76	0.38
50 % shade					
CO-3	0.27	0.30	0.31	0.45	0.35
CO-4	0.27	0.29	0.32	0.40	0.34
Suguna	0.28	0.30	0.33	0.43	0.37
IGFRI-3	0.26	0.32	0.34	0.53	0.45
DHN-6	0.25	0.27	0.29	0.30	0.29
PTH	0.40	0.48	0.52	0.71	0.34
LSD 5%	0.01	0.02	0.001	0.03	0.01

Considering the interaction effect, 'PTH' attained the highest position at all levels of shade and 'DHN-6' attained the lowest position. At 25 per cent shade, 'DHN-6' and 'CO-4' were at par and showed minimum SLW.

By the third harvest, SLW of crop in 25 per cent was comprable with SLW of crop in open condition and 50 per cent shade. Among the cultivars, 'PTH' recorded the highest and 'DHN-6' recorded the lowest SLW. 'DHN-6' was on par with 'CO-4'. In open condition, all the cultivars were at par. When grown in 25 per cent shade and in 50 per cent shade, SLW of all cultivars were comparable with each other.

In the fourth harvest, SLW at all shade levels were at par. Among the cultivars, 'PTH' and 'IGFRI-3' recorded the maximum while 'DHN-6' recorded the least. In full sunlight, 'PTH' and 'IGFRI-3' recorded the maximum SLW and the least was recorded by 'DHN-6', 'CO-4', 'Suguna' and 'CO-3' which were at par. At 25 per cent shade, 'PTH', 'IGFRI-3' and 'CO-3' were at par and showed maximum SLW, and 'DHN-6' showed the least. At 50 per cent shade, 'IGFRI-3', 'PTH' and 'Suguna' were at par and showed maximum SLW whereas 'DHN-6' had the minimum SLW.

During the second year, in the first harvest, among the cultivars, maximum SLW was observed in 'PTH' and the least in 'DHN-6' which was on par with 'IGFRI-3'. At all levels of shade, the maximum SLW was observed in 'PTH' and the least in 'DHN-6'. In 50 per cent and 25 per cent shade, 'DHN-6' was on par with 'IGFRI-3'.

In the second harvest, under all shade levels, 'PTH' recorded the highest SLW and 'DHN-6' the lowest. The SLW at 25 per cent was on par with SLW at 50 per cent and in open. 'DHN-6' was on par with 'CO-4' at 25 per cent and 50 per cent shade while it was on par with 'CO-3' at 50 per cent shade.

Similarly at the third and fourth harvest, 'PTH' and 'DHN-6' recorded the lowest at all shade levels. In the fourth harvest, the SLW of 'DHN-6' at 25 per cent and 50 per cent shade were at par. At fifth harvest, 'IGFRI-3' recorded maximum SLW and 'DHN-6' the least SLW at all shade levels.

Leaf: stem ratio

The leaf: stem ratio data of hybrid napier cultivars under varying shade levels are shown in Table 20 and Table 21. Crop recorded the highest leaf: stem ratio under 50 per cent shade. Ratio increased with increasing shade levels.

During the first year, maximum leaf: stem ratio was recorded at the third harvest. In the first harvest, under 50 per cent shade, the crop recorded maximum leaf: stem ratio of 1.69. With respect to cultivars, 'Suguna' recorded maximum leaf: stem ratio and 'PTH' recorded the least. Considering the interaction effect, at 50 per cent shade, 'CO-3' and 'Suguna' were on par showing the maximum leaf: stem ratio. Under 25 per cent shade, 'Suguna' recorded maximum leaf: stem ratio. In full sunlight, 'Suguna', 'CO-3', 'CO-4' and 'IGFRI-3' were on par showing the maximum leaf: stem ratio. At all shade levels 'PTH' showed the least leaf: stem ratio.

By the second harvest, the maximum leaf: stem ratio was 1.72 at 50 per cent shade. Among the cultivars, 'CO-3' (1.97) and 'Suguna' (1.96) were at par showing the maximum leaf: stem ratios. At the same time, 'PTH' (1.08) recorded the least. The data on interaction revealed that at 50 per cent shade, 'CO-3', 'Suguna' and 'CO-4' were at par showing maximum leaf: stem ratios. 'PTH' and 'IGFRI-3' showed minimum leaf: stem ratios. In 25 per cent shade, leaf: stem ratio of 'Suguna' and 'CO-3' were comparable with each other recording maximum values. When grown under open condition; 'CO-3', 'Suguna' and 'CO-4' (1.71) could produce comparable proportion of leaves to stems and recorded maximum leaf: stem ratio. 'PTH' recorded minimum leaf: stem ratio both under open condition and 25 per cent shade.

During the third harvest, maximum leaf: stem ratio recorded under 50 per cent shade was 3.02. Considering the cultivars' effect, leaf: stem ratio of 'CO-3' and 'Suguna' were comparable with each other and showed maximum leaf: stem ratio. The least was observed in 'PTH'. With respect to interaction effect, at all shade levels, 'CO-3' and 'Suguna' were on par and showed maximum leaf: stem ratio.

Table 20. Effect of shade on leaf - stem ratio of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Shade levels				
0	1.13	1.46	2.75	1.96
25	1.43	1.58	2.89	2.09
50	1.69	1.72	3.02	2.22
LSD 5%	0.05	0.08	0.07	0.04
Cultivars				
CO-3	1.55	1.97	3.43	2.34
CO-4	1.50	1.83	3.29	2.32
Suguna	1.74	1.96	3.42	2.37
IGFRI-3	1.47	1.29	2.75	2.16
DHN-6	1.35	1.40	2.86	2.13
PTH	0.91	1.08	1.56	1.22
LSD 5%	0.05	0.06	0.06	0.05
Open				
CO-3	1.22	1.85	3.30	2.19
CO-4	1.20	1.71	3.17	2.19
Suguna	1.25	1.84	3.31	2.19
IGFRI-3	1.20	1.25	2.71	2.04
DHN-6	1.09	1.18	2.65	2.02
PTH	0.82	0.92	1.38	1.11
25 % shade				
CO-3	1.39	1.96	3.42	2.30
CO-4	1.43	1.76	3.22	2.26
Suguna	1.94	1.98	3.47	2.38
IGFRI-3	1.53	1.27	2.73	2.20
DHN-6	1.38	1.43	2.89	2.17
PTH	0.90	1.09	1.59	1.22
50 % shade				
CO-3	2.03	2.11	3.57	2.51
CO-4	1.86	2.02	3.49	2.50
Suguna	2.02	2.04	3.50	2.54
IGFRI-3	1.65	1.34	2.80	2.24
DHN-6	1.58	1.58	3.04	2.20
PTH	1.01	1.22	1.69	1.32
LSD 5%	0.09	0.11	0.11	0.09

Table 21. Effect of shade on leaf - stem ratio of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Shade levels					
0	1.56	1.35	1.92	1.98	1.73
25	1.67	1.59	2.27	2.27	1.91
50	1.77	1.74	2.60	2.54	2.07
LSD 5%	0.05	0.07	0.10	0.12	0.10
Cultivars					
CO-3	2.10	1.89	2.58	2.45	2.18
CO-4	1.57	1.66	2.51	2.41	2.11
Suguna	2.24	1.89	2.96	2.69	2.37
IGFRI-3	1.89	1.51	2.12	2.83	2.49
DHN-6	1.64	1.49	1.78	1.58	1.52
PTH	0.56	0.92	1.64	1.61	0.72
LSD 5%	0.05	0.07	0.13	0.08	0.11
Open					
CO-3	2.04	1.76	2.30	2.23	1.95
CO-4	1.51	1.36	2.23	2.10	1.98
Suguna	2.20	1.66	2.33	2.23	2.10
IGFRI-3	1.83	1.29	1.90	2.79	2.44
DHN-6	1.30	1.24	1.42	1.32	1.37
PTH	0.50	0.81	1.33	1.19	0.56
25 % shade					
CO-3	2.07	1.85	2.60	2.43	2.20
CO-4	1.53	1.68	2.41	2.38	2.22
Suguna	2.23	1.89	3.17	2.86	2.42
IGFRI-3	1.89	1.58	2.15	2.82	2.32
DHN-6	1.76	1.57	1.73	1.58	1.52
PTH	0.55	0.96	1.53	1.54	0.75
50 % shade					
CO-3	2.18	2.06	2.86	2.69	2.39
CO-4	1.68	1.94	2.87	2.76	2.15
Suguna	2.29	2.11	3.37	2.99	2.59
IGFRI-3	1.95	1.66	2.29	2.87	2.71
DHN-6	1.85	1.66	2.17	1.84	1.70
PTH	0.64	1.00	2.05	2.09	0.84
LSD 5%	0.07	0.11	0.22	0.15	0.20

Under 50 per cent shade, both cultivars were on par with 'CO-4'. At all shade levels, the minimum leaf: stem ratio was observed in 'PTH'.

In the fourth harvest, maximum leaf: stem ratio was observed in 50 per cent shade. Among the cultivars, maximum was observed in 'Suguna', 'CO-3' and 'CO-4', all of them were on par. Whereas the minimum was observed in 'PTH'. At 50 per cent and open condition, 'CO-3', 'CO-4' and 'Suguna' were on par and showed maximum leaf: stem ratio but under 25 per cent shade, 'CO-3' and 'Suguna' showed maximum values. 'CO-4' was comparable with 'CO-3' at 25 per cent shade and showed maximum leaf: stem ratio. The least leaf: stem ratio was recorded in 'PTH' at all levels of shade.

In the second year also, maximum leaf: stem ratio was recorded under 50 per cent shade and minimum under open condition. The highest values were observed at fourth harvest. In the first year, among the cultivars, maximum leaf: stem ratio was recorded in 'Suguna' whereas 'PTH' recorded the least. At second harvest, 'Suguna' and 'CO-3' were on par and showed maximum leaf: stem ratio. The least was recorded in 'PTH'.

During the third harvest, 'Suguna' recorded the highest leaf: stem ratio at all shade levels. Under open condition, the leaf: stem ratios of 'CO-3' and 'Co- 4' were comparable with 'Suguna' and recorded maximum leaf: stem ratio. The lowest position was attained by 'PTH' at all levels of shade. In the fourth harvest, among the cultivars, 'IGFRI-3' attained first position and the lowest position was attained by 'DHN-6' and 'PTH'. Under 50 per cent shade, maximum was observed in 'Suguna' and minimum in 'DHN-6'. At 25 per cent shade, ratios of 'Suguna' and 'IGFRI-3' were comparable and showed maximum leaf: stem ratio. Ratios of 'PTH' and 'DHN-6' were comparable and showed minimum leaf: stem ratio. When grown in open condition, 'IGFRI-3' attained first position and 'PTH' attained the lowest position.

At the time of fifth harvest, among the cultivars maximum values were observed in 'IGFRI-3' and 'Suguna' which were on par. Under 50 per cent shade, the highest value was recorded in 'IGFRI-3' and was on par with 'Suguna'. Under 25 per cent shade, leaf to stem ratios of 'Suguna', 'IGFRI-3', 'CO-4' and 'CO-3' (2.20) were comparable and showed maximum values. In full sunlight, 'IGFRI-3' recorded the highest value, and the least was observed in 'PTH' at all levels of shade.

4.1.3. Physiological and Biochemical parameters

Chlorophyll content

Chlorophyll a, chlorophyll b, total chlorophyll content and chlorophyll b to chlorophyll a ratio during the first and second year are presented in Table 22. Chlorophyll content and its ratio showed an increasing trend with increasing shade levels. In both years, the highest chlorophyll content was noticed in plants grown under 50 per cent shade and the lowest was noticed in plants at full sunlight.

Chlorophyll a content in plants increased from 1.17 mg/g of fresh leaf weight to 1.55 mg/g of fresh leaf weight on increasing the shade to 50 per cent. Among the cultivars, 'IGFRI-3' had the highest content and 'PTH' had the lowest. There was significant interaction effect with respect to chlorophyll a content. 'DHN-6' grown under 50 per cent shade had the highest chlorophyll a content. Regarding the chlorophyll b content, maximum content in plants was 0.58 mg/g of fresh leaf weight at 50 per cent shade, followed by 0.46 mg/g of fresh leaf weight at 25 per cent and the least content was 0.38 mg/g of fresh leaf weight which was noticed in plants grown with full sunlight. 'DHN-6' recorded the maximum content at all levels of shade while 'CO-4' had the lowest content under all levels of shade.

With respect to total chlorophyll content, the crop had the highest contents at 50 per cent shade level, among which 'DHN-6' had the higest content. Considering the effect of cultivars alone, 'IGFRI-3' had the highest content and the lowest was recorded in 'PTH'. Regarding the chlorophyll b to chlorophyll a ratio, the highest value was observed at 50 per cent shade, and the lowest in full sunlight. Among the cultivars, 'DHN-6' had the highest ratio and 'CO-4' the lowest at all levels of shade. At 25 per cent shade, 'CO-3' was at par with CO-4' and showed the lowest ratio.

Table 22. Effect of shade on chlorophyll content (mg/g of fresh leaf weight) of hybrid napier cultivars at each harvest

Treatment	Chlorophyll a		Chlorophyll b		Total chlorophyll		Chlorophyll b/a	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
Shade levels								
0	1.17	1.19	0.38	0.32	2.55	2.52	0.33	0.26
25	1.35	1.30	0.46	0.40	2.96	2.81	0.34	0.31
50	1.55	1.58	0.58	0.53	3.46	3.46	0.38	0.34
LSD 5%	0.003	0.001	0.008	0.009	NS	0.006	0.002	0.003
Cultivars								
CO-3	1.37	1.38	0.45	0.43	2.99	2.98	0.33	0.31
CO-4	1.34	1.33	0.40	0.38	2.88	2.84	0.29	0.28
Suguna	1.32	1.28	0.47	0.38	2.93	2.75	0.35	0.29
IGFRI-3	1.41	1.31	0.50	0.38	3.12	2.81	0.36	0.29
DHN-6	1.37	1.42	0.54	0.48	3.11	3.12	0.39	0.33
PTH	1.31	1.43	0.49	0.44	2.91	3.09	0.37	0.31
LSD 5%	0.001	0.001	0.003	0.003	0.003	0.006	0.001	0.002
Open								
CO-3	1.23	1.27	0.36	0.35	2.65	2.70	0.30	0.28
CO-4	1.02	1.00	0.27	0.26	2.17	2.11	0.26	0.26
Suguna	1.16	1.13	0.39	0.28	2.57	2.35	0.33	0.25
IGFRI-3	1.23	1.18	0.42	0.28	2.71	2.44	0.34	0.24
DHN-6	1.17	1.29	0.44	0.36	2.61	2.76	0.38	0.28
PTH	1.17	1.31	0.41	0.34	2.58	2.75	0.36	0.27
25 % shade								
CO-3	1.42	1.41	0.43	0.41	3.06	3.02	0.31	0.28
CO-4	1.41	1.39	0.41	0.40	3.03	2.96	0.30	0.29
Suguna	1.35	1.14	0.47	0.35	2.97	2.47	0.35	0.30
IGFRI-3	1.35	1.18	0.47	0.35	3.00	2.54	0.35	0.30
DHN-6	1.28	1.35	0.49	0.46	2.88	2.96	0.39	0.34
PTH	1.28	1.35	0.48	0.43	2.87	2.93	0.37	0.33
50 % shade								
CO-3	1.47	1.46	0.55	0.52	3.27	3.23	0.38	0.36
CO-4	1.59	1.58	0.51	0.49	3.45	3.43	0.32	0.31
Suguna	1.46	1.58	0.56	0.50	3.26	3.44	0.38	0.32
IGFRI-3	1.63	1.58	0.60	0.51	3.65	3.43	0.37	0.32
DHN-6	1.69	1.63	0.69	0.61	3.83	3.64	0.42	0.37
PTH	1.47	1.64	0.56	0.54	3.28	3.59	0.39	0.33
LSD 5%	NS	0.007	0.003	0.003	NS	0.002	0.009	0.001

During the second year, among the cultivars, 'PTH' had the highest chlorophyll a content and 'Suguna' the least. The highest chlorophyll a content was obtained under 50 per cent shade in 'PTH' and 'DHN-6' which were at par. The lowest content was noticed in 'CO-3'. Under 25 per cent shade, 'CO-3' recorded the highest and 'Suguna' the least content. Under open, 'PTH' had the highest content and 'CO-4' the lowest. Regarding chlorophyll b content, 'DHN-6' had the highest content at all shade levels. The lowest content was noticed in 'CO-4' in full sunlight. At 25 per cent shade, 'Suguna' and 'IGFRI-3' were at par and recorded the lowest content. In 50 per cent shade, 'CO-4' had the lowest content.

Regarding total chlorophyll content, among the cultivars, the highest content was observed in 'DHN-6' whereas 'Suguna' had the least. With respect to interaction effect, the highest content was noticed in 'DHN-6' grown at 50 per cent shade and the lowest in 'CO-4' under open condition. At 50 per cent shade, 'CO-3' recorded the minimum content. In 25 per cent shade, 'CO-3' showed the highest content and 'Suguna' the lowest. Under open condition, 'DHN-6' had the highest content.

Considering the ratio of chlorophyll b to chlorophyll a, the highest value was observed at 50 per cent shade, and the lowest in full sunlight. Among the cultivars, 'DHN-6' showed the highest ratio under all shade levels. In full sunlight, 'DHN-6' and 'CO-3' were at par and the lowest was observed in 'IGFRI-3'. At 25 per cent shade, 'CO-3' recorded the least value whereas at 50 per cent shade, minimum was observed in 'CO-4'.

Light intensity

Light penetration through the plant canopy was measured with a lux meter and measurements on light intensity were expressed as percentage fraction of light interception by the plant canopy (Table 23). Light interception increased with increasing shade levels and maximum interception was recorded under 50 per cent shade and the least was recorded in full sunlight. In general, 'Suguna' recorded maximum light interception and 'PTH' recorded the least.

Table 23. Effect of shade on light interception, PAR interception and PAR transmission (%)

Treatment	Light interception (LI %)		PAR interception (IPAR %)		PAR transmission (TPAR %)	
	First year	Second year	First year	Second year	First year	Second year
Shade levels						
0	78.85	75.14	81.40	75.57	18.60	24.43
25	83.24	77.42	83.99	77.35	16.01	22.65
50	89.69	79.87	91.18	79.80	8.82	20.20
LSD 5%	0.70	0.81	0.49	0.59	0.49	0.59
Cultivars						
CO-3	86.79	80.29	89.48	80.39	10.52	19.61
CO-4	85.54	82.63	86.41	81.89	13.59	18.11
Suguna	88.51	82.62	89.88	81.38	10.12	18.62
IGFRI-3	83.48	74.23	85.08	76.98	14.92	23.02
DHN-6	81.87	77.99	83.20	78.41	16.80	21.59
PTH	77.36	67.10	79.11	66.39	20.89	33.61
LSD 5%	1.15	0.76	0.89	0.81	0.88	0.81
Open						
CO-3	81.47	79.26	85.29	78.92	14.71	21.08
CO-4	79.71	80.63	81.27	80.80	18.73	19.20
Suguna	82.63	80.11	84.26	79.80	15.74	20.20
IGFRI-3	78.80	70.36	80.71	74.79	19.29	25.21
DHN-6	76.35	75.22	79.42	75.08	20.58	24.92
PTH	74.14	65.26	77.47	64.05	22.53	35.95
25 % shade						
CO-3	85.78	79.79	87.68	80.58	12.32	19.42
CO-4	85.48	83.42	85.08	81.55	14.92	18.45
Suguna	88.66	82.82	88.91	80.62	11.09	19.38
IGFRI-3	81.58	74.83	82.71	77.12	17.29	22.88
DHN-6	80.39	77.44	80.75	78.41	19.25	21.59
PTH	77.54	66.23	78.81	65.83	21.19	34.17
50 % shade						
CO-3	93.13	81.83	95.47	81.68	4.53	18.32
CO-4	91.43	83.84	92.89	83.32	7.11	16.68
Suguna	94.24	84.93	96.46	83.73	3.54	16.27
IGFRI-3	90.07	77.49	91.80	79.04	8.20	20.96
DHN-6	88.88	81.30	89.43	81.74	10.57	18.26
PTH	80.41	69.82	81.05	69.29	18.95	30.71
LSD 5%	1.99	1.30	1.52	1.40	1.53	1.40

Considering the interaction effect, during the first harvest, the highest light interception value was noticed in 'Suguna' at 50 per cent shade (94.24 %) followed by 'CO-3' (93.13 %) and both were on par. The lowest value was noticed in 'PTH' at full sunlight (74.14 %).

In the second year, 'CO-4' and 'Suguna' were at par and maximum light interception was noticed in these two cultivars at 50 per cent shade. When grown under 50 per cent shade, 'Suguna' and 'CO-4' intercepted 84.93 percentage and 83.84 percentage of the incoming solar radiation while minimum light interception was noticed in cultivars when grown under full sunlight of which 'PTH' recorded the least (65.26 %).

Photosynthetically Active Radiation

The PAR measurements were expressed as percentage fraction of intercepted PAR and transmitted PAR (Table 23). PAR interception showed the same trend as that of light interception while PAR transmission showed an inverse trend.

PAR interception showed an increasing trend with increasing shade levels and maximum PAR interception was noticed in plants when grown under 50 percent shade. During the first year, 'Suguna' and 'CO-4' were at par and showed maximum PAR interception. Considering the interaction effect, maximum PAR interception was observed in 'Suguna' (96.46 %) and 'CO-3' (95.47 %) at 50 per cent shade while the least was observed in 'PTH,' in open condition (77.47 %).

In the second year, among the cultivars, 'CO-4' and 'Suguna' were at par and showed maximum PAR interception. Regarding the interaction effect, all cultivars showed maximum PAR interception at 50 per cent shade, of which 'Suguna' (83.73 %) and 'CO-4' (83.32 %) showed maximum PAR interception. 'PTH' had the minimum PAR interception at all shade levels, with its lowest value was at full sunlight (64.05 %).

Maximum PAR transmission was observed in plants when grown under full sunlight and transmission decreased with increasing shade levels. Among the cultivars, 'PTH' showed maximum PAR transmission.

In the first year, maximum PAR transmission was observed in 'PTH' under full sunlight (22.53 %). 'CO-3' and 'Suguna' were at par and showed minimum PAR transmission at all shade levels of which the lowest values were observed at 50 per cent shade. 'CO-3' transmitted only 3.54 percentage of the incoming PAR below the plant canopy and 'Suguna' transmitted 4.53 percentage.

At second harvest, among the cultivars, 'PTH' showed maximum PAR transmission. The cultivars 'CO-4' and 'Suguna' were at par and showed minimum PAR transmission. Regarding the interaction effect, maximum PAR transmission was observed in 'PTH' in full sunlight (35.95 %) and minimum under 50 per cent shade in 'Suguna' (16.27 %) and 'CO-4' (16.68 %).

4.1.4. Mortality of clumps

Mortality of clumps were monitored one month after the receipt of premonsoon showers. During the two years of study, clump mortality was not noticed.

4.1.5. Fodder yield

Fodder yield was significantly reduced under shade. In general, among the cultivars, 'Suguna' was superior in fodder yield in both years of study followed by CO-3 and the least by 'PTH'.

Fresh fodder yield

The data pertaining to fresh fodder yield are given in Table 24 and Table 25. Fresh fodder production reduced with increasing shade. In the first year, during the first harvest, among the cultivars, 'IGFRI-3' and 'Suguna' recorded the highest yield and 'PTH' the lowest. As interaction was significant, the performance of cultivars under different shade levels was also considered. In full sunlight, 'Suguna'

Table 24. Effect of shade on fresh fodder yield (Mg/ha) of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4	Total
Shade levels					
0	35.31	29.47	22.82	2.74	90.32
25	30.41	25.15	20.02	2.37	77.96
50	26.42	22.46	17.00	2.46	68.34
LSD 5%	2.09	1.21	1.73	0.37	3.33
Cultivars					
CO-3	32.93	33.07	25.51	2.94	94.46
CO-4	27.27	23.55	18.07	1.78	70.67
Suguna	36.22	32.44	28.45	3.43	100.54
IGFRI-3	36.79	22.87	20.11	2.21	81.98
DHN-6	29.81	25.34	15.58	2.40	73.14
PTH	21.27	16.87	11.94	2.38	52.45
LSD 5%	1.19	1.43	1.15	0.37	2.26
Open					
CO-3	37.71	36.27	31.28	3.05	108.31
CO-4	31.00	26.60	20.83	1.90	80.34
Suguna	41.70	35.59	30.35	3.71	111.34
IGFRI-3	39.75	24.83	25.46	1.80	91.86
DHN-6	35.48	34.52	14.71	2.68	87.40
PTH	26.19	18.96	14.25	3.29	62.70
25 % shade					
CO-3	35.94	32.25	26.03	2.68	96.89
CO-4	26.42	23.97	17.69	1.95	70.04
Suguna	33.94	31.31	28.09	3.81	97.15
IGFRI-3	37.28	24.73	17.90	1.75	81.65
DHN-6	28.80	22.57	17.90	1.96	71.24
PTH	20.11	16.05	12.50	2.11	50.77
50 % shade					
CO-3	25.14	30.71	19.24	3.09	78.17
CO-4	24.40	20.07	15.69	1.47	61.64
Suguna	33.03	30.43	26.90	2.77	93.14
IGFRI-3	33.34	19.04	16.98	3.08	72.43
DHN-6	25.13	18.93	14.15	2.57	60.77
PTH	17.50	15.59	9.06	1.75	43.89
LSD 5%	2.05	2.48	1.99	0.621	3.93

Table 25. Effect of shade on fresh fodder yield (Mg/ha) of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	Total
Shade levels						
0	24.74	45.43	26.95	32.66	13.13	142.91
25	20.48	33.09	23.90	26.96	11.26	115.68
50	18.57	27.22	21.84	23.82	10.03	101.48
LSD 5%	1.03	0.80	1.02	1.67	1.12	1.64
Cultivars						
CO-3	24.89	38.85	24.14	30.10	13.54	131.51
CO-4	22.93	31.62	26.44	29.59	14.09	124.66
Suguna	25.08	40.23	25.82	31.99	14.39	137.51
IGFRI-3	18.41	34.37	23.24	25.56	8.37	109.96
DHN-6	19.19	35.31	24.81	27.78	9.77	116.87
PTH	17.07	31.11	20.93	21.85	8.66	99.62
LSD 5%	1.73	1.49	1.37	1.69	0.97	3.20
Open						
CO-3	28.16	43.57	24.63	32.45	14.90	143.70
CO-4	26.20	44.25	33.25	38.11	17.59	159.39
Suguna	28.55	52.19	25.28	34.83	13.76	154.62
IGFRI-3	24.63	43.36	24.30	29.50	9.17	130.97
DHN-6	20.90	53.40	28.55	35.63	12.79	151.28
PTH	19.98	35.83	25.68	25.44	10.54	117.46
25 % shade						
CO-3	24.65	39.16	23.39	30.12	13.04	130.34
CO-4	22.09	27.59	22.25	26.84	12.98	111.75
Suguna	23.98	37.48	24.88	31.00	15.58	132.92
IGFRI-3	17.28	32.33	25.20	25.12	8.23	108.17
DHN-6	18.86	29.69	23.05	25.24	9.51	106.35
PTH	15.99	32.29	24.66	23.43	8.21	104.56
50 % shade						
CO-3	21.86	33.81	24.40	27.73	12.70	120.49
CO-4	20.50	23.01	23.82	23.83	11.70	102.85
Suguna	22.72	31.03	27.28	30.13	13.82	124.98
IGFRI-3	13.32	27.44	20.23	22.06	7.69	90.75
DHN-6	17.81	22.84	22.84	22.46	7.02	92.98
PTH	15.24	25.19	12.46	16.69	7.23	76.83
LSD 5%	3.01	2.59	2.37	2.91	1.69	5.55

and 'IGFRI-3' had comparable fresh fodder yields of 41.70 Mg/ha and 39.75 Mg/ha and recorded maximum yield. 'IGFRI-3' was on par with 'CO-3' which was on par with 'DHN-6'. At 25 per cent shade, 'IGFRI-3' and 'CO-3' had comparable yields and showed maximum fodder production. 'Suguna' and 'CO-3' were almost similar in performance. Under 50 per cent shade too, both 'IGFRI-3' and 'Suguna' had comparable yields and recorded the highest fodder yield. At all shade levels, 'PTH' had minimum fodder yield.

During the second harvest, with respect to cultivars, 'CO-3' and 'Suguna' had similar performance and recorded maximum yield while 'PTH' recorded the least. Regarding the interaction effect, under open condition, 'CO-3', 'Suguna' and 'DHN-6' were at par and showed maximum yield. At 25 per cent and 50 per cent shade levels, fresh yield of 'CO-3' and 'Suguna' were comparable and had the highest yield. 'PTH' attained the lowest position at all levels of shade.

At the third harvest, 'Suguna' attained the first position and 'PTH' attained the lowest. Under open, 'CO-3' and 'Suguna' were at par and showed maximum fodder production. Similarly, 'PTH' and 'DHN-6' had comparable yields but recorded the least production. Under 25 per cent and 50 per cent shades 'Suguna' had the highest fodder production and 'PTH' the lowest.

In the fourth harvest, fresh fodder yield at 25 per cent was comparable with the yield at 50 per cent and full sunlight. Considering the cultivar effect, 'Suguna' had the highest yield and 'CO-4' the lowest. In full sunlight; 'Suguna' and 'PTH' had comparable yields and showed maximum fodder production and the least was observed in 'IGFRI-3' and 'CO-4'. At 25 per cent shade, 'Suguna' recorded maximum yield while 'IGFRI-3', 'CO-4' and 'DHN-6' had comparable yields and recorded the lowest fresh fodder yield. When grown under 50 per cent shade, 'CO-3', 'IGFRI-3', 'Suguna', and 'DHN-6' were at par and showed maximum fodder production whereas 'CO-4' and 'PTH' showed the minimum.

Considering the annual fresh fodder production, among the cultivars, 'Suguna' attained the first position and 'PTH' the lowest. Under full sunlight and at

25 percent shade, 'Suguna' and 'CO-3' were on par and recorded maximum yield. Under 50 per cent shade, 'Suguna' had the highest fresh fodder production. 'PTH' was the lowest total fresh fodder yielder at all levels of shade. The highest total fresh fodder yields of 111.34 Mg/ha and 108.31 Mg/ha were recorded by 'Suguna' and 'CO-3' in full sunlight.

During the second year, in the first harvest, 'Suguna' and 'CO-3' were almost similar in performance recording the highest fresh fodder yield whereas 'PTH' and 'IGFRI-3' which were on par recorded the lowest yield. Interactions were also found to be significant. In full sunlight, 'Suguna', 'CO-3' and 'CO-4' had comparable yields. 'IGFRI-3' was at par with 'CO-4'. At 25 per cent shade, 'CO-3', 'Suguna' and 'CO-4' recorded maximum yield and were at par. Similarly, 'PTH', 'IGFRI-3' and 'DHN-6' had comparable fresh yields and recorded minimum yield. At 50 per cent shade also, 'Suguna', 'CO-3' and 'CO-4' had comparable yields. The lowest yielders were'IGFRI-3' and 'PTH'. 'DHN-6' was at par with 'CO-4' and 'PTH'.

During the second harvest, the highest yielder was 'Suguna' whereas the lowest yielders were 'PTH' and 'CO-4' which were on par. Under full sunlight, 'DHN-6' and 'Suguna' were at par and recorded maximum yield. The lowest yielder was 'PTH'. At 25 per cent shade, 'CO-3' and 'Suguna' were the highest yielders and they were on par, while 'CO-4' and 'DHN-6' were the lowest yielders. At 50 per cent shade, 'CO-3' had the highest yield. 'DHN-6' and 'CO-4' were at par and recorded minimum yield. 106 ar with 'CO-4' and 'DHN-6'.

In the third harvest, 'CO-4' and 'Suguna' were almost similar in performance and recorded maximum yield. 'DHN-6' and 'CO-3' were at par and their yields are comparable with 'Suguna' and 'IGFRI-3'. 'PTH' was the lowest yielder. Under open, 'CO-4' was the highest yielder. The cultivars 'IGFRI-3', 'CO-3', 'Suguna' and 'PTH' had comparable yields and recorded minimum fresh yield. At 25 per cent shade, all cultivars except 'CO-4' were similar in performance and showed the highest yield while 'CO-4' recorded the least. 'CO-4' was on par with 'CO-3' and 'DHN-6'. The highest yield noticed was in

'IGFRI-3'. At 50 per cent shade, 'Suguna' recorded maximum yield and 'PTH' recorded the least.

For the fourth harvest, 'Suguna' and 'CO-3' were on par and recorded maximum yield. 'CO-3' was on par with 'CO-4'. 'PTH' was the lowest yielder. In full sunlight, 'CO-4' recorded maximum yield. At 25 per cent, 'Suguna' and 'CO-3' were the highest yielders and were at par. 'PTH' was at par with 'IGFRI-3' and DHN-6. Under 50 per cent shade, 'Suguna' and 'CO-3' were at par and recorded maximum yield.

At fifth harvest, 'Suguna', 'CO-4' and 'CO-3' showed similar performance and recorded maximum yield. 'IGFRI-3' and 'PTH' were the lowest yielders which were on par. Under full sunlight, 'CO-4' recorded maximum yield. The lowest yielders were 'IGFRI-3' and 'PTH'. Under 25 and 50 per cent shade levels, 'Suguna' was the highest yielder while 'IGFRI-3', 'DHN-6', and 'PTH' were almost similar in performance and recorded minimum yield.

Considering the total fresh fodder yield, 'Suguna' was the highest yielder followed by 'CO-3' and the lowest yielder was 'PTH'. In full sunlight, 'CO-4' and 'Suguna' were almost similar in performance producing 159.39 Mg/ha and 154.62 Mg/ha. Under 25 and 50 per cent shade levels, 'Suguna' compared equally well with CO-3, fresh fodder yields being 132.92 Mg/ha and 124.98 Mg/ha for Suguna and 130.34 Mg/ha and 120.49 Mg/ha for 'CO-3' under corresponding levels of shade. The lowest yielder, 'PTH' recorded minimum value at 50 per cent shade. At 25 per cent shade, 'PTH' was on par with 'DHN-6' and IGFRI-3'. In full sunlight 'PTH' produced 117.46 Mg/ha of fresh fodder yield.

Dry fodder yield

The data pertaining to dry fodder yield are given in Table 26 and Table 27. The dry fodder yield followed almost the same trend as that of fresh fodder yield. During the first year, at first harvest, 'Suguna' and 'IGFRI-3' were on par and recorded maximum yield. Interactions were also found to be significant. Under full sunlight, 'Suguna' recorded the highest dry fodder yield of 7.84 Mg/ha. At 25 per

Table 26. Effect of shade on dry fodder yield (Mg/ha) of hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4	Total
Shade levels					
0	6.19	5.13	4.08	0.48	15.88
25	5.35	4.45	3.54	0.42	13.75
50	4.65	3.98	3.02	0.43	12.08
LSD 5%	0.35	0.24	0.30	0.07	0.62
Cultivars					
CO-3	6.00	6.02	4.64	0.54	17.19
CO-4	5.45	4.71	3.61	0.36	14.14
Suguna	6.81	6.10	5.35	0.64	18.90
IGFRI-3	6.62	4.11	3.62	0.40	14.75
DHN-6	3.88	3.30	2.02	0.31	9.51
PTH	3.61	2.87	2.03	0.40	8.92
LSD 5%	0.22	0.26	0.21	0.06	0.40
Open					
CO-3	6.86	6.60	5.69	0.56	19.72
CO-4	6.19	5.32	4.17	0.39	16.07
Suguna	7.84	6.70	5.70	0.70	20.93
IGFRI-3	7.16	4.47	4.58	0.32	16.53
DHN-6	4.61	4.49	1.92	0.35	11.36
PTH	4.45	3.22	2.42	0.56	10.65
25 % shade					
CO-3	6.54	5.87	4.73	0.49	17.64
CO-4	5.28	4.79	3.54	0.39	14.01
Suguna	6.39	5.89	5.28	0.71	18.26
IGFRI-3	6.71	4.45	3.22	0.32	14.70
DHN-6	3.75	2.94	2.33	0.25	9.26
PTH	3.41	2.73	2.13	0.35	8.64
50 % shade					
CO-3	4.58	5.58	3.51	0.56	14.23
CO-4	4.89	4.01	3.14	0.29	12.32
Suguna	6.21	5.72	5.06	0.52	17.52
IGFRI-3	6.01	3.43	3.06	0.55	13.04
DHN-6	3.26	2.46	1.84	0.33	7.91
PTH	2.98	2.65	1.54	0.29	7.46
LSD 5%	0.36	0.44	0.35	0.10	0.69

Table 27. Effect of shade on dry fodder yield (Mg/ha) of hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	Total
Shade levels						
0	4.38	7.90	4.72	5.72	2.32	25.05
25	3.62	5.81	4.18	4.74	2.00	20.36
50	3.28	4.80	3.85	4.20	1.80	17.91
LSD 5%	0.19	0.13	0.18	0.31	0.18	0.33
Cultivars						
CO-3	4.53	7.07	4.39	5.48	2.46	23.94
CO-4	4.58	6.32	5.29	5.92	2.82	24.93
Suguna	4.71	7.56	4.85	6.01	2.71	25.85
IGFRI-3	3.31	6.19	4.18	4.60	1.51	19.79
DHN-6	2.49	4.59	3.23	3.61	1.27	15.19
PTH	2.90	5.29	3.56	3.72	1.47	16.93
LSD 5%	0.30	0.27	0.25	0.29	0.17	0.59
Open						
CO-3	5.12	7.93	4.48	5.90	2.72	26.16
CO-4	5.24	8.85	6.66	7.63	3.51	31.88
Suguna	5.37	9.81	4.75	6.55	2.59	29.06
IGFRI-3	4.43	7.80	4.38	5.31	1.65	23.57
DHN-6	2.72	6.94	3.71	4.64	1.66	19.67
PTH	3.40	6.10	4.36	4.33	1.79	19.97
25 % shade						
CO-3	4.49	7.13	4.26	5.48	2.37	23.73
CO-4	4.42	5.52	4.46	5.37	2.60	22.34
Suguna	4.50	7.04	4.68	5.82	2.93	24.99
IGFRI-3	3.12	5.82	4.54	4.53	1.48	19.48
DHN-6	2.45	3.85	2.99	3.28	1.24	13.83
PTH	2.72	5.48	4.19	3.98	1.39	17.78
50 % shade						
CO-3	3.97	6.16	4.44	5.04	2.31	21.92
CO-4	4.10	4.61	4.76	4.77	2.34	20.57
Suguna	4.27	5.83	5.12	5.67	2.60	23.50
IGFRI-3	2.40	4.94	3.64	3.98	1.39	16.33
DHN-6	2.31	2.97	2.97	2.92	0.91	12.09
PTH	2.60	4.29	2.12	2.83	1.23	13.06
LSD 5%	0.52	0.46	0.42	0.51	0.29	1.01

cent shade, 'Suguna' was on par with 'IGFRI-3' and 'CO-3'. In 50 per cent shade, 'Suguna' and 'IGFRI-3' were at par. The lowest yielders were 'PTH' and 'DHN-6'.

At the second harvest, 'Suguna' and 'CO-3' had comparable dry matter production and recorded maximum yield. Both cultivars had almost similar performance under 25 per cent and 50 per cent shade levels. 'PTH' was the lowest yielder at all shade levels. 'DHN-6' was on par with 'PTH' at 25 per cent and 50 per cent shade. At the third harvest, 'Suguna' was the highest yielder whereas the lowest yielders were 'DHN-6' and 'PTH' which had comparable performance. Under full sunlight, 'Suguna' and 'CO-3' had comparable yields and minimum was observed in 'DHN-6'. The dry fodder yield of 'Suguna' was comparable at 25 per cent and 50 per cent shade. At both levels of shade, 'PTH' and 'DHN-6' were at par and showed the lowest dry fodder production.

During the fourth harvest, the dry fodder yields were comparable at all levels of shade. Among the cultivars, 'Suguna' recorded maximum yield. The lowest yielders were 'DHN-6' and 'CO-4' which were on par. 'CO-4' was on par with 'PTH' and 'IGFRI-3'. Under open condition, 'Suguna' recorded 0.70 Mg/ha dry fodder and had similar performance at 25 per cent shade. 'IGFRI-3', 'DHN-6' and 'CO-4' were at par and recorded minimum yield. At 25 per cent shade 'DHN-6' and 'PTH' were on par with 'IGFRI-3'. 'PTH' was also on par with 'CO-4' and 'CO-3'. At 50 per cent shade, 'CO-3', 'IGFRI-3' and 'Suguna' were on par. The other three cultivars, i.e., 'PTH', 'CO-4' and 'DHN-6' were on par and recorded minimum dry fodder yield.

Considering the total dry fodder yield, among the cultivars, 'Suguna' attained the first position and 'PTH' recorded the lowest. With respect to interaction effect, under full sunlight, the highest dry fodder yield of 20.93 Mg/ha was recorded by 'Suguna' followed by 'CO-3' (19.72 Mg/ha). Under 25 and 50 per cent shade, 'Suguna' recorded the highest dry fodder yield of 18.26 Mg/ha and 17.52 Mg/ha respectively. 'CO-3' followed 'Suguna' under 25 per cent and 50 per cent shade. At all shade levels, 'PTH' and 'DHN-6' were at par and recorded minimum yield.

During the second year, at the first harvest, 'Suguna', 'CO-4' and 'CO-3' had similar performance and showed maximum dry fodder production while 'DHN-6' had the lowest. Considering the interaction effect, at all levels of shade, 'Suguna', 'CO-4' and 'CO-3' were at par. The lowest yielder was'DHN-6'in all shade levels. At 25 per cent and 50 per cent shade, 'PTH' was on par with 'DHN-6'. In 50 per cent shade, 'IGFRI-3' was on par with 'DHN-6' and 'PTH'.

By the second harvest, 'Suguna' recorded maximum dry fodder yield while 'DHN-6' the minimum. Under full sunlight, 'Suguna' recorded maximum yield while 'PTH' recorded the least. At 25 per cent and 50 per cent shade, 'CO-3' and 'Suguna' had comparable yields and recorded the highest yield while 'DHN-6' recorded minimum yield.

At the third harvest, among the cultivars, 'CO-4' attained the first position and 'DHN-6' attained the lowest position. Under full sunlight, 'CO-4' had 6.66 Mg/ha of dry fodder yield. At 25 per cent shade, 'CO-4' had comparable yield with 'Suguna', 'IGFRI-3', and 'CO-3'. In 50 per cent shade, 'Suguna' and 'CO-4' had similar performance. Under full sunlight and 25 per cent shade, 'DHN-6' attained the lowest position, while 'PTH' recorded the least dry fodder production at 50 per cent shade.

In the fourth harvest, maximum fodder production was observed in 'Suguna' and 'CO-4' which were at par with each other and minimum was observed in 'DHN-6' and 'PTH'. Under full sunlight, 'CO-4' recorded the highest dry fodder yield while 'PTH' and 'DHN-6' recorded the least. At 25 per cent shade, 'Suguna', 'CO-3' and 'CO-4' were having similar fodder production potential whereas 'DHN-6' showed minimum potential. In 50 per cent shade, 'Suguna' had maximum dry fodder yield. 'PTH' and 'DHN-6' had the lowest yield.

At fifth harvest, 'CO-4' and 'Suguna' had similar performance in dry matter production and recorded maximum values while 'DHN-6' recorded the least. Under full sunlight, 'CO-4' attained the first position. At 25 per cent shade, 'Suguna' recorded the highest yield. In 50 per cent shade, 'Suguna', 'CO-4' and 'CO-3' were at par with each other. Under all levels of shade, 'IGFRI-3', 'DHN-6' and 'PTH' were at par with each other and exhibited the least dry fodder yield.

Considering the total dry fodder production, among the cultivars, 'Suguna' recorded the maximum dry fodder yield followed by 'CO-4' while 'DHN-6' recorded the least. Under full sunlight, 'CO-4' could produce 31.88 Mg/ha dry fodder which was followed by 'Suguna' (29.06 Mg/ha). The lowest yielders, 'DHN-6' and 'PTH' could produce 19.67 Mg/ha and 19.97 Mg/ha respectively. Under 25 and 50 per cent shade, 'Suguna' recorded the highest dry fodder yield of 24.99 Mg/ha and 23.50 Mg/ha respectively, followed by 'CO-3'. At 25 per cent and 50 per cent shade, 'DHN-6' recorded 13.83 Mg/ha and 12.09 Mg/ha respectively. At 50 per cent shade, 'PTH' was on par with 'DHN-6'.

4.1.6. Plant analysis

Representative plant samples from all the treatments were collected at third harvest for both years and used to estimate the five fractions of proximate analysis – crude protein, crude fibre, ether extract, total ash and nitrogen free extract of leaves and stems. Oxalate content and nutrients such as nitrogen, potassium, phosphorous, calcium and magnesium of leaves and stems at kharif, rabi and summer were also estimated during both years.

Proximate analysis

Crude protein

The data pertaining to crude protein content are given in Table 28, Table 29, Table 30 and Table 31. Crude protein content of leaves were higher than stems. The content remained unchanged under all levels of shade but substantial changes between the cultivars were observed. In general, 'IGFRI-3' recorded the highest crude protein content during both years.

During the first year, crude protein content in leaves of various cultivars ranged from 11.62 per cent to 14.25 per cent while that of stems ranged from 7.24 per cent to 9.69 per cent. Crude protein content of 'CO-3', 'CO-4' and 'Suguna'

Table 28. Effect of shade on proximate analysis of hybrid napier leaves during the first year (%)

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Shade levels					
0	13.08	26.53	2.20	51.15	8.17
25	13.02	25.19	2.21	52.80	7.78
50	12.98	23.90	2.21	54.52	7.25
LSD 5%	NS	1.12	NS	2.24	0.03
Cultivars					
CO-3	13.32	25.52	2.25	51.40	8.49
CO-4	13.15	24.93	2.42	51.92	8.40
Suguna	13.11	25.07	2.42	51.82	8.50
IGFRI-3	14.25	24.59	2.15	52.09	7.67
DHN-6	11.62	24.45	2.23	56.47	6.57
PTH	12.70	26.68	1.76	53.23	6.78
LSD 5%	0.92	0.71	0.15	1.08	0.06
Open					
CO-3	13.15	26.00	2.25	50.76	8.73
CO-4	13.21	26.18	2.38	50.38	8.66
Suguna	13.56	26.33	2.42	49.86	8.76
IGFRI-3	14.38	26.80	2.17	49.29	8.21
DHN-6	11.75	25.28	2.22	55.44	7.65
PTH	12.42	28.56	1.75	51.14	7.03
25 % shade					
CO-3	13.29	26.04	2.27	50.87	8.46
CO-4	13.48	25.05	2.40	51.44	8.33
Suguna	12.96	25.04	2.42	51.86	8.53
IGFRI-3	14.08	23.73	2.15	53.01	7.96
DHN-6	11.38	24.60	2.24	56.51	6.67
PTH	12.92	26.70	1.77	53.12	6.71
50 % shade					
CO-3	13.52	24.52	2.23	52.58	8.27
CO-4	12.77	23.57	2.48	53.94	8.21
Suguna	12.81	23.85	2.42	53.74	8.21
IGFRI-3	14.29	23.23	2.14	53.97	6.85
DHN-6	11.73	23.46	2.22	57.46	5.38
PTH	12.77	24.77	1.76	55.43	6.61
LSD 5%	NS	1.23	NS	1.86	0.10

Table 29. Effect of shade on proximate analysis of hybrid napier stems during the first year (%)

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Shade levels					
0	7.87	30.97	1.30	52.80	7.06
25	7.83	29.97	1.30	54.12	6.78
50	8.02	26.65	1.29	57.65	6.39
LSD 5%	NS	0.45	NS	0.65	0.15
Cultivars					
CO-3	7.79	28.65	1.30	54.74	7.51
CO-4	7.61	28.30	1.30	55.22	7.57
Suguna	7.71	29.54	1.25	53.92	7.58
IGFRI-3	9.69	30.01	1.37	52.01	6.92
DHN-6	7.24	27.08	1.36	59.07	5.24
PTH	7.39	31.60	1.21	54.17	5.63
LSD 5%	1.10	1.38	NS	1.66	0.18
Open					
CO-3	7.67	30.91	1.28	52.29	7.85
CO-4	7.67	30.39	1.30	52.80	7.84
Suguna	7.79	30.62	1.23	52.53	7.83
IGFRI-3	9.69	31.47	1.40	50.08	7.37
DHN-6	6.94	28.75	1.42	57.58	5.31
PTH	7.48	33.68	1.18	51.53	6.13
25 % shade					
CO-3	7.67	28.88	1.33	54.60	7.53
CO-4	7.50	28.78	1.29	54.80	7.63
Suguna	7.67	30.28	1.27	53.05	7.73
IGFRI-3	9.17	31.32	1.39	51.10	7.03
DHN-6	7.31	28.67	1.30	57.44	5.27
PTH	7.65	31.90	1.23	53.73	5.50
50 % shade					
CO-3	8.04	26.17	1.28	57.34	7.16
CO-4	7.67	25.72	1.30	58.07	7.25
Suguna	7.67	27.72	1.26	56.18	7.17
IGFRI-3	10.21	27.25	1.33	54.85	6.37
DHN-6	7.48	23.82	1.37	62.20	5.13
PTH	7.04	29.22	1.21	57.26	5.27
LSD 5%	NS	2.40	NS	2.88	0.32

Table 30. Effect of shade on proximate analysis of hybrid napier leaves during the second year (%)

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Shade levels					
0	13.16	26.71	2.24	49.34	8.55
25	13.07	25.17	2.19	51.57	8.00
50	13.06	23.96	2.26	53.20	7.53
LSD 5%	NS	0.73	NS	0.68	0.29
Cultivars					
CO-3	12.98	25.17	2.33	50.94	8.58
CO-4	12.83	25.47	2.39	50.88	8.43
Suguna	13.59	24.55	2.43	50.49	8.94
IGFRI-3	14.16	25.01	2.21	50.84	7.78
DHN-6	12.22	24.87	2.14	53.56	7.21
PTH	12.79	26.60	1.88	51.51	7.22
LSD 5%	1.05	1.13	0.18	1.46	0.22
Open					
CO-3	12.85	25.70	2.33	50.26	8.85
CO-4	12.79	26.68	2.38	49.45	8.70
Suguna	13.88	26.12	2.42	48.35	9.24
IGFRI-3	14.58	26.99	2.19	47.76	8.47
DHN-6	12.10	25.86	2.25	51.60	8.18
PTH	12.77	28.90	1.88	48.59	7.86
25 % shade					
CO-3	12.85	25.61	2.36	50.61	8.56
CO-4	13.19	25.77	2.39	50.27	8.38
Suguna	13.50	24.27	2.46	50.87	8.91
IGFRI-3	13.94	24.17	2.23	51.90	7.76
DHN-6	12.15	24.80	1.90	53.92	7.24
PTH	12.77	26.42	1.79	51.87	7.15
50 % shade					
CO-3	13.23	24.21	2.31	51.94	8.31
CO-4	12.50	23.97	2.39	52.93	8.22
Suguna	13.40	23.27	2.41	52.26	8.67
IGFRI-3	13.96	23.87	2.20	52.85	7.12
DHN-6	12.42	23.95	2.27	55.16	6.20
PTH	12.83	24.49	1.97	54.05	6.66
LSD 5%	NS	1.96	NS	2.53	0.38

Table 31. Effect of shade on proximate analysis of hybrid napier stems during the second year (%)

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Shade levels					
0	8.06	31.48	1.29	51.45	7.72
25	7.85	29.95	1.31	53.82	7.07
50	8.18	27.47	1.30	56.44	6.61
LSD 5%	NS	0.57	NS	0.95	0.22
Cultivars					
CO-3	7.97	29.28	1.33	53.61	7.80
CO-4	7.90	28.72	1.32	54.28	7.78
Suguna	8.06	29.77	1.25	52.77	8.15
IGFRI-3	9.38	30.49	1.28	51.91	6.95
DHN-6	7.42	28.24	1.37	56.83	6.14
PTH	7.46	31.31	1.24	54.02	5.96
LSD 5%	0.91	1.08	0.07	1.55	0.17
Open					
CO-3	8.04	32.18	1.34	49.88	8.56
CO-4	8.04	30.90	1.32	51.23	8.51
Suguna	8.02	31.23	1.24	50.58	8.92
IGFRI-3	9.48	31.68	1.27	50.28	7.29
DHN-6	7.48	29.62	1.35	54.90	6.66
PTH	7.31	33.26	1.22	51.84	6.37
25 % shade					
CO-3	7.67	28.69	1.33	54.57	7.74
CO-4	7.88	28.91	1.34	54.33	7.54
Suguna	7.67	30.54	1.25	52.49	8.05
IGFRI-3	8.96	31.13	1.30	51.66	6.96
DHN-6	7.48	28.69	1.37	56.32	6.14
PTH	7.48	31.75	1.23	53.56	5.97
50 % shade					
CO-3	8.21	26.95	1.32	56.40	7.12
CO-4	7.77	26.36	1.29	57.29	7.29
Suguna	8.50	27.53	1.27	55.22	7.48
IGFRI-3	9.69	28.65	1.27	53.79	6.60
DHN-6	7.31	26.41	1.37	59.28	5.62
PTH	7.58	28.93	1.28	56.65	5.55
LSD 5%	NS	1.87	NS	2.68	0.29

were comparable. In the second year, 'IGFRI-3' and 'Suguna' were at par and recorded the maximum content. Among the cultivars, content in leaves ranged from 12.22 per cent to 14.16 per cent whereas that of stems ranged from 7.42 per cent to 9.38 per cent.

Crude fibre

The crude fibre content of hybrid napier in leaves and stems at varying shade levels is given in Table 28, Table 29, Table 30 and Table 31. Crude fibre decreased with increasing shade levels and varied between the cultivars. Among the cultivars, 'PTH' recorded the highest and DHN-6' the lowest fibre content. The highest fibre content was noticed in stems in full sunlight.

During the first year, crude fibre content of leaves ranged from 23.23 per cent under 50 per cent shade to 28.56 per cent in full sunlight and that of stems ranged from 23.82 per cent under 50 per cent shade to 33.68 per cent in full sunlight. In the second year, with respect to crude fibre content of leaves, among the cultivars, 'PTH' and 'CO-4' had comparable values. The content in leaves and stem increased from 23.27 per cent to 28.90 per cent and 26. 36 per cent to 33.26 per cent respectively, for corresponding increase in light levels from 50 per cent to 100 per cent.

Ether extract

The data on crude fat content of hybrid napier leaves and stems are given in Table 28, Table 29, Table 30 and Table 31. The content was higher in leaves than stems. Shading had no significant effect on ether extract content but varied between the cultivars. Interaction effect was absent.

During the first year, the highest crude fat content of 2.42 per cent was observed in leaves of 'CO-4' and 'Suguna' while the lowest in 'PTH'. All the cultivars had comparable crude fat content in stems. In the second year, 'CO-3', 'CO-4' and 'Suguna' had comparable crude fat content in leaves recording maximum values. While in stems, maximum values were recorded in 'DHN-6', 'CO-3' and 'CO-4', which were at par. 'CO-4' was on par with 'Suguna' and 'IGFRI-3'.

Total ash

Total ash content of hybrid napier leaves and stems are given in Table 28, Table 29, Table 30 and Table 31. Total ash was higher in leaves than stems and the content decreased with increasing shade levels. Significant differences in ash content between cultivars were also observed. Among the cultivars, 'CO-3', 'CO-4' and 'Suguna' recorded maximum ash content.

During the first year, content in leaves ranged from 5.38 per cent in 'PTH' under 50 per cent shade to 8.73 per cent in 'CO-3' in full sunlight. In stems, the content ranged from 5.13 per cent to 7.85 per cent. The cultivars 'CO-3', 'CO-4' and 'Suguna' had comparable ash content. In the second year, 'Suguna' recorded maximum ash content and for leaves, the content ranged from 6.20 per cent to 9.24 per cent whereas for stems the content ranged from 5.55 per cent to 8.92 per cent.

Nitrogen free extract

The data pertaining to nitrogen free extract of hybrid napier leaves and stems are given in Table 28, Table 29, Table 30 and Table 31. Stems recorded maximum content of NFE and the content increased with increasing shade levels. There were significant differences between cultivars with respect to NFE. In general, 'DHN-6' recorded the highest NFE under all levels of shade. Interaction effects were also present.

During the first year, in leaves the content increased from 49.29 per cent in full sunlight to 57.46 per cent under 50 per cent shade and for stems, NFE increased from 50.08 per cent to 62.20 per cent for corresponding increase in shade levels to 25 per cent and 50 per cent. In the second year, the content in leaves ranged from 47.76 per cent for 'IGFRI-3' in open condition to 55.16 per cent for 'DHN-6' under 50 per cent shade. In stems, it ranged from 49.88 per cent in 'CO-3' in open condition to 59.28 per cent in 'DHN-6' under 50 per cent shade.

Percentage content of major nutrient elements

The data related to major nutrient elements are presented in Table 32, Table 33, and Table 34. Leaves recorded maximum content of nutrients compared to leaves. Effect of shade was noticed only in case of potassium content. The content of all nutrients varied among the cultivars. Interaction was noticed in case of potassium content only.

Nitrogen

During both years, 'IGFRI-3' recorded maximum nitrogen content. In the first year, the content in leaves of various cultivars ranged from 1.86 per cent to 2.28 per cent while in the second year the content ranged from 1.96 per cent to 2.27 per cent. In stems, the content increased from 1.16 per cent to 1.55 per cent for the first year whereas for the second year, the content ranged from 1.19 per cent to 1.50 per cent.

Phosphorous

All the cultivars had comparable phosphorous content, and for the first year, the content in leaves ranged from 0.202 per cent to 0.181 per cent, and from 0.149 per cent to 0.163 per cent in stems. In the second year, in leaves, maximum content observed was 0.20 per cent and in stems it was 0.163 per cent.

Potassium

All the cultivars except 'PTH' had comparable potassium content. The content decreased with increasing shade levels. The content in leaves ranged from 1.82 per cent under 50 per cent shade to 2.33 per cent in full sunlight and in stems from 1.20 per cent to 1.93 per cent for the first year. While for the second year, the content in leaves ranged from 1.51 per cent to 1.97 per cent. In stems, the content ranged from 1.33 per cent to 1.78 per cent.

Table 32. Effect of shade on primary nutrient content (%) of hybrid napier leaves

Treatment	Nitrogen		Phosphorous		Potassium	
	First year	Second year	First year	Second year	First year	Second year
Shade levels						
0	2.09	2.11	0.194	0.191	2.27	1.92
25	2.08	2.09	0.192	0.190	2.17	1.83
50	2.08	2.09	0.192	0.191	1.92	1.72
LSD 5%	NS	NS	NS	NS	0.04	0.06
Cultivars						
CO-3	2.13	2.08	0.199	0.196	2.23	1.88
CO-4	2.10	2.05	0.193	0.190	2.17	1.88
Suguna	2.10	2.17	0.196	0.194	2.14	1.86
IGFRI-3	2.28	2.27	0.185	0.186	2.13	1.85
DHN-6	1.86	1.96	0.181	0.178	1.99	1.63
PTH	2.03	2.05	0.202	0.200	2.07	1.84
LSD 5%	0.15	0.17	0.022	0.02	0.06	0.05
Open						
CO-3	2.10	2.06	0.200	0.195	2.33	1.97
CO-4	2.11	2.05	0.194	0.190	2.32	1.96
Suguna	2.17	2.22	0.196	0.194	2.30	1.96
IGFRI-3	2.30	2.33	0.186	0.185	2.30	1.96
DHN-6	1.88	1.94	0.182	0.179	2.14	1.72
PTH	1.99	2.04	0.204	0.200	2.23	1.94
25 % shade						
CO-3	2.13	2.06	0.199	0.197	2.25	1.87
CO-4	2.16	2.11	0.192	0.187	2.25	1.88
Suguna	2.07	2.16	0.195	0.194	2.21	1.89
IGFRI-3	2.25	2.23	0.186	0.187	2.21	1.85
DHN-6	1.82	1.94	0.179	0.176	1.97	1.67
PTH	2.07	2.04	0.201	0.200	2.17	1.84
50 % shade						
CO-3	2.16	2.12	0.197	0.196	2.12	1.79
CO-4	2.04	2.00	0.192	0.191	1.93	1.81
Suguna	2.05	2.14	0.195	0.193	1.91	1.72
IGFRI-3	2.29	2.23	0.184	0.186	1.87	1.75
DHN-6	1.88	1.99	0.181	0.179	1.86	1.51
PTH	2.04	2.05	0.200	0.201	1.82	1.75
LSD 5%	NS	NS	NS	NS	0.10	0.09

Table 33. Effect of shade on primary nutrient content (%) of hybrid napier stems

Treatment	Nitrogen		Phosphorous		Potassium	
	First year	Second year	First year	Second year	First year	Second year
Shade levels						
0	1.26	1.29	0.155	0.156	1.76	1.58
25	1.25	1.26	0.156	0.156	1.62	1.53
50	1.28	1.31	0.157	0.155	1.42	1.42
LSD 5%	NS	NS	NS	NS	0.03	0.02
Cultivars						
CO-3	1.25	1.28	0.156	0.156	1.69	1.65
CO-4	1.22	1.26	0.154	0.155	1.68	1.52
Suguna	1.23	1.29	0.155	0.154	1.62	1.48
IGFRI-3	1.55	1.50	0.149	0.151	1.55	1.43
DHN-6	1.16	1.19	0.159	0.156	1.45	1.44
PTH	1.18	1.19	0.163	0.163	1.60	1.54
LSD 5%	0.18	0.15	0.013	0.010	0.07	0.06
Open						
CO-3	1.23	1.29	0.154	0.157	1.93	1.78
CO-4	1.23	1.29	0.153	0.155	1.80	1.58
Suguna	1.25	1.28	0.154	0.155	1.77	1.51
IGFRI-3	1.55	1.52	0.147	0.151	1.77	1.52
DHN-6	1.11	1.20	0.159	0.157	1.58	1.50
PTH	1.20	1.17	0.163	0.164	1.72	1.60
25 % shade						
CO-3	1.23	1.23	0.156	0.156	1.71	1.68
CO-4	1.20	1.26	0.154	0.156	1.71	1.52
Suguna	1.23	1.23	0.154	0.152	1.59	1.49
IGFRI-3	1.47	1.43	0.148	0.152	1.56	1.45
DHN-6	1.17	1.20	0.159	0.155	1.56	1.47
PTH	1.22	1.20	0.163	0.163	1.56	1.55
50 % shade						
CO-3	1.29	1.31	0.157	0.156	1.43	1.50
CO-4	1.23	1.24	0.154	0.155	1.54	1.47
Suguna	1.23	1.36	0.155	0.154	1.48	1.45
IGFRI-3	1.63	1.55	0.152	0.149	1.32	1.32
DHN-6	1.20	1.17	0.159	0.155	1.20	1.33
PTH	1.13	1.21	0.162	0.163	1.52	1.47
LSD 5%	NS	NS	NS	NS	0.12	0.10

Table 34. Effect of shade on secondary nutrient content (%) of hybrid napier leaves and stems

Treatment	Ca leaves		Ca stems		Mg leaves		Mg stems	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
Shade levels								
0	0.279	0.349	0.218	0.295	0.328	0.325	0.315	0.311
25	0.269	0.345	0.225	0.291	0.324	0.323	0.310	0.311
50	0.267	0.346	0.225	0.294	0.326	0.324	0.309	0.309
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars								
CO-3	0.283	0.395	0.251	0.332	0.327	0.327	0.316	0.310
CO-4	0.310	0.408	0.261	0.374	0.328	0.329	0.311	0.313
Suguna	0.287	0.382	0.234	0.322	0.329	0.322	0.313	0.307
IGFRI-3	0.270	0.394	0.206	0.301	0.322	0.323	0.310	0.312
DHN-6	0.267	0.261	0.151	0.237	0.322	0.321	0.309	0.310
PTH	0.215	0.238	0.234	0.193	0.328	0.322	0.310	0.309
LSD 5%	0.022	0.038	0.013	0.028	0.011	0.009	0.008	0.007
Open								
CO-3	0.284	0.398	0.250	0.336	0.330	0.330	0.320	0.310
CO-4	0.310	0.412	0.262	0.375	0.327	0.327	0.313	0.313
Suguna	0.287	0.383	0.234	0.325	0.330	0.320	0.317	0.310
IGFRI-3	0.271	0.400	0.209	0.304	0.330	0.327	0.313	0.303
DHN-6	0.272	0.263	0.153	0.239	0.323	0.327	0.317	0.317
PTH	0.252	0.240	0.199	0.190	0.330	0.320	0.310	0.310
25 % shade								
CO-3	0.283	0.394	0.251	0.333	0.323	0.323	0.317	0.317
CO-4	0.312	0.404	0.261	0.370	0.320	0.333	0.310	0.310
Suguna	0.287	0.38	0.232	0.320	0.330	0.323	0.313	0.300
IGFRI-3	0.272	0.393	0.205	0.295	0.323	0.320	0.303	0.320
DHN-6	0.266	0.259	0.150	0.234	0.323	0.313	0.307	0.310
PTH	0.195	0.238	0.251	0.195	0.323	0.323	0.310	0.310
50 % shade								
CO-3	0.281	0.393	0.252	0.328	0.327	0.327	0.310	0.303
CO-4	0.307	0.408	0.259	0.376	0.337	0.327	0.310	0.317
Suguna	0.285	0.383	0.236	0.321	0.327	0.323	0.310	0.310
IGFRI-3	0.266	0.390	0.204	0.304	0.313	0.323	0.313	0.313
DHN-6	0.264	0.260	0.149	0.237	0.320	0.323	0.303	0.303
PTH	0.197	0.237	0.251	0.194	0.330	0.323	0.310	0.307
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS

Calcium and magnesium

There were significant differences in Ca content between the cultivars. During both years, 'CO-4' recorded the maximum content and 'PTH' the least, but during the first year, in stems, 'DHN-6' had the lowest Ca content. In case of Mg, all the cultivars had comparable amount in both leaves and stems.

Antinutritional factor

Oxalate content

Oxalate content of hybrid napier leaves and stems are presented in Table 35 and Table 36. Leaves showed higher content of oxalate compared to stems. During the first year, the crop had higher content of oxalate during the kharif season while during the second year, the crop showed maximum oxalate content in the rabi season. The content in plants increased with increasing shade levels.

During the first year, among the cultivars, 'IGFRI-3' showed the highest oxalate content. For the kharif season, in leaves, content increased from 2.14 per cent in 'CO-3' in full sunlight to 4.77 per cent in 'IGFRI-3' under 50 per cent shade. In full sunlight, the cultivars 'Suguna', 'DHN-6' and 'PTH' were on par with 'IGFRI-3'. In 25 per cent shade, all the cultivars except 'CO-4' and 'PTH' were on par with 'IGFRI-3' but at 50 per cent shade all the cultivars had comparable oxalate content. In stems, the content increased from 1.33 per cent to 3.96 per cent with increasing shade levels. In rabi, the content in leaves increased from 1.25 per cent in 'DHN-6' in full sunlight to 3.65 per cent in 'IGFRI-3' at 50 per cent shade, whereas stem contents ranged from 1.25 per cent to 1.59 per cent. In summer, the content in leaves ranged from 1.54 per cent to 3.42 per cent while in stems from 1.25 per cent to 1.84 per cent.

In the second year, all the cultivars had comparable amount of oxalate. During kharif, in leaves, the content ranged from 2.71 per cent in full sunlight to 4.72 per cent in 50 per cent shade and the corresponding increase for the stem content was from 1.24 per cent to 3.97 per cent. At the same time, the highest

Table 35. Effect of shade on oxalate content (%) of hybrid napier leaves

Treatment	Kharif		Rabi		Summer	
	First year	Second year	First year	Second year	First year	Second year
Shade levels						
0	2.80	3.08	1.92	3.85	1.70	1.93
25	3.59	3.57	2.50	4.35	2.19	2.63
50	4.47	4.46	3.18	4.72	3.28	3.55
LSD 5%	0.32	0.38	0.20	0.31	0.36	0.42
Cultivars						
CO-3	3.33	3.72	2.57	4.20	2.29	2.74
CO-4	3.34	3.65	2.62	4.49	2.43	2.90
Suguna	3.68	3.73	2.96	3.84	2.38	2.75
IGFRI-3	4.11	3.93	3.25	4.50	2.42	2.74
DHN-6	3.67	3.60	1.39	4.24	2.40	2.53
PTH	3.61	3.60	2.42	4.57	2.43	2.56
LSD 5%	0.38	NS	0.20	0.30	NS	0.30
Open						
CO-3	2.14	3.04	1.75	3.50	1.54	1.84
CO-4	2.50	3.25	1.79	4.04	1.61	2.08
Suguna	2.92	3.15	2.21	3.43	1.79	1.79
IGFRI-3	3.46	3.56	2.80	4.25	1.79	2.04
DHN-6	2.83	2.79	1.25	3.54	1.75	1.84
PTH	2.96	2.71	1.71	4.34	1.71	1.96
25 % shade						
CO-3	3.59	3.64	2.58	4.38	2.17	2.75
CO-4	3.33	3.54	2.58	4.50	2.25	2.79
Suguna	3.54	3.56	3.04	3.96	2.08	2.79
IGFRI-3	4.09	3.50	3.29	4.54	2.13	2.59
DHN-6	3.68	3.50	1.42	4.17	2.17	2.38
PTH	3.33	3.67	2.09	4.54	2.33	2.50
50 % shade						
CO-3	4.25	4.46	3.38	4.71	3.17	3.63
CO-4	4.17	4.17	3.49	4.92	3.42	3.84
Suguna	4.59	4.49	3.63	4.13	3.25	3.67
IGFRI-3	4.77	4.72	3.65	4.71	3.34	3.60
DHN-6	4.50	4.49	1.50	4.99	3.28	3.38
PTH	4.55	4.43	3.45	4.83	3.25	3.21
LSD 5%	0.65	0.66	0.34	0.52	0.30	0.52

Table 36. Effect of shade on oxalate content (%) of hybrid napier stems

Treatment	Kharif		Rabi		Summer	
	First year	Second year	First year	Second year	First year	Second year
Shade levels						
0	2.00	1.45	1.29	3.06	1.32	1.49
25	2.60	2.65	1.33	3.33	1.60	1.68
50	3.77	3.74	1.44	3.61	1.74	1.90
LSD 5%	0.32	0.19	0.18	0.17	0.13	0.20
Cultivars						
CO-3	2.61	2.55	1.34	3.10	1.45	1.77
CO-4	2.70	2.75	1.33	2.89	1.51	1.74
Suguna	2.72	2.49	1.47	3.21	1.58	1.70
IGFRI-3	3.31	2.87	1.39	3.46	1.66	1.85
DHN-6	2.38	2.38	1.25	3.13	1.49	1.54
PTH	3.01	2.65	1.33	4.21	1.64	1.56
LSD 5%	0.28	0.32	0.11	0.20	0.16	0.15
Open						
CO-3	1.33	1.43	1.29	2.75	1.28	1.58
CO-4	1.42	1.58	1.35	2.71	1.28	1.50
Suguna	2.46	1.50	1.33	2.92	1.27	1.42
IGFRI-3	3.08	1.71	1.25	3.08	1.35	1.79
DHN-6	1.40	1.24	1.25	2.75	1.25	1.25
PTH	2.29	1.25	1.25	4.13	1.50	1.42
25 % shade						
CO-3	2.75	2.54	1.28	3.04	1.50	1.79
CO-4	2.88	2.87	1.27	2.88	1.58	1.75
Suguna	2.19	2.42	1.50	3.17	1.63	1.69
IGFRI-3	2.87	2.92	1.33	3.54	1.78	1.83
DHN-6	2.08	2.24	1.25	3.13	1.50	1.50
PTH	2.79	2.88	1.33	4.21	1.58	1.54
50 % shade						
CO-3	3.75	3.69	1.46	3.50	1.58	1.92
CO-4	3.79	3.78	1.37	3.08	1.67	1.96
Suguna	3.51	3.55	1.59	3.54	1.84	2.00
IGFRI-3	3.96	3.97	1.59	3.75	1.83	1.92
DHN-6	3.67	3.64	1.25	3.50	1.71	1.88
PTH	3.94	3.82	1.42	4.30	1.84	1.71
LSD 5%	0.48	0.56	0.20	0.35	0.28	0.25

oxalate content for the experimental period was recorded in the rabi season and the content in leaves increased from 3.43 per cent in full sunlight to 4.99 per cent under 50 per cent shade. In stems, the content ranged from 2.71 per cent to 4.30 per cent. In the summer season, the content in leaves ranged from 1.79 per cent to 3.84 per cent whereas for the stems the content ranged from 1.25 per cent to 2.00 per cent.

4.2. EXPERIMENT II: NITROGEN NUTRITION AND CUTTING FREQUENCY IN HYBRID NAPIER GROWN UNDER RAINFED CONDITION

4.2.1. Morphological characters

Cutting frequency and nitrogen nutrition had significant effect on morphological characters of hybrid napier. In general, increasing trend in plant height, number of tillers, number of leaves, length and width of leaves was observed when more time was given between harvesting dates. Likewise, all the morphological characters increased with increasing nitrogen dose.

Plant height

The data pertaining to plant height are given in Table 37 and Table 38. Plant height increased with increasing the cutting interval and nitrogen rate. During the first year, plant height showed decreasing trend towards the final harvest. In general, maximum plant height was recorded at the first harvest of the first year. The effect of cutting frequency was observed from the second harvest only. The highest plant height (224.17 cm) for the first year was observed in plants harvested at 60 days of cutting interval and those fertilized with 400kg/ha N, during the second harvest.

In the first harvest, plant height increased with increasing nitrogen doses. Plant height ranged from 115.23 cm to 173.57 cm for nitrogen levels of 0 kg/ha N to 400 kg/ha N while interaction effect was absent. During the second harvest, considering the effect of cutting frequency alone, grass height ranged from 137.74 cm for cutting interval of 30 days to 183.34 cm for cutting interval of 60 days. With respect to nitrogen fertilization, plant height ranged from 116.07 cm to 190.13 cm for 0 kg/ha N and 400 kg/ha N. Regarding the interaction effect, plant height ranged from

Table 37. Effect of nitrogen nutrition and cutting frequency on plant height (cm) of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	148.83	137.74	108.54	97.78	51.78
45 days	149.03	146.54	114.67	52.21	NH
60 days	148.47	183.34	121.34	NH	NH
LSD 5%	NS	1.56	1.59	1.60	-
N levels (kg/ha)					
0	115.23	116.07	88.30	58.15	-
100	135.79	138.64	99.34	63.87	-
200	157.18	159.29	110.46	74.35	-
300	162.12	175.23	133.93	87.10	-
400	173.57	190.13	142.22	91.50	-
LSD 5%	1.61	2.01	2.05	2.53	
30 days					
0	115.34	103.87	84.87	77.47	37.93
100	135.10	122.00	90.80	83.87	46.60
200	157.47	143.33	102.67	98.87	52.20
300	162.00	151.07	127.33	112.03	57.93
400	174.23	168.43	137.03	116.67	64.23
45 days					
0	115.73	113.07	86.10	38.83	NH
100	136.27	130.63	99.20	43.87	
200	156.80	152.27	110.13	49.83	
300	162.60	158.93	134.90	62.17	
400	173.73	177.80	143.03	66.33	
60 days					
0	114.60	131.27	93.93	NH	NH
100	136.00	163.30	108.03		
200	157.27	182.27	118.57		
300	161.77	215.70	139.57		
400	172.73	224.17	146.60		
LSD 5%	NS	3.49	3.55	3.58	3.05

NH- No harvest

Table 38. Effect of nitrogen nutrition and cutting frequency on plant height (cm) of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	104.11	120.00	110.69	113.51	88.85	81.60	72.85
45 days	119.33	182.12	130.49	166.53	100.84	NH	NH
60 days	129.66	213.13	142.72	177.93	NH	NH	NH
LSD 5%	1.86	1.74	1.59	1.56	1.66	-	-
N levels (kg/ha)							
0	92.16	144.28	100.00	109.30	71.24	-	-
100	106.61	159.48	112.06	138.80	80.80	-	-
200	118.62	172.64	129.49	159.72	93.83	-	-
300	131.49	184.78	142.77	173.18	106.38	-	-
400	139.62	197.58	155.51	182.29	121.97	-	-
LSD 5%	2.40	2.25	2.06	2.01	2.62	-	
30 days							
0	70.50	99.77	82.97	70.90	64.83	58.67	50.73
100	98.50	111.33	97.77	99.24	77.23	71.83	64.30
200	107.40	120.70	117.50	116.33	85.50	78.00	74.17
300	119.00	128.53	123.00	136.37	99.43	94.63	82.53
400	125.17	139.67	132.20	144.70	117.27	104.83	92.53
45 days							
0	97.30	158.13	99.23	125.17	77.65	NH	NH
100	106.33	171.60	111.87	153.00	84.37		
200	118.17	180.07	131.53	173.83	102.17		
300	132.10	194.47	146.13	185.50	113.33		
400	142.73	206.33	163.67	195.17	126.67		
60 days							
0	108.67	174.93	117.80	131.83	NH	NH	NH
100	115.00	195.50	126.53	164.17			
200	130.30	217.17	139.43	189.00			
300	143.37	231.33	159.17	197.67			
400	150.97	246.73	170.67	207.00			
LSD 5%	4.15	3.89	3.56	3.48	3.70	3.39	3.12

NH- No harvest

103.87 cm for cutting frequency of 30 days at N rates of 0 kg/ha to 224.17 cm for cutting frequency of 60 days at N rates of 400 kg/ha.

During the third harvest, considering the effect of cutting interval, plant height ranged from 108.54 cm to 121.34 cm on delaying the harvesting from 30 days to 60 days. With respect to nitrogen fertilization alone, grass height increased from 88.30 cm to 142.22 cm for nitrogen rates ranging from 0 kg/ha to 400 kg/ha. Concerning the interaction effect, plant height increased from 84.87 cm at 30 days of harvesting without nitrogen to 146.60 cm at 60 days of harvesting with 400 kg/ha N.

Among the three cutting frequencies, the fourth cutting was done in the case of 30 and 45 days frequencies. No cutting beyond three harvests could be done in the case of 60 days frequency. In the fourth harvest, plants harvested at 30 days cutting frequency showed greater height than plants cut at 45 days frequency. At 30 days of harvesting interval, plant height increased from 77.47 cm to 116.67 cm on increasing the nitrogen levels from 0 kg/ha N to 400 kg/ha N. In the case of 45 days of cutting interval, the height ranged from 38.83 cm to 66.33 cm for nitrogen levels from 0 kg/ha N to 400kg/ha N.

The fifth cutting was possible only from plots with 30 days cutting interval where the plant height ranged from 37.93 cm to 64.23 cm when the nitrogen rates increased from 0 kg/ha N to 400 kg/ha N.

In the second year, a peak in plant height was observed at the second and the fourth cutting which coincided with the periods of South west and North east monsoon periods. During the first harvest, plant height increased from 70.50 cm to 150.97 cm for cutting intervals of 30 days and 60 days where the nitrogen levels increased from 0 kg/ha to 400kg/ha. By the second harvest, the highest plant height (246.73 cm) was observed in plants harvested at 60 days interval which received 400kg/ha N and the lowest (99.77 cm) was observed when plants where not fertilized and harvested at 30 days interval. The same trend was observed for the third and the fourth harvests also.

The fifth cutting was possible in the case of 30 and 45 days cutting frequencies. During the fifth harvest, plant height increased from 64.83 cm to 126.67 cm for cutting intervals of 30 days and 45 days respectively when the nitrogen rates increased from 0 kg/ha to 400 kg/ha. Two more harvests were taken from plants receiving 30 days cutting frequency. In such plots, plant height increased from 58.67 cm to 104.83 cm at the sixth harvest, and from 50.73 cm to 92.53 cm at the seventh harvest when nitrogen rates were increased from 0 kg/ha to 400 kg/ha.

Leaf length

Leaf lengths of hybrid napier at different cutting frequencies and nitrogen levels are given in Table 39 and Table 40. Maximum leaf length was attained at the second harvests during both years. During the first year, at the first harvest, leaf length was influenced only by the effect of varying doses of nitrogen whereas the interaction effect was observed from the second harvest onwards. In the first harvest, leaf lengths ranged from 52.20 cm to 86.66 cm when nitrogen levels increased from 0 kg/ha to 400 kg/ha.

At the second harvest, the crop showed the minimum leaf length of 56.63 cm at 0 kg/ha N when harvested at 30 days interval while it could attain a maximum of 124.33 cm for 60 days of harvesting interval at nitrogen rate of 400 kg/ha. Similarly, at the third harvest, leaf lengths ranged from 49.07 cm for 30 days of harvest to 112.00 cm for 60 days of harvest where the nitrogen levels were increased from 0 kg/ha to 400 kg/ha.

The fourth harvest, was done only from 30 days and 45 days cutting intervals. Maximum leaf length was observed when harvested at 30 days interval compared to 45 days of interval. Leaf lengths increased with increasing nitrogen levels in both cutting intervals.

The fifth cutting was possible only from 30 days interval where the leaves showed minimum length during the first year. Leaf length increased from 23 cm to 55.13 cm for increase in nitrogen levels from 0 kg/ha to 400 kg/ha.

Table 39. Effect of nitrogen nutrition and cutting frequency on leaf length (cm) of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	67.85	77.44	69.05	55.46	41.13
45 days	67.87	91.25	77.33	44.93	NH
60 days	67.77	97.53	86.74	NH	NH
LSD 5%	NS	1.20	1.46	1.67	-
N levels (kg/ha)					
0	52.20	66.03	56.28	32.65	-
100	58.43	74.69	67.02	40.92	-
200	65.00	87.27	76.77	46.90	-
300	76.88	102.97	86.82	61.08	-
400	86.66	112.74	101.64	69.42	-
LSD 5%	1.71	1.55	1.88	2.64	-
30 days					
0	52.00	56.63	49.07	37.97	23.00
100	58.63	66.23	59.03	47.50	34.00
200	65.00	80.23	67.53	53.17	43.00
300	76.63	87.83	77.03	66.67	50.53
400	87.00	96.27	92.60	72.00	55.13
45 days					
0	52.33	66.47	55.40	27.33	NH
100	58.27	76.07	67.63	34.33	
200	65.00	89.67	76.17	40.62	
300	77.27	106.40	87.10	55.50	
400	86.50	117.63	100.33	66.83	
60 days					
0	52.27	75.00	64.37	NH	NH
100	58.40	81.77	74.40		
200	65.00	91.90	86.60		
300	76.73	114.67	96.33		
400	86.47	124.33	112.00		
LSD 5%	NS	2.68	3.26	3.73	3.12

NH- No harvest

Table 40. Effect of nitrogen nutrition and cutting frequency on leaf length (cm) of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	73.06	92.09	83.99	65.09	47.85	43.65	43.69
45 days	79.88	106.73	95.04	72.88	56.80	NH	NH
60 days	89.03	122.95	112.92	84.15	NH	NH	NH
LSD 5%	1.07	1.31	1.43	1.18	1.28	-	
N levels (kg/ha)							
0	61.09	82.47	74.98	52.54	36.12	-	-
100	70.39	97.03	85.22	63.87	43.87	-	-
200	82.37	108.32	97.57	75.12	52.92	-	-
300	91.67	118.83	109.14	84.72	60.42	-	-
400	97.78	129.62	119.68	93.96	68.32	-	-
LSD 5%	1.38	1.68	1.85	1.52	2.02	-	-
30 days							
0	53.67	63.17	60.10	45.73	33.27	25.70	22.07
100	64.37	82.13	73.33	51.67	39.03	34.20	35.27
200	74.10	94.10	81.33	65.33	48.17	41.00	43.17
300	84.10	104.43	96.77	76.23	55.13	54.67	54.27
400	89.07	116.63	108.43	86.50	63.67	62.70	63.67
45 days							
0	61.83	81.90	71.83	52.77	38.97	NH	NH
100	69.97	91.97	85.70	63.80	48.70		
200	83.67	107.53	95.97	71.83	57.67		
300	88.33	120.77	103.83	83.67	65.70		
400	95.60	131.47	117.87	92.33	72.97		
60 days							
0	67.77	102.33	93.00	59.13	NH	NH	NH
100	76.83	117.00	96.63	76.13			
200	89.33	123.33	115.40	88.20			
300	102.57	131.30	126.83	94.27			
400	108.67	140.77	132.73	103.03			
LSD 5%	2.39	2.92	3.20	2.64	2.86	1.75	4.84

NH- No harvest

In the second year, maximum leaf length was attained at the second harvest and thereafter a declining trend was noticed. For all the four harvests, the least leaf length was when harvested at 30 days interval and grown without nitrogen fertilization. The highest length was noticed when harvested at 60 days interval and fertilized with 400 kg/ha N.

At the first harvest, leaf length increased from 53.67 cm to 108.67 cm on delaying the cutting from 30 days to 60 days and for corresponding increase in nitrogen levels from 0 kg/ha to 400kg/ha. In the second harvest, the crop could attain maximum leaf length of 140.77 cm which was the highest value recorded during the experimental period when harvested at 60 days interval and fertilized with 400 kg/ha.

The fifth harvest was taken only from plots receiving 30 days and 45 days cutting intervals where the higher leaf length was observed when harvested at 60 days interval and applied with 400 kg/ha N. The least leaf length was attained when harvested at 30 days interval and grown without nitrogen fertilization.

The crop showed the lowest leaf length during the final two harvests (sixth and seventh) from 30 days interval. For these two harvests leaf length increased with increasing nitrogen levels.

Leaf width

Leaf width of hybrid napier is shown in Table 41and Table 42. During the first year, maximum leaf width was attained at the first harvest and thereafter decreased towards the final harvest. In general, maximum leaf width was obtained by the crop when grown with 400 kg/ha N and harvested at 60 days after the previous harvest.

During the first harvest, effect of cutting frequency on leaf width was not significant whereas increase in leaf width with increasing dose of nitrogen was

Table 41. Effect of nitrogen nutrition and cutting frequency on leaf width (cm) of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	2.45	1.65	1.45	1.40	0.84
45 days	2.42	2.10	1.56	1.26	NH
60 days	2.43	2.29	2.03	NH	NH
LSD 5%	NS	0.05	0.02	0.02	-
N levels (kg/ha)					
0	1.89	1.49	1.22	0.98	-
100	2.04	1.74	1.46	1.08	-
200	2.36	1.95	1.64	1.28	-
300	2.87	2.25	1.94	1.60	-
400	3.01	2.64	2.13	1.69	-
LSD 5%	0.08	0.07	0.03	0.04	-
30 days					
0	1.93	1.27	1.00	1.02	0.64
100	2.03	1.43	1.20	1.10	0.74
200	2.37	1.56	1.42	1.32	0.83
300	2.90	1.87	1.75	1.72	0.95
400	3.00	2.13	1.90	1.82	1.03
45 days					
0	1.87	1.50	1.10	0.93	NH
100	2.03	1.76	1.35	1.07	
200	2.33	1.99	1.51	1.24	
300	2.87	2.35	1.82	1.48	
400	3.00	2.89	2.00	1.57	
60 days					
0	1.87	1.71	1.56	NH	NH
100	2.07	2.04	1.83		
200	2.37	2.29	1.99		
300	2.83	2.53	2.26		
400	3.03	2.90	2.49		
LSD 5%	NS	0.12	0.05	0.06	0.09

NH- No harvest

Table 42. Effect of nitrogen nutrition and cutting frequency on leaf width (cm) of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	2.15	2.65	1.99	1.53	1.20	1.12	1.02
45 days	2.49	3.20	2.10	1.71	1.33	NH	NH
60 days	2.87	3.45	2.45	1.89	NH	NH	NH
LSD 5%	0.04	0.03	0.02	0.03	0.02	-	-
N levels (kg/ha)							
0	2.20	2.55	1.78	1.45	1.06	-	-
100	2.33	2.72	1.98	1.58	1.16	-	-
200	2.48	3.05	2.17	1.72	1.26	-	-
300	2.65	3.41	2.37	1.83	1.37	-	-
400	2.86	3.77	2.59	1.98	1.47	-	-
LSD 5%	0.05	0.04	0.02	0.04	0.03	-	-
30 days							
0	2.03	2.21	1.62	1.22	1.00	0.88	0.80
100	2.10	2.29	1.83	1.42	1.10	1.04	0.93
200	2.13	2.49	2.00	1.52	1.19	1.13	1.03
300	2.20	3.03	2.20	1.64	1.32	1.21	1.13
400	2.29	3.21	2.30	1.87	1.40	1.35	1.20
45 days							
0	2.22	2.59	1.71	1.50	1.12	NH	NH
100	2.36	2.83	1.90	1.60	1.23		
200	2.54	3.16	2.13	1.70	1.32		
300	2.61	3.47	2.30	1.82	1.42		
400	2.73	3.97	2.45	1.91	1.54		
60 days							
0	2.35	2.85	2.00	1.62	NH	NH	NH
100	2.52	3.02	2.19	1.71			
200	2.79	3.51	2.40	1.93			
300	3.13	3.71	2.60	2.02			
400	3.54	4.13	3.03	2.15			
LSD 5%	0.08	0.07	0.04	0.08	0.05	0.05	0.06

NH- No harvest

observed. The leaf width increased from 1.89 cm to 3.01cm with increasing dose of nitrogen from 0 kg/ha to 400 kg/ha.

For the second and the third harvests, delaying the harvests from 30 days to 60 days along with increasing the nitrogen rates from 0 kg/ha to 400 kg/ha, leaf width increased from 1.27cm to 2.90 cm and from 1.0 cm to 2.49 cm respectively. The fourth harvest was restricted to 30 days and 45 days of cutting intervals. Among the two cutting frequencies, the crop attained maximum leaf width when harvested at 30 days interval and applied with 400 kg/ha N. The fifth harvest was restricted to 30 days of cutting frequencies, where the crop attained the least leaf width during the experiment and the leaf width increased from 0.64 cm to 1.03 cm when the nitrogen rates were increased from 0 kg/ha to 400 kg/ha.

During the second year, the crop attained the highest leaf width at the second harvest, and thereafter, decreased towards the final harvest. The highest leaf width recorded was 4.13 cm when harvested at 60 days interval and fertilized with 400 kg N/ha. In all the harvests, minimum leaf width was attained when grown without nitrogen and harvested at 30 days interval. At the first four harvests, higher leaf width was attained when fertilized with 400 kg/ha N and on delaying the harvest to 60 days.

The fifth harvest was possible only from 30 days and 45 days of cutting intervals where the maximum leaf width was observed in crops harvested at 45 days interval and fertilized with 400 kg/ha N. The final two harvests (sixth and seventh) were confined to 30 days of cutting frequency, where the crop fertilized with 400 kg/ha N attained maximum leaf width.

Number of tillers

Nitrogen fertilization and cutting frequency effects on tiller production of hybrid napier are shown in Table 43 and Table 44. Tiller number showed an increasing trend towards the final harvest during both the years. In general, increasing the nitrogen rates and delaying the harvesting had a significant facilitating effect on number of tillers per clump.

Table 43. Effect of nitrogen nutrition and cutting frequency on no. of tillers /clump of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	14.27	20.81	26.47	33.39	37.62
45 days	14.20	23.28	34.82	40.55	NH
60 days	14.09	26.09	39.34	NH	NH
LSD 5%	NS	0.45	1.69	0.56	-
N levels (kg/ha)					
0	8.46	16.03	20.98	24.05	-
100	11.60	18.57	27.20	29.33	-
200	13.79	22.21	33.37	38.33	-
300	16.51	28.62	41.11	43.93	-
400	20.59	31.54	45.07	49.22	-
LSD 5%	0.62	0.59	2.19	0.89	-
30 days					
0	8.43	13.67	17.10	22.33	29.10
100	11.77	15.77	22.83	27.77	32.60
200	13.87	19.77	26.00	33.67	36.00
300	16.67	26.43	31.33	37.77	44.53
400	20.63	28.43	35.10	45.43	45.87
45 days					
0	8.50	15.67	21.10	25.77	NH
100	11.50	18.43	26.00	30.90	
200	14.00	22.10	33.67	43.00	
300	16.53	28.43	44.67	50.10	
400	20.47	31.77	48.67	53.00	
60 days					
0	8.43	18.77	24.73	NH	NH
100	11.53	21.50	32.77		
200	13.50	24.77	40.43		
300	16.33	31.00	47.33		
400	20.67	34.43	51.43		
LSD 5%	NS	1.01	3.79	1.26	4.44

NH- No harvest

Table 44. Effect of nitrogen nutrition and cutting frequency on no. of tillers /clump of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	15.51	22.07	32.45	45.87	51.98	58.53	61.47
45 days	19.49	25.20	42.84	50.70	55.77	NH	NH
60 days	26.19	32.89	49.47	55.97	NH	NH	NH
LSD 5%	0.36	0.60	0.75	0.63	0.70	-	-
N levels (kg/ha)							
0	14.23	19.96	31.59	38.06	41.17	-	-
100	17.92	23.46	37.72	45.39	48.72	-	-
200	20.32	27.06	41.56	51.17	55.00	-	-
300	23.21	29.93	45.98	58.11	60.00	-	-
400	26.30	33.20	51.09	61.50	64.48	-	-
LSD 5%	0.46	0.77	0.97	0.82	1.11	-	
30 days							
0	9.50	15.20	24.33	30.33	38.17	47.00	51.00
100	12.93	18.60	28.50	37.33	47.10	51.67	54.17
200	15.53	22.33	31.50	47.00	53.00	60.33	62.67
300	18.43	25.53	36.83	55.33	58.67	65.33	67.67
400	21.17	28.67	41.07	59.33	62.97	68.33	71.83
45 days							
0	11.43	18.67	28.77	37.67	44.17	NH	NH
100	16.33	21.67	39.33	47.17	50.33		
200	19.33	25.33	44.17	50.17	57.00		
300	23.37	28.17	48.43	57.33	61.33		
400	26.97	32.17	53.50	61.17	66.00		
60 days							
0	21.77	26.00	41.67	46.17	NH	NH	NH
100	24.50	30.10	45.33	51.67			
200	26.10	33.50	49.00	56.33			
300	27.83	36.10	52.67	61.67			
400	30.77	38.77	58.70	64.00			
LSD 5%	0.79	1.34	1.68	1.41	1.57	1.29	1.57

NH- No harvest

As the first harvest in the first year was done uniformly at 75 days after planting, cutting frequency effects was absent. However, tiller number per clump increased from 8.46 to 20.59 with increasing nitrogen rates from 0 kg/ha to 400 kg/ha. At the second and the third harvest, number of tillers per clump ranged from 13.67 to 34.43 and from 17.10 to 51.43 respectively when the harvesting was delayed from 30 days to 60 days and for a corresponding increase in nitrogen rates from 0 kg/ha to 400 kg/ha.

At the fourth harvest, cutting was done only from 30 days and 45 days cutting intervals and higher number of tillers per clump was obtained from 45 days of cutting interval but fertilized with 400 kg/ha N. The fifth harvest was confined to 30 days of cutting interval where maximum number of tillers per clump was obtained for higher doses of nitrogen, i.e. for 300 kg/ha N and 400 kg/ha N which were at par.

After the final harvest in the first year, tiller number decreased at the first harvest during the second year but increased towards the final harvest. In the first harvest, number of tillers per clump ranged from 9.50 to 30.77 at cutting intervals of 30 days and 60 days and for corresponding increase in nitrogen from 0 kg/ha to 400 kg/ha.

For 60 days of cutting interval, the highest number of tillers per clump (64) was obtained at the fourth harvest for crop fertilized with 400 kg/ha N. While for 45 days of cutting interval, it was 66 number of tillers per clump at nitrogen rate of 400 kg/ha and obtained at the fifth harvest. Similarly, for 30 days of cutting interval, the crop attained the highest number of tillers at the seventh harvest on receiving 400 kg/ha N.

Number of leaves

The data pertaining to number of leaves per plant are given in Table 45 and Table 46. In general, delaying harvest and increasing nitrogen levels had a significant facilitating effect on leaf production, and number of leaves per clump increased towards the final harvest. Even though the crop showed an increasing

Table 45. Effect of nitrogen nutrition and cutting frequency on no. of leaves/clump of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	96.25	111.53	131.70	150.27	131.08
45 days	95.75	162.80	191.13	182.40	NH
60 days	95.19	200.69	246.00	NH	NH
LSD 5%	NS	3.02	3.21	2.58	-
N levels (kg/ha)					
0	42.28	95.29	114.24	108.23	-
100	69.60	113.31	139.14	132.00	-
200	96.52	157.53	198.77	172.50	-
300	115.58	202.21	236.74	197.48	-
400	154.67	223.37	259.16	221.48	-
LSD 5%	4.12	3.90	4.15	4.09	-
30 days					
0	42.17	68.33	85.50	100.50	87.30
100	70.60	78.83	110.83	124.95	113.87
200	97.07	108.72	130.00	151.50	126.00
300	116.67	145.38	156.67	169.95	156.02
400	154.75	156.38	175.50	204.45	172.20
45 days					
0	42.50	86.17	108.83	115.95	NH
100	69.00	110.60	130.00	139.05	
200	98.00	165.75	203.50	193.50	
300	115.73	213.25	245.67	225.00	
400	153.50	238.25	267.67	238.50	
60 days					
0	42.17	131.37	148.40	NH	NH
100	69.20	150.50	176.60		
200	94.50	198.13	262.82		
300	114.33	248.00	307.88		
400	155.75	275.47	334.32		
LSD 5%	NS	6.76	7.18	5.78	6.06

NH- No harvest

Table 46. Effect of nitrogen nutrition and cutting frequency on no. of leaves/clump of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	124.11	132.40	161.73	229.33	259.90	293.50	245.87
45 days	175.35	188.61	255.24	304.20	348.58	NH	NH
60 days	261.93	296.04	356.50	391.77	NH	NH	NH
LSD 5%	3.25	4.56	3.62	3.97	3.86	-	-
N levels (kg/ha)							
0	132.19	151.96	180.59	233.61	216.88	-	-
100	165.16	178.06	231.94	277.11	268.75	-	-
200	186.42	204.51	263.00	310.11	317.67	-	-
300	212.03	234.48	294.09	350.78	346.00	-	-
400	239.86	259.41	319.50	370.56	371.92	-	-
LSD 5%	4.19	5.88	4.68	5.12	6.10	-	-
30 days							
0	76.00	91.20	119.17	151.67	190.83	238.33	204.00
100	103.47	111.60	142.50	186.67	235.50	258.33	216.67
200	124.27	134.00	157.50	235.00	265.00	302.50	250.67
300	147.47	153.20	184.17	276.67	293.33	326.67	270.67
400	169.33	172.00	205.33	296.67	314.83	341.67	287.33
45 days							
0	102.90	130.67	172.60	226.00	242.92	NH	NH
100	147.00	151.67	236.00	283.00	302.00		
200	174.00	178.03	264.00	301.00	370.33		
300	210.30	225.33	290.60	344.00	398.67		
400	242.57	257.33	313.00	367.00	429.00		
60 days							
0	217.67	234.00	250.00	323.17	NH	NH	NH
100	245.00	270.90	317.33	361.67			
200	261.00	301.50	367.50	394.33			
300	278.33	324.90	407.50	431.67			
400	307.67	348.90	440.17	448.00			
LSD 5%	7:26	10.19	8.10	8.87	8.63	6.27	6.27

NH- No harvest

trend in leaf production, leaf production was reduced in both years by the later harvests, in the case of 30 days cutting frequency. During the first year, at the first harvest, number of leaves per plant ranged from 42.28 to 154.67 when nitrogen rate increased from 0 kg/ha to 400 kg/ha and the effect of cutting frequency was absent. The highest number of leaves (334.32) was recorded at the third harvest when harvesting was delayed to 60 days and fertilized with 400 kg/ha N. For 30 days and 45 days of cutting interval, the highest number of leaves was obtained at the fourth harvest for higher dose of nitrogen (400 kg/ha).

When the observations were continued through the second year, number of leaves per plant ranged from 76 to 307.67 for 30 days and 60 days of cutting frequency on increasing nitrogen rates from 0 kg/ha to 400 kg/ha. The highest number of leaves (448) was recorded at 60 days cutting frequency at 400 kg/ha N during the fourth harvest. Maximum number of leaves produced at 30 days and 45 days of cutting frequency were 341.67 (at the sixth harvest) and 429 (at the fifth harvest) respectively on fertilizing with 400 kg/ha N.

4.2.2. Growth analysis

Leaf area index (LAI)

The effect of nitrogen nutrition and cutting frequency on leaf area index of hybrid napier is shown in Table 47 and Table 48. Increasing nitrogen rates along with lagged harvests had a significant facilitating effect on LAI.

During the first year, the effect of cutting frequency on LAI was noticed from the second harvest onwards. The highest LAI was recorded at the second harvest. In the first harvest, LAI increased with increasing nitrogen rates and it increased from 7.03 to 8.87 for increase in nitrogen rates from 0 kg/ha to 400 kg/ha and LAI at 300 kg/ha N and 400 kg/ha N were at par.

At the second harvest, considering the effect of nitrogen nutrition, LAI at 300 kg/ha was on par with LAI at 200 kg/ha and 400 kg/ha. Regarding the interaction effect, LAI increased from 3.23 to 13.76 on delaying the harvest from 30

Table 47. Effect of nitrogen nutrition and cutting frequency on leaf area index of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	8.20	5.86	6.08	2.51	0.53
45 days	8.20	9.50	8.15	0.96	NH
60 days	8.15	12.95	11.22	NH	NH
LSD 5%	NS	0.16	0.17	0.10	-
N levels (kg/ha)					
0	7.03	7.43	6.27	0.99	-
100	7.71	8.70	7.78	1.61	-
200	8.54	10.18	9.32	1.92	-
300	8.76	10.36	9.46	2.04	-
400	8.87	10.51	9.58	2.11	-
LSD 5%	0.11	0.20	0.21	0.16	-
30 days					
0	7.02	3.23	3.38	1.22	0.43
100	7.69	4.97	5.00	2.39	0.50
200	8.61	6.86	7.18	2.79	0.55
300	8.79	7.10	7.35	3.00	0.57
400	8.88	7.14	7.47	3.14	0.59
45 days					
0	7.03	7.60	5.99	0.76	NH
100	7.75	8.72	7.70	0.84	
200	8.59	10.25	8.86	1.05	
300	8.75	10.32	9.01	1.07	
400	8.87	10.62	9.19	1.09	
60 days					
0	7.03	11.45	9.45	NH	NH
100	7.70	12.42	10.63		
200	8.41	13.43	11.90		
300	8.74	13.66	12.03		
400	8.87	13.76	12.10		
LSD 5%	NS	0.35	0.37	0.23	0.06

NH- No harvest

Table 48. Effect of nitrogen nutrition and cutting frequency on leaf area index of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	8.14	9.68	5.98	6.06	1.91	2.93	0.32
45 days	9.14	12.44	6.62	6.45	2.95	NH	NH
60 days	9.80	13.51	6.98	6.30	NH	NH	NH
LSD 5%	0.35	0.15	0.14	0.12	0.10	-	-
N levels (kg/ha)							
0	6.91	9.46	3.80	4.36	1.00	-	-
100	7.99	10.84	5.66	5.85	1.73	-	-
200	9.36	12.38	7.61	7.00	3.01	-	-
300	10.14	13.29	7.74	7.04	3.17	-	-
400	10.71	13.40	7.83	7.10	3.22	-	-
LSD 5%	0.45	0.19	0.17	0.15	0.16	-	-
30 days							
0	6.13	7.20	3.22	3.58	0.72	2.13	0.26
100	7.13	8.76	4.98	5.49	1.03	2.56	0.27
200	8.44	10.61	7.09	6.92	2.37	3.28	0.31
300	9.26	10.87	7.23	7.08	2.66	3.28	0.37
400	9.72	10.94	7.39	7.21	2.76	3.39	0.39
45 days							
0	6.86	10.17	3.66	4.59	1.28	NH	NH
100	8.20	11.68	5.74	5.92	2.43		
200	9.42	13.27	7.80	7.21	3.66		
300	10.34	13.45	7.93	7.30	3.67		
400	10.85	13.63	8.01	7.24	3.69		
60 days							
0	7.73	11.02	4.52	4.91	NH	NH	NH
100	8.65	12.07	6.26	6.13			
200	10.23	13.26	7.93	6.86			
300	10.82	15.57	8.07	6.75			
400	11.55	15.63	8.10	6.85			
LSD 5%	0.78	0.32	0.30	0.26	0.23	0.34	0.34

NH- No harvest

days to 60 days and increasing the nitrogen rates from 0 kg/ha to 400 kg/ha. When harvested at 60 days interval, LAI at 200 kg/ha N, 300 kg/ha N and 400 kg/ha N were at par. Likewise, when harvested at 45 days interval, LAI at 300 kg/ha N was on par with LAI at 200 kg/ha N and 400 kg/ha N. Similarly, on increasing the cutting frequency at 30 days interval, LAI at 300 kg/ha N was on par with LAI at 400 kg/ha N.

In the third harvest, in general, the crop could produce similar LAI on fertilizing with 200 kg/ha N, 300 kg/ha N and 400 kg/ha N, at all cutting frequencies. The LAI ranged from 3.38 to 12.10 on decreasing the harvesting frequencies from 30 days to 60 days and for a corresponding increase in nitrogen from 0 kg/ha to 400 kg/ha N.

During the fourth harvest, LAI was observed only for 30 days and 45 days of cutting frequencies. Maximum LAI was recorded on harvesting the crop at 30 days interval, where the values ranged from 1.22 to 3.14 on increasing the nitrogen rates from 0 kg/ha N to 400 kg/ha N. LAI at 300 kg N/ha was on par with LAI at 200 kg/ha N and 400 kg/ha N. At 45 days interval, LAI increased from 0.76 to 1.09 when nitrogen rates increased from 0 kg/ha N to 400 kg/ha N. The crop could produce similar LAI at 200 kg/ha N, 300 kg/ha N and 400 kg/ha N. Similarly, at the final harvest also, LAI at 200 kg/ha N were on par with LAI at 100 kg/ha N, 300 kg/ha N, and 400 kg/ha N.

At the beginning of the second year, LAI ranged from 6.13 to 11.55 for increasing nitrogen from 0 kg/ha N to 400 kg/ha N and also for corresponding decrease in cutting frequencies from 30 days to 60 days. Under all cutting regimes, the crop could produce similar LAI at 300 kg/ha N and 400 kg/ha N.

The highest LAI during the experiment (15.63) was recorded at the second harvest in the second year when harvesting was delayed to 60 days and fertilized with 400 kg/ha N. In this harvest also, under all cutting regimes, the crop could produce similar LAI at 300 kg/ha N and 400 kg/ha N. When harvesting frequencies were increased to 45 days and 30 days, LAI at 300 kg/ha N was on par with LAI at 200 kg/ha N and 400 kg/ha N.

During the third and the fourth harvests, the crop could produce similar LAI at nitrogen rates of 200 kg/ha N, 300 kg/ha N and 400 kg/ha N under all harvesting intervals while the maximum was recorded at 60 days interval. In the fifth harvest, maximum LAI recorded at 45 days of harvesting interval. When harvested at 30 days interval, the crop could produce similar LAI at 300 kg/ha N and 400 kg/ha N whereas at 45 days interval, LAI at 200 kg/ha N, 300 kg/ha N and 400 kg/ha N were at par. In the sixth harvest also, the crop could produce similar LAI at 200 kg/ha N, 300 kg/ha N and 400 kg/ha N under 30 days of cutting interval. At the final harvest, significant differences in LAI with increasing nitrogen was absent.

Leaf area ratio (LAR)

The data pertaining to LAR are given in Table 49 and Table 50. Cutting frequencies and nitrogen nutrition had significant effect on LAR of hybrid napier. Increasing cutting frequencies along with supplementation of lower doses of nitrogen had a significant positive effect on LAR. Consequently, at all harvests, maximum LAR was attained under 30 days of harvesting interval at 0 kg/ha N.

During the first year, LAR increased towards the final harvest. In the first harvest, the ratio decreased from 1.58 to 1.12 for increasing nitrogen rates from 0 kg/ha to 400 kg/ha. Significant differences due to cutting frequency was evident from the second harvest onwards. At the second and the third harvests, for 45 days and 60 days of cutting frequencies, the crop had similar LAR at nitrogen rates of 300 kg/ha and 400 kg/ha. In the third harvest, the ratio at 60 days of cutting frequency at 200 kg/ha was on par with LAR at 300 kg/ha. When harvested at 45 days and 60 days of cutting intervals, the crop could produce similar LAR at nitrogen dose of 400kg/ha.

In the fourth and the fifth harvests, LAR at 300 kg/ha and 400 kg/ha were at par under all cutting regimes. Correspondingly, LAR at 300kg/ha under 45 days of harvest was on par with LAR at 400 kg/ha under 30 days of harvest. In the final

Table 49. Effect of nitrogen nutrition and cutting frequency on leaf area ratio (dm^2/g) of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	1.29	1.71	1.91	2.00	1.34
45 days	1.29	1.58	1.60	1.90	NH
60 days	1.28	1.46	1.53	NH	NH
LSD 5%	NS	0.03	0.03	0.03	
N levels (kg/ha)					
0	1.58	1.82	1.93	2.11	-
100	1.37	1.68	1.81	2.05	-
200	1.21	1.55	1.65	1.96	-
300	1.16	1.46	1.53	1.86	-
400	1.12	1.41	1.47	1.79	-
LSD 5%	0.02	0.03	0.04	0.05	-
30 days					
0	1.57	1.94	2.17	2.18	1.48
100	1.36	1.83	2.07	2.11	1.38
200	1.22	1.71	1.92	2.04	1.30
300	1.16	1.57	1.74	1.90	1.27
400	1.12	1.48	1.64	1.80	1.25
45 days					
0	1.58	1.86	1.87	2.04	NH
100	1.38	1.66	1.76	2.00	
200	1.21	1.53	1.55	1.89	
300	1.15	1.43	1.44	1.81	
400	1.12	1.41	1.39	1.78	
60 days					
0	1.58	1.66	1.75	NH	NH
100	1.37	1.54	1.62		
200	1.19	1.42	1.49		
300	1.15	1.37	1.42		
400	1.12	1.33	1.37		
LSD 5%	NS	0.06	0.07	0.06	0.12

NH- No harvest

Table 50. Effect of nitrogen nutrition and cutting frequency on leaf area ratio (dm^2/g) of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	1.84	1.85	1.89	1.41	1.37	1.30	1.36
45 days	1.85	1.70	1.77	1.23	1.38	NH	NH
60 days	1.74	1.43	1.57	1.04	NH	NH	NH
LSD 5%	0.06	0.02	0.03	0.02	0.03	-	-
N levels (kg/ha)							
0	1.80	1.86	1.97	1.39	1.58	-	-
100	1.81	1.74	1.86	1.32	1.49	-	-
200	1.80	1.65	1.74	1.21	1.34	-	-
300	1.82	1.56	1.61	1.13	1.25	-	-
400	1.81	1.50	1.54	1.10	1.22	-	-
LSD 5%	0.08	0.03	0.03	0.02	0.04	-	-
30 days							
0	1.84	2.06	2.12	1.55	1.53	1.45	1.49
100	1.83	1.94	2.01	1.50	1.45	1.37	1.42
200	1.82	1.85	1.92	1.41	1.36	1.30	1.36
300	1.85	1.74	1.76	1.32	1.28	1.23	1.31
400	1.85	1.63	1.66	1.28	1.24	1.13	1.23
45 days							
0	1.84	1.89	1.99	1.40	1.63	NH	NH
100	1.86	1.78	1.89	1.32	1.52		
200	1.83	1.68	1.77	1.21	1.31		
300	1.87	1.61	1.63	1.15	1.23		
400	1.83	1.56	1.56	1.09	1.20		
60 days							
0	1.74	1.62	1.79	1.21	NH	NH	NH
100	1.73	1.50	1.68	1.13			
200	1.76	1.41	1.54	1.02			
300	1.73	1.34	1.45	0.93			
400	1.75	1.31	1.40	0.91			
LSD 5%	0.13	0.04	0.06	0.04	0.06	0.08	0.06

NH- No harvest

harvest, LAR at 300 kg/ha was also comparable with LAR at 200 kg/ha and 100 kg/ha.

In the second year, at the first harvest, at 30 days and 45 days of harvest, LAR were at par. Correspondingly, there were no significant difference in LAR with increasing nitrogen levels. At the second harvest, LAR ranged from 1.31 to 2.06. The highest LWR for the second year (2.12) was recorded at the third harvest.

During the third, fourth and fifth harvests, at 60 days of harvesting interval, the crop could produce comparable LAR at 300 kg/ha N and 400 kg/ha N. Consequently, in the fifth harvest, LAR at 300 kg/ha N and 400 kg/ha N were at par under all cutting regimes. The ratio produced at 30 days of harvest at 400 kg/ha N was comparable with ratios at 45 days of harvest with 300 kg/ha N and 400 kg/ha N.

The final two harvests recorded the lowest ratios during the second year. For the sixth and the seventh harvests, the ratio ranged from 1.13 to 1.45 and 1.23 to 1.49 respectively.

Leaf weight ratio (LWR)

Leaf weight ratio of hybrid napier at different nitrogen nutrition and cutting regimes is given in Table 51 and Table 52. Cutting frequencies and nitrogen nutrition had significant effect on LWR of hybrid napier. Frequent harvesting along with supplementation of lower dose of nitrogen had substantial positive effect on LWR. Significant differences due to cutting frequency was evident from the second harvest onwards. Subsequently, at all harvests, maximum LWR was attained under 30 days of harvesting interval from zero nitrogen fertilized plots.

During the first year, LWR increased towards the third harvest and started decreasing. In the first harvest, the ratio ranged from 0.54 to 0.65 for nitrogen rates from 0 kg/ha to 400 kg/ha. In all harvests, LWR for 0 kg/ha N and 100 kg/ha N were comparable with each other. Likewise, the ratios at 300 kg/ha N and 400 kg/ha N were at par. In general, in most of the harvests under all cutting regimes, LWR

Table 51. Effect of nitrogen nutrition and cutting frequency on leaf weight ratio of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	0.58	0.67	0.78	0.70	0.68
45 days	0.58	0.65	0.77	0.69	NH
60 days	0.58	0.63	0.76	NH	NH
LSD 5%	NS	0.01	0.002	0.01	-
N levels (kg/ha)					
0	0.65	0.68	0.78	0.72	-
100	0.60	0.67	0.78	0.71	-
200	0.56	0.65	0.77	0.70	-
300	0.55	0.63	0.76	0.68	-
400	0.54	0.63	0.76	0.67	-
LSD 5%	0.01	0.01	0.003	0.01	-
30 days					
0	0.65	0.70	0.79	0.74	0.70
100	0.60	0.69	0.78	0.72	0.69
200	0.56	0.67	0.78	0.71	0.68
300	0.55	0.65	0.77	0.69	0.68
400	0.54	0.65	0.77	0.67	0.67
45 days					
0	0.65	0.68	0.78	0.71	NH
100	0.60	0.67	0.78	0.69	
200	0.56	0.65	0.77	0.69	
300	0.55	0.63	0.76	0.67	
400	0.54	0.63	0.76	0.67	
60 days					
0	0.65	0.67	0.78	NH	NH
100	0.60	0.65	0.77		
200	0.55	0.62	0.76		
300	0.55	0.61	0.76		
400	0.54	0.61	0.75		
LSD 5%	NS	0.01	0.01	0.01	0.01

NH- No harvest

Table 52. Effect of nitrogen nutrition and cutting frequency on leaf weight ratio of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	0.68	0.67	0.71	0.70	0.66	0.65	0.72
45 days	0.68	0.64	0.69	0.68	0.65	NH	NH
60 days	0.64	0.59	0.63	0.62	NH	NH	NH
LSD 5%	0.01	0.01	0.01	0.01	0.01	-	-
N levels (kg/ha)							
0	0.66	0.67	0.71	0.69	0.68	-	-
100	0.66	0.65	0.70	0.68	0.67	-	-
200	0.66	0.63	0.68	0.67	0.66	-	-
300	0.66	0.62	0.66	0.65	0.64	-	-
400	0.66	0.61	0.64	0.63	0.63	-	-
LSD 5%	NS	0.01	0.01	0.01	0.01	-	-
30 days							
0	0.68	0.70	0.73	0.71	0.69	0.67	0.74
100	0.68	0.69	0.72	0.71	0.67	0.67	0.73
200	0.67	0.67	0.71	0.70	0.66	0.66	0.72
300	0.68	0.67	0.69	0.68	0.65	0.65	0.71
400	0.67	0.64	0.68	0.68	0.64	0.60	0.71
45 days							
0	0.68	0.66	0.72	0.71	0.68	NH	NH
100	0.68	0.65	0.71	0.70	0.67		
200	0.67	0.64	0.70	0.69	0.65		
300	0.68	0.62	0.67	0.67	0.64		
400	0.67	0.61	0.65	0.64	0.62		
60 days							
0	0.64	0.63	0.67	0.66	NH	NH	NH
100	0.64	0.61	0.66	0.64			
200	0.64	0.59	0.63	0.62			
300	0.64	0.58	0.61	0.59			
400	0.64	0.57	0.59	0.58			
LSD 5%	NS	0.01	0.01	0.01	0.01	0.05	0.01

NH- No harvest

recorded for each nitrogen levels were comparable with LWR produced for every 100 kg additional increase in nitrogen. Moreover, on delaying the harvesting by 15 days from the corresponding cutting frequency could produce comparable LWR for every 100 kg additional gain of nitrogen fertilizer. By the final harvest, LWR ranged from 0.67 to 0.70.

In the second year, at the first harvest, at 30 days and 45 days of harvest, LWR were at par. Correspondingly, there were no significant differences in LWR with increasing nitrogen levels. At the second harvest, in general, the ratio at nitrogen rate of 300 kg/ha was on par with LWR at 200 kg/ha and 400 kg/ha. Considering the interaction effect, the ratio ranged from 0.57 to 0.70. The highest value was attained at 30 days of harvest from zero nitrogen fertilized plots and was on par with the ratio obtained at nitrogen dose of 100 kg/ha.

During the third harvest, LWR ranged from 0.59 to 0.73. Under all cutting regimes, the crop could produce comparable LWR at nitrogen levels of 0 kg/ha and 100 kg/ha. Consequently, LWR values at 30 days with increasing nitrogen rates from 0 kg/ha to 200 kg/ha were comparable with corresponding increase in nitrogen rates at 45 days of harvesting interval. At 45 days of harvest, LWR for 300 kg/ha N was comparable with LWR for nitrogen rates from 0 kg/ha to 100 kg/ha at 60 days of harvest. In the third and the fourth harvests, the ratio at 45 days of harvest with 400 kg/ha N was on par with the ratio at 60 days of harvest with 100 kg/ha N.

By the fourth harvest, for 30 days and 45 days of harvests LWR at 100 kg/ha N was comparable with LWR at 0 kg/ha N and 200 kg/ha N. The crop could produce comparable LWR at nitrogen rates of 300 kg/ha and 400 kg/ha.

In the fifth harvest, LWR at 30 days and 45 days of harvest were comparable. During the fifth, sixth and seventh harvests, at 30 days of cutting interval, LWR recorded for each nitrogen levels were comparable with LWR produced for every 100 kg additional increase in nitrogen.

Specific leaf weight (SLW)

Specific leaf weight of hybrid napier at each harvest is given in Table 53 and Table 54. SLW increased with increasing nitrogen levels and delayed harvesting. However, SLW values of cutting intervals were significantly different only during the second and third harvests in the first year and the third and fourth harvests in the second year. In general, cutting frequency of 60 days showed higher SLW values. Effect of nitrogen level were significant in most harvests except in first and second harvests in the second year.

In the first and second years, SLW of nitrogen levels of 300 kg/ha and 400 kg/ha were non- significant in most harvests. Interactions between cutting frequency and nitrogen levels were significant in the second and third harvests in the first year, and second, third, sixth and seventh harvests in the second year.

In the first year, at the first harvest, SLW at 300 kg/ha and 400 kg/ha were. Interaction effects were non-significant at the first harvest. In the second harvest, the crop recorded comparable SLW when fertilized with nitrogen rates of 200 kg/ha and 300 kg/ha. Similarly, when considering the interaction effect, under all cutting frequencies, SLW recorded for each nitrogen levels were comparable with SLW produced for every 100 kg additional increase in nitrogen.

By the third harvest, SLW for the plots receiving 100 kg/ha N and without nitrogen were on par. At higher levels of nitrogen, i.e. at 200 kg/ha, 300 kg/ha and 400 kg/ha under longer cutting intervals of 45 days and 60 days, SLW remained at par.

At the fourth harvest, there were no significant differences in SLW with varying cutting frequencies. The SLW remained comparable for every 100 kg additional increase in nitrogen at all cutting intervals. In the final harvest, there were no significant differences in SLW with varying nitrogen levels but difference was noticed between the unfertilized plots and plots receiving higher dose of nitrogen (300 kg/ha and 400 kg/ha).

Table 53. Effect of nitrogen nutrition and cutting frequency on specific leaf weight (g/dm^2) of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	0.46	0.40	0.41	0.35	0.51
45 days	0.45	0.42	0.49	0.36	NH
60 days	0.46	0.43	0.50	NH	NH
LSD 5%	NS	0.01	0.01	NS	-
N levels (kg/ha)					
0	0.41	0.38	0.41	0.34	-
100	0.44	0.40	0.43	0.35	-
200	0.46	0.42	0.47	0.36	-
300	0.48	0.43	0.50	0.37	-
400	0.48	0.45	0.52	0.37	-
LSD 5%	0.01	0.01	0.01	0.006	-
30 days					
0	0.42	0.36	0.37	0.34	0.47
100	0.44	0.38	0.38	0.34	0.50
200	0.46	0.39	0.41	0.35	0.52
300	0.48	0.42	0.44	0.37	0.53
400	0.49	0.44	0.47	0.37	0.54
45 days					
0	0.41	0.37	0.42	0.35	NH
100	0.44	0.40	0.44	0.35	
200	0.46	0.42	0.50	0.36	
300	0.48	0.44	0.53	0.37	
400	0.48	0.45	0.54	0.38	
60 days					
0	0.41	0.40	0.45	NH	NH
100	0.44	0.42	0.48		
200	0.46	0.44	0.51		
300	0.48	0.45	0.53		
400	0.48	0.45	0.55		
LSD 5%	NS	0.01	0.02	NS	0.05

NH- No harvest

Table 54. Effect of nitrogen nutrition and cutting frequency on specific leaf weight (g/dm^2) of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	0.37	0.37	0.38	0.49	0.48	0.50	0.53
45 days	0.37	0.38	0.39	0.56	0.48	NH	NH
60 days	0.37	0.42	0.40	0.60	NH	NH	NH
LSD 5%	NS	NS	0.01	0.01	NS	-	-
N levels (kg/ha)							
0	0.37	0.36	0.36	0.50	0.43	-	-
100	0.37	0.38	0.38	0.52	0.45	-	-
200	0.37	0.39	0.39	0.56	0.49	-	-
300	0.37	0.40	0.41	0.58	0.51	-	-
400	0.37	0.41	0.42	0.58	0.52	-	-
LSD 5%	NS	NS	0.01	0.01	0.01	-	-
30 days							
0	0.37	0.34	0.34	0.46	0.45	0.46	0.50
100	0.37	0.35	0.36	0.47	0.46	0.49	0.51
200	0.37	0.36	0.37	0.50	0.49	0.50	0.53
300	0.37	0.38	0.39	0.52	0.51	0.52	0.55
400	0.37	0.39	0.41	0.53	0.51	0.53	0.58
45 days							
0	0.37	0.35	0.36	0.51	0.42	NH	NH
100	0.36	0.37	0.38	0.53	0.44		
200	0.37	0.38	0.39	0.57	0.50		
300	0.36	0.39	0.41	0.58	0.52		
400	0.37	0.39	0.42	0.58	0.52		
60 days							
0	0.37	0.39	0.38	0.54	NH	NH	NH
100	0.37	0.41	0.39	0.56			
200	0.37	0.42	0.41	0.62			
300	0.37	0.43	0.42	0.64			
400	0.36	0.43	0.42	0.64			
LSD 5%	NS	NS	0.01	0.02	NS	0.03	0.03

NH- No harvest

In the second year, at the first and second harvests, the effect of nitrogen nutrition and cutting frequency and their interactions were non-significant. By the second harvest, only interaction effect was noticed where the significant difference became nil for every 100 kg additional increase in nitrogen on delaying the harvesting by 15 days this trend was followed in case of interaction effects for the subsequent harvests too. There was no change in SLW with higher dose of nitrogen i.e. 300 kg/ha and 400 kg/ha for all the harvests. Towards the final harvests, the significant effect of nitrogen on SLW decreased gradually for every 100 kg additional increase in nitrogen.

During the third harvest, SLW at 45 days of cutting frequency was on par with SLW at 30 days and 60 days of harvesting frequency. Also SLW produced for 100 kg/ha and 200 kg/ha as well as for 300 kg/ha and 400 kg/ha were at par. In the fourth harvest, the effect of nitrogen on SLW was noticed only from 200 kg/ha N.

At the fifth harvest, there was no significant effect of cutting frequency on SLW. Moreover, for the final three harvests, SLW remained comparable with increasing nitrogen levels.

Leaf: stem ratio

The data on leaf to stem ratio of hybrid napier at each harvest are given in Table 55 and Table 56. During both years, leaf to stem ratio increased up to the third harvest and thereafter started decreasing towards the final harvests. A higher leaf to stem ratio was recorded at the third harvest in both years.

Nitrogen nutrition and cutting frequencies had significant influence on leaf to stem ratio of hybrid napier. Leaf to stem ratio increased with increasing cutting frequencies. However, higher supplementation of nitrogen had a negative effect on leaf to stem ratio. Interaction effect was also found to be significant.

During the first year, at the first harvest, the effect of cutting frequency was non-significant but nitrogen levels showed significant difference. The ratio ranged from 1.18 to 1.88 for corresponding decrease in nitrogen rates from 400 kg/ha to 0 kg/ha. During the first and the second harvests, the ratio at 300 kg/ha was on par with ratios at 200 kg/ha and 400 kg/ha. In the second harvest, the ratio ranged from 1.53 to 2.29. At all cutting frequencies, plots without nitrogen supplementation recorded maximum proportion of leaves. When harvested at 30 days interval and fertilized with 100 kg/ha N, crop could produce only the same proportion of leaves as in case of plots without N supplementation. Similarly, leaf to stem ratio at 300 kg/ha and 400 kg/ha were at par. At 45 days and 60 days of cutting intervals, leaf to stem ratio at 200 kg/ha, 300 kg/ha and 400 kg/ha were at par.

In the third harvest, the highest ratio of 3.74 during the experiment was recorded in plots grown without nitrogen supplementation and harvested at 30 days interval. At cutting frequencies of 30 days and 45 days, the crop could produce the same proportion of leaves at nitrogen levels of 300 kg/ha and 400 kg/ha. For 60 days of harvesting interval, leaf to stem ratios for nitrogen levels of 200 kg/ha, 300 kg/ha and 400 kg/ha were at par, which were also on par with ratio for 45 days of cutting frequency at 400 kg/ha N.

During the fourth and fifth harvests, the highest ratio was recorded at 30 days of cutting interval and for zero level of nitrogen while the lowest under the same cutting regime, but with 400 kg/ha N. In the fourth harvest, at 45 days of harvesting interval, leaf to stem ratios for nitrogen levels of 300 kg/ha and 400 kg/ha were at par. During the final harvest, at 30 days of harvesting interval, leaf to stem ratios for nitrogen levels of 200 kg/ha, 300 kg/ha and 400 kg/ha were at par. Similarly, the ratio at 100 kg/ha was at par with ratios recorded for 0 kg/ha and 200 kg/ha.

In the second year also, the highest ratio was recorded for zero level of nitrogen at 30 days of cutting frequency while the least for nitrogen rate of 400 kg/ha at 60 days of cutting frequency. At the first harvest, there was significant difference in leaf to stem ratio due to cutting frequency but the influence of nitrogen nutrition was absent. During the second harvest, the ratio ranged from 1.31 to 2.35. At 45 days and 60 days of cutting frequencies, the crop could produce the same proportion of leaves and stem under 300 kg/ha and 400 kg/ha of nitrogen.

Table 55. Effect of nitrogen nutrition and cutting frequency on leaf - stem ratio of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5
Cutting frequency					
30 days	1.41	2.04	3.48	2.41	2.16
45 days	1.41	1.88	3.35	2.18	NH
60 days	1.40	1.72	3.21	NH	NH
LSD 5%	NS	0.05	0.04	0.05	-
N levels (kg/ha)					
0	1.88	2.15	3.60	2.60	-
100	1.51	2.02	3.46	2.42	-
200	1.25	1.84	3.32	2.30	-
300	1.22	1.72	3.22	2.15	-
400	1.18	1.68	3.14	2.00	-
LSD 5%	0.04	0.06	0.05	0.08	-
30 days					
0	1.87	2.29	3.74	2.78	2.28
100	1.50	2.20	3.56	2.58	2.23
200	1.26	2.02	3.46	2.41	2.15
300	1.23	1.88	3.36	2.26	2.09
400	1.19	1.82	3.28	1.99	2.05
45 days					
0	1.88	2.16	3.58	2.41	NH
100	1.52	2.03	3.48	2.25	
200	1.25	1.85	3.33	2.18	
300	1.22	1.68	3.22	2.04	
400	1.18	1.69	3.13	2.01	
60 days					
0	1.89	2.01	3.47	NH	NH
100	1.51	1.82	3.33		
200	1.22	1.64	3.18		
300	1.22	1.59	3.08		
400	1.18	1.53	3.02		
LSD 5%	NS	0.11	0.09	0.12	0.09

NH- No harvest

Table 56. Effect of nitrogen nutrition and cutting frequency on leaf - stem ratio of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7
Cutting frequency							
30 days	2.09	2.08	2.44	2.29	1.96	1.86	2.60
45 days	2.08	1.76	2.23	2.17	1.89	NH	NH
60 days	1.76	1.48	1.73	1.63	NH	NH	NH
LSD 5%	0.11	0.04	0.05	0.04	0.05	-	-
N levels (kg/ha)							
0	1.99	2.01	2.44	2.28	2.13	-	-
100	1.97	1.87	2.32	2.17	2.05	-	-
200	1.98	1.75	2.15	2.07	1.92	-	-
300	2.00	1.68	1.95	1.88	1.81	-	-
400	1.96	1.55	1.80	1.73	1.71	-	-
LSD 5%	0.14	0.06	0.06	0.06	0.08	-	-
30 days							
0	2.12	2.35	2.72	2.46	2.18	2.05	2.87
100	2.08	2.19	2.59	2.41	2.06	1.98	2.65
200	2.08	2.07	2.45	2.34	1.95	1.92	2.59
300	2.11	2.01	2.25	2.16	1.84	1.82	2.49
400	2.06	1.78	2.16	2.08	1.75	1.52	2.40
45 days							
0	2.08	1.96	2.53	2.48	2.09	NH	NH
100	2.08	1.85	2.46	2.36	2.03		
200	2.06	1.75	2.28	2.21	1.88		
300	2.13	1.65	2.05	2.02	1.78		
400	2.05	1.56	1.84	1.75	1.66		
60 days							
0	1.77	1.72	2.06	1.90	NH	NH	NH
100	1.75	1.56	1.90	1.75			
200	1.80	1.42	1.71	1.66			
300	1.74	1.37	1.56	1.46			
400	1.76	1.31	1.42	1.36			
LSD 5%	0.24	0.10	0.11	0.10	0.11	0.29	0.17

NH- No harvest

The crop showed the highest ratio at the third harvest, and values ranged from 1.42 to 2.72. For 45 days of cutting frequency, leaf to stem ratios at nitrogen levels of 0 kg/ha and 100 kg/ha were at par. In the fourth harvest, at 30 days and 45 days of cutting frequencies, leaf to stem ratios at nitrogen levels of 0 kg/ha and 100 kg/ha were at par. In addition, the ratio at 45 days of cutting frequency and 100 kg/ha N was at par with ratio recorded at 30 days of cutting frequency at zero levels of nitrogen. Similarly, at 60 days of cutting interval, the crop could produce similar proportion of leaves and stem under 300 kg/ha and 400 kg/ha of nitrogen.

In the fifth harvest, at 45 days of cutting frequency leaf to stem ratios at nitrogen levels of 300 kg/ha was on par with ratios recorded at 200 kg/ha and 400 kg/ha of nitrogen. The ratios at 400 kg/ha under both cutting frequencies were on par with each other.

At the sixth harvest, under 30 days of cutting frequency, all ratios except the ratio at 400 kg/ha were on par. In the final harvest, crop had same proportion of leaves and stems on increasing nitrogen rates from 200 kg/ha to 400 kg/ha.

4.2.3. Mortality of clumps

The mortality of clumps was monitored one month after the receipt of premonsoon showers during both years of study but clump mortality was absent.

4.2.4. Fodder yield

In general, there were five harvests during the first year and seven during the second year. For the first year, individually, there were five harvests for 30 days of cutting interval, four harvests for 45 days of cutting interval and three for 60 days of cutting interval. Correspondingly, in the second year, for 30 days, 45 days and 60 days of cutting frequencies, there were, seven, five and four harvests respectively. There were substantial influence of cutting frequencies and nitrogen levels on fodder yield and their interaction effects were also present. Fodder yield increased with extended harvesting intervals and increasing nitrogen levels. Hence, the maximum fodder yield was recorded at 60 days of harvesting for 400 kg/ha of nitrogen.

Fresh fodder yield

The data pertaining to fresh fodder yield is given in Table 57 and Table 58. During the first year, fodder yield decreased with advancing harvests. In all the harvests extending cutting frequency from 30 days to 60 days increased yields. Increasing nitrogen levels had a facilitating role on the yield. The highest yield was from plots receiving 400 kg/ha of N in all the harvests followed by 300 kg/ha N. The total yield also showed the same trend.

At the first harvest, for single cut at 75 days after planting, fresh fodder yield ranged from 24.49 Mg/ha to 43.56 Mg/ha with increasing nitrogen rates from 0 kg/ha to 400 kg/ha. Interaction was non-significant. In the second harvest, fodder yield increased from 23.18 Mg/ha to 41.57 Mg/ha with increasing nitrogen rates from 0 kg/ha to 400 kg/ha. Interaction was significant from second harvest onwards.

In the third harvest, maximum fresh fodder yield produced for 400 kg/ha N for 30 days of harvest was 25.02 Mg/ha, for 45 days of harvest was 36.21Mg/ha and for 60 days of harvest was 48.45 Mg/ha.

A fourth harvest, was possible from 30 days and 45 days cutting intervals. At 45 days of harvest, crop had comparable yields for higher dose of nitrogen, i.e. 200 kg/ha, 300 kg/ha and 400 kg/ha. Correspondingly, the fresh fodder yield obtained from plots without nitrogen fertilizer and from 100 kg/ha N had comparable yields. The fifth harvest recorded minimum yield for the first year, where the highest fresh fodder yield was 2.60 Mg/ha at 30 days of harvest for 400 kg/ha N. Also, fresh fodder yield at 200 kg/ha N and 300 kg/ha N were at par.

Considering the total fresh fodder yield, maximum yield of 148.75 Mg/ha was recorded at 60 days of cutting interval for higher dose of nitrogen i.e. 400 kg/ha. Regarding the individual harvests, for increasing dose of nitrogen from 0 kg/ha to 400 kg/ha, the total fresh fodder yield increased from 46.98 Mg/ha to

Table 57. Effect of nitrogen nutrition and cutting frequency on fresh fodder yield (Mg/ha) of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5	Total
Cutting frequency						
30 days	35.91	19.49	18.13	7.02	2.19	82.74
45 days	35.93	33.83	28.74	2.81	NH	101.31
60 days	35.88	49.18	40.95	NH	NH	126.02
LSD 5%	NS	0.28	0.24	0.26	-	0.46
N levels (kg/ha)						
0	24.49	23.18	18.63	2.56	-	68.53
100	30.98	29.38	24.51	4.26	-	88.37
200	38.88	36.94	31.97	5.30	-	112.08
300	41.64	39.76	34.70	5.97	-	120.90
400	43.56	41.57	36.56	6.48	-	126.88
LSD 5%	0.41	0.36	0.31	0.41	-	0.59
30 days						
0	24.57	9.17	8.56	3.08	1.59	46.98
100	31.02	14.91	13.30	6.21	1.98	67.42
200	38.81	22.03	20.60	7.53	2.30	91.27
300	41.63	24.78	23.18	8.68	2.46	100.74
400	43.52	26.55	25.02	9.60	2.60	107.29
45 days						
0	24.45	22.42	17.59	2.05	NH	66.52
100	30.97	28.87	24.07	2.31		86.22
200	39.00	36.79	31.51	3.06		110.35
300	41.65	39.60	34.32	3.25		118.83
400	43.58	41.45	36.21	3.35		124.60
60 days						
0	24.44	37.94	29.73	NH	NH	92.11
100	30.94	44.37	36.17			111.47
200	38.82	52.00	43.79			134.62
300	41.63	54.90	46.60			143.13
400	43.58	56.71	48.45			148.75
LSD 5%	NS	0.62	0.53	0.57	0.19	1.02

NH- No harvest

Table 58 . Effect of nitrogen nutrition and cutting frequency on fresh fodder yield (Mg/ha) of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7	Total
Cutting frequency								
30 days	24.31	29.33	17.86	24.00	7.93	12.65	1.31	117.39
45 days	27.17	40.62	21.20	29.34	12.34	NH	NH	130.67
60 days	30.93	52.61	25.01	34.13	NH	NH	NH	142.68
LSD 5%	0.32	0.33	0.31	0.31	0.36	-	-	0.67
N levels (kg/ha)								
0	21.11	28.70	10.77	17.68	3.45	-	-	83.57
100	24.38	35.03	16.93	24.82	6.33	-	-	109.15
200	28.57	42.27	24.28	32.25	12.44	-	-	140.70
300	30.75	48.02	26.60	34.78	13.92	-	-	154.81
400	32.54	50.25	28.20	36.26	14.53	-	-	163.00
LSD 5%	0.41	0.43	0.39	0.40	0.57	-	-	0.86
30 days								
0	18.37	19.18	8.34	12.68	2.58	8.07	0.96	70.17
100	21.40	24.84	13.62	20.09	3.90	10.29	1.03	95.16
200	25.40	31.46	20.30	26.92	9.56	13.80	1.27	128.72
300	27.46	34.24	22.57	29.48	11.41	14.62	1.53	141.31
400	28.90	36.90	24.49	30.85	12.20	16.47	1.74	151.56
45 days								
0	20.54	29.56	10.12	18.04	4.32	NH	NH	82.57
100	24.20	36.09	16.67	24.59	8.77			110.31
200	28.27	43.49	24.27	32.71	15.31			144.06
300	30.34	45.83	26.71	34.99	16.44			154.30
400	32.51	48.13	28.24	36.38	16.87			162.12
60 days								
0	24.42	37.37	13.86	22.32	NH	NH	NH	97.96
100	27.53	44.15	20.50	29.80				121.97
200	32.04	51.85	28.27	37.13				149.31
300	34.44	63.99	30.52	39.88				168.83
400	36.21	65.72	31.88	41.54				175.34
LSD 5%	0.71	0.74	0.68	0.69	0.80	1.08	0.14	1.49

NH- No harvest

107.29 Mg/ha at 30 days of harvest, from 66.52 Mg/ha to 124.60 Mg/ha at 45 days of harvest and from 92.11 Mg/ha to 148.75 Mg/ha.

After the summer months, the first harvest of the second year recorded the highest fresh fodder yield of 36.21 Mg/ha for 60 days of cutting frequency at 400 kg/ha N while the lowest fresh fodder yield was 18.37 Mg/ha for 30 days of cutting frequency at 0 kg/ha N. Fresh fodder yields produced from 30 days of cutting frequency at 300 kg/ha N and 400 kg/ha N were on par with yields produced from 60 days of harvest at 100 kg/ha N and from 45 days of harvest at 200 kg/ha respectively. The crop grown without nitrogen but harvested at 60 days of cutting frequency could produce comparable fodder yield as that of crop harvested at 45 days interval with 100 kg/ha N.

The highest fresh fodder yield during the experiment was recorded in the second harvest where yield increased from 19.18 Mg/ha at 30 days of harvest to 65.72 Mg/ha at 60 days of harvest when nitrogen rates increased from 0 kg/ha to 400 kg/ha. In the third harvest, fresh fodder yield at 30 days of harvest from nitrogen fertilized plots of 100 kg/ha, 200 kg/ha and 400 kg/ha were comparable with corresponding nitrogen levels of 0 kg/ha and 100 kg/ha at 60 days of harvest, and at 200 kg/ha under 45 days of harvest. Similarly, fodder yields from plots of 400 kg/ha at 45 days of harvest and from plots of one half of the highest recommended dose (200 kg/ha) at 60 days of harvesting were at par.

In the fourth harvest, the crop harvested at 30 days of cutting interval supplemented with 300 kg/ha N had similar performance with crop harvest at 60 days of cutting interval but supplemented with one third of the corresponding recommended dose of nitrogen. During the fifth harvest, maximum fodder yield was recorded at 45 days of harvest with its highest yield at 400 kg/ha N (16.87 Mg/ha). A sixth and seventh harvests were possible from 30 days cutting intervals only. In the final two harvests, more yields were recorded for higher dose of nitrogen. For the seventh harvest, yield declined drastically and none of the treatments could yield more than 2 Mg/ha.

Considering the total fresh fodder yield, the highest fodder production was during the second year. The annual fresh fodder yield ranged from 70.17 Mg/ha to 175.34 Mg/ha on delaying the harvesting from 30 days to 60 days and for corresponding increase in nitrogen from 0 kg/ha N to 400 kg/ha N.

Dry fodder yield

Dry fodder yield at different cutting regimes and nitrogen levels are presented in Table 59 and Table 60. During the first year, dry fodder yield decreased towards the final harvests. Dry fodder yield also followed the same trend as that of fresh yield. For all the harvests, the highest yield was recorded for 400 kg/ha N at 60 days of harvest. Interactions between cutting intervals and nitrogen levels were significant from second harvest onwards.

During the first year, dry fodder yield decreased towards the final harvest while for 60 days of cutting interval maximum was recorded in the second harvest. At the first harvest, for single cut at 75 days after planting, dry matter production increased from 4.46 Mg/ha to 7.93 Mg/ha with increasing nitrogen rates from 0 kg/ha to 400 kg/ha. Interaction was non- significant.

In the second harvest, dry fodder yield increased from 1.67 Mg/ha to 10.32 Mg/ha with increasing nitrogen rates from 0 kg/ha to 400 kg/ha for corresponding delay in harvesting from 30 days to 60 days. The highest, dry fodder yield recorded during the first year was 10.32 Mg/ha from nitrogen supplemented plots of 400 kg/ha at 60 days of harvest. During the third harvest, dry matter production ranged from 1.56 Mg/ha to 8.82 Mg/ha.

The fourth harvest was from 30 days and 45 days cutting intervals. Yield from 30 days of harvest was higher, where the dry matter production ranged from 0.56 Mg/ha to 1.75 Mg/ha and for 45 days of harvest, it increased from 0.37 Mg/ha to 0.61 Mg/ha, for increasing nitrogen rates from 0 kg/ha to 400 kg/ha.

In view of the total dry matter production, annual dry fodder yield ranged from 8.55 Mg/ha to 27.07 Mg/ha for increasing nitrogen from 0 kg/ha to 400 kg/ha

Table 59. Effect of nitrogen nutrition and cutting frequency on dry fodder yield (Mg/ha) of hybrid napier at each harvest during the first year

Treatment	HI	H2	H3	H4	H5	Total
Cutting frequency						
30 days	6.54	3.55	3.30	1.28	0.40	15.06
45 days	6.54	6.16	5.23	0.51	NH	18.44
60 days	6.53	8.95	7.45	NH	NH	22.94
LSD 5%	NS	0.05	0.04	0:05	-	0.08
N levels (kg/ha)						
0	4.46	4.22	3.39	0.47	-	12.47
100	5.64	5.35	4.46	0.78	-	16.08
200	7.07	6.72	5.82	0.97	-	20.40
300	7.58	7.24	6.32	1.09	-	22.00
400	7.93	7.57	6.65	1.18	-	23.09
LSD 5%	0.07	0.07	0.06	0.08	-	0.11
30 days						
0	4.47	1.67	1.56	0.56	0.29	8.55
100	5.65	2.71	2.42	1.13	0.36	12.27
200	7.06	4.01	3.75	1.37	0.42	16.61
300	7.58	4.51	4.22	1.58	0.45	18.33
400	7.92	4.83	4.55	1.75	0.47	19.53
45 days						
0	4.45	4.08	3.20	0.37	NH	12.10
100	5.64	5.25	4.38	0.42		15.69
200	7.10	6.70	5.73	0.56		20.08
300	7.58	7.21	6.25	0.59		21.63
400	7.93	7.54	6.59	0.61		22.68
60 days						
0	4.45	6.90	5.41	NH	NH	16.76
100	5.63	8.07	6.58			20.29
200	7.06	9.47	7.97			24.50
300	7.58	9.99	8.48			26.05
400	7.93	10.32	8.82			27.07
LSD 5%	NS	0.11	0.10	0.11	0.04	0.19

NH- No harvest

Table 60. Effect of nitrogen nutrition and cutting frequency on dry fodder yield (Mg/ha) of hybrid napier at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	H6	H7	Total
Cutting frequency								
30 days	4.42	5.34	3.25	4.37	1.44	2.30	0.24	21.36
45 days	4.95	7.40	3.86	5.34	2.25	NH	NH	23.78
60 days	5.63	9.58	4.55	6.21	NH	NH	NH	25.97
LSD 5%	0.06	0.06	0.06	0.06	0.07	-	-	0.12
N levels (kg/ha)								
0	3.84	5.22	1.96	3.22	0.63	-	-	15.21
100	4.44	6.37	3.08	4.52	1.15	-	-	19.87
200	5.20	7.69	4.42	5.87	2.27	-	-	25.61
300	5.60	8.74	4.84	6.33	2.54	-	-	28.18
400	5.92	9.15	5.13	6.60	2.65	-	-	29.67
LSD 5%	0.08	0.08	0.07	0.07	0.10	-	-	0.16
30 days								
0	3.34	3.49	1.52	2.31	0.47	1.47	0.17	12.77
100	3.89	4.52	2.48	3.66	0.71	1.87	0.19	17.32
200	4.62	5.73	3.69	4.90	1.74	2.51	0.23	23.43
300	5.00	6.23	4.11	5.37	2.08	2.66	0.28	25.72
400	5.26	6.72	4.46	5.62	2.22	3.00	0.32	27.58
45 days								
0	3.74	5.38	1.84	3.28	0.79	NH	NH	15.03
100	4.40	6.57	3.03	4.48	1.59			20.08
200	5.15	7.91	4.42	5.95	2.79			26.22
300	5.52	8.34	4.86	6.37	2.99			28.08
400	5.92	8.76	5.14	6.62	3.07			29.50
60 days								
0	4.44	6.80	2.52	4.06	NH	NH	NH	17.83
100	5.01	8.03	3.73	5.42				22.20
200	5.83	9.44	5.15	6.76				27.17
300	6.27	11.65	5.56	7.26				30.73
400	6.59	11.96	5.80	7.56				31.91
LSD 5%	0.13	0.14	0.13	0.13	0.15	0.20	0.02	0.27

NH- No harvest

and delaying harvesting from 30 days to 60 days. The dry fodder yield from plots without nitrogen supplementation at 45 days of harvest was on par with yield at 30 days of harvest with nitrogen rates of 100 kg/ha. Similarly, yield from 45 days of harvest with 200 kg /ha was comparable with the dry fodder yield from 60 days of harvest at 100 kg/ha.

During the second year, for the first harvest, dry fodder yield ranged from 3.34 Mg/ha to 6.59 Mg/ for increasing nitrogen from 0 kg/ha N to 400 kg/ha N and delaying harvesting from 30 days to 60 days. Dry matter production at 30 days of cutting frequency at 300 kg/ha N and at 400 kg/ha N were at par with corresponding dry fodder yield at 60 days of harvest at 100 kg/ha N and at 45 days of harvest at 200 kg/ha N. Similarly, yield at 45 days of harvest with 400 kg/ha N was on par with yield at 60 days of harvest with 200 kg/ha N.

The second harvest gave the highest dry fodder yield during the second year. The highest dry matter production recorded for 400 kg/ha at cutting frequencies of 30 days, 45 days and 60 days were 6.72 Mg/ha, 8.76 Mg/ha and 11.96 Mg/ha respectively.

In the third harvest, the crop could produce similar yield as that of 30 days of harvest under 100 kg/ha N, 200 kg/ha N and 400 kg/ha N for corresponding harvests at 60 days under 0 kg/ha N, 100 kg/ha N and at 45 days with 200 kg/ha N. Consequently, the dry matter production at 45 days of harvest under higher dose of 400 kg/ha N was on par with dry fodder yield at 60 days of harvest under 200 kg/ha N. During the third harvest, the dry fodder yield at 30 days of harvest at 300 kg/ha N was comparable with yield at 60 days of harvest with 100 kg/ha N.

During the fifth harvest, higher fodder yield was recorded at 45 days of harvest with its highest yield at 400 kg/ha N. The sixth and seventh harvest were relevant for 30 days cutting intervals. In the sixth harvest, dry matter produced at 200 kg/ha N and 300 kg/ha N were at par. The dry fodder yield at sixth harvest was significant with increasing dose of nitrogen from nitrogen rates of 200 kg/ha N onwards.

Considering the total dry matter production, the second year was better than the first year. Where the yield increased from 12.77 Mg/ha to 31.91 Mg/ha for increasing nitrogen from 0 kg/ha N to 400 kg/ha N and delaying harvesting from 30 days to 60 days. Corresponding maximum dry fodder yield recorded at higher dose of nitrogen for delay in harvests by 30 days and subsequently by 15 days and 30 days were, 27.58 Mg/ha, 29.50 Mg/ha and 31.91 Mg/ha.

4.2.5. Plant analysis

Plant samples from all the treatments were collected and used to estimate the five fractions of proximate analysis – crude protein, crude fibre, ether extract, total ash and nitrogen free extract of leaves and stems. Percentage content of nutrient elements such as nitrogen, potassium, phosphorous, calcium and magnesium of leaves and stems were estimated during both years. Antinutritional factors such as oxalate and nitrate content were also analyzed during kharif, rabi and summer.

Proximate analysis

Crude protein

Crude protein content of hybrid napier leaves and stems are presented in Table 61 to Table 64. Cutting frequency and nitrogen nutrition significantly affected the crude protein content of hybrid napier. Increasing the cutting interval decreased the crude protein content. While increasing the nitrogen levels had a positive effect on crude protein content. Interactions were also present. Leaves had more content of crude protein than stems.

In the first year, crude protein content in leaves ranged from 6.98 per cent for 60 days of harvest at 0 kg/ha N to 14.67 per cent for 30 days of harvest at 400 kg/ha N while in stems the highest crude protein content recorded was 13 per cent for 30 days of harvest at 400 kg/ha N. Correspondingly the crop could produce comparable amount of crude protein in leaves when fertilized with 300 kg/ha N and 400 kg/ha N at 45 days and 60 days of harvests.

Table 61. Effect of nitrogen nutrition and cutting frequency on proximate analysis of hybrid napier leaves (%) during the first year

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Cutting frequency					
30 days	11.83	22.13	2.25	54.99	8.81
45 days	11.29	25.87	2.26	51.99	8.59
60 days	10.33	26.53	2.24	53.03	7.87
LSD 5%	0.54	0.65	NS	0.94	0.23
N levels (kg/ha)					
0	7.21	26.83	2.03	55.51	8.43
100	9.72	25.91	2.06	53.96	8.35
200	12.40	25.46	2.26	51.41	8.47
300	12.72	23.15	2.45	53.23	8.44
400	13.70	22.86	2.46	52.57	8.42
LSD 5%	0.70	0.85	0.06	1.21	NS
30 days					
0	7.54	23.62	2.02	58.03	8.80
100	10.21	22.83	2.05	56.18	8.73
200	13.35	22.50	2.25	53.06	8.84
300	13.38	20.78	2.46	54.55	8.83
400	14.67	20.93	2.44	53.13	8.83
45 days					
0	7.10	27.88	2.03	54.35	8.63
100	9.71	27.25	2.10	52.37	8.57
200	13.25	26.68	2.26	49.27	8.54
300	12.92	24.00	2.45	52.02	8.62
400	13.48	23.52	2.46	51.96	8.58
60 days					
0	6.98	29.00	2.03	54.14	7.85
100	9.25	27.65	2.02	53.32	7.76
200	10.58	27.20	2.26	51.92	8.04
300	11.88	24.67	2.45	53.14	7.87
400	12.96	24.13	2.46	52.61	7.84
LSD 5%	1.20	1.46	0.10	2.10	NS

Table 62. Effect of nitrogen nutrition and cutting frequency on proximate analysis of hybrid napier stems (%) during the first year

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Cutting frequency					
30 days	9.68	24.89	1.27	56.18	7.98
45 days	8.84	28.59	1.28	53.59	7.71
60 days	8.15	29.19	1.26	54.47	6.93
LSD 5%	0.51	0.66	NS	0.90	0.19
N levels (kg/ha)					
0	6.29	29.40	1.02	55.78	7.51
100	7.14	28.30	1.05	55.94	7.57
200	8.59	27.84	1.30	54.82	7.46
300	10.31	26.40	1.49	54.22	7.59
400	12.13	25.84	1.48	52.97	7.58
LSD 5%	0.66	0.85	0.05	1.16	NS
30 days					
0	6.94	26.56	1.02	57.41	8.08
100	7.52	25.00	1.06	58.51	7.91
200	9.83	24.53	1.30	56.37	7.96
300	11.13	24.25	1.46	55.19	7.98
400	13.00	24.10	1.51	53.44	7.96
45 days					
0	6.75	30.47	1.04	54.21	7.53
100	7.08	29.77	1.06	54.35	7.74
200	8.48	29.07	1.29	53.39	7.77
300	10.00	27.02	1.53	53.65	7.80
400	11.88	26.60	1.46	52.34	7.72
60 days					
0	5.19	31.17	0.99	55.73	6.93
100	6.81	30.13	1.04	54.96	7.06
200	7.46	29.90	1.29	54.71	6.64
300	9.79	27.93	1.47	53.82	6.98
400	11.50	26.82	1.48	53.14	7.06
LSD 5%	1.14	1.47	NS	2.00	NS

Table 63. Effect of nitrogen nutrition and cutting frequency on proximate analysis of hybrid napier leaves (%) during the second year

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Cutting frequency					
30 days	11.80	22.48	2.27	54.70	8.75
45 days	11.15	25.83	2.27	52.13	8.63
60 days	10.30	26.72	2.26	52.92	7.81
LSD 5%	0.53	0.64	NS	0.78	0.25
N levels (kg/ha)					
0	7.04	26.90	2.04	55.56	8.46
100	9.90	26.08	2.10	53.58	8.35
200	11.83	25.55	2.27	51.91	8.44
300	12.69	23.68	2.45	52.79	8.39
400	13.98	22.84	2.47	52.39	8.32
LSD 5%	0.69	0.82	0.07	1.01	NS
30 days					
0	7.31	23.93	2.05	57.88	8.82
100	10.44	23.17	2.09	55.56	8.75
200	12.63	22.87	2.28	53.45	8.79
300	13.88	21.40	2.46	53.51	8.76
400	14.77	21.05	2.47	53.09	8.62
45 days					
0	6.98	27.52	2.04	54.78	8.68
100	10.00	27.07	2.10	52.26	8.57
200	12.10	26.59	2.26	50.37	8.67
300	12.60	24.50	2.45	51.84	8.61
400	14.06	23.47	2.48	51.39	8.60
60 days					
0	6.81	29.25	2.02	54.03	7.88
100	9.25	28.00	2.10	52.92	7.73
200	10.75	27.20	2.26	51.92	7.87
300	11.58	25.13	2.45	53.01	7.82
400	13.10	24.00	2.46	52.69	7.75
LSD 5%	1.19	1.43	NS	1.74	NS

Table 64. Effect of nitrogen nutrition and cutting frequency on proximate analysis of hybrid napier stems (%) during the second year

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Cutting frequency					
30 days	9.57	24.68	1.27	56.48	8.01
45 days	8.76	28.79	1.27	53.49	7.70
60 days	8.05	29.64	1.27	54.05	6.99
LSD 5%	0.49	0.61	NS	0.80	0.15
N levels (kg/ha)					
0	5.99	29.71	1.03	55.75	7.53
100	7.21	28.91	1.05	55.24	7.59
200	8.58	27.60	1.29	54.97	7.55
300	10.35	26.61	1.49	54.01	7.54
400	11.83	25.67	1.49	53.40	7.60
LSD 5%	0.63	0.78	0.04	1.03	NS
30 days					
0	6.67	26.87	1.04	57.43	8.00
100	7.56	25.20	1.03	58.18	8.03
200	9.98	24.13	1.30	56.59	8.00
300	11.19	23.82	1.48	55.56	7.95
400	12.46	23.37	1.49	54.65	8.04
45 days					
0	6.48	30.80	1.03	54.05	7.64
100	7.35	30.33	1.04	53.51	7.76
200	8.31	29.27	1.29	53.42	7.71
300	10.00	27.00	1.52	53.79	7.70
400	11.65	26.53	1.47	52.66	7.68
60 days					
0	4.81	31.47	1.01	55.76	6.95
100	6.71	31.20	1.08	54.02	6.99
200	7.46	29.41	1.29	54.90	6.94
300	9.85	29.00	1.48	52.68	6.98
400	11.40	27.12	1.50	52.90	7.08
LSD 5%	1.09	1.35	NS	1.78	NS

For the second year, content in leaves ranged from 6.81 per cent for 60 days of harvest at 0 kg/ha N to 14.77 per cent for 30 days of harvest at 400 kg/ha N; whereas in stems, the highest crude protein content observed was 12.46 per cent for 30 days of harvest at 400 kg/ha N. Content in leaves at 300 kg/ha N and 400 kg/ha N at 30 days of harvest were at par. Similarly for 45 days and 60 days of harvests, at 200 kg/ha N and 300 kg/ha N, content in leaves were comparable with each other.

Crude fibre

The data on crude fibre content of hybrid napier leaves and stems are presented in Table 61 to Table 64. Crude fibre content of stems were more than that of leaves. Content in plants decreased with more frequent harvesting and increasing nitrogen levels. Interaction effect was also observed. In general, at all cutting intervals, there was no change in fibre content at 300 kg/ha N and 400 kg/ha N. Similarly, no change was noticed at 100 kg/ha N and 200 kg/ha N.

During both years, lower crude fibre content was observed in plants harvested at 30 days of interval and fertilized with more than 300 kg/ha N. Leaves and stems became more fibrous when nitrogen fertilization was not done and harvesting was delayed to 60 days. The fibre content in stems was less than 25 per cent when harvested at 30 days and fertilized with more than 200 kg/ha N. On extending the harvesting interval by 60 days and fertilizing with more than 200 kg/ha N, the crude fibre content in stems reduced much lesser than 30 per cent.

Ether extract

Crude fat content of hybrid napier leaves and stems are presented in Table 61, Table 62, Table 63 and Table 64. Crude fat content in leaves were more than that of stems. There was no change in fat content on delaying the cutting frequency from 30 days to 60 days but nitrogen nutrition significantly affected the crude fat content. Increasing the nitrogen levels had a positive effect on crude fat content. Interactions were absent.

Significant effect of nitrogen nutrition on crude fat content was noticed on applying more than 100 kg/ha. Even though there was significant change in fat content with increasing nitrogen levels, the fat content at higher levels of nitrogen i.e. at 300 kg/ha and 400 kg/ha were comparable with each other. At higher levels of nitrogen, i.e., at more than 200 kg/ha N, fat content in leaves was more than 2.20 per cent, and in stems, it was more than 1.30 per cent.

Total ash

Total ash content of hybrid napier leaves and stems are given in Table 61, Table 62, Table 63 and Table 64. Substantial decrease in ash content with increasing cutting interval was noticed in leaves and stems of hybrid napier but the content remained unchanged with varying levels of nitrogen fertilizer. Maximum ash content was observed in leaves and stems at 30 days of harvest but for the second year, in leaves the crop had comparable contents at 30 days and 45 days of harvest. Interactions were absent.

Nitrogen free extract

The data on nitrogen free extract of hybrid napier leaves and stems are presented in Table 61, Table 62, Table 63 and Table 64. Cutting frequency and nitrogen nutrition significantly affected the NFE of leaves and stems. Considering the effect of cutting frequency alone, maximum content was noticed in leaves and stems at 30 days of harvest and minimum at 45 days of harvest. With respect to nitrogen nutrition, in leaves, content increased with increasing N levels up to 100 kg/ha and thereafter, started decreasing. It started increasing on applying 300 kg/ha N but again decreased at higher dose of 400 kg/ha N. However, in stems NFE content decreased with increasing nitrogen levels.

Percentage content of major nutrient elements

The data related to each nutrient elements are presented in Table 65, Table 66, and Table 67. Leaves recorded maximum content of nutrients compared to stems.

Table 65. Effect of nitrogen nutrition and cutting frequency on primary nutrient content (%) of hybrid napier leaves

Treatment	Nitrogen		Phosphorous		Potassium	
	First year	Second year	First year	Second year	First year	Second year
Cutting frequency						
30 days	1.89	1.89	0.227	0.199	3.22	2.11
45 days	1.81	1.78	0.197	0.191	2.20	1.89
60 days	1.65	1.65	0.167	0.161	1.85	1.66
LSD 5%	0.09	0.09	0.013	0.012	0.08	0.06
N levels						
(kg/ha)	1.15	1.13	0.199	0.184	2.41	1.91
0	1.56	1.58	0.195	0.182	2.41	1.88
100	1.98	1.89	0.196	0.182	2.45	1.88
200	2.04	2.03	0.195	0.185	2.43	1.90
300	2.19	2.24	0.200	0.186	2.40	1.86
400						
LSD 5%	0.11	0.11	NS	NS	NS	NS
30 days						
0	1.21	1.17	0.228	0.203	3.23	2.11
100	1.63	1.67	0.231	0.196	3.16	2.08
200	2.14	2.02	0.221	0.191	3.28	2.10
300	2.14	2.22	0.222	0.201	3.26	2.13
400	2.35	2.36	0.232	0.205	3.16	2.11
45 days						
0	1.14	1.12	0.202	0.192	2.18	1.96
100	1.55	1.60	0.195	0.198	2.20	1.88
200	2.12	1.94	0.19	0.189	2.22	1.87
300	2.07	2.02	0.197	0.189	2.19	1.91
400	2.16	2.25	0.202	0.189	2.19	1.81
60 days						
0	1.12	1.09	0.167	0.158	1.82	1.67
100	1.48	1.48	0.16	0.153	1.88	1.67
200	1.69	1.72	0.177	0.165	1.85	1.65
300	1.90	1.85	0.166	0.165	1.84	1.66
400	2.07	2.10	0.164	0.165	1.85	1.66
LSD 5%	0.19	0.19	NS	NS	NS	NS

Table 66. Effect of nitrogen nutrition and cutting frequency on primary nutrient content (%) of hybrid napier stems

Treatment	Nitrogen		Phosphorous		Potassium	
	First year	Second year	First year	Second year	First year	Second year
Cutting frequency						
30 days	1.55	1.53	0.186	0.183	2.31	1.67
45 days	1.41	1.40	0.163	0.166	1.85	1.58
60 days	1.30	1.29	0.154	0.156	1.46	1.42
LSD 5%	0.08	0.08	0.01	0.012	0.10	0.06
N levels (kg/ha)						
0	1.01	0.96	0.165	0.166	1.89	1.56
100	1.14	1.15	0.168	0.169	1.91	1.54
200	1.37	1.37	0.166	0.169	1.87	1.56
300	1.65	1.66	0.172	0.167	1.84	1.57
400	1.94	1.89	0.167	0.171	1.86	1.55
LSD 5%	0.11	0.10	NS	NS	NS	NS
30 days						
0	1.11	1.07	0.185	0.182	2.35	1.69
100	1.20	1.21	0.183	0.185	2.43	1.65
200	1.57	1.60	0.187	0.184	2.28	1.67
300	1.78	1.79	0.19	0.181	2.19	1.68
400	2.08	1.99	0.183	0.181	2.29	1.65
45 days						
0	1.08	1.04	0.16	0.165	1.85	1.57
100	1.13	1.18	0.164	0.162	1.85	1.58
200	1.36	1.33	0.159	0.167	1.88	1.60
300	1.60	1.60	0.171	0.161	1.87	1.59
400	1.90	1.86	0.163	0.174	1.82	1.57
60 days						
0	0.83	0.77	0.151	0.151	1.48	1.42
100	1.09	1.07	0.157	0.158	1.46	1.38
200	1.19	1.19	0.152	0.157	1.46	1.42
300	1.57	1.58	0.156	0.158	1.45	1.42
400	1.84	1.82	0.153	0.158	1.46	1.44
LSD 5%	0.18	0.17	NS	NS	NS	NS

Nitrogen

Nitrogen content in leaves and stems were significantly influenced by cutting interval and nitrogen levels. Nitrogen content decreased with increasing cutting interval and increased with increasing nitrogen levels. At higher levels of nitrogen, i.e., at 300 kg/ha N and 400 kg/ha N, N content in leaves were comparable with each other. Interaction effects were also present.

In the first year, content in leaves increased from 1.12 per cent at 60 days of harvest to 2.35 per cent at 30 days of harvest for corresponding increase in nitrogen levels from 0 kg/ha to 400 kg/ha. In stems, the content ranged from 0.83 per to 2.08 per cent. During the second year, content in leaves ranged from 1.09 per cent to 2.36 per cent, and in stems, it ranged from 0.77 per cent to 1.99 per cent.

Phosphorous

Phosphorous content in leaves and stems were significantly influenced by increasing the cutting interval but remained unaltered with increasing nitrogen levels. The content decreased with increasing cutting interval. Interaction effect was absent. In the first year, in leaves the content decreased from 0.227 per cent to 0.167 per cent whereas in stems, from 0.186 per cent to 0.154 per cent on delaying the harvests from 30 days to 60 days. In the second year, corresponding decline in leaf content was 0.199 per cent to 0.161 per cent and for stems it was from 0.183 per cent to 0.156 per cent.

Potassium

Substantial decrease in potassium content of plants was noticed on delaying the harvest from 30 days to 60 days but there was no influence of increasing nitrogen levels, and interactions were absent. Maximum potassium content was observed during the first year. In the first year, the content in leaves decreased from 3.22 per cent to 1.85 per cent whereas in stems, the content decreased from 2.31 per cent to 1.46 per cent when harvesting interval was increased from 30 days to 60

Table 67. Effect of nitrogen nutrition and cutting frequency on secondary nutrient content (%) of hybrid napier leaves and stems

Treatment	Ca leaves		Ca stems		Mg leaves		Mg stems	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
Cutting frequency								
30 days	0.434	0.413	0.414	0.385	0.327	0.327	0.313	0.311
45 days	0.285	0.368	0.263	0.350	0.323	0.323	0.309	0.305
60 days	0.251	0.317	0.236	0.278	0.309	0.312	0.302	0.305
LSD 5%	0.01	0.02	0.01	0.02	0.01	0.01	0.01	NS
N levels (kg/ha)								
0	0.243	0.267	0.220	0.231	0.300	0.301	0.293	0.296
100	0.290	0.314	0.260	0.296	0.311	0.309	0.301	0.300
200	0.348	0.370	0.323	0.344	0.324	0.324	0.311	0.310
300	0.349	0.410	0.354	0.384	0.330	0.332	0.316	0.310
400	0.387	0.468	0.364	0.432	0.333	0.336	0.318	0.319
LSD 5%	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
30 days								
0	0.281	0.293	0.242	0.242	0.303	0.303	0.297	0.297
100	0.374	0.361	0.333	0.343	0.317	0.310	0.307	0.303
200	0.483	0.443	0.466	0.403	0.333	0.333	0.317	0.313
300	0.501	0.468	0.519	0.446	0.340	0.340	0.320	0.313
400	0.532	0.502	0.511	0.489	0.343	0.347	0.323	0.327
45 days								
0	0.237	0.263	0.222	0.244	0.300	0.300	0.293	0.297
100	0.258	0.318	0.245	0.302	0.310	0.307	0.303	0.293
200	0.296	0.378	0.259	0.353	0.330	0.330	0.310	0.307
300	0.280	0.421	0.281	0.405	0.337	0.340	0.317	0.310
400	0.353	0.458	0.306	0.446	0.340	0.337	0.320	0.320
60 days								
0	0.210	0.245	0.194	0.206	0.297	0.300	0.290	0.293
100	0.237	0.263	0.203	0.244	0.307	0.310	0.293	0.303
200	0.266	0.290	0.245	0.276	0.310	0.310	0.307	0.310
300	0.265	0.341	0.263	0.300	0.313	0.317	0.310	0.307
400	0.277	0.444	0.274	0.361	0.317	0.323	0.310	0.310
LSD 5%	0.03	0.04	0.03	0.04	0.02	0.02	0.01	NS

days. For the second year, corresponding decline in leaf content was from 2.11 per cent to 1.66 per cent and in stems from 1.67 per cent to 1.42 per cent.

Calcium and Magnesium

Calcium and magnesium content of leaves and stems were significantly influenced by cutting frequencies and nitrogen levels. Contents in leaves and stems were reduced on delaying the harvest from 30 days to 60 days. Significant change in Ca and Mg content was noticed with increasing nitrogen levels.

During the first year, in general, Ca content of leaves at 200 kg/ha N and 300 kg/ha N were at par. Similarly, stem content at 300 kg/ha N and 400 kg/ha N were at par. Maximum Ca content in leaves and stems were obtained on fertilizing with 400 kg/ha N and harvesting at 30 days interval, whereas the contents recorded were 0.532 per cent and 0.511 per cent respectively. In the second year, the highest content recorded in leaves was 0.502 per cent and for stems 0.489 per cent.

Magnesium content in leaves at 30 days and 45 days of harvest were at par whereas the content in stem at 45 days of harvest was on par with that at 30 days and 60 days of harvest. There was no change in Mg content on increasing the nitrogen content above 200 kg/ha N.

Antinutritional factors

Oxalate content

Oxalate content of hybrid napier leaves and stems are presented in Table 68 and Table 69. Leaves had higher content of oxalate compared to stems. In general, there was significant changes in oxalate content with increasing cutting frequency and nitrogen levels. Leaves had higher content of oxalates compared to stems. Higher oxalate content was recorded in the rabi season of the second year.

In the first year, during the kharif season, there was no change in oxalate content for single cut crop but the content increased with increasing nitrogen levels. The content was more than 4 per cent in leaves when fertilized with 200 kg /ha. In general, during both years, the crop had comparable amount of oxalate at 300 kg/ha and 400 kg/ha. For the second year, in kharif, lower oxalate content was noticed in plants harvested at 45 days of harvest and the content was above 4 per cent in leaves from nitrogen fertilized plots. However, in stems, it exceeded the safe limit at 200 kg/ha.

During the rabi season, oxalate content in leaves and stems were more than 4 per cent. In the first year, the crop harvested at 45 days of cutting interval recorded higher oxalate content while during the second year there was no effect of cutting frequency on oxalate content. In both years, leaves had comparable content of oxalate at 300 kg/ha and 400 kg/ha. Interactions were absent in the second year.

For summer harvested fodder, there was no influence of cutting frequency on oxalate content but content increased with increasing nitrogen levels. Interactions were absent. In the first year, oxalate content exceeded the safe limit only in leaves when fertilized with 400 kg/ha. Similarly, for the second year, safe limit was exceeded in leaves at 300 kg/ha and in stems at 400 kg/ha.

Nitrate content

Nitrate content of hybrid napier leaves and stems are presented in Table 70 and Table 71. In general, compared to leaves, stems showed less nitrate content. Exceptions were noticed when the content reached the brim or exceeded the safe limit of 1000 ppm. There were significant effects of cutting frequency and nitrogen levels on nitrate content of leaves and stems.

In kharif, during the first year, there was no significant changes in nitrate contents for cutting frequency but its content increased with increasing nitrogen levels. In stems, the content exceeded the safe limit and nitrate accumulation was noticed. In the second year, the lowest nitrate content was observed in plants harvested at 45 days of cutting interval. At 30 days of harvest, with 300 kg/ha and 400 kg/ha nitrate content in stems were more than leaves. Nitrate accumulation at toxic level was noticed in stems when fertilized with 400 kg/ha and harvested at 60 days of cutting frequency.

Table 68. Effect of nitrogen nutrition and cutting frequency on oxalate content (%) of hybrid napier leaves

Treatment	Kharif		Rabi		Summer	
	First year	Second year	First year	Second year	First year	Second year
Cutting frequency						
30 days	4.04	4.57	4.94	7.25	3.48	3.69
45 days	4.09	4.17	5.31	7.25	3.48	3.75
60 days	4.06	5.25	4.83	7.26	3.50	3.71
LSD 5%	NS	0.16	0.18	NS	NS	NS
N levels (kg/ha)						
0	2.81	3.45	4.39	6.63	2.52	2.75
100	3.46	4.47	4.79	7.13	2.80	3.11
200	4.36	4.83	5.03	7.42	3.78	3.86
300	4.78	5.22	5.34	7.49	3.89	4.26
400	4.92	5.35	5.57	7.59	4.42	4.60
LSD 5%	0.23	0.21	0.23	0.22	0.20	0.27
30 days						
0	2.79	3.55	4.34	6.67	2.54	2.67
100	3.48	4.17	4.63	7.13	2.79	3.12
200	4.33	4.67	4.96	7.42	3.75	3.88
300	4.73	5.19	5.23	7.46	3.88	4.21
400	4.88	5.29	5.54	7.55	4.42	4.59
45 days						
0	2.84	2.42	4.67	6.75	2.54	2.83
100	3.50	4.08	5.04	7.09	2.87	3.17
200	4.39	4.54	5.29	7.38	3.75	3.83
300	4.77	4.88	5.67	7.50	3.83	4.25
400	4.94	4.92	5.89	7.54	4.38	4.67
60 days						
0	2.79	4.38	4.17	6.46	2.49	2.75
100	3.40	5.17	4.71	7.17	2.75	3.04
200	4.35	5.29	4.83	7.46	3.84	3.88
300	4.83	5.58	5.13	7.51	3.96	4.33
400	4.94	5.84	5.29	7.69	4.46	4.54
LSD 5%	NS	0.36	0.40	NS	NS	NS

Table 69. Effect of nitrogen nutrition and cutting frequency on oxalate content (%) of hybrid napier stems

Treatment	Kharif		Rabi		Summer	
	First year	Second year	First year	Second year	First year	Second year
Cutting frequency						
30 days	2.49	3.94	4.64	6.86	3.05	3.27
45 days	2.48	3.48	4.85	6.86	3.04	3.26
60 days	2.46	4.63	4.53	6.84	3.05	3.23
LSD 5%	NS	0.20	0.17	NS	NS	NS
N levels (kg/ha)						
0	1.51	2.54	4.00	5.56	2.23	2.15
100	1.86	3.57	4.29	6.75	2.31	2.47
200	2.24	4.29	4.70	7.19	3.24	3.52
300	3.12	4.70	5.03	7.25	3.50	3.99
400	3.65	4.96	5.34	7.52	3.96	4.14
LSD 5%	0.23	0.26	0.21	0.24	0.22	0.26
30 days						
0	1.58	2.25	3.88	5.57	2.21	2.09
100	1.86	3.55	4.34	6.79	2.34	2.54
200	2.20	4.21	4.67	7.17	3.21	3.58
300	3.13	4.75	5.10	7.30	3.50	4.00
400	3.67	4.92	5.23	7.46	4.00	4.13
45 days						
0	1.50	2.17	4.21	5.63	2.23	2.17
100	1.87	3.21	4.29	6.71	2.34	2.46
200	2.23	3.84	4.92	7.21	3.25	3.59
300	3.13	3.88	5.21	7.25	3.46	3.96
400	3.66	4.30	5.63	7.50	3.92	4.13
60 days						
0	1.45	3.21	3.92	5.48	2.24	2.21
100	1.85	3.96	4.25	6.75	2.26	2.42
200	2.28	4.83	4.50	7.19	3.25	3.38
300	3.11	5.46	4.79	7.20	3.53	4.00
400	3.61	5.67	5.17	7.59	3.96	4.17
LSD 5%	NS	0.45	0.37	NS	NS	NS

Table 70. Effect of nitrogen nutrition and cutting frequency on nitrate content (ppm) of hybrid napier leaves

Treatment	Kharif		Rabi		Summer	
	First year	Second year	First year	Second year	First year	Second year
Cutting frequency						
30 days	733.48	383.96	281.30	223.00	584.26	318.09
45 days	733.68	217.08	209.24	205.75	650.14	341.48
60 days	735.72	323.46	366.20	451.21	805.52	512.34
LSD 5%	NS	6.69	12.60	6.92	9.27	14.19
N levels (kg/ha)						
0	595.52	182.10	174.01	229.59	389.59	210.26
100	647.34	267.14	230.71	264.86	556.28	258.09
200	708.77	288.01	265.00	299.26	655.84	358.36
300	777.80	357.76	354.25	326.65	815.19	450.00
400	942.02	445.81	403.94	346.24	982.97	676.47
LSD 5%	10.99	8.64	16.26	8.93	11.96	18.32
30 days						
0	592.91	294.24	185.61	186.53	367.30	179.13
100	645.70	351.84	200.62	196.53	421.62	196.09
200	707.96	375.34	222.97	223.25	531.86	275.72
300	775.10	379.87	384.77	248.47	795.26	343.82
400	945.70	518.52	412.55	260.20	805.27	595.67
45 days						
0	596.00	118.31	98.76	124.68	444.47	176.95
100	645.12	148.15	169.75	205.26	547.65	199.59
200	706.42	170.78	206.79	220.72	646.09	276.73
300	777.66	274.69	259.26	232.51	794.59	415.63
400	943.20	373.46	311.63	245.60	817.90	638.47
60 days						
0	597.64	133.75	237.65	377.57	356.99	274.69
100	651.20	301.44	321.76	392.80	699.58	378.60
200	711.93	317.90	365.22	453.80	789.58	522.63
300	780.65	418.72	418.72	498.97	855.71	590.53
400	937.14	445.47	487.65	532.92	1325.73	795.26
LSD 5%	NS	14.97	28.17	15.47	20.72	31.74

Table 71. Effect of nitrogen nutrition and cutting frequency on nitrate content (ppm) of hybrid napier stems

Treatment	Kharif		Rabi		Summer	
	First year	Second year	First year	Second year	First year	Second year
Cutting frequency						
30 days	897.97	380.16	204.60	136.52	431.06	114.18
45 days	906.08	184.63	134.95	117.05	561.80	167.41
60 days	918.71	631.08	161.89	202.34	915.74	191.30
LSD 5%	26.75	9.67	4.28	3.30	6.10	5.27
N levels (kg/ha)						
0	400.60	136.36	112.36	122.43	296.72	96.23
100	505.62	225.89	129.43	131.20	383.83	133.05
200	594.08	255.55	160.71	153.02	572.17	157.55
300	684.88	427.03	188.52	161.20	811.13	177.23
400	2352.76	948.26	244.69	192.01	1117.14	224.10
LSD 5%	34.54	12.49	5.53	4.26	7.88	6.80
30 days						
0	398.86	281.68	145.68	118.31	288.08	58.64
100	502.14	330.96	159.46	127.36	314.92	67.90
200	593.87	349.79	176.95	133.42	386.37	109.49
300	682.55	408.52	195.23	142.03	409.13	147.94
400	2312.42	529.83	345.68	161.48	756.80	186.95
45 days						
0	401.70	98.77	60.70	75.10	293.43	81.90
100	505.46	143.00	92.83	83.64	348.90	157.41
200	592.69	156.38	146.75	132.77	494.85	177.86
300	684.87	221.34	183.09	141.99	697.53	187.61
400	2345.67	303.65	191.36	151.77	974.27	232.27
60 days						
0	401.23	28.64	130.72	173.87	308.64	148.15
100	509.26	203.70	136.00	182.60	487.66	173.85
200	595.68	260.49	158.44	192.87	835.28	185.29
300	687.21	651.23	187.24	199.59	1326.74	196.15
400	2400.19	2011.30	197.03	262.79	1620.36	253.08
LSD 5%	59.82	21.63	9.58	7.37	13.64	11.77

For crops harvested in the rabi season, nitrate content was within the safe limit. The lowest content was noticed in crops harvest at 45 days of harvest. The highest content was noticed in crops when fertilized with 400 kg/ha and harvested at 60 days interval.

During the summer season, for both years, the lowest nitrate content was noticed in plants harvested at 30 days interval. For the first year, in general, stem accumulation of nitrate was noticed at higher dose of nitrogen at 400 kg/ha. For all cutting intervals and at varying nitrogen levels, nitrate content was within the safe limit but at 60 days of harvest the content exceeded the safe limit in leaves, at 400 kg N/ha and in stems, at 300 kg /ha and 400 kg/ha. In the second year, nitrate content did not exceed more than 1000 ppm in any of the treatments.

4.2.6. Nitrogen use efficiency

The data on nitrogen use efficiency of hybrid napier is given in Table 72. There were significant effects of nitrogen nutrition and cutting frequency on nitrogen use efficiency of hybrid napier. Considering the effect of cutting frequency alone, maximum efficiency was recorded at 45 days of harvest while with respect to nitrogen levels the maximum was recorded under 200 kg/ha N.

In view of interaction effect, the highest efficiency of 47.92 kg dry fodder/kg N applied was recorded at 45 days of harvest with 200 kg/ha. For all cutting frequencies, the maximum efficiency was recorded under 200 kg/ha N. When fertilized with 100 kg/ha and 200 kg/ha, maximum efficiency was recorded at 45 days of harvest. At 300 kg/ha N, NUE at 30 days and 45 days of harvests were at par, and the efficiency decreased after 45 days of harvest. For higher dose of 400 kg /ha, NUE decreased on delaying the harvest.

4.2.7. Soil analysis

Soil analysis was done before and after the experiment. The data pertaining to soil analysis before and after the experiment are presented in Table 1 and

Table 72. Effect of nitrogen nutrition and cutting frequency on nitrogen use efficiency of hybrid napier (kg dry fodder/kg N applied)

Cutting frequency (days)	Nitrogen levels (kg/ha)				Factor 1 mean (Cutting frequency)
	100	200	300	400	
30	41.35	46.79	37.89	32.24	39.57
45	43.18	47.92	37.62	31.31	40.01
60	39.47	42.70	36.97	30.49	37.42
Factor 2 mean (Nitrogen levels)	41.33	45.81	37.50	31.35	
LSD 5%	Factor 1- 0.41		Factor 2- 0.47		Interaction- 0.81

Table 73. Effect of nitrogen nutrition and cutting frequency on soil organic carbon (SOC %) and available NPK (kg/ha) after the experiment

Treatment	SOC	Av. N	Av. P	Av. K
Cutting frequency				
30 days	1.56	432.72	33.48	136.74
45 days	1.71	397.14	30.99	129.27
60 days	1.84	368.57	27.68	123.76
LSD 5%	0.05	11.04	1.00	1.77
N levels (kg/ha)				
0	1.87	317.84	48.85	145.81
100	1.76	372.30	35.06	139.64
200	1.73	398.68	28.23	131.83
300	1.62	437.39	24.25	122.54
400	1.51	471.17	17.21	109.78
LSD 5%	0.06	14.25	1.29	2.29
30 days				
0	1.69	354.50	55.54	154.34
100	1.61	404.90	40.70	150.71
200	1.56	438.93	28.54	137.01
300	1.53	466.43	22.70	128.32
400	1.40	498.83	19.93	113.30
45 days				
0	1.89	325.43	47.15	146.44
100	1.73	370.01	35.78	137.03
200	1.74	384.47	30.03	131.29
300	1.64	437.24	25.65	121.47
400	1.52	468.57	16.32	110.09
60 days				
0	2.03	273.60	43.85	136.64
100	1.95	342.00	28.69	131.19
200	1.90	372.63	26.12	127.19
300	1.68	408.50	24.39	117.82
400	1.61	446.11	15.37	105.95
LSD 5%	0.11	24.68	2.23	3.96

Table. 73 Soil organic carbon content increased after the experiment but the available N, P and K in soil were reduced after the experiment.

Significant changes in soil organic carbon content were noticed with increasing cutting frequency and nitrogen levels. Interaction effect was also observed. After the experiment, all the plots had more than one per cent of soil organic carbon. Considering the effect of cutting frequency, the content in soil increased with increasing cutting frequency but declining trend was noticed with increasing nitrogen levels. The highest content was observed in plots not fertilized with nitrogen but harvested at 60 days of cutting frequency. However, the lowest was noticed in plots fertilized with 400 kg/ha and harvested at 30 days intervals.

Regarding the available nitrogen content, the content decreased with increasing harvesting intervals and decreasing nitrogen levels. The highest content was noticed in plots treated with 400 kg/ha and harvested at 30 days interval. At 45 days and 60 days of cutting interval, there were no change in available nitrogen content of soil at higher doses of nitrogen, i.e., at 200 kg/ha, 300 kg/ha and 400 kg/ha.

Similarly, the available phosphorous content in soil decreased with increasing cutting intervals and increasing nitrogen levels. The highest was observed in unfertilized nitrogen plots but harvested at 30 days interval. When harvested at 45 days and 60 days of cutting frequencies, there were no change in available P content of soil at higher doses of nitrogen, i.e., at 300 kg/ha and 400 kg/ha.

Correspondingly, the available K content in soil decreased with increasing cutting intervals and increasing nitrogen levels. In general, K availability in each plots were comparable with K availability in those plots on delaying harvest to 15 days but fertilized at a lower dose of nitrogen. The highest soil K availability was observed in unfertilized nitrogen plots, which were harvested at 30 days interval. K availability in plots treated with 400 kg/ha N were comparable at 30 days and 45 days of cutting frequencies.

4.3. EXPERIMENT III: CUTTING HEIGHT MANAGEMENT IN HYBRID NAPIER GROWN UNDER RAINFED CONDITION

4.3.1. Morphological characters

The experiment on effective management of the crop under strictly rainfed conditions was carried out by cutting the crop at different stubble heights of 5 cm, 10 cm, 15 cm and 20 cm. The cultivars coopted for the experiment 'CO-3', 'CO-4', 'Suguna', 'DHN-6' and 'PTH' responded in a positive significant manner for the production of tillers and leaves, but did not revealed any differential response as regards to plant height, leaf length and leaf width.

Plant height

The data on plant height are presented in Table 74 and Table 75. In both years of study, cutting height management had no significant effect on plant height, but the effect of cultivars were significant on plant height. Interaction effects were absent between the treatments.

In the first year, maximum plant height was higher at the first harvest, and thereafter, showed a decreasing trend towards the final harvest. During the first harvest, 'Suguna' was the tallest (183.08 cm) while 'CO-3' (158.23 cm) the shortest. In the second harvest, 'DHN-6' and 'Suguna' were at par and showed higher plant heights, 158.48 cm and 157.22 cm respectively. The lowest plant height was observed in 'PTH' (135.38 cm). In the third harvest, 'DHN-6' attained the first position (114.38 cm) and 'CO-4' attained the lowest (106.68 cm). At the fourth harvest, higher plant height of 57.36 cm was observed in 'PTH' and lower height was observed in 'DHN-6' (47.31 cm).

During the second year, higher plant height was noticed during the second harvest, but plant height at the fourth harvest was comparable with plant height at the second harvest. In the first harvest, 'DHN-6' and 'PTH' were at par and were the tallest, heights being, 137.33 cm and 136.07 cm respectively. The lowest height was noticed in 'CO-3' (119.25 cm).

Table 74. Effect of cutting height management on plant height (cm) in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	171.78	150.72	111.27	51.17
10 cm	171.89	150.33	111.02	51.13
15 cm	171.74	150.57	111.27	51.43
20 cm	171.97	150.93	111.34	51.13
LSD 5%	NS	NS	NS	NS
Cultivars				
CO-3	158.23	153.53	110.17	49.16
CO-4	176.08	148.59	106.68	50.42
Suguna	183.08	157.22	112.98	51.83
DHN-6	161.16	158.48	114.38	47.31
PTH	180.69	135.38	111.93	57.36
LSD 5%	1.75	1.49	1.16	0.95
5 cm				
CO-3	158.00	154.07	110.17	49.30
CO-4	176.03	148.47	107.20	50.10
Suguna	183.33	157.03	112.83	52.23
DHN-6	161.13	158.57	114.57	47.20
PTH	180.40	135.47	111.57	57.03
10 cm				
CO-3	158.27	153.37	110.10	48.73
CO-4	175.77	149.17	106.50	50.70
Suguna	183.17	157.07	112.03	51.60
DHN-6	161.53	156.63	114.40	47.10
PTH	180.73	135.40	112.07	57.53
15 cm				
CO-3	158.43	152.60	110.20	49.17
CO-4	175.97	148.23	106.60	50.47
Suguna	182.67	157.10	113.57	52.33
DHN-6	160.67	159.53	113.87	47.50
PTH	180.97	135.40	112.10	57.67
20 cm				
CO-3	158.20	154.07	110.20	49.43
CO-4	176.53	148.50	106.40	50.40
Suguna	183.17	157.67	113.47	51.17
DHN-6	161.30	159.20	114.67	47.43
PTH	180.67	135.23	111.97	57.20
LSD 5%	NS	NS	NS	NS

Table 75. Effect of cutting height management on plant height (cm) in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	128.15	175.23	122.57	173.93	95.03
10 cm	130.39	175.43	122.63	174.16	94.75
15 cm	128.61	175.50	121.99	173.37	94.79
20 cm	128.71	175.09	122.53	173.84	94.60
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO-3	119.25	177.74	130.51	173.24	94.38
CO-4	127.39	173.13	125.02	177.75	95.51
Suguna	124.80	180.81	132.55	182.82	104.58
DHN-6	137.33	182.46	120.70	183.61	81.90
PTH	136.07	162.42	103.38	151.71	97.58
LSD 5%	3.54	1.60	1.65	1.38	1.43
5 cm					
CO-3	119.33	177.47	130.63	173.50	94.73
CO-4	124.33	173.13	125.50	178.17	95.70
Suguna	124.60	180.80	132.13	182.93	104.43
DHN-6	137.17	182.67	121.17	183.27	82.07
PTH	135.33	162.10	103.40	151.77	98.20
10 cm					
CO-3	119.33	178.10	130.23	173.90	94.73
CO-4	135.07	173.10	125.47	177.57	95.07
Suguna	124.37	180.77	133.13	183.03	104.90
DHN-6	137.30	182.63	121.13	184.40	81.50
PTH	135.90	162.53	103.17	151.90	97.53
15 cm					
CO-3	119.30	177.90	130.13	172.17	94.00
CO-4	124.93	173.23	124.43	177.27	95.63
Suguna	124.83	181.13	132.30	182.17	104.90
DHN-6	137.33	182.73	119.73	183.60	82.30
PTH	136.67	162.50	103.37	151.67	97.10
20 cm					
CO-3	119.03	177.50	131.03	173.40	94.07
CO-4	125.23	173.07	124.67	178.00	95.63
Suguna	125.40	180.53	132.63	183.13	104.07
DHN-6	137.53	181.80	120.77	183.17	81.73
PTH	136.37	162.53	103.57	151.50	97.50
LSD 5%	NS	NS	NS	NS	NS

'Suguna' attained the first position in the succeeding harvests. At the second harvest, 'DHN-6' and 'Suguna' were at par and recorded maximum height, 182.46 cm and 180.81 cm respectively while the least was recorded in 'PTH' (162.42 cm). During the third harvest, maximum plant height recorded was 132.55 cm by 'Suguna' and was followed by 'CO-3' (130.51 cm) while 'PTH' recorded the least (103.38 cm). In the fourth harvest, 'DHN-6' and 'Suguna' were at par and recorded maximum plant height, 183.61 cm and 182.82 cm respectively. The lowest height was recorded in 'PTH' (151.71 cm). At the fourth harvest, the first position was attained by 'Suguna' (104.58 cm), and 'DHN-6' attained the lowest position (81.90 cm).

Leaf length

The data pertaining to leaf length is given in Table 76 and Table 77. There were no significant influence of cutting height management on leaf length while cultivar effects on leaf length were present. There were no interaction effects between cutting heights and cultivars.

During both years, leaf length was maximum at second harvests. In the first year, the leaf length at the first and the third harvests were comparable. At the first and second harvests, 'DHN-6' recorded the highest leaf length, 89.78 cm and 95.39 cm respectively. In the third harvest, 'CO-3' (73.75 cm), 'Suguna' (72.98 cm) and 'CO-4' (70.07) showed higher leaf lengths and were comparable with each other. In the fourth harvest, 'Suguna' attained the first position (39.93 cm).

By the second year, leaf length was higher in the second harvest and thereafter started decreasing toward the final harvest. At the first harvest, the leaf lengths of 'DHN-6' (88.30 cm), 'Suguna' (87.03 cm), and 'CO-3' (87.02 cm) were comparable and showed higher leaf lengths. At the second harvest, 'CO-4' (110.45 cm), 'CO-3' (108.93 cm), and 'Suguna' (108.05 cm) had similar leaf lengths and recorded higher leaf length. During the third harvest, 'CO-3' attained the first position (94.26 cm). In the fourth harvest, 'Suguna' (74.96 cm),

Table 76. Effect of cutting height management on leaf length (cm) in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	70.49	85.31	62.00	33.50
10 cm	70.97	85.63	62.17	33.29
15 cm	70.32	85.38	61.76	33.25
20 cm	70.67	85.21	62.33	33.21
LSD 5%	NS	NS	NS	NS
Cultivars				
CO-3	70.16	88.33	73.75	35.42
CO-4	67.14	87.03	70.07	35.00
Suguna	68.32	85.40	72.98	39.93
DHN-6	89.78	95.39	66.87	29.90
PTH	57.66	70.77	26.67	26.32
LSD 5%	1.42	2.22	1.77	1.48
5 cm				
CO-3	69.93	88.53	74.11	35.63
CO-4	66.57	86.67	69.73	35.00
Suguna	68.33	85.03	73.13	40.00
DHN-6	90.07	94.97	67.03	30.77
PTH	57.53	71.33	25.97	26.10
10 cm				
CO-3	70.47	87.57	73.83	35.70
CO-4	67.73	87.47	69.87	34.87
Suguna	68.10	86.60	73.20	40.00
DHN-6	90.50	95.53	66.63	29.40
PTH	58.03	71.00	27.30	26.47
15 cm				
CO-3	70.17	88.77	72.90	34.67
CO-4	67.03	87.00	69.93	35.00
Suguna	67.97	84.70	72.50	40.67
DHN-6	89.00	95.83	66.53	29.33
PTH	57.43	70.60	26.93	26.60
20 cm				
CO-3	70.07	88.43	74.13	35.67
CO-4	67.23	87.00	70.73	35.13
Suguna	68.87	85.27	73.07	39.03
DHN-6	89.53	95.23	67.27	30.10
PTH	57.63	70.13	26.47	26.10
LSD 5%	NS	NS	NS	NS

Table 77. Effect of cutting height management on leaf length (cm) in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	82.08	103.45	82.40	67.71	56.73
10 cm	82.69	103.29	81.68	67.67	57.23
15 cm	82.25	103.08	82.51	67.45	57.12
20 cm	81.87	103.80	81.81	67.62	57.09
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO-3	87.02	108.93	94.26	68.23	57.68
CO-4	85.20	110.45	81.40	72.52	67.08
Suguna	87.03	108.05	91.86	74.96	59.75
DHN-6	88.30	102.03	86.06	74.77	61.26
PTH	63.57	87.58	56.92	47.59	39.43
LSD 5%	1.85	2.43	2.30	2.02	1.56
5 cm					
CO-3	86.77	109.07	94.33	68.43	57.80
CO-4	85.60	109.77	81.83	72.30	67.47
Suguna	86.70	107.90	92.90	75.40	59.47
DHN-6	87.67	102.27	86.20	74.73	60.80
PTH	63.67	88.27	56.73	47.70	38.13
10 cm					
CO-3	87.47	108.47	93.83	68.97	57.80
CO-4	85.43	110.70	80.83	72.33	67.27
Suguna	87.80	108.33	91.17	74.90	60.23
DHN-6	88.73	101.93	85.73	74.87	60.70
PTH	64.03	87.03	56.83	47.27	40.13
15 cm					
CO-3	86.60	109.40	94.57	67.60	57.47
CO-4	84.93	111.10	82.10	73.13	67.27
Suguna	87.27	107.03	92.70	74.60	59.13
DHN-6	88.60	101.40	85.87	74.60	61.83
PTH	63.83	86.47	57.30	47.33	39.90
20 cm					
CO-3	87.23	108.77	94.30	67.93	57.67
CO-4	84.83	110.23	80.83	72.30	66.33
Suguna	86.33	108.93	90.67	74.93	60.17
DHN-6	88.20	102.50	86.43	74.87	61.70
PTH	62.73	88.57	56.80	48.07	39.57
LSD 5%	NS	NS	NS	NS	NS

'DHN-6' (74.77 cm), and 'CO-4' (72.52 cm) had comparable leaf lengths and recorded higher leaf length. At the fifth harvest, 'CO-4' (67.08 cm) attained the first position.In general, 'PTH' showed the lowest leaf length during both the years, of which the least value was noticed in the final harvest of the first year (26.32 cm).

Leaf width

The leaf width at each harvest is presented in Table 78 and Table 79. Cutting height did not show any significant effect on leaf width, but leaf width varied between the cultivars. The interaction effects were also absent between various treatments. The leaves attained maximum width during the second harvest of the second year.

In the first year, the highest leaf width was observed at the first harvest and started decreasing towards the final harvest. During the first and the second year, 'DHN-6' recorded higher leaf width, 3.00 cm and 2.54 cm respectively. In the third harvest, 'CO-4' (1.97 cm) attained the first position. At the fourth harvest, 'CO-3' (1.24 cm) and 'Suguna' (1.20 cm) showed similar leaf widths with higher leaf width.

During the second year, leaves attained maximum width at the second harvest, then started decreasing towards the final harvest. In general 'DHN-6' attained higher leaf width. At the first and the second harvests, 'DHN-6' attained maximum leaf widths of 3.11 cm and 3.27 cm respectively. In the third harvest, 'Suguna' (2.25 cm) and 'DHN-6' (2.22 cm) had comparable leaf widths and showed maximum values. At the fourth and the fifth harvests, maximum leaf width obtained were 2.02 cm and 1.70 cm respectively by 'DHN-6'. During both years, minimum leaf width was observed in 'PTH' of which the lowest value was attained in the fourth harvest of the first year (0.40 cm).

Number of tillers

The data pertaining to number of tillers per clump are given in Table 80 and Table 81. Tiller production in hybrid napier was significantly influenced by cutting

Table 78. Effect of cutting height management on leaf width (cm) in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	2.16	1.91	1.40	1.01
10 cm	2.14	1.88	1.42	1.02
15 cm	2.15	1.90	1.39	1.01
20 cm	2.14	1.86	1.38	1.03
LSD 5%	NS	NS	NS	NS
Cultivars				
CO- 3	2.27	1.99	1.47	1.24
CO-4	2.38	2.34	1.97	1.07
Suguna	2.19	1.96	1.52	1.20
DHN- 6	3.00	2.54	1.58	1.18
PTH	0.88	0.62	0.46	0.40
LSD 5%	0.03	0.18	0.05	0.04
5 cm				
CO- 3	2.29	1.95	1.47	1.22
CO- 4	2.39	2.33	1.95	1.05
Suguna	2.18	1.97	1.53	1.21
DHN- 6	3.04	2.67	1.60	1.17
PTH	0.88	0.62	0.46	0.40
10 cm				
CO- 3	2.25	2.01	1.45	1.25
CO- 4	2.36	2.31	1.97	1.07
Suguna	2.19	1.93	1.53	1.19
DHN- 6	2.98	2.53	1.69	1.16
PTH	0.90	0.63	0.47	0.41
15 cm				
CO- 3	2.26	1.99	1.48	1.25
CO- 4	2.40	2.36	1.97	1.04
Suguna	2.19	2.00	1.52	1.19
DHN- 6	3.00	2.55	1.53	1.19
PTH	0.88	0.61	0.44	0.40
20 cm				
CO- 3	2.29	2.00	1.47	1.24
CO- 4	2.39	2.34	2.00	1.12
Suguna	2.19	1.96	1.50	1.19
DHN- 6	2.96	2.39	1.48	1.19
PTH	0.86	0.60	0.46	0.40
LSD 5%	NS	NS	NS	NS

Table 79. Effect of cutting height management on leaf width (cm) in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	2.31	2.66	1.89	1.66	1.35
10 cm	2.27	2.63	1.92	1.64	1.36
15 cm	2.30	2.67	1.89	1.65	1.36
20 cm	2.30	2.66	1.93	1.61	1.35
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO- 3	2.55	3.15	2.12	1.72	1.28
CO- 4	2.58	3.03	2.09	1.76	1.55
Suguna	2.50	2.87	2.25	1.90	1.52
DHN- 6	3.11	3.27	2.22	2.02	1.70
PTH	0.73	0.95	0.85	0.80	0.71
LSD 5%	0.06	0.09	0.07	0.09	0.07
5 cm					
CO- 3	2.56	3.17	2.11	1.73	1.28
CO-4	2.57	3.00	2.03	1.80	1.56
Suguna	2.50	2.93	2.23	1.90	1.53
DHN- 6	3.13	3.27	2.21	2.04	1.67
PTH	0.77	0.93	0.85	0.81	0.70
10 cm					
CO- 3	2.55	3.07	2.13	1.70	1.28
CO- 4	2.53	3.06	2.13	1.73	1.55
Suguna	2.50	2.85	2.24	1.96	1.53
DHN- 6	3.10	3.28	2.26	1.99	1.73
PTH	0.67	0.91	0.86	0.80	0.69
15 cm					
CO- 3	2.54	3.20	2.12	1.77	1.29
CO- 4	2.60	3.02	2.07	1.77	1.56
Suguna	2.49	2.88	2.23	1.87	1.54
DHN- 6	3.13	3.27	2.19	2.03	1.71
PTH	0.71	0.96	0.84	0.80	0.71
20 cm					
CO- 3	2.56	3.17	2.11	1.67	1.28
CO- 4	2.60	3.02	2.13	1.73	1.55
Suguna	2.49	2.83	2.28	1.87	1.47
DHN- 6	3.07	3.27	2.24	1.99	1.70
PTH	0.76	1.00	0.87	0.78	0.75
LSD 5%	NS	NS	NS	NS	NS

Table 80. Effect of cutting height management on tiller production in hybrid napier cultivars at each harvest during the first year (No. of tillers/clump)

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	11.57	15.62	37.20	44.48
10 cm	11.75	16.20	38.84	46.88
15 cm	11.54	17.21	40.38	49.03
20 cm	11.46	18.56	42.76	49.88
LSD 5%	NS	0.85	0.59	0.87
Cultivars				
CO-3	11.26	16.23	44.77	46.40
CO-4	09.71	14.33	39.56	43.38
Suguna	14.82	18.42	36.27	44.89
DHN-6	08.96	11.83	27.08	32.71
PTH	13.16	23.69	51.30	70.47
LSD 5%	0.87	0.95	0.66	0.98
5 cm				
CO-3	11.00	15.50	40.50	42.29
CO-4	09.93	13.17	37.50	38.90
Suguna	14.83	16.00	33.17	42.76
DHN-6	08.77	10.27	25.54	30.20
PTH	13.33	23.17	49.27	68.25
10 cm				
CO-3	11.60	16.03	44.10	45.12
CO-4	09.77	14.53	39.43	42.85
Suguna	15.17	17.00	35.20	43.00
DHN-6	09.23	10.33	25.77	32.67
PTH	13.00	23.10	49.70	70.78
15 cm				
CO-3	11.27	16.00	46.33	48.82
CO-4	09.53	14.33	39.77	45.61
Suguna	14.33	19.20	35.90	46.04
DHN-6	09.00	13.17	27.83	33.63
PTH	13.56	23.33	52.07	71.06
20 cm				
CO-3	11.17	17.37	48.14	49.35
CO-4	09.60	15.27	41.53	46.17
Suguna	14.93	21.47	40.80	47.76
DHN-6	08.83	13.53	29.17	34.33
PTH	12.77	25.17	54.17	71.80
LSD 5%	NS	1.90	1.32	1.95

Table 81. Effect of cutting height management on tiller production in hybrid napier cultivars at each harvest during the second year (No. of tillers/clump)

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	26.39	28.19	44.51	53.38	58.65
10 cm	26.70	28.83	45.16	52.91	59.02
15 cm	26.66	30.06	45.35	52.60	58.70
20 cm	27.17	30.94	45.21	53.09	58.39
LSD 5%	NS	1.20	NS	NS	NS
Cultivars					
CO-3	23.17	25.13	42.91	48.56	55.28
CO-4	20.33	24.44	40.03	47.98	54.09
Suguna	22.49	26.00	46.33	55.96	56.78
DHN-6	19.56	22.84	29.75	36.21	44.65
PTH	48.11	49.09	66.27	76.26	82.64
LSD 5%	1.57	1.35	1.97	1.72	2.16
5 cm					
CO-3	22.47	24.33	42.32	49.17	56.33
CO-4	20.50	23.50	40.40	47.90	53.77
Suguna	22.33	23.43	46.67	56.67	56.33
DHN-6	18.50	22.17	26.63	36.50	43.97
PTH	48.17	47.50	66.50	76.67	82.83
10 cm					
CO-3	23.88	24.63	42.83	48.77	55.67
CO-4	20.11	23.77	39.44	47.60	54.30
Suguna	22.17	25.17	46.00	55.67	57.03
DHN-6	19.67	22.53	30.93	36.17	44.64
PTH	47.70	48.03	66.60	76.33	83.43
15 cm					
CO-3	22.50	25.11	43.43	48.20	54.63
CO-4	19.89	24.67	39.90	48.00	54.67
Suguna	22.44	27.83	46.50	55.00	56.77
DHN-6	20.11	23.00	30.80	36.00	45.33
PTH	48.33	49.67	66.13	75.78	82.10
20 cm					
CO-3	23.83	26.44	43.04	48.10	54.47
CO-4	20.83	25.83	40.37	48.43	53.61
Suguna	23.00	27.57	46.17	56.50	57.00
DHN-6	19.94	23.67	30.63	36.17	44.67
PTH	48.22	51.17	65.83	76.27	82.20
LSD 5%	NS	2.69	NS	NS	NS

height management and cultivars. In both years, tiller production showed an increasing trend towards the final harvest. During the summer periods, tiller decline was noticed, but with the onset of premonsoon showers, regeneration was observed. Maximum number of tillers were produced when cut at 20 cm height and tiller production was much reduced when plants were cut at 5 cm height. In general, among the cultivars, 'PTH' showed maximum number of tillers and 'DHN-6' the minimum.

In the first harvest, 'Suguna' showed maximum number of tillers (14.82). Tiller number of 'DHN-6' (8.96) and 'CO-4' (9.71) were comparable and had the minimum number of tillers. At second harvest, tiller production at 10 cm of cutting height was comparable with the tiller production at 5 cm and 15 cm of plant cutting heights. Maximum number of tillers were produced by 'PTH' when cut at 20 cm height (25.17) while the least number of tillers was observed in 'DHN-6' when cut at 5 cm height (10.27). In all the cultivars, tiller number at 10 cm and 15 cm cutting heights were comparable with the tiller number at 5 cm and 20 cm cutting heights.

In the third harvest, 'PTH' recorded maximum number of tillers (54.17) followed by 'CO-3' (48.14) when cut at 20 cm height. During the fourth harvest, tiller production of cultivars were comparable when harvested at 15 cm and 20 cm heights. Considering the interaction effects, maximum number of tillers were noticed in 'PTH' when cuts were provided 10 cm above ground level. It could produce a maximum of 71.80 tillers when cut at 20 cm height.

In the second year, cutting height management had no significant effect on tiller production, except that observed at the second harvest. The tillering potential varied significantly between the cultivars. During the second year also, maximum number of tillers were observed in 'PTH' and the least was observed in 'DHN-6'. Interaction effect was absent.

Considering the cultivar effect, at the first harvest, 'PTH' could produce 48.11 tillers. Tiller production in 'DHN- 6' and 'CO-4' were comparable and showed minimum number of tillers, 19.56 and 20.33 respectively. In the second harvest, higher tiller production was observed when plants were cut at 15 cm and 20 cm. Among the cultivars, 'PTH' attained the highest position (49.09) and 'DHN-6' attained the lowest position (22.84). During the third and the fourth harvests tiller production was higher in 'PTH' (66.27 and 76.26).

Maximum number of tillers were observed at the final harvest of the crop of which 'PTH' produced higher number of tillers (82.64). The lowest number of tillers was observed in 'DHN-6' (44.65) in the final harvest too.

Number of leaves

Number of leaves per clump at each harvest are presented in Table 82 and Table 83. Leaf production in hybrid napier varied between the cultivars when harvested at different cutting heights. Higher number of leaves were produced when cultivars were harvested at 20 cm height. Leaf production increased towards the final harvest but was reduced during summer months and again increased with the onset of premonsoon showers. In general, 'PTH' produced maximum number of leaves and 'DHN-6' the minimum.

During the first year, at the first harvest, 'Suguna' (103.72) produced the highest number of leaves. In the second harvest, 'PTH' and 'Suguna' were at par and produced 166.47 and 164.67 leaves respectively. 'CO-4' recorded the lowest number of leaves (102.24). Interaction effects were absent in both harvests.

At the third harvest, 'PTH' could produce a maximum of 323.67 leaves per clump when harvested at 20 cm height. The least was observed in 'DHN-6' when plants were harvested below 10 cm above ground level. In the fourth harvest, maximum number of leaves were observed in 'PTH' when harvested above 15 cm. It could produce a maximum of 325.33 leaves when harvested at 20 cm height. Similarly, when plants were harvested below 10 cm, leaf production was reduced and the minimum value was observed in 'DHN-6,' (312.33 no. of leaves at 5 cm of harvesting height).

Table 82. Effect of cutting height management on leaf number in hybrid napier cultivars at each harvest during the first year (No. of leaves/clump)

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	80.22	128.57	209.10	218.43
10 cm	81.57	133.83	218.33	225.45
15 cm	79.91	143.00	226.59	235.49
20 cm	79.51	153.32	237.49	241.59
LSD 5%	NS	6.60	3.03	2.66
Cultivars				
CO-3	78.81	146.03	223.01	226.44
CO-4	72.81	102.24	217.66	224.28
Suguna	103.72	164.67	216.95	227.50
DHN-6	67.19	119.00	149.05	154.68
PTH	78.99	166.47	307.72	318.29
LSD 5%	6.11	7.38	3.39	2.98
5 cm				
CO-3	77.00	139.50	202.50	209.80
CO-4	74.50	94.53	206.25	212.00
Suguna	103.83	144.00	200.67	215.67
DHN-6	65.75	102.67	140.48	142.33
PTH	80.00	162.17	295.60	312.33
10 cm				
CO-3	81.20	144.30	220.50	222.62
CO-4	73.25	101.31	216.88	219.47
Suguna	106.17	153.00	212.87	222.33
DHN-6	69.25	106.33	142.22	148.00
PTH	78.00	164.20	299.20	314.83
15 cm				
CO-3	78.87	144.00	231.67	232.33
CO-4	71.50	103.20	220.40	231.33
Suguna	100.33	172.80	215.40	231.00
DHN-6	67.50	131.67	153.08	162.13
PTH	81.34	163.33	312.40	320.67
20 cm				
CO-3	78.17	156.30	237.38	241.00
CO-4	72.00	109.92	227.10	234.33
Suguna	104.53	188.87	238.87	241.00
DHN-6	66.25	135.33	160.42	166.27
PTH	76.60	176.17	323.67	325.33
LSD 5%	NS	14.75	6.78	5.96

Table 83. Effect of cutting height management on leaf number in hybrid napier cultivars at each harvest during the second year (No. of leaves/clump)

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	204.46	226.83	278.39	314.39	344.40
10 cm	205.07	234.70	290.42	326.72	355.53
15 cm	204.97	249.89	301.93	338.10	366.27
20 cm	204.37	256.83	310.50	352.93	375.87
LSD 5%	NS	3.38	2.87	3.53	2.99
Cultivars					
CO-3	196.26	212.73	279.76	316.95	329.83
CO-4	186.00	206.25	262.67	319.00	328.92
Suguna	197.58	215.50	318.83	331.33	337.58
DHN-6	155.74	220.33	230.96	246.94	267.08
PTH	287.99	355.50	384.33	450.96	539.17
LSD 5%	5.41	3.78	3.21	3.95	3.35
5 cm					
CO-3	195.53	200.17	265.12	300.13	315.00
CO-4	184.50	195.33	248.67	305.00	313.33
Suguna	197.67	200.33	307.67	315.33	324.00
DHN-6	155.63	204.67	213.83	224.33	245.67
PTH	288.97	333.67	356.67	427.17	524.00
10 cm					
CO-3	197.67	204.17	280.10	313.67	324.33
CO-4	187.67	201.33	259.00	313.33	324.00
Suguna	198.00	207.33	317.33	324.33	334.67
DHN-6	154.33	214.67	221.67	240.60	260.67
PTH	287.67	346.00	374.00	441.67	534.00
15 cm					
CO-3	196.17	218.10	285.67	320.33	336.33
CO-4	185.00	212.00	267.33	323.00	334.67
Suguna	198.33	225.33	324.00	334.67	341.33
DHN-6	156.67	227.67	240.67	251.83	275.33
PTH	288.67	366.33	392.00	460.67	543.67
20 cm					
CO-3	195.67	228.50	288.17	333.67	343.67
CO-4	186.83	216.33	275.67	334.67	343.67
Suguna	196.33	229.00	326.33	351.00	350.33
DHN-6	156.33	234.33	247.67	271.00	286.67
PTH	286.67	376.00	414.67	474.33	555.00
LSD 5%	NS	7.56	6.41	7.90	6.70

In the second year also, maximum number of leaves were observed in plants when cut at 20 cm height. During the second year also, 'PTH' produced maximum number of leaves and 'DHN-6' the least.

At the first harvest, cutting height management did not influence leaf production. Interaction effect was also absent. Maximum number of leaves was observed in 'PTH' (287.99) and minimum was noticed in 'DHN-6' (155.74). Number of leaves increased towards the final harvest and maximum number of leaves recorded was 555.00 number of leaves per clump in 'PTH' when harvested at 20 cm height while the lowest producer of leaves-'DHN-6' could produce a maximum of 245.67 leaves by the final harvest when harvested at 5 cm height. When harvested at 20 cm, 'DHN-6' could produce 286.67 number of leaves per clump.

4.3.2. Growth analysis

The significant influence of cutting height was prominent only in leaf area index and regrowth rate of crop. Cutting height management could not produce any considerable effect on leaf to stem ratio, leaf area ratio, leaf weight ratio and specific leaf weight of crop. Interaction effects were absent in these growth parameters. However, significant effect of cultivars were noticed in growth of hybrid napier.

Leaf area index (LAI)

Leaf area index of hybrid napier cultivars at different cutting heights are given in Table 84 and Table 85. Harvesting of various cultivars at different heights had considerable influence on leaf area index of hybrid napier. The highest LAI was noticed in plants when harvested at 20 cm height. During both years, LAI attained the highest value at second harvests. In general, among the cultivars, maximum LAI was observed in 'Suguna' and the least was observed in 'PTH'.

Influence of cutting height was prominent from the second harvest onwards, as cutting height management was commenced at the time of first harvest.

Table 84. Effect of cutting height management on leaf area index in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	7.01	7.16	5.64	0.62
10 cm	7.08	7.48	6.03	0.94
15 cm	7.12	8.11	6.63	1.17
20 cm	7.04	8.52	7.42	1.33
LSD 5%	NS	0.32	0.26	0.08
Cultivars				
CO-3	8.47	9.95	9.25	1.22
CO-4	8.30	8.89	7.41	1.30
Suguna	9.33	9.69	9.29	1.41
DHN-6	5.40	6.87	3.28	0.63
PTH	3.79	3.70	2.92	0.50
LSD 5%	0.40	0.36	0.29	0.09
5 cm				
CO-3	8.32	9.42	8.37	0.74
CO-4	8.22	7.73	6.19	0.77
Suguna	9.32	9.16	8.65	0.82
DHN-6	5.42	6.33	2.73	0.37
PTH	3.76	3.16	2.26	0.38
10 cm				
CO-3	8.63	9.79	8.90	1.15
CO-4	8.34	8.44	6.77	1.11
Suguna	9.25	9.27	8.93	1.32
DHN-6	5.44	6.56	2.89	0.65
PTH	3.72	3.36	2.67	0.44
15 cm				
CO-3	8.80	9.99	9.57	1.44
CO-4	8.16	9.52	7.42	1.58
Suguna	9.28	9.80	9.56	1.58
DHN-6	5.51	7.11	3.54	0.73
PTH	3.85	4.10	3.06	0.54
20 cm				
CO-3	8.15	10.60	10.16	1.57
CO-4	8.50	9.87	9.28	1.74
Suguna	9.47	10.51	10.02	1.92
DHN-6	5.24	7.48	3.97	0.76
PTH	3.83	4.16	3.68	0.66
LSD 5%	NS	0.72	0.59	0.18

Table 85. Effect of cutting height management on leaf area index in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	6.38	11.50	6.62	6.19	2.75
10 cm	7.03	12.03	7.19	6.42	3.24
15 cm	7.76	12.76	7.83	7.08	3.82
20 cm	8.36	13.37	8.54	7.47	4.42
LSD 5%	0.54	0.67	0.33	0.40	0.19
Cultivars					
CO-3	9.73	14.15	7.88	7.23	3.99
CO-4	9.67	13.74	10.94	8.63	5.33
Suguna	9.64	15.54	8.32	8.29	4.21
DHN-6	5.21	12.80	6.39	7.40	2.79
PTH	2.65	5.85	4.20	2.39	1.47
LSD 5%	0.60	0.75	0.37	0.44	0.22
5 cm					
CO-3	8.53	12.89	6.67	6.57	3.12
CO-4	8.48	12.83	9.93	7.95	4.28
Suguna	8.23	14.32	7.15	7.63	3.12
DHN-6	4.38	12.14	5.75	6.57	1.99
PTH	2.30	5.34	3.62	2.22	1.26
10 cm					
CO-3	9.51	13.76	7.43	6.76	3.74
CO-4	9.15	13.47	10.37	8.31	4.88
Suguna	9.26	14.97	7.88	7.70	3.79
DHN-6	4.82	12.37	6.18	7.03	2.55
PTH	2.42	5.55	4.10	2.32	1.26
15 cm					
CO-3	10.09	14.58	8.21	7.59	4.28
CO-4	10.29	13.97	11.35	8.92	5.68
Suguna	10.04	16.25	8.57	8.59	4.55
DHN-6	5.67	12.91	6.53	7.85	3.09
PTH	2.70	6.08	4.47	2.43	1.48
20 cm					
CO-3	10.81	15.35	9.23	8.01	4.82
CO-4	10.78	14.68	12.12	9.36	6.50
Suguna	11.03	16.60	9.66	9.23	5.39
DHN-6	5.98	13.78	7.08	8.16	3.53
PTH	3.18	6.43	4.59	2.59	1.85
LSD 5%	1.20	1.50	0.74	0.88	0.43

During the first year, at the first harvest, 'Suguna' attained the highest LAI (9.33). In the second harvest, cultivars attained maximum LAI when harvested above 15 cm of which 'CO-3' showed maximum LAI at 20 cm of cutting height (10.60). 'Suguna' was on par with 'CO-3'. The lowest LAI was recorded in 'PTH' when harvested below 10 cm height. During the third harvest too, 'Suguna' and 'CO-3' were at par and showed maximum LAI at 20 cm of cutting height.

During the experiment, the least LAI value was observed at the fourth harvest and the highest value at this stage was 1.92 for 'Suguna' at 20 cm of cutting height which was on par with 'CO-3'. Lower values were noticed in 'DHN-6' (0.37) and 'PTH' (0.38), which were at par.

In the second year, at first harvest, 'CO-3' (9.75), 'CO-4' (9.67) and 'Suguna' (9.64) were at par and recorded higher LAI when harvested above 10 cm of harvesting height. During the course of the experiment, the highest LAI values were noticed during the second harvest when plants were harvest above 15 cm height. The highest LAI obtained was 16.60 in 'Suguna' when harvested at 20 cm height. LAI of 'CO-3', 'CO-4' and 'Suguna' were comparable. At the third and the fifth harvests, the highest LAI was observed in 'CO-4' at 20 cm of cutting height. During the fifth harvest, 'CO-4' and 'Suguna' were at par and recorded maximum LAI.The lowest LAI was observed in 'PTH' in the second year and the value obtained was 1.26 when harvested at 5cm height.

Leaf area ratio (LAR)

Leaf area ratio of hybrid napier cultivars at different cutting heights are given in Table 86 and Table 87. Cutting height management could not produce any considerable changes in LAR but significant influence of cultivars were noticed. Interaction effects were also absent.

In the first year, among the cultivars, the highest LAR was noticed in 'CO-4' and the lowest was noticed in 'PTH'. During the course of experiment, the highest LAR was observed at the fourth harvest. LAR values of all cultivars except 'PTH' were comparable at the fourth harvest.

Table 86. Effect of cutting height management on leaf area ratio (dm^2/g) in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	1.16	1.42	1.49	1.78
10 cm	1.16	1.42	1.48	1.80
15 cm	1.17	1.43	1.49	1.79
20 cm	1.15	1.39	1.49	1.77
LSD 5%	NS	NS	NS	NS
Cultivars				
CO-3	1.21	1.47	1.58	1.88
CO-4	1.35	1.66	1.65	1.94
Suguna	1.21	1.42	1.57	1.91
DHN-6	1.19	1.50	1.53	1.89
PTH	0.85	1.01	1.12	1.29
LSD 5%	0.07	0.06	0.06	0.11
5 cm				
CO-3	1.20	1.50	1.56	1.92
CO-4	1.35	1.65	1.62	1.92
Suguna	1.21	1.44	1.57	1.88
DHN-6	1.19	1.52	1.54	1.89
PTH	0.86	1.00	1.13	1.28
10 cm				
CO-3	1.24	1.48	1.57	1.91
CO-4	1.35	1.68	1.64	1.97
Suguna	1.20	1.42	1.57	1.91
DHN-6	1.19	1.50	1.53	1.90
PTH	0.84	0.99	1.11	1.30
15 cm				
CO-3	1.25	1.45	1.57	1.87
CO-4	1.34	1.70	1.65	1.95
Suguna	1.21	1.40	1.57	1.95
DHN-6	1.20	1.52	1.55	1.89
PTH	0.86	1.06	1.10	1.30
20 cm				
CO-3	1.16	1.44	1.59	1.83
CO-4	1.37	1.61	1.67	1.93
Suguna	1.22	1.41	1.57	1.91
DHN-6	1.16	1.47	1.52	1.87
PTH	0.85	1.00	1.13	1.29
LSD 5%	NS	NS	NS	NS

Table 87. Effect of cutting height management on leaf area ratio (dm^2/g) in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	1.55	1.48	1.54	1.12	1.35
10 cm	1.56	1.47	1.51	1.09	1.28
15 cm	1.56	1.47	1.51	1.11	1.31
20 cm	1.55	1.48	1.53	1.10	1.33
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO-3	1.82	1.71	1.76	1.16	1.33
CO-4	1.73	1.49	1.58	1.10	1.43
Suguna	1.74	1.52	1.65	1.21	1.52
DHN-6	1.78	1.76	1.67	1.55	1.56
PTH	0.72	0.90	0.95	0.52	0.75
LSD 5%	0.12	0.09	0.08	0.08	0.09
5 cm					
CO-3	1.82	1.70	1.78	1.17	1.33
CO-4	1.74	1.51	1.61	1.12	1.46
Suguna	1.71	1.52	1.64	1.24	1.53
DHN-6	1.76	1.77	1.71	1.56	1.54
PTH	0.72	0.92	0.95	0.54	0.89
10 cm					
CO-3	1.83	1.71	1.74	1.14	1.33
CO-4	1.73	1.51	1.56	1.09	1.37
Suguna	1.75	1.50	1.65	1.17	1.46
DHN-6	1.77	1.73	1.67	1.53	1.55
PTH	0.72	0.89	0.95	0.53	0.70
15 cm					
CO-3	1.82	1.73	1.74	1.18	1.36
CO-4	1.75	1.48	1.57	1.11	1.41
Suguna	1.74	1.55	1.63	1.20	1.54
DHN-6	1.82	1.73	1.65	1.57	1.56
PTH	0.70	0.89	0.97	0.50	0.70
20 cm					
CO-3	1.80	1.71	1.78	1.16	1.31
CO-4	1.71	1.48	1.59	1.09	1.47
Suguna	1.76	1.52	1.67	1.22	1.54
DHN-6	1.76	1.80	1.67	1.54	1.59
PTH	0.75	0.91	0.92	0.51	0.72
LSD 5%	NS	NS	NS	NS	NS

In the second year, maximum LAR was noticed at the first harvest. During the first and the second harvest also all cultivars were at par except 'PTH'. In the third harvest, 'CO-3' showed maximum LAR.

During the tenure of the experiment, minimum LAR was noticed in the fourth harvest of the second year. At this stage, the highest LAR recorded was 1.55 in 'DHN-6' while the least was 0.52 in 'PTH'. In the fifth harvest again, 'DHN-6' had comparatively higher LAR (1.56).

Leaf weight ratio (LWR)

The data on leaf weight ratio are given in Table 88 and Table 89. Harvesting at different cutting heights did not influence the LWR of crop, nonetheless, cultivar effect was significant. Interaction effects were absent.

In both years, LWR reached the peak at third harvests. During the first year, in all the harvests, 'CO-3', 'CO-4' and 'Suguna' were at par with higher LWR. At the fourth harvest, 'DHN-6' was on par with 'CO-3', 'CO-4' and 'Suguna'. The lowest LWR values were with 'PTH'.

During the second year, during the first two harvests, 'Suguna' and 'CO-3' had comparable ratios and showed high values. In the succeeding three harvests, 'CO-4' was on par with 'Suguna' and 'CO-3' and showed comparatively higher LWR. In the second year also, the lowest ratio was with 'PTH'. However, 'DHN-6' was on par with 'PTH' at the third and the fourth harvests.

Specific leaf weight (SLW)

Specific leaf weight of hybrid napier cultivars at different cutting heights are presented in Table 90 and Table 91. Considerable changes in SLW were not noticed when harvested at different heights. However, it varied between the cultivars. Interaction effect was also absent. During the course of experiment, the crop had the highest SLW at the fourth harvest of the second year. Among the cultivars, 'PTH' recorded maximum SLW.

Table 88. Effect of cutting height management on leaf weight ratio in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	0.54	0.59	0.72	0.65
10 cm	0.53	0.59	0.72	0.65
15 cm	0.54	0.59	0.72	0.65
20 cm	0.53	0.58	0.72	0.65
LSD 5%	NS	NS	NS	NS
Cultivars				
CO-3	0.57	0.64	0.77	0.68
CO-4	0.57	0.62	0.76	0.68
Suguna	0.58	0.65	0.77	0.68
DHN-6	0.51	0.54	0.71	0.67
PTH	0.45	0.48	0.58	0.51
LSD 5%	0.03	0.02	0.02	0.01
5 cm				
CO-3	0.57	0.64	0.77	0.68
CO-4	0.57	0.61	0.76	0.68
Suguna	0.58	0.65	0.77	0.69
DHN-6	0.51	0.54	0.71	0.67
PTH	0.45	0.48	0.58	0.51
10 cm				
CO-3	0.57	0.64	0.77	0.68
CO-4	0.57	0.62	0.76	0.68
Suguna	0.58	0.65	0.77	0.68
DHN-6	0.51	0.54	0.71	0.67
PTH	0.44	0.48	0.58	0.51
15 cm				
CO-3	0.58	0.63	0.77	0.69
CO-4	0.57	0.62	0.77	0.68
Suguna	0.58	0.65	0.77	0.69
DHN-6	0.51	0.54	0.72	0.67
PTH	0.46	0.50	0.58	0.51
20 cm				
CO-3	0.55	0.63	0.78	0.68
CO-4	0.58	0.61	0.77	0.68
Suguna	0.58	0.64	0.77	0.68
DHN-6	0.50	0.54	0.71	0.67
PTH	0.46	0.47	0.58	0.51
LSD 5%	NS	NS	NS	NS

Table 89. Effect of cutting height management on leaf weight ratio in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	0.57	0.58	0.64	0.62	0.59
10 cm	0.58	0.57	0.64	0.62	0.57
15 cm	0.58	0.58	0.64	0.63	0.57
20 cm	0.58	0.58	0.64	0.62	0.58
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO-3	0.68	0.65	0.69	0.68	0.65
CO-4	0.61	0.58	0.68	0.68	0.66
Suguna	0.68	0.63	0.70	0.68	0.65
DHN-6	0.55	0.54	0.58	0.56	0.56
PTH	0.35	0.47	0.57	0.52	0.37
LSD 5%	0.04	0.02	0.02	0.03	0.04
5 cm					
CO-3	0.67	0.64	0.69	0.68	0.65
CO-4	0.61	0.58	0.68	0.68	0.66
Suguna	0.68	0.63	0.70	0.69	0.66
DHN-6	0.55	0.55	0.58	0.56	0.56
PTH	0.34	0.47	0.57	0.52	0.44
10 cm					
CO-3	0.68	0.66	0.69	0.67	0.65
CO-4	0.62	0.58	0.68	0.67	0.65
Suguna	0.68	0.63	0.70	0.68	0.62
DHN-6	0.55	0.54	0.58	0.56	0.56
PTH	0.35	0.46	0.57	0.53	0.35
15 cm					
CO-3	0.68	0.66	0.69	0.68	0.65
CO-4	0.62	0.58	0.68	0.68	0.66
Suguna	0.69	0.63	0.69	0.68	0.66
DHN-6	0.56	0.55	0.58	0.57	0.56
PTH	0.33	0.47	0.58	0.52	0.34
20 cm					
CO-3	0.68	0.65	0.69	0.67	0.65
CO-4	0.61	0.58	0.68	0.68	0.67
Suguna	0.68	0.63	0.70	0.69	0.66
DHN-6	0.55	0.54	0.58	0.56	0.57
PTH	0.37	0.48	0.56	0.52	0.35
LSD 5%	NS	NS	NS	NS	NS

Table 90. Effect of cutting height management on specific leaf weight (g/dm^2) in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	0.47	0.42	0.49	0.37
10 cm	0.46	0.42	0.49	0.36
15 cm	0.46	0.42	0.49	0.37
20 cm	0.47	0.42	0.48	0.37
LSD 5%	NS	NS	NS	NS
Cultivars				
CO-3	0.47	0.43	0.49	0.37
CO-4	0.42	0.37	0.46	0.35
Suguna	0.48	0.46	0.49	0.36
DHN-6	0.43	0.36	0.46	0.36
PTH	0.53	0.48	0.52	0.40
LSD 5%	0.02	0.01	0.02	0.02
5 cm				
CO-3	0.48	0.43	0.49	0.36
CO-4	0.42	0.37	0.47	0.36
Suguna	0.48	0.45	0.49	0.36
DHN-6	0.43	0.36	0.46	0.35
PTH	0.53	0.49	0.51	0.40
10 cm				
CO-3	0.46	0.43	0.49	0.36
CO-4	0.42	0.37	0.47	0.35
Suguna	0.48	0.46	0.49	0.36
DHN-6	0.43	0.36	0.46	0.35
PTH	0.53	0.49	0.53	0.40
15 cm				
CO-3	0.46	0.44	0.49	0.37
CO-4	0.43	0.37	0.46	0.35
Suguna	0.48	0.46	0.49	0.35
DHN-6	0.42	0.36	0.46	0.36
PTH	0.53	0.47	0.52	0.40
20 cm				
CO-3	0.47	0.44	0.49	0.38
CO-4	0.42	0.38	0.46	0.36
Suguna	0.48	0.46	0.49	0.36
DHN-6	0.43	0.37	0.47	0.36
PTH	0.54	0.47	0.51	0.40
LSD 5%	NS	NS	NS	NS

Table 91. Effect of cutting height management on specific leaf weight (g/dm^2) in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	0.38	0.40	0.44	0.61	0.44
10 cm	0.38	0.40	0.44	0.63	0.45
15 cm	0.38	0.41	0.44	0.63	0.44
20 cm	0.39	0.40	0.44	0.63	0.44
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO-3	0.37	0.38	0.39	0.58	0.49
CO-4	0.36	0.39	0.43	0.61	0.46
Suguna	0.39	0.42	0.42	0.57	0.43
DHN-6	0.31	0.31	0.35	0.36	0.36
PTH	0.48	0.52	0.60	1.01	0.49
LSD 5%	0.02	0.02	0.02	0.04	0.02
5 cm					
CO-3	0.37	0.38	0.39	0.59	0.49
CO-4	0.35	0.39	0.42	0.60	0.45
Suguna	0.40	0.42	0.42	0.56	0.43
DHN-6	0.31	0.31	0.34	0.36	0.37
PTH	0.48	0.51	0.60	0.97	0.49
10 cm					
CO-3	0.37	0.38	0.39	0.59	0.49
CO-4	0.36	0.39	0.44	0.62	0.48
Suguna	0.39	0.42	0.42	0.58	0.42
DHN-6	0.31	0.31	0.35	0.36	0.36
PTH	0.49	0.52	0.60	1.01	0.49
15 cm					
CO-3	0.37	0.38	0.40	0.58	0.48
CO-4	0.35	0.39	0.43	0.61	0.47
Suguna	0.40	0.41	0.43	0.57	0.43
DHN-6	0.31	0.32	0.35	0.37	0.36
PTH	0.47	0.53	0.59	1.04	0.48
20 cm					
CO-3	0.38	0.38	0.39	0.58	0.49
CO-4	0.36	0.40	0.43	0.62	0.46
Suguna	0.39	0.42	0.42	0.57	0.43
DHN-6	0.31	0.30	0.35	0.36	0.36
PTH	0.49	0.53	0.61	1.04	0.49
LSD 5%	NS	NS	NS	NS	NS

The highest SLW recorded during the first year was 0.53 g/dm^2 by 'PTH', at the first harvest. In the first three harvests, 'DHN-6' and 'CO-4' were at par and showed lower specific leaf weight. At the final harvest, SLW of all cultivars were comparable except for 'PTH'.

During the second year also, maximum SLW was recorded in 'PTH' whereas the minimum was recorded in 'DHN-6'. The highest SLW attained by 'PTH' during the experiment was 1.01 g/dm^2 at the fourth harvest. At the final harvest, all cultivars except 'DHN-6' had comparable SLW.

Leaf: stem ratio

The data on leaf to stem ratio are presented in Table 92 and Table 93. Cutting at varying heights did not have significant effect on leaf to stem ratio of hybrid napier but the ratio varied between the cultivars. Interactions were also absent. During both years, the highest leaf to stem ratio was recorded at third harvests. In general, 'CO-3', CO-4' and 'Suguna' had comparable leaf to stem ratios showing high values. The least was observed in 'PTH'.

In the first year, at the first harvest, ratios of 'CO-3', CO-4' and 'Suguna' were comparable, of which the highest value was recorded in 'Suguna' (1.37). At second harvest, 'Suguna' and 'CO-3' recorded maximum leaf to stem ratio. The highest leaf to stem ratio (3.38) was attained at the third harvest by 'CO-3', whereas the ratios of 'Suguna' and 'CO-4' were comparable with 'CO-3'. During the fifth harvest also, maximum ratio was observed in 'CO-3', CO-4' and 'Suguna'. The lowest ratio recorded during the first year was observed in 'PTH' (0.84) at the first harvest.

During the second year, in general, 'Suguna' recorded the highest ratio. At the beginning of the second year, the highest ratio noticed was 2.22 in 'Suguna'. In the second harvest, 'CO-3' was a little above 'Suguna' but both were at par. The highest ratio of the year was at the third harvest, of which maximum values was with 'Suguna' (2.31) and 'CO-3' (2.26). In the final harvest also, the three cultivars 'Suguna', 'CO-4' and 'CO-3' had comparable ratios showing maximum

Table 92. Effect of cutting height management on leaf – stem ratio in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4
Cutting height				
5 cm	1.18	1.47	2.74	1.90
10 cm	1.17	1.48	2.77	1.91
15 cm	1.19	1.49	2.78	1.92
20 cm	1.17	1.43	2.80	1.91
LSD 5%	NS	NS	NS	NS
Cultivars				
CO-3	1.32	1.76	3.38	2.17
CO-4	1.34	1.60	3.25	2.14
Suguna	1.37	1.85	3.35	2.16
DHN-6	1.03	1.18	2.50	2.04
PTH	0.84	0.94	1.37	1.05
LSD 5%	0.12	0.13	0.23	0.10
5 cm				
CO-3	1.34	1.80	3.36	2.16
CO-4	1.31	1.57	3.13	2.13
Suguna	1.37	1.87	3.33	2.18
DHN-6	1.06	1.18	2.49	2.00
PTH	0.82	0.94	1.38	1.04
10 cm				
CO-3	1.33	1.79	3.37	2.16
CO-4	1.32	1.62	3.26	2.13
Suguna	1.36	1.88	3.38	2.14
DHN-6	1.03	1.17	2.44	2.05
PTH	0.80	0.93	1.40	1.06
15 cm				
CO-3	1.36	1.73	3.33	2.18
CO-4	1.33	1.66	3.29	2.13
Suguna	1.38	1.85	3.35	2.19
DHN-6	1.03	1.19	2.56	2.05
PTH	0.87	1.00	1.36	1.05
20 cm				
CO-3	1.26	1.71	3.46	2.17
CO-4	1.39	1.56	3.33	2.15
Suguna	1.38	1.79	3.34	2.14
DHN-6	0.99	1.17	2.52	2.04
PTH	0.85	0.90	1.36	1.05
LSD 5%	NS	NS	NS	NS

Table 93 . Effect of cutting height management on leaf –stem ratio in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5
Cutting height					
5 cm	1.53	1.41	1.89	1.77	1.59
10 cm	1.54	1.41	1.87	1.74	1.47
15 cm	1.57	1.43	1.89	1.76	1.51
20 cm	1.53	1.42	1.89	1.76	1.53
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO-3	2.09	1.88	2.26	2.11	1.86
CO-4	1.61	1.40	2.12	2.12	1.97
Suguna	2.22	1.72	2.31	2.16	1.89
DHN-6	1.24	1.20	1.40	1.29	1.29
PTH	0.54	0.89	1.32	1.11	0.62
LSD 5%	0.28	0.14	0.19	0.19	0.21
5 cm					
CO-3	2.07	1.82	2.28	2.17	1.85
CO-4	1.62	1.40	2.14	2.13	1.99
Suguna	2.20	1.71	2.30	2.19	1.93
DHN-6	1.23	1.22	1.40	1.27	1.29
PTH	0.53	0.90	1.32	1.10	0.89
10 cm					
CO-3	2.11	1.91	2.22	2.10	1.90
CO-4	1.63	1.39	2.10	2.08	1.91
Suguna	2.20	1.72	2.32	2.10	1.71
DHN-6	1.22	1.18	1.39	1.27	1.28
PTH	0.55	0.86	1.31	1.16	0.54
15 cm					
CO-3	2.10	1.91	2.27	2.12	1.87
CO-4	1.63	1.39	2.13	2.10	1.97
Suguna	2.31	1.71	2.28	2.16	1.94
DHN-6	1.30	1.22	1.40	1.35	1.27
PTH	0.50	0.90	1.36	1.09	0.52
20 cm					
CO-3	2.09	1.88	2.29	2.07	1.82
CO-4	1.58	1.41	2.12	2.16	2.03
Suguna	2.19	1.73	2.33	2.20	1.96
DHN-6	1.22	1.17	1.39	1.26	1.30
PTH	0.58	0.91	1.30	1.10	0.54
LSD 5%	NS	NS	NS	NS	NS

leaf to stem ratio. The lowest ratio recorded during the experiment was 0.54 in 'PTH' during the first harvest of the second year.

Regrowth rate

The data on regrowth rate of hybrid napier cultivars from different cutting height management, after each harvests are shown in Table 94 and Table 95. Significant difference in regrowth rate of cultivars were noticed when harvested at different cutting heights. Influence of cultivars and its interaction effects were also present.

Hybrid napier showed maximum regrowth rate when harvested at 20 cm height with a declining trend when harvested at lower cutting heights. The highest regrowth rate was attained after the first harvest in both years of study, which seems to decrease towards final harvests. In general, 'CO-3', 'CO-4' and 'Suguna' had comparable regrowth rate with marked regrowth rate values. However regrowth rate of 'PTH' and 'DHN-6' were poorer.

In the first year, after the first harvest, among the cultivars, 'Suguna' and 'CO-3' were at par and showed maximum regrowth rate. Both cultivars attained the highest regrowth rate when harvested at 20 cm height, (5.99 g/day and 5.87 g/day) while 'PTH' had the lowest. After the second harvest also, the cultivars 'Suguna' and 'CO-3' had comparable rates showing higher values. The lowest rate was observed in 'DHN-6' when harvested at 5 cm height.

During the course of experiment, the crop recorded minimum regrowth rate after the third harvest. At that time too, 'Suguna' recorded maximum regrowth rate and 'DHN-6' the least. When harvested at 5 cm and 15 cm, 'Suguna', 'CO-4' and 'CO-3' were at par and showed maximum regrowth rate. 'PTH' had similar regrowth rates at 10 cm and 15 cm of cutting heights.

After the final harvest in the first year, the crop showed an increasing trend in regrowth rate on receipt of premonsoon showers and reached its peak after the first harvest of the second year. However, regrowth rate decreased after

Table 94. Effect of cutting height management on regrowth rate (g/day) in hybrid napier cultivars after each harvest during the first year

Treatment	AH1	AH2	AH3
Cutting height			
5 cm	3.94	2.96	0.27
10 cm	4.14	3.16	0.41
15 cm	4.48	3.47	0.51
20 cm	4.83	3.87	0.59
LSD 5%	0.05	0.10	0.02
Cultivars			
CO-3	5.42	4.70	0.52
CO-4	4.29	3.60	0.53
Suguna	5.47	4.74	0.59
DHN-6	3.66	1.71	0.27
PTH	2.91	2.09	0.31
LSD 5%	0.06	0.11	0.02
5 cm			
CO-3	5.02	4.29	0.31
CO-4	3.74	3.05	0.32
Suguna	5.08	4.42	0.35
DHN-6	3.33	1.42	0.16
PTH	2.54	1.60	0.24
10 cm			
CO-3	5.28	4.52	0.48
CO-4	4.03	3.30	0.45
Suguna	5.21	4.56	0.56
DHN-6	3.49	1.52	0.27
PTH	2.72	1.93	0.27
15 cm			
CO-3	5.50	4.86	0.61
CO-4	4.48	3.59	0.65
Suguna	5.59	4.86	0.65
DHN-6	3.74	1.83	0.31
PTH	3.09	2.22	0.33
20 cm			
CO-3	5.87	5.11	0.69
CO-4	4.91	4.45	0.72
Suguna	5.99	5.12	0.81
DHN-6	4.06	2.10	0.33
PTH	3.32	2.60	0.41
LSD 5%	0.12	0.22	0.05

AH- after harvest

Table 95. Effect of cutting height management on regrowth rate (g/day) in hybrid napier cultivars after each harvest during the second year

Treatment	ASH	AH1	AH2	AH3	AH4
Cutting height					
5 cm	1.09	6.11	3.43	4.36	1.60
10 cm	1.19	6.46	3.80	4.65	1.98
15 cm	1.31	6.83	4.12	5.04	2.28
20 cm	1.42	7.14	4.45	5.36	2.63
LSD 5%	0.02	0.05	0.05	0.05	0.05
Cultivars					
CO-3	1.45	6.61	3.58	4.98	2.40
CO-4	1.52	7.36	5.54	6.26	2.99
Suguna	1.50	8.17	4.04	5.50	2.22
DHN-6	0.79	5.83	3.05	3.83	1.43
PTH	1.00	5.19	3.54	3.69	1.58
LSD 5%	0.02	0.06	0.06	0.06	0.05
5 cm					
CO-3	1.27	6.06	2.99	4.51	1.87
CO-4	1.32	6.79	4.94	5.65	2.34
Suguna	1.30	7.57	3.48	4.94	1.63
DHN-6	0.67	5.48	2.70	3.37	1.03
PTH	0.87	4.65	3.04	3.31	1.13
10 cm					
CO-3	1.41	6.43	3.41	4.74	2.25
CO-4	1.43	7.15	5.34	6.09	2.85
Suguna	1.44	7.99	3.83	5.27	2.07
DHN-6	0.74	5.73	2.96	3.67	1.31
PTH	0.92	4.98	3.47	3.49	1.43
15 cm					
CO-3	1.50	6.77	3.78	5.15	2.53
CO-4	1.59	7.56	5.78	6.46	3.21
Suguna	1.57	8.39	4.20	5.71	2.36
DHN-6	0.84	5.99	3.16	4.01	1.59
PTH	1.04	5.45	3.67	3.88	1.69
20 cm					
CO-3	1.62	7.17	4.16	5.53	2.94
CO-4	1.71	7.94	6.09	6.84	3.55
Suguna	1.70	8.75	4.64	6.08	2.80
DHN-6	0.92	6.13	3.39	4.26	1.78
PTH	1.15	5.68	3.99	4.08	2.06
LSD 5%	0.04	0.12	0.12	0.11	0.10

ASH- after summer harvest; AH- after harvest the second harvest; however, on receipt of north east monsoon an increasing trend was noticed, but thereafter, it decreased.

During the early period of the second year, 'CO-4' and 'Suguna' had similar regrowth rates and showed maximum regrowth. 'DHN-6' had the least regrowth rate. For the experimental period, the peak regrowth rate was observed after the first harvest. The highest value was recorded in 'Suguna' when harvested at 20 cm height (8.75 g/day) and 'PTH' had the least when harvested at 5 cm height (4.65 g/day).

After the second harvest, throughout the experiment , 'CO-4' showed maximum regrowth rate at all cutting levels while 'DHN-6' had the least. However, after the third harvest, regrowth rate of 'PTH' was a little lower than 'DHN-6'.

4.3.3. Mortality of clumps

During both years of study mortality of clumps were monitored one month after the receipt of premonsoon showers but could not find any clump mortality.

4.3.4. Fodder yield

Fodder yield of hybrid napier cultivars were significantly influenced by cutting height management. Both fresh and dry fodder yield increased with increasing cutting height. Cultivars had the highest fodder yield when harvested at 20 cm height. Substantial reduction in yield was noticed with decreasing cutting height. Interaction effects were also found to be significant. Since the cutting height management was started at the first harvest, the influence of different harvesting heights were evident only from the second harvests onwards.

There were four harvests in the first year and five in the second year. Maximum fodder yield was recorded during the second year. In the first year, the crop had maximum fodder yield at the first harvest, thereafter decreased towards the final harvest. There were no harvests after the fourth harvest, as crop growth was stunted due to cessation of rainfall during the summer months.

After the first year growth, on receipt of premonsoon showers, the crop growth recuperated and showed an increasing trend in yield. In the second year, maximum fodder yield was recorded at the second harvest. The yield slightly declined by the third harvest. However, the yield again improved by the fourth harvest. Then, it declined sharply by the fifth harvest as the rain subsided. No further harvest could be taken due to the cessation of rainfall.

Fresh fodder yield

The data on fresh fodder yield of hybrid napier cultivars at different harvests are given in Table 96 and Table 97. In general, 'PTH' had the lowest fodder yield. In the first year, at the first harvest, 'Suguna' had the highest fresh fodder yield (41.06 Mg/ha) followed by 'CO-3' while 'PTH' had the lowest (26.23 Mg/ha). During the second harvest, among the cultivars, 'CO-3' recorded maximum yield and was followed by 'Suguna'. When harvested at 20 cm height, 'CO-3' (40.32 Mg/ha) and 'Suguna' (39.82 Mg/ha) had comparable yields and showed higher fodder yield while 'DHN-6' was on par with 'Suguna'. All the cultivars recorded lower fodder yield when harvested at 5 cm height.

During the third harvest also, at all cutting heights, the cultivars 'CO-3' and 'Suguna' had comparable yields showing higher yields at 20 cm height (35.11 Mg/ha and 34.02 Mg/ha). At the fourth harvest, 'Suguna' recorded maximum yield. It had the highest yield when harvested at 20 cm height (5.37 mg/ha). When harvested at 5cm and 20 cm, cultivars 'DHN6' and 'PTH' were at par and recorded minimum yield. Similarly at 5 cm and 15 cm, 'CO-3', 'CO-4' and 'Suguna' were at par and had maximum fresh yield.

Considering the total fresh fodder yield, 'Suguna' and 'CO-3' had comparable yield potential and produced maximum yield. 'Suguna' and 'CO-3' could produce higher annual fresh fodder when harvested at 20 cm height, 120.44 Mg/ha and 118.69 Mg/ha respectively. The lowest yielder 'PTH' produced a maximum of 73.05 Mg /ha of fresh fodder when harvested at 20 cm height. When harvested at 5cm, 'Suguna' and 'CO-3' could produce only, 106.52 Mg /ha

Table 96. Effect of cutting height management on fresh fodder yield (Mg/ha) in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4	Total
Cutting height					
5 cm	34.16	28.47	20.66	1.94	85.22
10 cm	34.28	29.92	22.15	2.90	89.24
15 cm	34.29	32.32	24.42	3.60	94.64
20 cm	34.40	34.86	27.23	4.15	100.65
LSD 5%	NS	0.35	0.65	0.13	1.21
Cultivars					
CO-3	38.37	37.20	32.25	3.60	111.42
CO-4	30.71	26.82	22.48	3.33	83.35
Suguna	41.06	36.36	31.50	3.93	112.86
DHN-6	35.05	35.16	16.48	2.56	89.25
PTH	26.23	21.42	15.35	2.31	65.30
LSD 5%	0.75	0.40	0.72	0.15	1.35
5 cm					
CO-3	38.23	34.46	29.46	2.11	104.27
CO-4	30.59	23.40	19.05	2.00	75.03
Suguna	41.02	33.78	29.40	2.31	106.52
DHN-6	35.04	32.04	13.62	1.52	82.22
PTH	25.89	18.65	11.77	1.74	58.05
10 cm					
CO-3	38.18	36.23	31.05	3.32	108.78
CO-4	30.87	25.16	20.62	2.81	79.46
Suguna	41.07	34.66	30.30	3.69	109.71
DHN-6	35.07	33.56	14.58	2.63	85.85
PTH	26.22	19.97	14.17	2.01	62.38
15 cm					
CO-3	38.53	37.80	33.41	4.22	113.95
CO-4	30.47	28.01	22.45	4.04	84.97
Suguna	40.94	37.16	32.32	4.33	114.76
DHN-6	35.25	35.98	17.59	2.96	91.78
PTH	26.27	22.68	16.34	2.43	67.73
20 cm					
CO-3	38.53	40.32	35.11	4.73	118.69
CO-4	30.90	30.71	27.81	4.51	93.94
Suguna	41.22	39.82	34.02	5.37	120.44
DHN-6	34.84	39.02	20.15	3.12	97.13
PTH	26.52	24.41	19.10	3.03	73.05
LSD 5%	NS	0.79	1.46	0.31	2.70

Table 97. Effect of cutting height management on fresh fodder yield (Mg/ha) in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	Total
Cutting height						
5 cm	22.77	44.25	24.58	31.17	11.32	134.09
10 cm	24.82	46.73	27.23	33.30	14.03	146.12
15 cm	27.46	49.44	29.48	36.14	16.16	158.69
20 cm	29.83	51.58	31.88	38.42	18.65	170.35
LSD 5%	0.32	0.39	0.36	0.36	0.32	0.73
Cultivars						
CO-3	29.45	45.39	24.62	34.19	16.46	150.11
CO-4	27.98	46.00	34.61	39.12	18.69	166.40
Suguna	29.49	54.34	26.85	36.54	14.73	161.96
DHN-6	22.58	56.07	29.37	36.79	13.72	158.52
PTH	21.63	38.18	26.05	27.13	11.60	124.56
LSD 5%	0.37	0.44	0.40	0.40	0.37	0.82
5 cm						
CO-3	25.83	41.65	20.54	30.97	12.86	131.84
CO-4	24.44	42.45	30.89	35.33	14.65	147.75
Suguna	25.55	50.30	23.17	32.82	10.86	142.69
DHN-6	19.16	52.66	25.91	32.44	9.94	140.11
PTH	18.91	34.18	22.37	24.31	8.29	108.05
10 cm						
CO-3	28.54	44.17	23.41	32.52	15.46	144.10
CO-4	26.49	44.68	33.35	38.03	17.80	160.34
Suguna	28.19	53.09	25.45	35.04	13.73	155.50
DHN-6	20.95	55.06	28.49	35.27	12.60	152.36
PTH	19.94	36.64	25.50	25.65	10.53	118.25
15 cm						
CO-3	30.51	46.46	25.96	35.33	17.34	155.61
CO-4	29.40	47.26	36.11	40.38	20.09	173.23
Suguna	30.80	55.80	27.93	37.95	15.70	168.18
DHN-6	23.98	57.57	30.42	38.53	15.25	165.75
PTH	22.62	40.08	27.00	28.51	12.43	130.64
20 cm						
CO-3	32.92	49.27	28.56	37.95	20.19	168.88
CO-4	31.61	49.65	38.06	42.77	22.20	184.31
Suguna	33.38	58.20	30.84	40.39	18.62	181.43
DHN-6	26.21	58.98	32.62	40.94	17.08	175.83
PTH	25.02	41.78	29.30	30.03	15.16	141.29
LSD 5%	0.72	0.86	0.79	0.80	0.74	1.64

and 104.27 Mg /ha of fresh fodder respectively. The poorest yielder, 'PTH' could produce only 58.05 Mg/ha of fresh fodder in the first year.

The first harvest in the second year was done, one month after the premonsoon showers. In the second year also, the crop recorded maximum fresh fodder yield when harvested at 20 cm height. 'PTH' recorded lower fresh fodder yield in all the harvests for the second year also. At the first harvest, among the cultivars, ''Suguna' and 'CO-3' were at par and showed maximum yield. Considering the interaction effect, 'Suguna' attained the first position when harvested at 20 cm followed by 'CO-3'.

During the second harvest, 'DHN-6' recorded maximum yield at all cutting heights, with its highest yield at 20 cm height (58.98 Mg/ha) which was the topmost yield attained during the experiment. When harvested at 20 cm height, both 'DHN-6' and 'Suguna' were at par. During the peak period, the lowest yielder 'PTH' could produce a maximum of 41.78 Mg/ha when harvested at 20 cm height and a minimum of 34.18 Mg/ha at 5cm. Corresponding yield of 'DHN-6', the highest yielder, at 5cm was 52.66 Mg/ha.

'CO-4' attained the first position for the succeeding harvests at all cutting heights. Although 'PTH' was the lowest yielder at all harvests, at the third harvest, yield of 'CO-3' was a little lower than 'PTH'. The crop recorded comparatively lower yields at the final harvest wherein the highest yield recorded was 22.20 Mg/ha by 'CO-4' at 20 cm height while the lowest yield recorded was 8.29 Mg/ha in 'PTH' when harvested at 5cm.

Considering the total fresh fodder yield obtained during the second year, 'CO-4' attained the first position while 'PTH' the last position at all cutting heights. Maximum total yield per year attained by 'CO-4' was 184.31 Mg/ha at 20 cm height followed by 'Suguna', 181.43 Mg/ha. 'PTH' could produce 141.29 Mg/ha at 20 cm height. All the cultivars had the lowest yield at 5 cm height where 'CO-4' could produce a maximum of 147.75 Mg/ha/yr while 'PTH' could produce 108.05 Mg/ha.

Dry fodder yield

Dry fodder yield of hybrid napier cultivars at each harvest are presented in Table 98 and Table 99. Significant influence of different cutting heights on hybrid napier cultivars were noticed from the second harvest onwards. Dry fodder yield followed the same trend as that of fresh fodder yield. At the first harvest, 'Suguna' recorded maximum dry fodder yield and followed by 'CO-3'. 'PTH' recorded the lowest dry fodder yield at all harvests.

In the second harvest, 'Suguna' and 'CO-3' were at par and showed maximum yield. Both cultivars recorded maximum yield when harvested at 20 cm height (7.49 Mg/ha and 7.34 Mg/ha). At the third harvest also, 'Suguna' and 'CO-3' had comparable yields and could produce maximum yields. At the fourth harvest, among the cultivars, 'Suguna' recorded maximum fodder yield. Although 'PTH' was the lowest yielder, at the third and the fourth harvest, dry fodder yield of 'DHN-6' was a little lower than 'PTH'.

In view of the total dry fodder yield, in the first year, 'Suguna' was the highest yielder while 'PTH' was the poorest yielder. When harvested at 20 cm, 'Suguna' could produce annual dry fodder yield of 23.67 Mg/ha while it could produce only 20.47 Mg/ha when harvested at 5 cm. However, 'PTH' could produce 12.94 Mg/ha of dry fodder at 20 cm of cutting height and 10.17 Mg/ha at 5 cm. At 5cm cutting height, dry fodder yield of 'DHN-6' and 'PTH' were comparable and showed lower values.

During the second year, in general, 'CO-4' showed maximum fodder yield while 'PTH' and 'DHN-6' lower values. At the first harvest, 'Suguna' and 'CO-4' were at par having higher dry fodder yield, with its maximum under 20 cm of cutting height. Most cultivars recorded maximum dry fodder yield at the second harvest of which 'Suguna' attained the first position when harvested at 20 cm height (10.94 Mg/ha). The lowest yielder 'PTH' could produce a maximum of 7.10 Mg/ha when harvested at 20 cm height. When harvested at 5 cm height, 'Suguna' could produce 9.46 Mg/ha and 'PTH' yielded 5.81 Mg/ha.

Table 98. Effect of cutting height management on dry fodder yield (Mg/ha) in hybrid napier cultivars at each harvest during the first year

Treatment	HI	H2	H3	H4	Total
Cutting height					
5 cm	5.95	4.93	3.69	0.69	15.26
10 cm	5.97	5.18	3.96	1.03	16.14
15 cm	5.97	5.60	4.34	1.28	17.20
20 cm	6.00	6.04	4.84	1.49	18.37
LSD 5%	NS	0.07	0.12	0.05	0.24
Cultivars					
CO-3	6.98	6.77	5.87	1.32	20.94
CO-4	6.14	5.36	4.50	1.35	17.35
Suguna	7.72	6.83	5.93	1.49	21.97
DHN-6	4.56	4.57	2.14	0.67	11.94
PTH	4.46	3.64	2.61	0.79	11.50
LSD 5%	0.14	0.07	0.14	0.06	0.26
5 cm					
CO-3	6.96	6.27	5.36	0.78	19.37
CO-4	6.12	4.68	3.81	0.81	15.41
Suguna	7.71	6.35	5.53	0.88	20.47
DHN-6	4.56	4.17	1.77	0.40	10.89
PTH	4.40	3.17	2.00	0.60	10.17
10 cm					
CO-3	6.95	6.59	5.65	1.22	20.41
CO-4	6.17	5.03	4.13	1.13	16.47
Suguna	7.72	6.51	5.70	1.40	21.33
DHN-6	4.56	4.36	1.89	0.69	11.51
PTH	4.46	3.39	2.41	0.69	10.95
15 cm					
CO-3	7.01	6.88	6.08	1.55	21.52
CO-4	6.09	5.60	4.49	1.63	17.81
Suguna	7.69	6.99	6.08	1.64	22.40
DHN-6	4.58	4.68	2.29	0.77	12.32
PTH	4.47	3.86	2.78	0.83	11.93
20 cm					
CO-3	7.01	7.34	6.39	1.73	22.48
CO-4	6.18	6.14	5.56	1.82	19.70
Suguna	7.75	7.49	6.40	2.04	23.67
DHN-6	4.53	5.07	2.62	0.82	13.04
PTH	4.51	4.15	3.25	1.04	12.94
LSD 5%	NS	0.15	0.28	0.11	0.53

Table 99. Effect of cutting height management on dry fodder yield (Mg/ha) in hybrid napier cultivars at each harvest during the second year

Treatment	HI	H2	H3	H4	H5	Total
Cutting height						
5 cm	4.02	7.64	4.29	5.44	2.00	23.39
10 cm	4.38	8.07	4.75	5.81	2.48	25.49
15 cm	4.84	8.54	5.15	6.30	2.85	27.67
20 cm	5.25	8.92	5.57	6.70	3.28	29.72
LSD 5%	0.06	0.07	0.07	0.06	0.06	0.30
Cultivars						
CO-3	5.36	8.26	4.48	6.22	3.00	27.32
CO-4	5.60	9.20	6.92	7.83	3.74	33.28
Suguna	5.54	10.22	5.05	6.87	2.77	30.45
DHN-6	2.94	7.29	3.82	4.78	1.78	20.61
PTH	3.68	6.49	4.43	4.61	1.97	21.18
LSD 5%	0.07	0.08	0.07	0.07	0.06	0.15
5 cm						
CO-3	4.70	7.58	3.74	5.64	2.34	24.00
CO-4	4.89	8.49	6.18	7.06	2.93	29.55
Suguna	4.80	9.46	4.36	6.17	2.04	26.83
DHN-6	2.49	6.85	3.37	4.22	1.29	18.21
PTH	3.21	5.81	3.80	4.13	1.41	18.37
10 cm						
CO-3	5.20	8.04	4.26	5.92	2.81	26.23
CO-4	5.30	8.94	6.67	7.61	3.56	32.07
Suguna	5.30	9.98	4.78	6.59	2.58	29.23
DHN-6	2.72	7.16	3.70	4.58	1.64	19.81
PTH	3.39	6.23	4.34	4.36	1.79	20.11
15 cm						
CO-3	5.55	8.46	4.72	6.43	3.16	28.32
CO-4	5.88	9.45	7.22	8.08	4.02	34.65
Suguna	5.79	10.49	5.25	7.14	2.95	31.62
DHN-6	3.12	7.48	3.95	5.01	1.98	21.55
PTH	3.84	6.81	4.59	4.85	2.11	22.21
20 cm						
CO-3	5.99	8.97	5.20	6.91	3.68	30.74
CO-4	6.32	9.93	7.61	8.55	4.44	36.86
Suguna	6.28	10.94	5.80	7.59	3.50	34.11
DHN-6	3.41	7.67	4.24	5.32	2.22	22.86
PTH	4.26	7.10	4.98	5.10	2.58	24.02
LSD 5%	0.13	0.15	0.14	0.14	0.13	0.30

For the succeeding harvests, 'CO-4' recorded maximum yield. 'DHN-6' recorded the lowest yield both at the third and fifth harvests while 'PTH' recorded the least at the fourth harvest. The crop recorded minimum yield during the final harvest, where the highest yield recorded was 4.44 Mg/ha in 'CO-4' when harvested at 20 cm. 'CO-4' could produce only 2.93 Mg/ha at 5cm height. The lowest yield was recorded by 'DHN-6' where it could produce 2.22 Mg/ha at 20 cm and 1.29 Mg/ha at 5 cm height.

Considering the total dry fodder yield, 'CO-4' recorded the highest value followed by 'Suguna' and 'CO-3'. At all cutting heights, 'DHN-6' showed minimum dry fodder yield. 'CO-4' produced a maximum of 36.86 Mg/ha per year when harvested at 20 cm height, however, it could produce only 29.55 Mg/ha at 5 cm of cutting height. At 20 cm height, 'DHN-6' gave 22.86 Mg/ha of dry fodder. When harvested at 5 cm height, both 'DHN-6' and 'PTH' were at par and could produce only 18.21 Mg/ha and 18.37 Mg/ha.

4.3.5. Plant analysis

Plant samples from all the treatments were collected at third harvest for both years and used to estimate the five fractions of proximate analysis – crude protein, crude fibre, ether extract, total ash and nitrogen free extract of leaves and stems. Percentage content of nutrient elements such as nitrogen, potassium, phosphorous, calcium and magnesium of leaves and stems were estimated during both years.

Proximate analysis

Crude protein

Crude protein content of leaves and stems are given in Table 100, Table 101, Table 102 and Table 103. The crude protein content of leaves were more than stem content. Crude protein content in plant parts were not affected by the cutting height management but varied between the cultivars. In the first year, the content ranged between 11.90 per cent and 13.06 per cent in leaves whereas stem content of all the

Table 100. Effect of cutting height management on proximate analysis of hybrid napier leaves (%) during the first year

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Cutting height					
5 cm	12.53	26.96	2.19	50.18	8.15
10 cm	12.62	26.86	2.19	50.19	8.14
15 cm	12.62	26.75	2.21	50.18	8.25
20 cm	12.59	26.92	2.19	50.10	8.21
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO-3	13.06	26.37	2.30	49.44	8.83
CO-4	12.68	26.85	2.46	49.52	8.49
Suguna	12.95	26.47	2.30	49.66	8.62
DHN-6	11.90	26.11	2.32	51.96	7.71
PTH	12.35	28.56	1.60	50.22	7.27
LSD 5%	0.80	0.77	0.07	1.06	0.31
5 cm					
CO-3	13.15	26.70	2.29	49.14	8.72
CO-4	12.42	27.39	2.45	49.30	8.44
Suguna	12.79	26.35	2.29	49.90	8.67
DHN-6	11.75	25.85	2.30	52.49	7.61
PTH	12.52	28.50	1.62	50.05	7.31
10 cm					
CO-3	12.79	26.13	2.28	49.91	8.89
CO-4	12.77	26.43	2.44	49.83	8.52
Suguna	13.08	26.57	2.27	49.70	8.38
DHN-6	12.04	26.24	2.32	51.65	7.75
PTH	12.42	28.93	1.62	49.87	7.16
15 cm					
CO-3	13.52	26.24	2.32	49.09	8.83
CO-4	12.40	26.34	2.48	50.27	8.51
Suguna	13.15	26.34	2.31	49.50	8.71
DHN-6	12.04	26.38	2.33	51.50	7.75
PTH	12.00	28.42	1.63	50.52	7.43
20 cm					
CO-3	12.77	26.42	2.30	49.61	8.90
CO-4	13.15	27.22	2.46	48.69	8.48
Suguna	12.79	26.64	2.32	49.53	8.73
DHN-6	11.75	25.97	2.31	52.22	7.75
PTH	12.48	28.37	1.54	50.44	7.18
LSD 5%	NS	NS	NS	NS	NS

Table 101. Effect of cutting height management on proximate analysis of hybrid napier stems (%) during the first year

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Cutting height					
5 cm	7.40	33.48	1.29	50.62	7.21
10 cm	7.59	31.60	1.30	52.29	7.22
15 cm	7.31	29.92	1.31	54.13	7.34
20 cm	7.67	28.71	1.30	55.17	7.16
LSD 5%	NS	0.78	NS	1.09	NS
Cultivars					
CO-3	7.57	30.48	1.32	52.72	7.91
CO-4	7.40	30.59	1.32	52.80	7.89
Suguna	7.58	31.68	1.23	51.73	7.78
DHN-6	7.21	29.98	1.41	55.23	6.18
PTH	7.69	31.91	1.22	52.78	6.40
LSD 5%	NS	0.87	0.05	1.22	0.40
5 cm					
CO-3	7.29	32.65	1.29	50.73	8.04
CO-4	7.67	33.42	1.31	49.71	7.90
Suguna	7.67	35.07	1.23	48.23	7.81
DHN-6	6.94	32.35	1.41	53.24	6.06
PTH	7.42	33.93	1.19	51.21	6.26
10 cm					
CO-3	7.67	31.95	1.33	51.22	7.83
CO-4	6.94	30.75	1.33	53.20	7.79
Suguna	7.67	32.35	1.23	50.94	7.81
DHN-6	7.67	30.38	1.40	54.21	6.33
PTH	8.02	32.55	1.23	51.85	6.35
15 cm					
CO-3	7.31	29.41	1.32	54.01	7.95
CO-4	7.31	29.03	1.33	54.43	7.89
Suguna	7.31	30.57	1.22	53.03	7.87
DHN-6	6.94	29.20	1.41	56.23	6.22
PTH	7.67	31.38	1.24	52.96	6.75
20 cm					
CO-3	8.02	27.90	1.32	54.92	7.83
CO-4	7.67	29.15	1.32	53.87	8.00
Suguna	7.67	28.75	1.23	54.73	7.62
DHN-6	7.31	27.97	1.40	57.23	6.09
PTH	7.67	29.78	1.20	55.11	6.24
LSD 5%	NS	1.75	NS	2.44	NS

Table 102 . Effect of cutting height management on proximate analysis of hybrid napier leaves (%) during the second year

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Cutting height					
5 cm	12.34	27.28	2.19	49.78	8.41
10 cm	12.48	26.94	2.19	50.04	8.35
15 cm	12.70	26.64	2.19	49.94	8.52
20 cm	12.48	26.80	2.19	50.15	8.39
LSD 5%	NS	NS	NS	NS	NS
Cultivars					
CO-3	12.78	26.46	2.31	49.56	8.90
CO-4	12.59	27.25	2.46	48.94	8.75
Suguna	12.68	26.78	2.25	49.32	8.97
DHN-6	12.14	25.99	2.30	51.59	7.98
PTH	12.32	28.10	1.62	50.47	7.50
LSD 5%	NS	0.91	0.06	1.57	0.34
5 cm					
CO-3	13.15	27.12	2.29	48.56	8.88
CO-4	12.04	27.39	2.46	49.37	8.75
Suguna	12.77	27.10	2.25	48.95	8.92
DHN-6	11.69	26.13	2.31	51.80	8.07
PTH	12.04	28.67	1.62	50.22	7.45
10 cm					
CO-3	12.42	26.32	2.32	50.04	8.90
CO-4	12.77	27.25	2.47	48.79	8.72
Suguna	12.77	27.03	2.24	49.02	8.93
DHN-6	12.40	26.30	2.30	51.16	7.84
PTH	12.04	27.80	1.61	51.17	7.37
15 cm					
CO-3	13.15	26.02	2.32	49.60	8.92
CO-4	12.77	27.30	2.46	48.70	8.76
Suguna	12.77	26.49	2.26	49.32	9.17
DHN-6	12.42	25.63	2.29	51.61	8.06
PTH	12.42	27.78	1.62	50.49	7.69
20 cm					
CO-3	12.40	26.37	2.31	50.04	8.88
CO-4	12.77	27.08	2.47	48.91	8.77
Suguna	12.42	26.48	2.25	50.00	8.85
DHN-6	12.04	25.91	2.29	51.80	7.96
PTH	12.77	28.15	1.62	49.98	7.49
LSD 5%	NS	NS	NS	NS	NS

Table 103. Effect of cutting height management on proximate analysis of hybrid napier stems (%) during the second year

Treatment	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
Cutting height					
5 cm	7.74	33.82	1.30	49.39	7.75
10 cm	7.96	31.96	1.30	51.03	7.75
15 cm	8.04	30.08	1.30	52.88	7.71
20 cm	7.89	29.04	1.30	54.00	7.77
LSD 5%	NS	0.63	NS	0.93	NS
Cultivars					
CO-3	8.30	31.04	1.30	50.79	8.57
CO-4	7.85	31.06	1.33	51.24	8.53
Suguna	7.86	32.12	1.25	50.15	8.62
DHN-6	7.58	29.56	1.41	54.85	6.61
PTH	7.94	32.35	1.23	52.09	6.39
LSD 5%	0.61	0.71	0.04	1.04	0.14
5 cm					
CO-3	8.02	33.07	1.30	49.04	8.57
CO-4	8.04	33.95	1.33	48.19	8.49
Suguna	7.31	35.10	1.22	47.76	8.60
DHN-6	7.31	32.23	1.42	52.36	6.67
PTH	8.02	34.77	1.22	49.61	6.39
10 cm					
CO-3	8.40	32.37	1.29	49.37	8.58
CO-4	7.67	30.92	1.33	51.60	8.49
Suguna	8.04	33.07	1.25	49.02	8.62
DHN-6	7.67	30.74	1.42	53.54	6.63
PTH	8.04	32.70	1.23	51.61	6.42
15 cm					
CO-3	8.40	29.84	1.29	51.94	8.53
CO-4	8.40	30.05	1.33	51.74	8.49
Suguna	8.04	31.37	1.25	50.65	8.68
DHN-6	7.31	27.44	1.38	57.42	6.45
PTH	8.04	31.72	1.24	52.63	6.38
20 cm					
CO-3	8.40	28.90	1.29	52.81	8.59
CO-4	7.31	29.32	1.32	53.43	8.63
Suguna	8.04	28.93	1.26	53.17	8.59
DHN-6	8.04	27.82	1.40	56.08	6.66
PTH	7.67	30.22	1.23	54.52	6.37
LSD 5%	NS	1.41	NS	2.07	NS

cultivars were comparable. In the second year also, all cultivars had comparable crude protein content in both leaves and stems.

Crude fibre

Crude fibre content of leaves and stems are presented in Table 100, Table 101, Table 102 and Table 103. Crude fibre content of stems increased with decreasing the cutting height and the maximum was recorded in cultivars when harvested at 5 cm height. The content also varied between the cultivars.

During the first year, in leaves, 'PTH' had the highest content of crude fibre. Interaction was absent. With respect to stem content, the values decreased from 35.07 per cent at 5 cm of cutting height to 27.90 per cent at 20 cm of cutting height. In the second year, 'PTH' and 'CO-4' had the highest content in leaves and for the stems the content ranged between 27.82 per cent at 20 cm of cutting height for 'DHN-6' to 35.10 per cent at 5 cm of cutting height for 'Suguna'.

Ether extract

The data pertaining to crude fat content are present as ether extract in Table 100, Table 101, Table 102 and Table 103. There were no effects of cutting height management on fat content but the content varied between the cultivars. During both years, 'CO-4' had the highest content of crude fat in leaves while in stems, 'DHN-6' recorded the highest content.

Total ash

Total ash content of hybrid napier leaves and stems are presented in Table 100, Table 101, Table 102 and Table 103. There was no significant effect of cutting height management on ash content of leaves and stems but the content varied between the cultivars. Leaves recorded higher content of ash compared to stems. During both years, the cultivars 'CO-3', CO-4' and 'Suguna' had comparable ash content in leaves and stems, and recorded the highest content, while 'PTH' had the least content of ash.

Nitrogen free extract

Nitrogen free extract of hybrid napier cultivars are given in Table 100, Table 101, Table 102 and Table 103. NFE varied between the cultivars. Cutting height management had significant effect on NFE of stems where the content increased with increasing cutting height. During the first year, in leaves, 'Suguna' recorded maximum content, whereas in stems, 'DHN-6' had the highest content. In stems, the content ranged from 48.23 per cent to 57.23 per cent when cutting height was increased from 5 cm to 20 cm.

In the second year, 'DHN-6' and 'PTH' had comparable amount of NFE in leaves and recorded the highest content. NFE of stems were found to be higher in 'DHN-6'. The content ranged from 47.76 per cent at 5 cm of cutting height to 56.08 per cent at 20 cm of cutting height.

Percentage content of nutrient elements

Percentage content of nutrient elements such as N, P, K, Ca and Mg are presented in Table 104, Table 105 and Table 106. In general, the leaves had higher content of nutrients compared to the stems. The content varied between the cultivars while cutting height management showed no significant effects on nutrient content of leaves and stems.

Nitrogen

In the first year, nitrogen content in leaves of cultivars 'CO-3', 'CO-4' and 'Suguna' were comparable with each other showing maximum content, while in the second year, all the cultivars were at par. Nitrogen content of stems were also comparable in all cultivars. Interactions were absent.

Phosphorous

During both years, phosphorous content of leaves varied between the cultivars. 'PTH', 'Suguna' and 'CO-3' were at par and had the highest content of

Table 104. Effect of cutting height management on primary nutrient content (%) of hybrid napier leaves

Treatment	Nitrogen		Phosphorous		Potassium	
	First year	Second year	First year	Second year	First year	Second year
Cutting height						
5 cm	2.00	1.97	0.194	0.193	2.15	1.73
10 cm	2.02	2.00	0.193	0.192	2.15	1.74
15 cm	2.02	2.03	0.195	0.195	2.13	1.73
20 cm	2.01	2.00	0.194	0.192	2.14	1.75
LSD 5%	NS	NS	NS	NS	NS	NS
Cultivars						
CO-3	2.09	2.04	0.194	0.194	2.28	1.85
CO-4	2.03	2.01	0.189	0.188	2.24	1.77
Suguna	2.07	2.03	0.197	0.195	2.15	1.68
DHN-6	1.90	1.94	0.184	0.184	1.90	1.70
PTH	1.98	1.97	0.205	0.203	2.15	1.69
LSD 5%	0.13	NS	0.012	0.012	0.04	0.12
5 cm						
CO-3	2.10	2.10	0.195	0.195	2.30	1.87
CO-4	1.99	1.93	0.188	0.189	2.26	1.77
Suguna	2.05	2.04	0.196	0.194	2.15	1.69
DHN-6	1.88	1.87	0.184	0.182	1.89	1.67
PTH	2.00	1.93	0.205	0.203	2.16	1.67
10 cm						
CO-3	2.05	1.99	0.195	0.193	2.27	1.89
CO-4	2.04	2.04	0.188	0.187	2.24	1.75
Suguna	2.09	2.04	0.193	0.192	2.16	1.65
DHN-6	1.93	1.98	0.185	0.183	1.91	1.72
PTH	1.99	1.93	0.204	0.202	2.15	1.69
15 cm						
CO-3	2.16	2.10	0.194	0.196	2.28	1.83
CO-4	1.98	2.04	0.189	0.190	2.20	1.77
Suguna	2.10	2.04	0.203	0.200	2.13	1.68
DHN-6	1.93	1.99	0.182	0.182	1.89	1.68
PTH	1.92	1.99	0.205	0.205	2.15	1.68
20 cm						
CO-3	2.04	1.98	0.192	0.193	2.26	1.83
CO-4	2.10	2.04	0.191	0.186	2.26	1.78
Suguna	2.05	1.99	0.195	0.192	2.15	1.71
DHN-6	1.88	1.93	0.187	0.189	1.91	1.70
PTH	2.00	2.04	0.205	0.203	2.14	1.73
LSD 5%	NS	NS	NS	NS	NS	NS

Table 105. Effect of cutting height management on primary nutrient content (%) of hybrid napier stems

Treatment	Nitrogen		Phosphorous		Potassium	
	First year	Second year	First year	Second year	First year	Second year
Cutting height						
5 cm	1.18	1.24	0.158	0.158	1.77	1.55
10 cm	1.22	1.27	0.157	0.159	1.77	1.55
15 cm	1.17	1.29	0.158	0.159	1.79	1.55
20 cm	1.23	1.26	0.157	0.158	1.78	1.56
LSD 5%	NS	NS	NS	NS	NS	NS
Cultivars						
CO-3	1.21	1.33	0.154	0.156	1.90	1.61
CO-4	1.18	1.26	0.155	0.157	1.87	1.58
Suguna	1.21	1.26	0.158	0.159	1.84	1.53
DHN-6	1.15	1.21	0.158	0.157	1.45	1.50
PTH	1.23	1.27	0.162	0.164	1.84	1.54
LSD 5%	NS	0.10	NS	NS	0.04	0.06
5 cm						
CO-3	1.17	1.28	0.154	0.154	1.88	1.59
CO-4	1.23	1.29	0.156	0.156	1.86	1.58
Suguna	1.23	1.17	0.158	0.159	1.84	1.52
DHN-6	1.11	1.17	0.158	0.157	1.44	1.50
PTH	1.19	1.28	0.163	0.165	1.83	1.54
10 cm						
CO-3	1.23	1.34	0.155	0.158	1.89	1.61
CO-4	1.11	1.23	0.155	0.157	1.89	1.57
Suguna	1.23	1.29	0.157	0.160	1.81	1.52
DHN-6	1.23	1.23	0.157	0.157	1.46	1.51
PTH	1.28	1.29	0.162	0.163	1.81	1.54
15 cm						
CO-3	1.17	1.34	0.154	0.157	1.91	1.60
CO-4	1.17	1.34	0.156	0.156	1.86	1.58
Suguna	1.17	1.29	0.159	0.161	1.86	1.53
DHN-6	1.11	1.17	0.158	0.157	1.45	1.50
PTH	1.23	1.29	0.162	0.164	1.85	1.54
20 cm						
CO-3	1.28	1.34	0.154	0.156	1.90	1.62
CO-4	1.23	1.17	0.155	0.157	1.86	1.58
Suguna	1.23	1.29	0.157	0.158	1.84	1.54
DHN-6	1.17	1.29	0.158	0.157	1.44	1.51
PTH	1.23	1.23	0.162	0.162	1.84	1.54
LSD 5%	NS	NS	NS	NS	NS	NS

Table 106. Effect of cutting height management on secondary nutrient content (%) of hybrid napier leaves and stems

Treatment	Ca leaves		Ca stems		Mg leaves		Mg stems	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
Cutting height								
5 cm	0.266	0.330	0.222	0.299	0.333	0.323	0.310	0.309
10 cm	0.265	0.330	0.221	0.296	0.334	0.322	0.311	0.309
15 cm	0.264	0.328	0.220	0.298	0.331	0.324	0.310	0.309
20 cm	0.265	0.326	0.221	0.296	0.334	0.321	0.311	0.310
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars								
CO-3	0.290	0.372	0.247	0.356	0.334	0.327	0.310	0.310
CO-4	0.311	0.428	0.265	0.388	0.341	0.337	0.315	0.316
Suguna	0.278	0.375	0.234	0.340	0.333	0.318	0.311	0.310
DHN-6	0.253	0.255	0.209	0.222	0.330	0.320	0.308	0.306
PTH	0.194	0.214	0.150	0.180	0.328	0.313	0.309	0.305
LSD 5%	0.015	0.022	0.016	0.025	0.010	0.012	0.010	0.007
5 cm								
CO-3	0.289	0.373	0.252	0.354	0.333	0.327	0.310	0.310
CO-4	0.315	0.430	0.265	0.390	0.343	0.337	0.313	0.317
Suguna	0.278	0.379	0.234	0.343	0.330	0.320	0.310	0.310
DHN-6	0.253	0.256	0.209	0.222	0.333	0.323	0.307	0.307
PTH	0.194	0.215	0.150	0.184	0.327	0.310	0.310	0.303
10 cm								
CO-3	0.293	0.373	0.249	0.351	0.337	0.327	0.310	0.313
CO-4	0.308	0.427	0.263	0.388	0.343	0.333	0.317	0.317
Suguna	0.278	0.379	0.234	0.338	0.337	0.320	0.313	0.307
DHN-6	0.252	0.256	0.208	0.226	0.327	0.317	0.310	0.303
PTH	0.195	0.214	0.151	0.176	0.327	0.313	0.307	0.303
15 cm								
CO-3	0.288	0.370	0.241	0.360	0.330	0.330	0.307	0.307
CO-4	0.311	0.429	0.266	0.388	0.340	0.340	0.320	0.313
Suguna	0.277	0.373	0.234	0.340	0.330	0.317	0.307	0.310
DHN-6	0.254	0.253	0.211	0.222	0.327	0.320	0.307	0.310
PTH	0.190	0.214	0.148	0.181	0.327	0.313	0.310	0.307
20 cm								
CO-3	0.289	0.370	0.246	0.360	0.337	0.323	0.313	0.310
CO-4	0.309	0.425	0.266	0.385	0.337	0.337	0.310	0.317
Suguna	0.279	0.369	0.234	0.338	0.333	0.313	0.313	0.313
DHN-6	0.251	0.255	0.208	0.220	0.333	0.320	0.310	0.303
PTH	0.195	0.213	0.150	0.178	0.330	0.313	0.308	0.307
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS

phosphorous. There were no significant differences between the cultivars with respect to P content in stems. Interaction effects were also absent.

Potassium

Potassium content of leaves were higher than the stem content. The highest content was recorded during the first year compared to the second year. There was no influence of cutting height management on K content of plant parts but content varied between the cultivars. The cultivars 'CO-3' and 'CO-4' had the highest content in both leaves and stems.

Calcium and Magnesium

Calcium and magnesium content of leaves were higher than stems. There were no effect of cutting height management on Ca and Mg content while significant effects of cultivars were noticed. Interaction effect was absent.

Among the cultivars, 'CO-4' recorded the highest Ca content during both years in leaves and stems while 'PTH' had the lowest content. The highest Ca content was recorded in the second year (0.428 per cent in leaves and 0.388 per cent in stems of 'CO-4').

Magnesium content of leaves varied between the cultivars; while in stems, the contents were comparable among cultivars. During both years, Mg content in leaves of 'CO-3' and 'CO-4' were at par and recorded the highest content. However, in the first year, Mg content in leaves of 'CO-3', 'CO-4' and 'Suguna' were comparable with each other.

Discussion

5. DISCUSSION

Field experiments were conducted over a period of two years during 2013-2014 and 2014-2015 at the Agronomy Research Farm of Kerala Agricultural University, Vellanikkara to assess the feasibility of introducing hybrid napier cultivars under tree crop based farming system and to find out optimum nitrogen levels and harvesting management practices suitable for rainfed conditions. Six popular cultivars of hybrid napier (CO-3, CO-4, Suguna, IGFRI-3, DHN-6, and PTH) were included in the study and the cultivars were differentiated based on various characters. The experiments were done under three heads; (1) Shade tolerance of hybrid napier cultivars; (2) Nitrogen nutrition and cutting frequency in hybrid napier grown under rainfed condition; and (3) Cutting height management in hybrid napier grown under rainfed condition. The results obtained from three different experiments are discussed based on available literature.

5.1. EXPERIMENT I: SHADE TOLERANCE OF HYBRID NAPIER CULTIVARS

The planting was done on 03-07-2013 using rooted slips and the plants established well. The growth was rather slow during the initial periods and later the growth was fast. After the cessation of rainfall, the crop growth rate was slow during the summer periods. However, none of the cultivars dried out and clump mortality was not observed in any of the cultivars. This means that the six cultivars included in the study are well suited for rainfed cultivation in the humid tropics. The first harvesting was done at 75 days after planting and in total there were nine harvests over a period of two years (four in the first year and five in the second year).

Shading had significant effect on morpho-physiological and yield response of hybrid napier cultivars and the performance of cultivars varied under different shade levels. In both years, increasing shade levels had a facilitating effect on plant height, leaf length, leaf width, leaf area index, leaf area ratio, leaf weight ratio, leaf-stem ratio, chlorophyll content, and light/PAR interception. However, number of tillers, number of leaves, specific leaf weight, and fodder yield were significantly reduced under shade.

5.1.1. Morpho- physiological responses

Morphological and physiological acclimatization to shade is common for all plants but the extent of changes varies with plant species and genotype (Pierson *et al.*, 1990). In the present experiment, the plants showed maximum plant height, leaf length, and leaf width under 50 per cent shade. As shading stimulates the synthesis of auxin and gibberellins, plants show shade avoidance syndromes such as increased plant height and etiolated leaves, because these hormones promotes cell division, cell elongation, apical dominance, and inter nodal elongation (Keuskamp *et al.*, 2010).

In the present experiment, plants showed an increase in plant height of 10-15cm for every 25 per cent increase in shade level (Table 2 and Table 3). Among the cultivars, 'Suguna' attained maximum plant height. Seasonal variation in plant height was also observed. During the first year, plants showed maximum height during the first harvest (Table 2 and Fig.5), because of the initially allowable establishment time for growth till the time of the first harvest. Moreover, there was enough soil moisture along with intermitted rainfall and sunshine, which are conducive for growth of hybrid napier (Pandey and Roy, 2011). The plants showed decrease in height towards the later part of the experiment due to cessation of rainfall and moisture stress. On receipt of summer showers, plant growth was recuperated, and in the second year, maximum height was attained for the second and the fourth harvest due to the receipt of higher amounts of rainfall during their regrowth period.

Leaf length and leaf width decide the leaf size of the plant, and leaf size is an indication of the photosynthetic area of plants, which is determined by the number and size of cells of which the leaf is built and influenced by light, moisture regime, and supply of nutrients (Arnon, 1975). Maximum leaf length and width were attained during the sixth harvest (second harvest in the second year) which

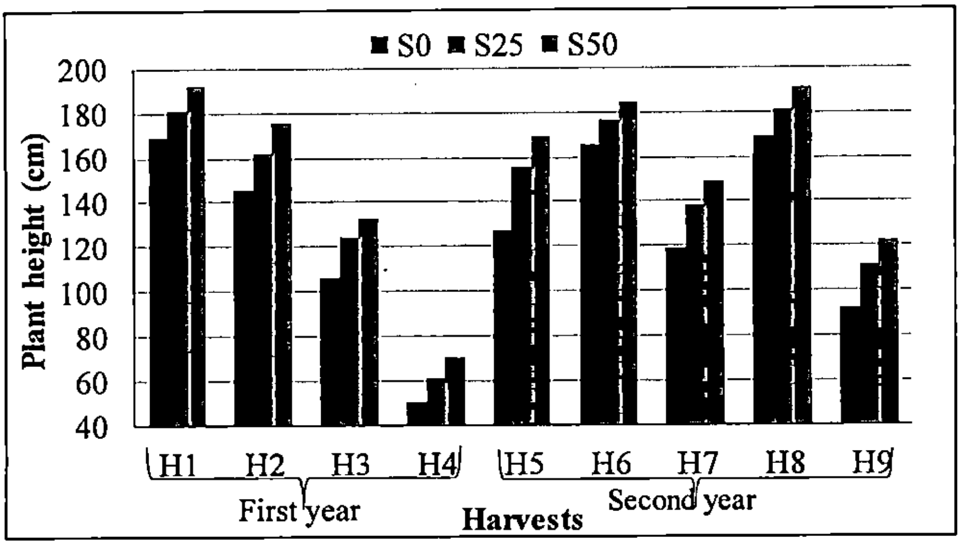

Fig. 5. Effect of shade on plant height of hybrid napier at each harvest

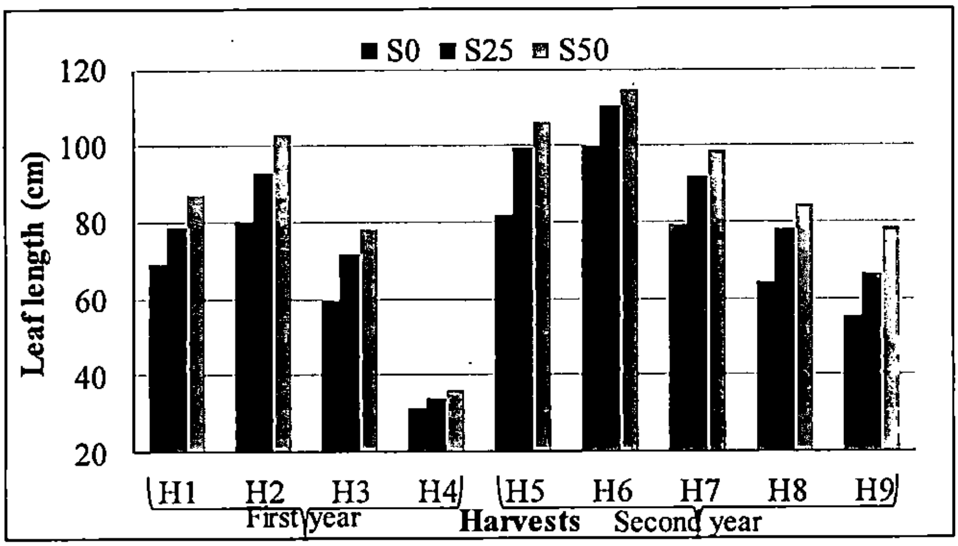

Fig. 6. Effect of shade on leaf length of hybrid napier at each harvest

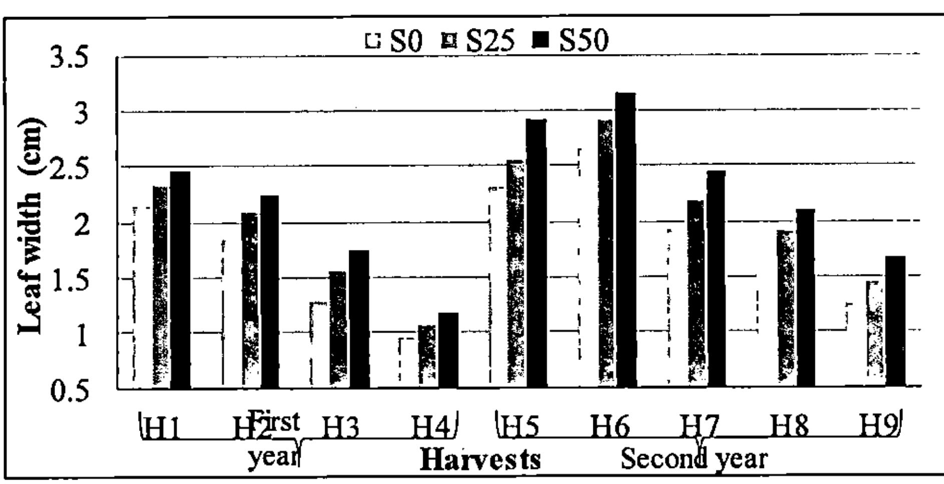

Fig. 7. Effect of shade on leaf width of hybrid napier at each harvest

was the peak stage of growth for plants due to the receipt of enough rainfall (Fig. 6 and Fig. 7).

For every 25 per cent increase in shade level, plants showed an increase in leaf length of 10-20 cm. Over the two years, maximum leaf length was shown by 'Suguna' followed by 'CO-3' and 'DHN-6', which were on par. According to Reynolds (1995), reduced light diminishes the capacity of plants to accumulate carbohydrates, and plants try to adjust to low light levels through various mechanisms such as reduced rate of respiration and increased leaf area. These changes improve the competitive ability of plants and thus help to reduce the respiratory load. As given in Table 4 and Table 5, in general, under 50 per cent shade, 'Suguna' had the highest mean leaf length. When leaf width s considered (Table 6 and Table 7), it showed the average increase in the range of 0.15-0.25 cm for every 25 per cent increase in shade level. Over the two years, the cultivar 'DHN-6' exhibited maximum leaf width.

The complex phenomenon of tillering in grasses is the mixture of the genetic, physiological and environmental factors (Assuero and Tognetti, 2010). During the initial stage of plant growth, tiller production was less and a gradual increase in number of tillers was observed towards the final harvests (Fig. 8, Table 8 and Table 9). However, after the final harvest of the first year, tiller decline was noticed, until the first harvest of the second year due to dearth of soil moisture during summer periods. It is well known that moisture availability and defoliation stimulate the axillary buds (Busso *et al.*, 1989). The tillers produced during the periods of adequate rainfall were robust and produced after the cessation of rain were very lean and weak.

The results indicate that increasing shade levels had a negative effect on tiller production and the rate of tillering varied among the cultivars (Table 8 and Table 9). In the present experiment, the relative percentage reduction in number of tillers was 10 for every 25 per cent increase in shade level (Fig.19). Gautier *et al.* (1999) observed that shading reduced tillering by delaying the development of tiller buds into tillers. In general, among the cultivars, the highest number of tillers was

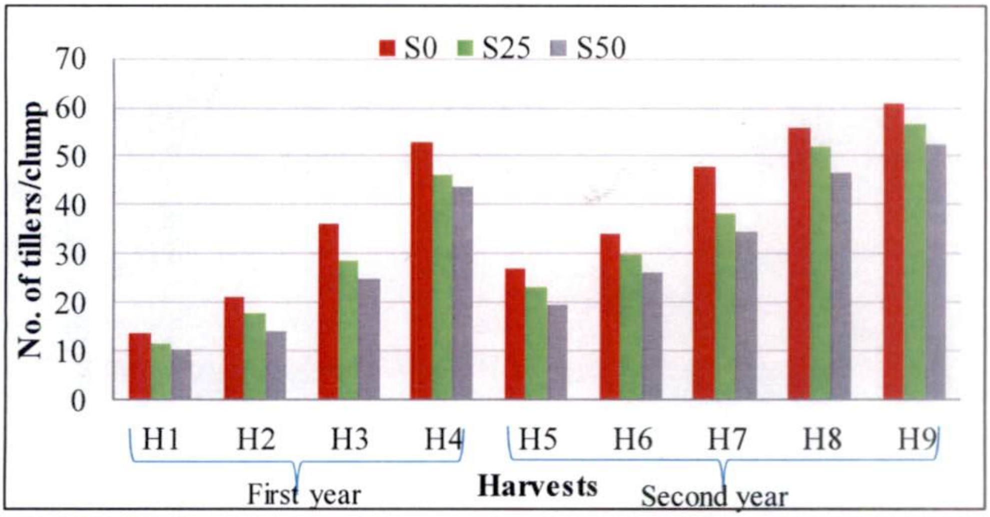

Fig. 8. Effect of shade on tiller production of hybrid napier at each harvest

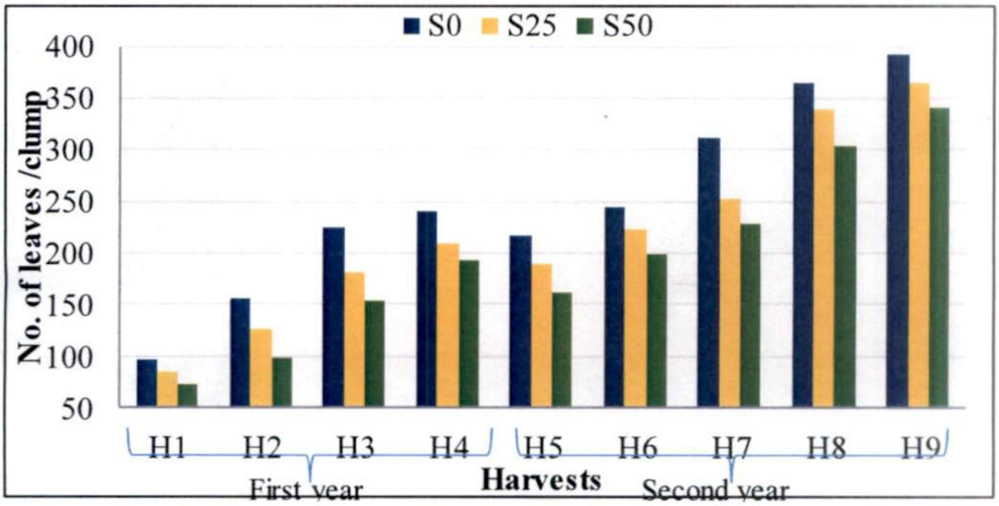

Fig. 9. Effect of shade on leaf production of hybrid napier at each harvest

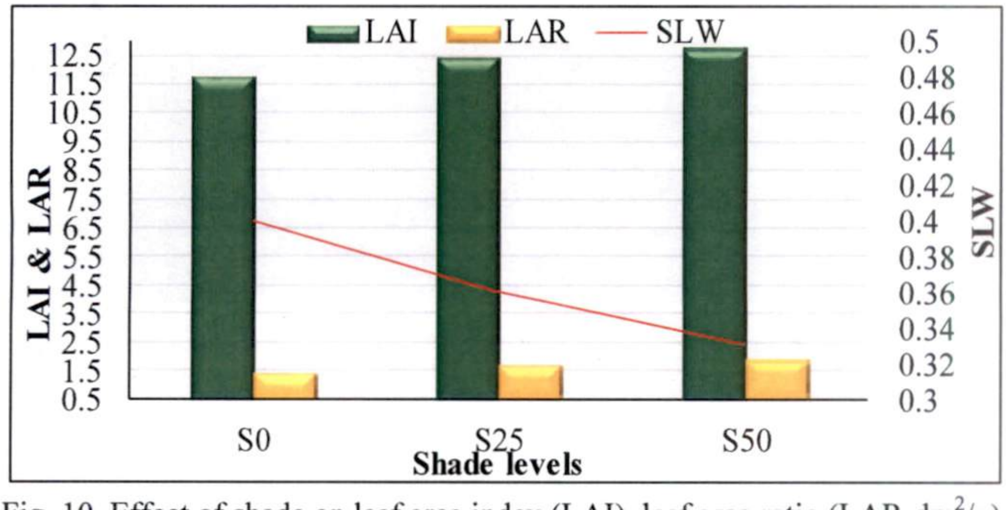

Fig. 10. Effect of shade on leaf area index (LAI), leaf area ratio (LAR-dm^2/g) and specific leaf weight (SLW-g/dm^2) of hybrid napier at sixth harvest

observed in 'PTH' followed by 'IGFRI-3' under all levels of shade and the lowest number was recorded in 'DHN-6'.

The rate of leaf production depends on the number of tillers produced, and hence, the number of leaves produced followed the same trend as that of tiller number (Table 10 and Table 11). The maximum number of leaves was produced under full sunlight compared to shaded conditions (Fig.9). According to Gautier *et al.* (1999), shading delayed phyllochron in plants, which in turn, decreased the rate of leaf development. Relative percentage reduction in number of leaves was 10 for every 25 per cent increase in shade level (Fig.19). Over a period of two years, number of leaves was higher for 'PTH', followed by 'IGFRI3' because of the profuse tillering ability these cultivars.

The data pertaining to leaf area index are given in Table 12 and Table 13. Leaf area index (LAI) showed an increasing trend with increasing shade levels. Therefore, throughout the experiment, maximum LAI was recorded under 50 per cent shade. Over the two years, the highest LAI values were recorded in the second and sixth harvests. The luxurious plant growth and more number of tillers produced as a result of availability of sufficient moisture and nitrogen nutrition resulted in maximum LAI during the second harvests.

Shading had significant effect on LAI. Even though the maximum leaf production was noticed in plants grown under full sunlight, the LAI produced was maximum under 50 per cent shade which can be attributed to the elongated leaf growth under increasing shade levels. Yet another reason is that leaf grown under shade had lower specific leaf weight (Table 18 and Table 19) which means a higher specific leaf area (Fig. 10).

Among the cultivars, 'Suguna' showed maximum LAI because of the ability of the cultivar to produce more number of elongated and expanded leaves. The cultivar 'CO-3', 'CO-4' and 'IGFRI-3' had almost comparable LAI with 'Suguna'. The lowest LAI was observed in 'PTH' as the leaves were short and narrow with less SLA.

Leaf area ratio of hybrid napier cultivars at each harvest are presented in Table 14 and Table 15. Plants showed an increase in leaf area ratio (LAR) with increasing shade levels and the highest LAR was observed in cultivars when grown under 50 per cent shade. The increase in LAI and decrease in SLW caused an increase in LAR with increasing shade levels (Fig.10). As Nagasuga (2005) stated Napier grass when grown under shade, allocates more assimilates to the leaves, and hence it could attain higher leaf area and leaf area ratio under reduced light.

In some harvests, the LAR was lower for certain cultivars even though they had higher LAI. This could be attributed to the high plant dry matter yield causing a proportionate reduction in LAR. The cultivar 'PTH' showed the lowest LAR mainly because of the decreased LAI.

The specific leaf weight (SLW) values of the cultivars were negatively affected with increasing shade (Table 18 and Table 19). Under reduced light, plants invest less for specific leaf weight (inverse of specific leaf area), and leaves are much longer and thinner under reduced light (Kephart and Buxton, 1996; Lin *et al*., 2001). Therefore, specific leaf area would be much higher causing an overall increase in leaf area under shaded situations with much lesser SLW (Pierson *et al*., 1990).

The leaf weight ratio (LWR) (Table 16 and Table 17) and leaf –stem ratio (Table 20 and Table 21) in hybrid napier increased with increasing shade levels (Fig.11). Both ratios increased towards the final harvest because the proportion of stem accumulation was reduced with decreasing soil moisture. Forages when grown under shade maintain a higher leaf – stem ratio and LWR by reducing stem growth (Singh, 1994) as shading reduce biomass allocation to stems (Cruz, 1997). In general, among the cultivars, 'Suguna' and CO-3' had higher ratios while 'PTH' had the least. This is due to high proportion of leaf dry matter accumulation in 'Suguna' and 'CO-3' compared to 'PTH' and other cultivars.

Shading had significant facilitating effects on the content of total chlorophyll, chlorophyll a, chlorophyll b and chlorophyll b/a ratio (Fig. 12 and Table 22). Chlorophyll a, chlorophyll b and total chlorophyll were higher under

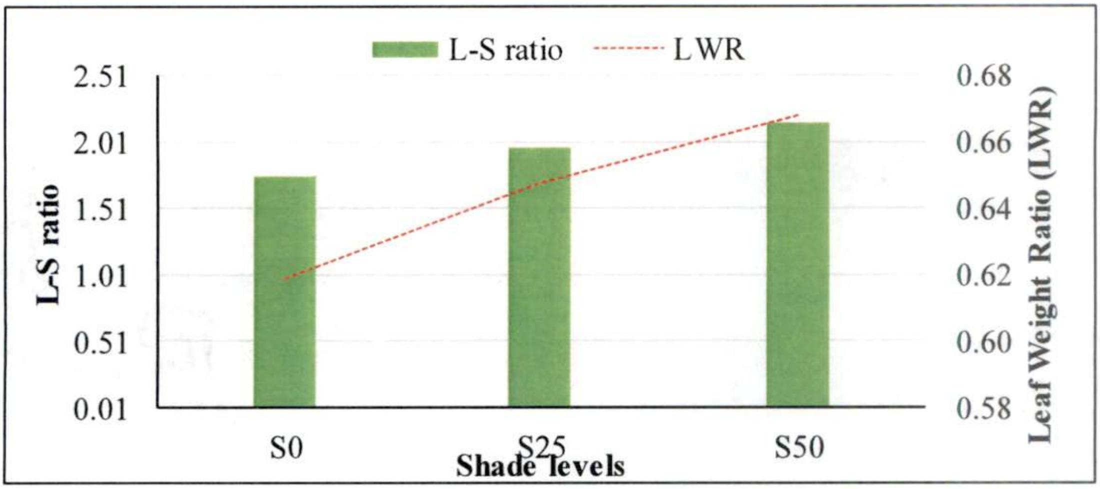

Fig. 11. Effect of shade on mean leaf –stem ratio and LWR of hybrid napier

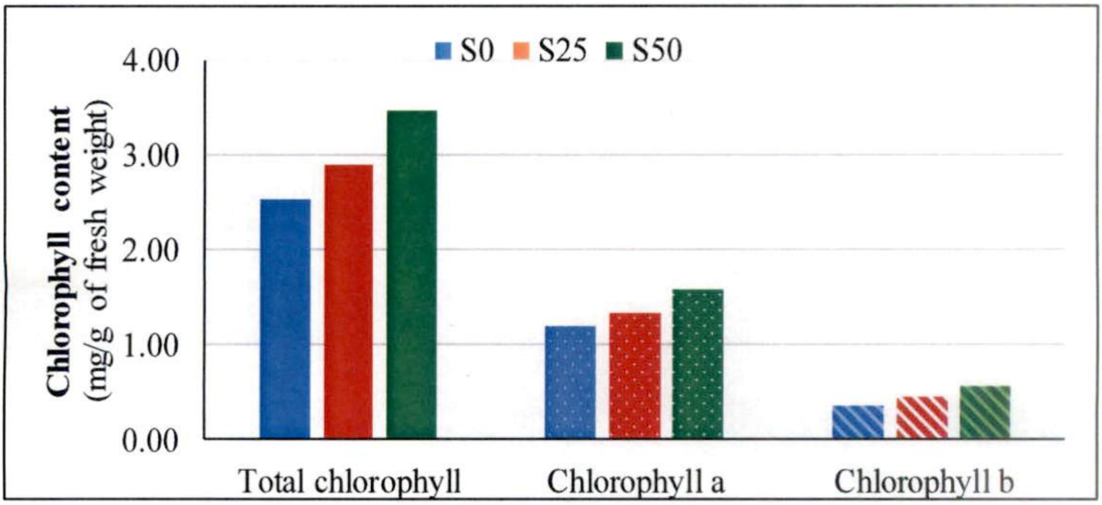

Fig. 12. Effect of shade on chlorophyll content of hybrid napier

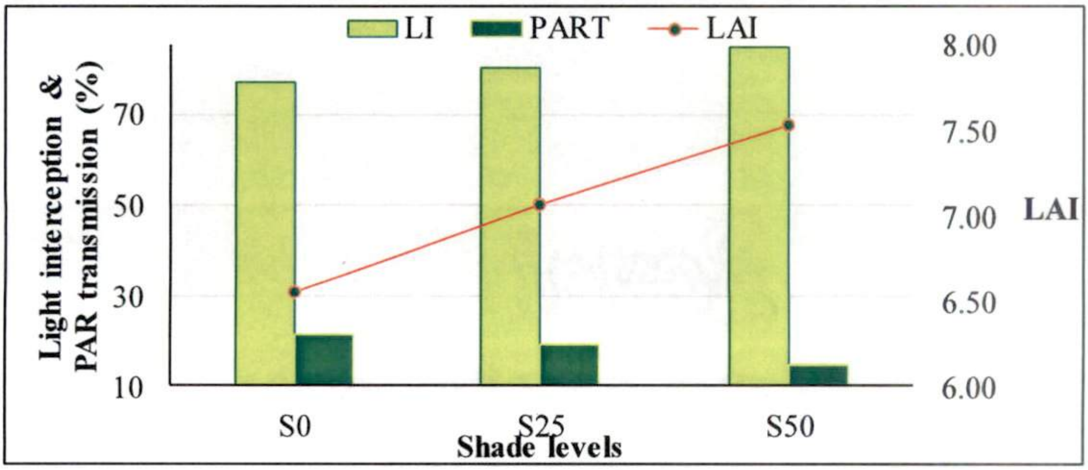

Fig. 13. Relationship between leaf area index (LAI), light interception (LI) and PAR transmission (PART) at varying shade levels in hybrid napier canopy

50 per cent shade. There were significant differences in chlorophyll content between the cultivars also. Acclimatization response occurs among genetically uniform plants grown at different light intensities. Chlorophyll b/a ratio would be lower in foliage of canopy more exposed to light as compared to shaded foliage layers (Baig *et al.*, 2005). In general, among the cultivars, 'DHN-6' had the highest content and 'CO-4' the least.

Increasing chlorophyll content with decreasing light availability in fodder grasses (Mullakoya, 1982) is an adaptive mechanism of plants to maintain photosynthetic efficiency (Attridge, 1990). Therefore, shade tolerance in forage species is allied with high content of chlorophyll per chloroplast (Evans and Seemann, 1996). Moreover, shaded plants have more spongy tissues and the chloroplast in spongy tissue have large grana; hence, the photosynthetic pigments are more concentrated in chloroplast of spongy tissues causing an increase in total chlorophyll content (Terashima and Hikosaka, 1995). As reduced light induces more production of chlorophyll b molecules, a higher chlorophyll b to chlorophyll a ratio is obtained under shaded condition (Misra and Misra, 1997; Evans and Poorter, 2001). Increased chlorophyll b content helps the plants to harvest more light under shade by facilitating more production of PSII reaction centers, thereby reducing the synthesis of ATP syntetase and conserving the energy spend for ATP synthesis (Anderson, 1986).

5.1.2. Light regime within plants

The data on light interception, PAR interception and PAR transmission are presented in Table 23. Light interception and PAR interception increased with increasing shade levels while PAR transmission reduced under varying shade levels. Light interception and PAR transmission to the lower layers depend on the leaf area index of plant canopy. Increasing LAI with increasing shade levels increased the light and PAR interception. However, it reduced the PAR transmission to the lower layers (Fig.13). Hence, maximum light interception occurs at high LAI but it can reduce the PAR transmission to lower leaves (Lunagaria and Shekh, 2006). According to Candido *et al.* (2005a), at the earlier stage of fodder grass development, each increment in leaf area is an indication of the substantial increment in PAR interception. The light penetration through the plant canopy of napier reduces asymptotically as a function of LAI (Andrade *et al.*, 2005). Considering the cultivars over a period of two years, the cultivars, 'Suguna', 'CO-3' and 'CO-4' had maximum light and PAR interception due to their higher LAI.

The decreasing PAR availability under increasing shade levels has detrimental effect on bajra, napier, and their hybrids as they have C_4 photosynthetic path way. Bellasio and Griffiths (2014) stated that C_4 plants have a biochemical carbon concentrating mechanism that increases the CO_2 concentration around Rubisco in the bundle sheath, where CO_2 assimilation takes place. In reduced light environment, this mechanism seems to be negatively affected reducing the photosynthetic efficiency of plants, finality reducing plant growth.

5.1.3. Fodder production

The data on fresh and dry fodder yield are presented in (Table 24, 25, 26 and 27). There were four harvests during the first year and five during the second year. The highest yield was recorded during the first harvest for the first year and the second harvest during the second year, which coincided with the periods of south west monsoons. Later on, declining trend was noticed towards the final harvest. A slight increase in yield was noticed in the eighth harvest (fourth harvest of second year) than the previous harvest due to the receipt of rainfall, during the period. The highest fodder yield was recorded during the second year as the crop attained maximum number of tillers and leaves by the second harvest (Fig.15).

Fodder yield was significantly reduced under shade (Fig.14 and Table 24, 25, 26 and 27). As suggested by Senevirathna *et al.* (2003), reduction in solar radiation negatively affects photosynthetic productivity and carbohydrates assimilation. Negative effects of shade on fodder yield of hybrid napier under coconut was reported by Pandey *et al.* (2011). Among the cultivars, 'Suguna' was superior in fodder yield in both years of study closely followed by CO-3 and the least by 'PTH'. As interaction was significant, the performance of cultivars under different shade levels was also considered. During the first year under full sunlight,

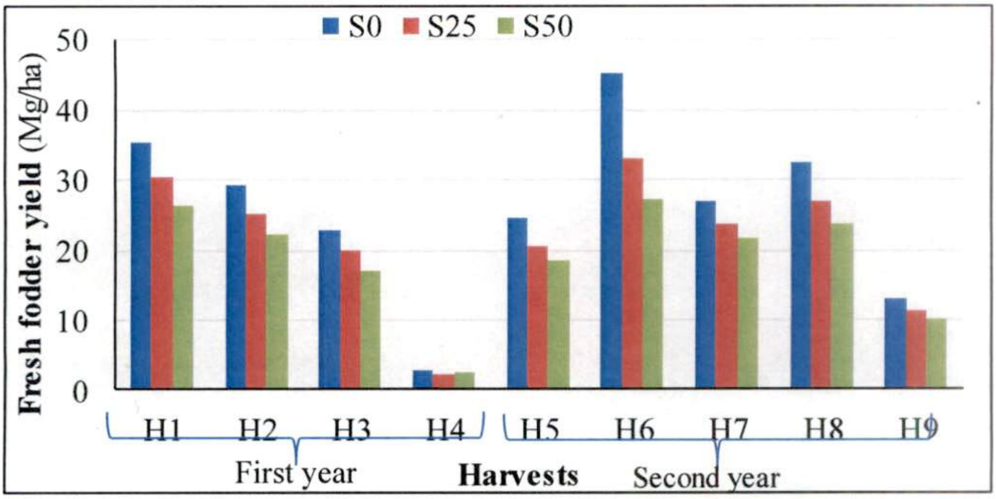

Fig. 14. Effect of shade on fresh fodder yield of hybrid napier at each harvest

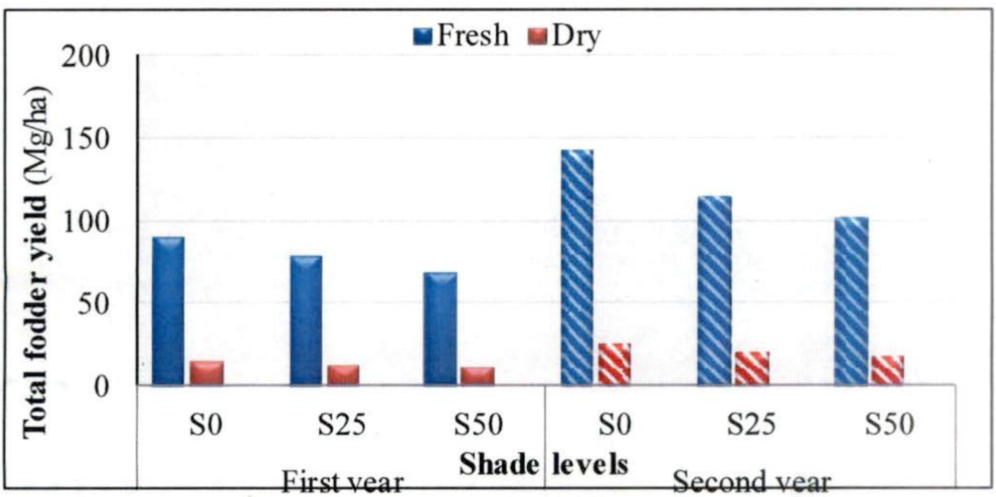

Fig. 15. Effect of shade on total fodder yield of hybrid napier

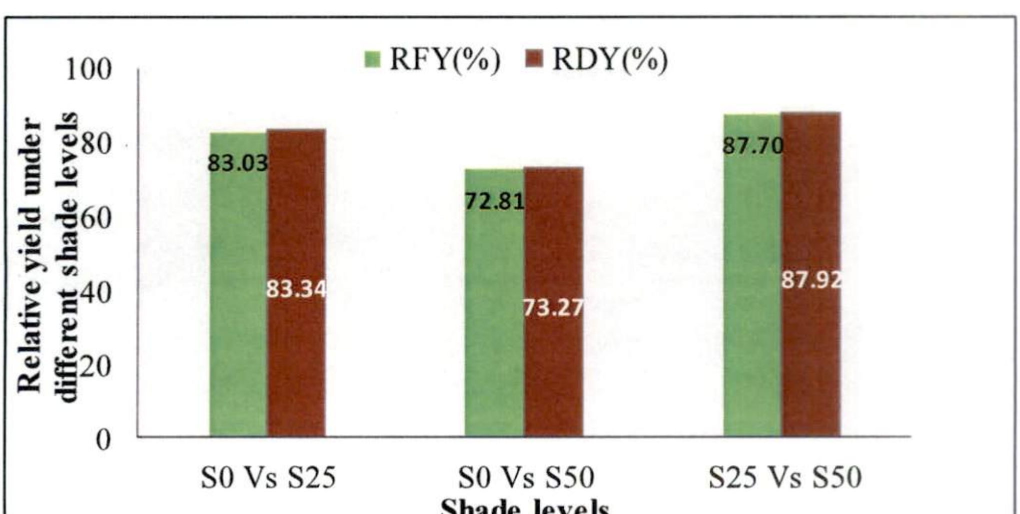

Fig. 16. Relative yield of hybrid napier under varying shade levels (RFY- relative fresh yield, RDY- Relative dry yield)

'Suguna' (111.34 Mg/ha/yr) and 'CO-3' (108.31 Mg/ha/yr) were on par. The same trend was also noticed under 25 per cent shade level.

In the second year, under full sunlight, annual yield of 'CO-4' (159.39 Mg/ha) and 'Suguna' (154.62Mg/ha) were almost similar in performance. Under 25 and 50 per cent shade levels, 'Suguna' compared equally well with CO-3, fresh fodder yield being 132.92 and 124.98 Mg/ha for Suguna and 130.34 and 120.49 Mg/ha for 'CO-3'.

The dry fodder yield followed the same trend as that of fresh fodder yield. In full sunlight, in the first year, the highest yield was recorded by 'Suguna' (20.93 Mg/ha) followed by 'CO-3' (19.72 Mg/ha). Under 25 and 50 per cent shade, 'Suguna' recorded the highest dry fodder yield of 18.26 and 17.52 Mg/ha respectively followed by 'CO-3'. During the second year, under full sunlight, 'CO-4' (31.88Mg/ha) recorded the highest dry fodder yield followed by 'Suguna' (29.06Mg/ha). Under 25 and 50 per cent shade, 'Suguna' recorded the highest dry fodder yield of 24.99 Mg/ha and 23.50 Mg/ha respectively followed by 'CO-3' (23.73 Mg/ha and 21.92 Mg/ha respectively).

In general, the relative yields of hybrid napier under 25 per cent and 50 per cent shade with full sunlight as base level were about 83 per cent and 73 per cent. However, when base level was raised to 25 per cent, the relative yield was about 88 per cent (Fig.16). This trend in yield reduction observed under shaded situation is well elucidated based on the following reasons.

The most important yield attributing factors such as tiller and leaf production directly affects fodder production. The data on relative reduction in tiller numbers and leaf numbers with increasing shade levels is presented in Fig.19. The relative reduction in these parameters were worked out from the data on first and second year observations. The relative percentage reduction for 25 percent shade was worked out taking open condition as base level and that of 50 percent shade was worked out taking open condition and 25 percent shade level as base levels.

The rate of fodder production is a function of tiller production and leaf growth (Selvi and Subramanian, 1993). The relative percentage reduction in number of leaves was directly related to the relative percentage reduction in number of tillers (Fig.19). The average relative percentage reduction in number of leaves with respect to open condition was 13.46 and 23.46 with corresponding values of 13.85 and 23.08 in the relative percentage reduction of tillers, as the shade levels were raised to 25 per cent and 50 per cent respectively. The relative percent reduction in number of leaves for 50 per cent shade level when viewed with a base shade level of 25 per cent was 11.62 with a corresponding value of 10.72 in the relative per cent reduction of tillers. This trend was also reflected in relative percentage reduction of yield as 16.37 and 26.66 when the shade levels were raised to 25 and 50 per cent respectively. The relative percentage reduction in yield for 50 per cent shade level when viewed with a base shade level of 25 per cent was 12.31. Pandey *et al.* (2011) observed that in grasses total reduction in yield was in the range of 18-75 percent for a corresponding reduction in light from 32 to 59 per cent.

In general, percentage reduction in fodder yield was approximately 10 for every 25 per cent reduction in light intensity. Relative percentage reduction in yield depends on cultivars too (Fig.17). Among the cultivars studied, 'CO-3' (9.92 %), 'Suguna'(13.39%) and 'IGFRI-3'(14.26%) recorded less than 15 per cent yield reduction under 25 per cent shade.

The next important factor is that plants grown under shade have low dry matter production due to their more succulent growth (Gordon *et al.*, 1962) and the higher proportion of spongy tissues (Anita and Lakshmi, 2014). In addition, shading delays phenology, regrowth, and plant maturity (Pierson *et al.*, 1990), which could reduce the harvested produce from plants grown under shade compared to those plants grown in full sunlight, because all plants grown under varying light intensities received similar cutting frequency. The reduction in proportion of stem (Table 20 and Table 21) under reduced light also affected fodder production. Forages when grown under shade maintain a higher leaf – stem ratio by reducing stem growth (Singh, 1994) as shading reduce biomass allocation to stems (Cruz, 1997). This can cause considerable reduction in fodder yield under reduced light.

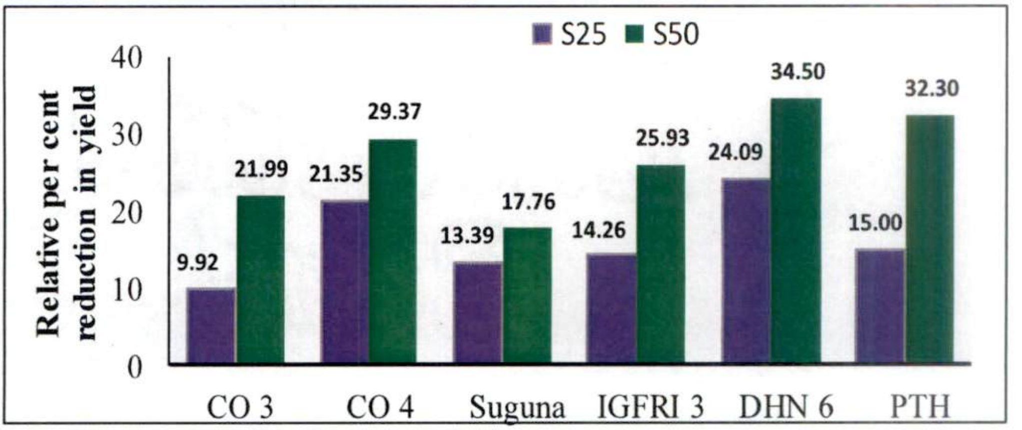

Fig. 17. Relative per cent reduction in yield of hybrid napier cultivars under varying shade levels

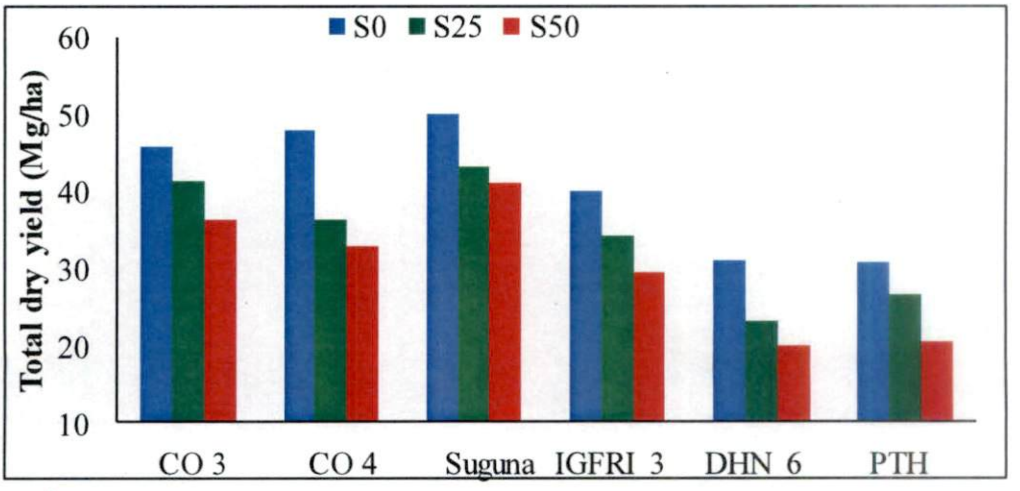

Fig. 18. Effect of shade on dry fodder yield of hybrid napier cultivars

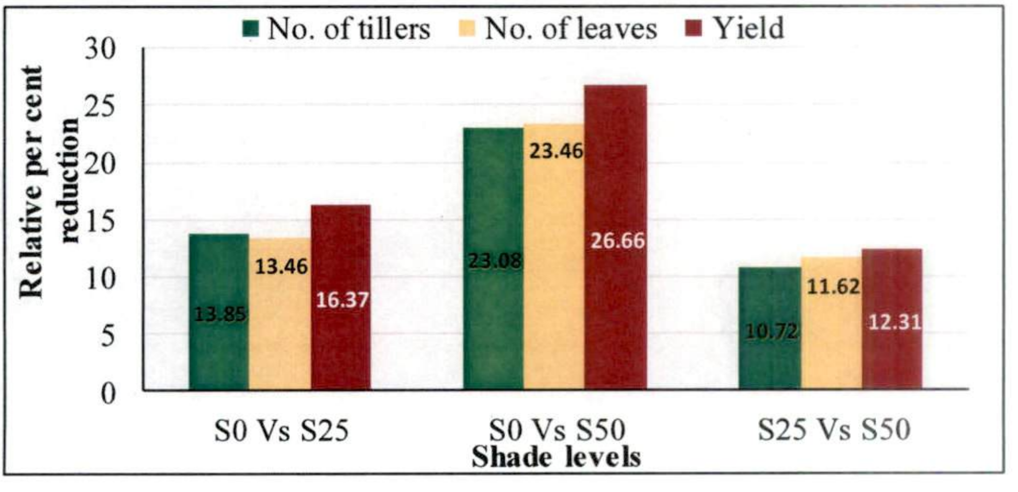

Fig. 19. Relative per cent reduction in no. of tillers, no. of leaves and yield of hybrid napier under varying shade levels

Considering the physiological aspects and light regime within the plant canopy, there exist a negative association between leaf area and photosynthesis per unit area which was well documented by many researchers (Van den Boogaard *et al.*, 1997; Villar *et al.*, 1998; Bultynck *et al.*, 2004). Shading of young leaves on old leaves due to the increase in leaf area under reduced light change the quantity and quality of light penetrating through the plant canopy profile with reduced red to far red ratio. This is characterized by stem and leaf elongation and inhibition of tillering in fodder grass (Candido *et al.*, 2005a ; da Silva *et al.*, 2012) ultimately reducing fodder yields.

According to Donald (1963), a crop or pasture should have sufficient foliage to intercept the PAR, but once the LAI increased beyond the optimum LAI, a stage is reached where the lowest leaves would be shaded and their rate of respiration would exceed the rate of photosynthesis and reaches a negative balance of the rate of dry matter increase. The optimum LAI can vary with the shade levels or the light intensities. When the leaf area increases beyond the optimum, self-shadowing will occur and this will greatly reduce the photosynthetic rate of a certain number of leaves (Pedreira and Pedreira, 2007).

In the present investigation, increase in LAI with increasing shade levels reduced the light penetration and PAR transmission (Fig.13) to the lower layers, which may have negatively affected the photosynthetic efficiency of lower leaves and the final fodder yield.

The increase in SLA (or decrease in SLW) and LAR with increasing shade levels also negatively affected fodder yields. The general belief is that higher leaf area gives higher yield. However in the present study contrary results were obtained. This can be well elucidated as stated by Niinemets *et al.* (2007). According to him, 'size dependency of biomass allocation varies with plant genotype and environment'. The net return on biomass decreases with unit increase in SLA and LAR because large leaves invest more in mid ribs and other support tissues than smaller leaves. Hence, large leaves have lower quantity of photosynthetically active compounds per unit mass. This results in lower metabolic rate of large leaves with maximum SLA (Niinemets *et al.*, 2006). On the other hand, small leaves have maximum SLW due to high fraction of productive tissues which results in much better biomass allocation (Milla *et al.*, 2008).

The reduction in yield under reduced light is also associated with less nitrogen use efficiency under reduced light intensity. In normal situations under reduced light, plants have lower shoot to root biomass and the rate of nitrogen mineralization in soil will be higher. This phenomenon will facilitate higher nitrogen uptake by plants, which in turn, increases the leaf nitrogen concentration. However, this compensatory mechanism is much less pronounced in hybrid napier under shaded situation (Pandey *et al.*, 2011).

The proportion of photosynthetic pigments also has a role in shade tolerance. Increasing chlorophyll b/a ratio (Table 22) reduce the biomass production in plants, because as suggested by Anderson (1986), under shade, the leaves function for greater investment of leaf resources in light harvesting rather than energy processing. Therefore, it is an adaptive mechanism of plants to produce more of PS II to PS I reaction centres. Increasing chlorophyll b content helps the plants to harvest more light under shade by facilitating more production of PSII reaction centres, thereby, reducing the synthesis of ATP syntetase and conserving the energy spend for ATP synthesis. Anything that affect the ATP synthesis can affect the dry matter production and the fodder production too.

5.1.4. Nutritive value and quality

Significant effects of shade were noticed on nutritive value and quality of leaves and stems. Only with some fractions studied, nitrogen, P, crude protein, crude fat, Ca and Mg contents were unaffected (Tables 28, 29, 30,31,32, 33 and 34). However, significant differences were noticed among cultivars irrespective of shading. Almost all the nutrients except crude fibre were higher in leaves compared to stems.

Various reasons for non-significant effects of shade on nutrient content are well documented by many researchers. According to Wilson (1996), significant effect of shade on nutritive quality of forages can be observed only after a long exposure, i.e. for more than two months whereas in the present study all the harvests except the first harvests of both years were done at 45 days intervals. As per Buxton (1995) and Baig *et al.* (2005), substantial influence of shade on nutrient content could be noticed in tropical forages only at higher levels of shade even more than 50 per cent.

For fodder grasses, generally crude protein content increases with increasing shade (Wilson, 1996; Parissi and Koukoura, 2009). However, in the present experiment such a trend was absent. The absence of significant differences in crude protein content can be explained. The nitrogen use efficiency in hybrid napier is less pronounced under shaded situation (Pandey *et al.*, 2011) which can also affect the crude protein content under reduced light.

Significant reduction in crude fibre content with increasing shade level can be substantiated. The reduced PAR delays the ontogenic development of fodder grasses (Bos and Neuteboom, 1998) and delays plant maturity, thereby reducing the fibre content (Pierson *et al.*, 1990).

Shading reduced the ash content because potassium content (a major part of ash) was reduced under increasing shade. The luxurious growth of plants in full sunlight might have resulted in luxury consumption of potassium but had no significant effect on Ca and Mg content. These results are in accordance with the findings of Gutmanis *et al.* (2001) and Parissi and Koukoura (2009). Potassium and phosphorous contents in plants were less in the second year probably due to the cutting and removal of biomass at regular intervals.

The substantial reduction in crude fibre content and ash content with increasing shade increased the NFE content of hybrid napier with increasing shade as these are the fractions of proximate analysis.

Among the cultivars, crude protein content was higher in 'IGFRI-3,' followed by 'CO-3', 'CO-4', and 'Suguna' as these trend was followed in case of nitrogen content also. The leaf and stem fibre content of all cultivars were much below 30 per cent and 35 per cent respectively, among which the highest was observed in 'PTH' and the least in 'DHN-6' due to its succulent nature. Similarly, all cultivars had more than 2 per cent crude fat content except for 'PTH' in their leaves and more than 1 per cent in their stems. The NFE was more than 50 per cent in leaves compared to stems.

Considering the mineral contents, 'PTH' had the highest phosphorous content. The potassium content of almost all the cultivars were comparable with each other except for 'DHN-6'. None of the cultivars had less than 0.2 per cent of Ca and Mg in their leaves and stems, only exception was noticed in case of stems of 'PTH' during second year.

Oxalates are salts of oxalic acid which are common constituents of tropical fodder grasses, which interfere with absorption and availability of nutrients to the animals (Table 35 and Table 36), .The oxalate content in leaves were more than that of stems. Substantial increase in oxalate content with increasing shade was noticed in cultivars (Moreau and Savage, 2009) because the oxalate production in plants is associated with glycolate cycle and photosynthesis, also binding of oxalate with minerals is more under shade (Noonan and Savage, 1999).

However, the safe limits of less than 4 per cent were surpassed only during the periods of luxury growth of plants and that was observed only in leaves. The oxalate content of napier hybrids is higher during June and July due to the peak in growth during rainy season (Singh, 2002). Hence the highest content was noticed during Kharif season and the unexpected increase in oxalate content in the second year Rabi season could also be the result of luxurious growth of plants on the receipt of sufficient amount of rainfall just a few days before the eighth harvest (Fig.1, Table 35 and 36) which coincided with the oxalate analysis for the Rabi season.

The oxalate content varies with cultivar also (Chaudhary *et al.*, 2007). In the present study 'IGFRI-3' had the highest oxalate content in both leaves and stems. 'PTH' had the highest content only during the periods of peak growth. All other cultivars had comparable contents.

5.2. EXPERIMENT II: NITROGEN NUTRITION AND CUTTING FREQUENCY IN HYBRID NAPIER GROWN UNDER RAINFED CONDITION

Planting was done on 20-06-2013 using rooted slips, and the plants established well. The growth was rather slow during the initial periods and later the growth was fast. After the cessation of rainfall, the crop growth rate was rather slow during the summer periods. However, clump mortality was not observed. The first harvesting was done at 75 days after planting for all the treatments. Over a period of two years, there were twelve, nine, and seven harvests respectively for 30 days, 45 days and 60 days of cutting frequencies. The assigned dose of nitrogen fertilizer was applied in three splits as basal and after each harvest which coincided with periods of rainfall.

Cutting frequency and nitrogen nutrition had significant effects on morpho-physiological and yield responses of hybrid napier. In both years, increasing cutting intervals and nitrogen nutrition had facilitating effect on plant growth, yield, and yield attributes.

5.2.1. Morpho- physiological responses

Throughout the experiment, delayed harvesting with increasing nitrogen fertilizer showed maximum plant height, leaf length, and leaf width. In the first harvest, as all the plants received uniform cutting frequency, they performed uniformly. However, an exception was noticed at the fourth harvest because the regrowth period after the third harvest for 30 days cutting frequency received rainfall whereas for 45 days of harvest there was no rain during the regrowth period.

Over a period of two years, maximum plant height, leaf length, and leaf width were recorded in the second harvest of the second year for plants harvested at

60 days interval and fertilized with 400 kg/ha N (Tables 37, 38, 39, 40, 41 and 42). The time allowed for growth was more in 60 days cutting intervals, in addition, the coincidence of enough soil moisture, higher dose of fertilizer and sunshine paved the way for maximum plant height, leaf length and leaf width. It has already been reported that increasing the harvest interval increases the plant height in napier grass (Singh and Joshi, 2002).

The present results agree with the studies of many previous researchers. For example, Shehzad *et al.* (2012) reported that the plant height and leaf growth are significantly influenced by harvesting intervals and delayed harvesting increases plant height, stem diameter, and leaf growth. According to Onyeonagu and Asiegbu (2012), extending the cutting interval from 4 weeks to 8 weeks increase plant height in bunch fodder grasses by 74 per cent.

Plant height in hybrid napier increases for every increment in nitrogen levels as nitrogen promotes plant growth through internodal elongation (Turkhede and Rajendra, 1978). Jayakumar (1997) reported that plant height in hybrid napier could attain a maximum of 174.82 cm on application of 200 kg/ha N.

During the initial stages of plant growth, tiller production and leaf production were less and a gradual increase was observed towards the final harvests (Tables 43, 44, 45 and 46). However, after the final harvest of the first year, tiller decline was noticed until the first harvest of the second year due to dearth of soil moisture during summer periods. Increasing nitrogen nutrition and cutting intervals had facilitating effect on leaf and tiller production. Tiller density in bunch fodder grasses increase with increasing cutting interval and nitrogen nutrition (Onyeonagu and Asiegbu, 2012).

The frequent cutting at 30 days interval reduces light interception by plant canopy, which delay the phyllochron and basal bud development to tillers (Gautier *et al.*, 1999). The initial growth rate of napier grass are low for 2-3 weeks hence early harvesting adversely affect stubble regeneration (Snijders *et al.*, 2011). In addition, the emerging leaf acts as a strong sink that can deprive other sinks such as tiller buds for local carbohydrates reserve (Bos and Neuteboom, 1998). These explain for reduced number of tillers at frequent harvesting.

The delayed harvesting protects the meristems from frequent damage and nitrogen facilitates plant growth through increased activity of meristems (Hazary *et al.*, 2015). According to Afzal *et al.* (2012), increasing nitrogen levels could improve all yield attributing factors of fodder grasses such as increased plant height, number of leaves, and number of tillers.

An increase in tiller and leaf production as seen in the present experiment with delayed harvesting at higher levels of nitrogen can increase the LAI (Table 47 and Table 48). Higher LAI (more than 10) was attained at the second harvest in both years. According to Jayakumar (1997), leaf area index of hybrid napier increase with increased rate of nitrogen fertilization and could reach up to a maximum of 13.94 on the application of full dose of nitrogen (200 kg/ha). Higher LAI of 20.79 was reported in 'CO-3' by Kumar *et al.* (2011).

In the present experiment, LAI of the crop decreased towards the final harvests in both years as leaf expansion and elongation were reduced with decreasing rainfall on proceeding towards the summer seasons. According to Arnon (1975), leaf size is determined by the number and the size of the cells of which the leaf is built and is influenced by light, moisture regime, and the supply of nutrients.

In the opinion of Wong and Sturr (1995), frequent defoliation reduces the leaf area index in tropical forages and delaying the harvest assist in restoration of leaf area index. Frequent defoliation removes leaf meristems and reduces carbon reserves for leaf development.

From a nutritional point of view, increasing nitrogen levels promote cell division and elongation, which affect leaf expansion and elongation rate in plants. This ultimately increases the leaf area and leaf area index of fodder grasses (El Noeman *et al.*, 1990).

LAR and LWR are measures of relative leafiness of a plant and both ratios decrease with delayed harvesting and increasing nitrogen nutrition (Tables 49, 50, 51 and 52). This trend in reduction can be explained based on the leaf- stem ratio data given in Table 55 and Table 56. The leaf- stem ratio decreased with increasing cutting intervals at higher levels of nitrogen. This increase in stem portion with considerable reduction in leaves reduced the proportion of leaf area and leaf weight, finally resulting in decrease in LAR and LWR.

The decline in leaf-stem ratio with delayed harvesting was reported by several researchers. Delayed harvesting accelerate leaf senescence and increase stem accumulation, thereby, reducing the leaf – stem ratio in fodder grasses (Paciullo *et al.*, 2001; Mello and Pedreira, 2004). However, frequent defoliation at 30 days interval especially during periods of less soil moisture reduces stem accumulation as it does not provide sufficient time for stem development and adversely affect crop growth (Asiegbu and Onyeonagu, 2008).

However, the SLW increased with increasing cutting interval and nitrogen nutrition (Table 53 and Table 54) as delayed harvesting provides sufficient time for leaf tissue development. In addition, nitrogen nutrition maintains continuous supply of nutrients for cellular development. The significant effects of nitrogen nutrition, however, was lost towards the summer season as the effect was masked by lack of soil moisture. These findings are similar in lines to that of Milla *et al.* (2008), where plants have lower SLA and LAR under long periods of growth.

5.2.2. Fodder production

The data on fresh and dry fodder yields are given in Tables 57, 58, 59 and 60. During the first year, there were five, four, and three harvests respectively for 30 days, 45 days, and 60 days of cutting intervals. In the second year, there were seven, five and four harvests for respective cutting intervals. Kumar *et al.* (2011) reported an average of three good harvests per year under rainfed conditions from 'CO-3' cultivar at Kollam, Kerala.

There were no harvests after January for the first year and after December for the second year as stunting and drying of plants were observed due to soil moisture stress in the summer months. Water stress developed during crop growth period considerably affects growth leading to substantial reduction in yield and quality (Govindarajan *et al.*, 1996).

During the experiment, the crop had the highest total fodder yield in the second year, because, the crop by that time developed maximum number of tillers and leaves. In the first year, maximum yield was obtained for the first harvest, which can be attributed to the interplay of all the favourable conditions such as soil moisture, sunshine, and soil fertility. However, when fertilized with 400 kg/ha N and harvested at 60 days interval, the crop had the highest yield in the second harvest compared to the first. Because, by that time, the crop had established well and developed extensive root system for full exploitation of the soil moisture and high level of fertilizer. In addition, the time allowed for growth was also higher compared to other harvests.

Substantial changes in fresh and dry fodder yield were noticed with increasing nitrogen levels with delayed harvest. The crop had the highest fresh and dry fodder yield when fertilized with 400 kg/ha N and harvested at 60 days intervals. The highest total annual fresh and dry fodder yield recorded during the experiment were 175.34 Mg/ha and 31.91 Mg/ha respectively (Table 58 and Table 60).

The above increase in yield can be attributed to the increase in yield attributing factors such as plant height, leaf length, leaf width, number of tillers, number of leaves, LAI, and leaf-stem ratio with increasing nitrogen nutrition and delayed harvests. Similar results were also reported by Wadi *et al.* (2003) and Amin (2011).

The yield response curve of hybrid napier increased linearly with increasing nitrogen levels (Fig.20). However, the curve was less pronounced after 200 kg/ha. According to Pieterse and Rethman (2002), even though the fodder yield in napier and its hybrids increased with increasing nitrogen levels up to 400 kg/ha,

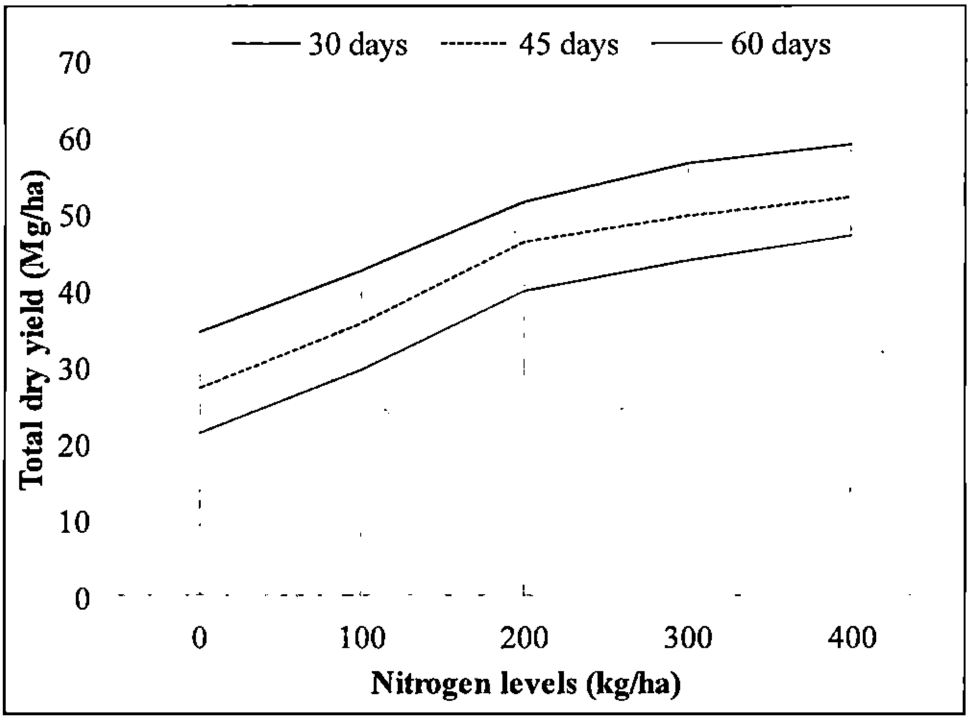

Fig. 20. Effect of nitrogen nutrition and cutting frequency on total dry fodder yield of hybrid napier

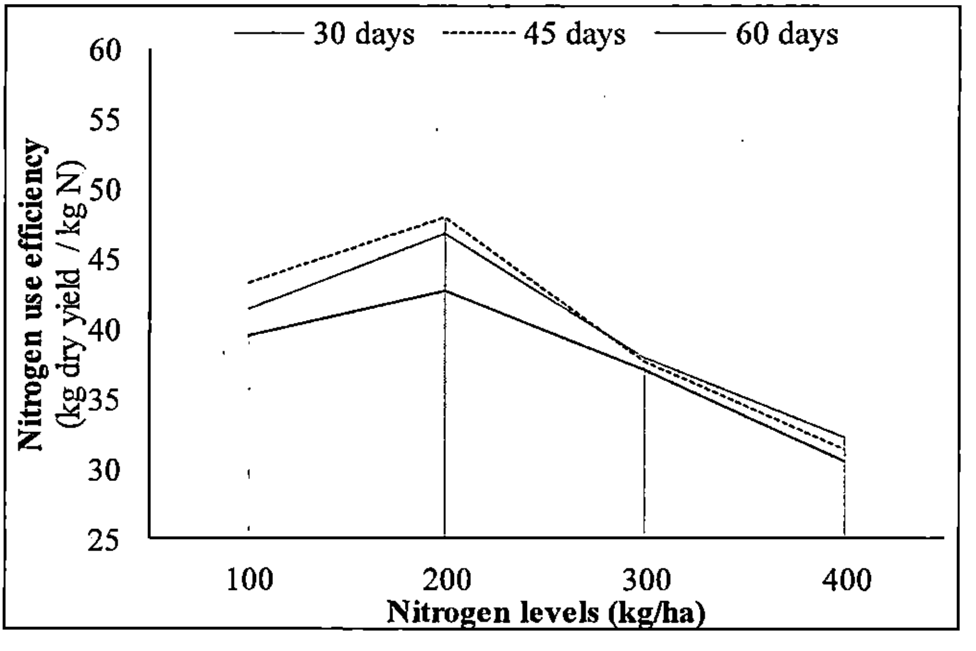

Fig. 21. Nitrogen use efficiency of hybrid napier at different cutting frequencies under varying nitrogen levels

the optimum dose is 150 kg/ha at low pH (< 4) under irrigated conditions in the tropics. The soil moisture depletion under rainfed situation might have resulted in poor response of the crop towards applied nitrogen.

In view of the dry matter production and digestibility, Wandera (1997) suggested that the appropriate stage for harvesting napier is 7- 9 weeks of maturity. Increased nitrogen fertilization and shorter cutting interval could increase the crude protein and fat content of forage grasses (Warner *et al.*, 2015). Singh *et al.* (2000) observed that increasing the cutting interval would increase the fresh fodder yield in hybrid napier and harvesting at 6 weeks interval is the optimum stage for maximum dry matter production without affecting fodder quality.

In the tropics, cutting of napier at 2 to 4 months interval gives the highest dry matter yield (Wandera, 1997). Manyawu *et al.* (2003), opined that napier and its hybrids should be harvested between 6 and 7 weeks to optimize the nutritive value and herbage production. de la Ribera *et al.* (2008), opined that harvesting in napier should not be delayed beyond 75 days as delayed harvesting results in stunted growth. Considering the opinion of various researchers and from the present study, the best cutting interval of hybrid napier under rainfed conditions in the humid tropics seems to be 60 days.

5.2.3. Nutritive value and quality

The data on nutritive value of hybrid napier at increasing nitrogen levels at varying cutting frequencies are given in Table 61 to Table 71. Significant effect of nitrogen nutrition and cutting frequencies on nutritive quality of hybrid napier was observed. Ecological and management factors such as rainfall and fertilization along with the interaction of genotype, season, and age of the crop significantly influence the fodder production potential and quality of napier grass (de la Ribera *et al.*, 2008).

Crude protein content gives an approximate value of protein content in forages. The significant differences noted in nitrogen content reflected in crude protein content also. Crude protein content in plants increased with increasing nitrogen levels. However, the content decreased with delayed harvesting. Crowder and Chheda (1982) opined that decrease in nitrogen content and crude protein content with delayed harvesting is the result of accumulation of cell wall constituent, which is the severest in leaf blades. At 30 days harvest, with 400 kg/ha N, leaves had more than 14 per cent crude protein and more than 12 per cent in stems. Even at delayed harvesting at 60 days of cutting frequencies with 400 kg/ha N the crop had more than 12 per cent and 11 per cent crude protein in leaves and stems. Nitrogen increases leaf protein by enhancing the production of photosynthetic enzymes rubisco and PEP carboxylase (da Silva *et al.*, 2012).

Crude fibre content in plants increased with delayed harvesting but decreased with increasing nitrogen nutrition. However, the crop had not more than 32 per cent in stems even at lower dose of nitrogen with delayed harvesting. Crude fat content increased with increasing nitrogen levels; however, the content remained unchanged at all cutting intervals. The nitrogen free extract was the lowest at 45 days of harvest and the maximum was observed at 30 days of harvest. The content decreased with increasing nitrogen levels but again increased at higher levels of nitrogen.

Similar findings were reported by many researchers. Hazary *et al.* (2015) reported that increasing nitrogen levels increase the crude protein and crude fat content but decrease the crude fibre content of fodder grass. This is due to the fact that increased application of nitrogen helps in rapid synthesis of carbohydrates into protein and protoplasm leaving low proportion for cell wall synthesis and maintain succulent growth (Johnson *et al.*, 2001). Crude fibre content of hybrid napier decrease with increasing rate of nitrogen fertilization and may reach to 28.60 per cent on applying 200 kg nitrogen per hectare (Jayakumar, 1997). According to Amin (2011), as nitrogen fertilization reduces the fibre content of forages, the highest crude fibre content is obtained from plants not treated with nitrogen and the lowest is recorded from plants fertilized with higher dose of nitrogen. In the case of early stage harvested crop, as the total nonstructural carbohydrates reserve has been utilized after each harvest for the initial regrowth, the fibre content is much less than the matured crop (Wong, 1991).

In the present experiment, delayed harvesting reduced the content of phosphorus, potassium, calcium, and magnesium, and these reduction ultimately lowered total ash content with increasing cutting interval. This declining trend is attributed to the dilution effect caused by increasing dry matter accumulation with increasing plant maturity (Paciullo *et al.*, 2001; da Silva *et al*, 2012). Buxton (1995) opined that early harvesting delays lignification of cell wall and improve quality of forages.

There were no change in total ash, phosphorus, and potassium content with increasing nitrogen levels. Increasing nitrogen levels could not produce substantial changes in ash content of forages (Afzal *et al.*, 2012). This could be due to the antagonistic effect of higher levels of nitrogen on the uptake of phosphorus and potassium (Doberman and Fairhurst, 2000). However, the content of Ca and Mg increased with increasing nitrogen nutrition. Similar trend was also reported in napier grass by Tripathi *et al.* (1979). Even though napier grass could accumulate more K compared to other tropical grasses, there was no substantial effect of N fertilization on K content. Similarly, nitrogen fertilization increased the uptake of cations such as Ca and Mg, and thereby, increase their concentration in leaves of napier.

The status of antinutritional factors like oxalate and nitrate accumulation was also studied from representative samples during Kharif, Rabi and Summer harvests. In general, there were not much effects of cutting frequencies on oxalate contents. However, significant influence of cutting frequency was noticed in nitrate content. Both oxalate and nitrate content increased with increasing nitrogen levels.

In the first year, for the Kharif season harvests, the oxalate content at all cutting intervals were at par as the harvesting was done at 75 days after planting for all the treatments. In the Rabi season, the content decreased with delayed harvesting as the oxalate production is more under active growth stages. The content was higher at 45 days of harvest because the crop received more amount of rain during the regrowth period, which resulted in active crop growth.

In the second year, for Kharif season, the content decreased with plant maturity but the cloudy atmosphere (Appendix1) during a few days before the 60 days harvest increases the oxalate content. As the oxalate synthesis is associated with glycolate cycle and photosynthesis, reduced light affect oxalate synthesis causing higher production of oxalates under low light stress during cloudy days (Noonan and Savage, 1999; Moreau and Savage, 2009). In the Rabi season, before all the cuttings, the crop received sufficient rain with nitrogen nutrition resulting in active crop growth with higher production of oxalate compared to other seasons. Oxalate content in grasses is the highest during periods of rapid growth and even more than 6 per cent has been reported (Cheeke, 1995).For all summer harvests, the content was comparatively less as the crop growth was slow due to lack of sufficient rain and nitrogen nutrition.

During the active periods of growth because of sufficient rains, oxalate content in leaves and stems were above the toxicity limit especially for higher dose of nitrogen (more than 200 kg/ha). Oxalate content of hybrid napier grass increased with increasing nitrogen and decreased with delayed harvesting (Mani and Kothandaraman, 1981).

Nitrate content of hybrid napier leaves and stems are presented in Table 70 and Table 71. In general, compared to leaves, stems had lesser nitrate content. Exceptions were noticed when the content reached or exceeded the safe limit of 1000 ppm. There were significant effects of cutting frequency and nitrogen levels on nitrate content of leaves and stems. The nitrate usually accumulate in lower parts, within 15cm -20 cm above ground (Sindhu *et al.*, 2011) and under normal harvesting the crop is harvested leaving 10 -20 cm above the ground excluding the lower parts. Hence, in the present investigation the crop had higher content in the leaves. As reported by Faulkner and Hutjens (2014), cutting the plants at 15- 20 cm exclude the nitrate accumulated plant parts and thus avoiding nitrate toxicity.

In Kharif, during the first year, there was no change in nitrate content for single cut crop but the content increased with increasing nitrogen levels as all the treatments received uniform harvests (75 days after planting). In stems, the content exceeded the safe limit (1000 ppm) and nitrate accumulation was noticed in stems. In the second year, the least nitrate content was observed in plants harvested at 45 days of cutting interval. At 30 days of harvest, with 300 kg/ha N and 400 kg/ha N, nitrate content in stems were more than leaves. Nitrate accumulation at toxic level was noticed in stems when fertilized with 400 kg/ha N and harvested at 60 days of cutting frequency.

Kemp *et al.* (1978) and Popov (1979) opined that napier is not an active accumulator of nitrate; however, the content is higher in early harvested crops and when fertilized with higher dose of nitrogen. However, in the present experiment, the content was higher at 60 days harvest in the second harvest, because the atmosphere was cloudy for a few days before the crop harvest. As Singh (1994) reported low light stress in cloudy days could reduce the activity of nitrate reductase.

For the crops harvested in the Rabi season, the nitrate content was within the safe limit, because the crop received sufficient rains which might have diluted the nitrate content Nordfeldt *et al.* (1951) reported that the dilution effect of nitrate during rainfall along with plant maturity reduces the nitrate accumulation. Compared to 30 days harvest, the content of nitrate was less in 45 days of harvest. As suggested by Sindhu *et al.* (2011) and Pathmasiri *et al.* (2014), lower levels of nitrate in mature plants may be due to decreased uptake or increased enzyme activity to convert the nitrate into protein.

The highest content was noticed in crops fertilized with 400 kg/ha N and harvested at 60 days interval. The less sunshine hours with high relative humidity reduces transpiration rates causing decreased translocation of nitrate to the reduction site, ultimately resulting in nitrate accumulation (Breimer, 1982). In the present experiment, this has taken place in 60 days harvested crop resulting in higher nitrate content compared to other harvests. Before the Rabi season harvests of the first and second year, the crop experienced high atmospheric humidity with low sunshine hours (Appendix I and II).

During the summer season, for both years, the lowest nitrate content was noticed in plants harvested at 30 days interval. After the nitrogen top dressing, the 30 days cutting frequency received two harvests compared to the 60 days harvest (that received only one) which may have well distributed the nitrogen removed from the soil between the two harvests. However, in the case of sixty days cutting interval, the remaining nitrogen gets accumulated and the soil moisture deficit aggravated the nitrate concentration in plants. Another reason could be that the root system of frequently harvested (30 days) crop is less proliferated which may have reduced the nitrate uptake under reduced soil moisture.

For the first year, in general, stem accumulation of nitrate was noticed at higher dose of nitrogen at 400 kg/ha N. For all cutting intervals and at varying nitrogen levels, nitrate content was below 1000 ppm but at 60 days of harvest the content exceeded 1000 ppm in leaves at 400 kg N/ha and in stems, at 300 kg/ha N and 400 kg/ha N.

In the second year, nitrate content did not exceed more than 1000 ppm. Because the harvesting was stopped by November and December and the earlier harvests were good compared to the first year, most of the fertilizers could be effectively used by plants hence residual effect of nitrogen was less compared to the first year and no nitrogen accumulation was noticed.

Throughout the experiment, the crop had not accumulated higher nitrogen content but exemptions were noticed only under certain situations. The split application of fertilizers might have reduced the nitrate accumulation, and in turn, nitrate toxicity (Singh *et al.,* 2000). As reported by Pathmasiri *et al.* (2014), it seems the cultivar selected was also not a heavy nitrogen accumulator. Compared to guinea grass, hybrid napier cultivar 'CO-3' is safe for animal feeding as it has less tendency for nitrate accumulation.

5.2.4. Nitrogen use efficiency

The data on nitrogen use efficiency of hybrid napier is given in Table 72. There were significant effects of nitrogen nutrition and cutting frequency on nitrogen use efficiency of hybrid napier. Considering the effect of cutting frequency alone, maximum efficiency was recorded at 45 days of harvest while with respect to nitrogen levels, maximum NUE was recorded under 200 kg/ha N.

In view of interaction effect, the highest efficiency of 47.92 kg dry fodder per kilogram N applied was recorded at 45 days of harvest with 200 kg/ha N. Eriksen and Whitney (1981) recorded 41 per cent nitrogen recovery in napier grass, but when compared to other tropical grasses, the nitrogen recovery in napier grass is much lower because of the very high yield of napier grass under zero nitrogen fertilized plots. This is because of its extensive root system in the soil so that it could capture nitrogen from vast areas in the soil.

For all cutting frequencies, maximum efficiency was recorded under 200 kg/ha N. When fertilized with 100 kg/ha N and 200 kg/ha N, maximum efficiency was recorded at 45 days of harvest. For higher doses, NUE decreased on delaying the harvest (Fig.21 and Table 72). As the yield increases, the differences between yield of treated plot and control plot became narrow.

According to Crowder and Chheda (1982), nitrogen recovery depends on two major factors- the amount of nitrogen applied and cutting interval. Application of nitrogen at 400 kg/ha N and harvesting at 45 days interval could yield 50 to 65 kg of dry matter per kilogram of nitrogen under irrigated condition but it can vary under rainfed situations. Commonly obtained value of nitrogen recovery is between 30 per cent and 65 percent in fodder grasses. *Pennisetum purpureum* had nitrogen recovery value of 53.6 when top dressed annually with 220, 480 and 960 kg/ha N.

Grasses have more response for applied nitrogen on delayed harvest and yield more per kilogram of nitrogen. In napier, on an average, nitrogen use efficiency increase from 21 kg to 40.1 kg dry matter for each kilogram of nitrogen applied over cutting intervals of 4 weeks to 12 weeks (Snijders *et al.*, 2011) The nitrogen recovery of urea is 40.6 per cent at soil pH of 4.8 (Figarella *et al.*, 1972).

5.2.5. Soil analysis

Soil analysis was done before and after the experiment. The data pertaining to soil analysis before and after the experiment are presented in Table 1and Table 73. Soil organic carbon content increased after the experiment but the available N, P and K in soil declined after the experiment.

The data on soil analysis before the experiments shows that the soil is high in all the available nutrients. Significant changes in soil organic carbon content was noticed with increasing cutting frequency and nitrogen levels. Interaction effect was also observed. After the experiment, all the plots had more than 1 per cent of soil organic carbon. Considering the effect of cutting frequencies, the content in soil increased with increasing cutting frequencies but a declining trend was noticed with increasing nitrogen levels (Fig. 22 and Table 73). The highest content of organic carbon was observed in plots not fertilized with nitrogen but harvested at 60 days of cutting frequency. The least organic carbon was noticed in plots fertilized with 400 kg/ha N and harvested at 30 days intervals.

Regarding the available nitrogen content, its content decreased with increasing harvesting intervals and decreasing nitrogen levels. The highest content was noticed in plots treated with 400 kg/ha N and harvested at 30 days interval. At 45 days and 60 days of cutting interval, there were no changes in available nitrogen content of soil at higher doses of nitrogen, i.e., at 200 kg/ha N, 300 kg/ha N and 400 kg/ha N. Increasing nitrogen levels in soil would substantially increase the nitrogen content (Mazzoncini *et al.*, 2011) and hasten the organic matter decomposition in soil, thereby, reducing the carbon content of soil (Russell *et al.*, 2009). Delayed harvesting may increase root proliferation and add some of the old leaves to the soil. This can be the reason for increase in organic carbon content of the soil.

Similarly, the available phosphorous content in soil decreased with increasing cutting intervals and increasing nitrogen levels. Maximum P was

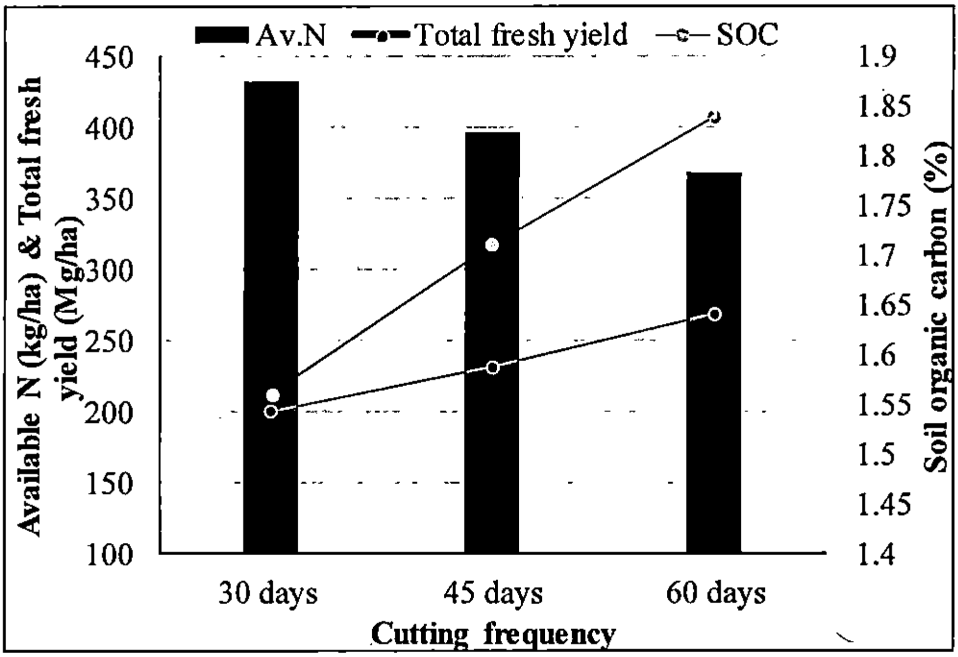

Fig. 22. Effect of cutting frequency on total fresh yield, available N and soil organic carbon

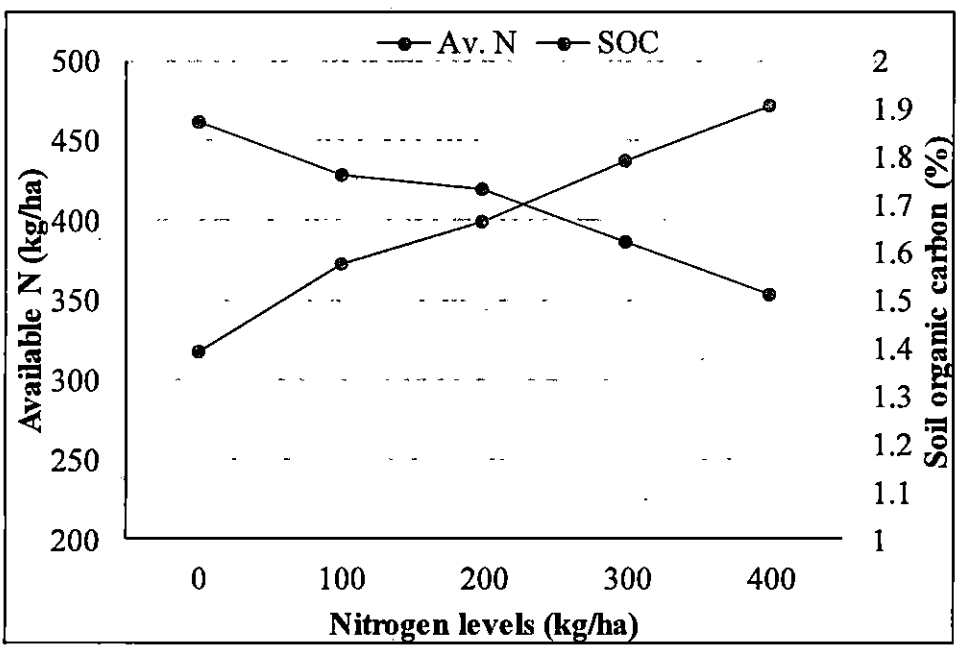

Fig.23.Effect of nitrogen nutrition on available nitrogen and soil organic carbon

observed in unfertilized nitrogen plots but harvested at 30 days interval. When harvested at 45 days and 60 days of cutting frequencies, there were no changes in available P content of soil at higher doses of nitrogen, *i.e.*, at 300 kg/ha N and 400 kg/ha N.

The available K content in the soil decreased with increasing cutting intervals and increasing nitrogen levels. The highest available K was observed in unfertilized nitrogen plots which were harvested at 30 days interval. K availability in plots treated with 400 kg/ha N were comparable at 30 days and 45 days of cutting frequencies. After the experiment, all the plots were medium in available K. However, after the experiment, the plots fertilized with 400 kg/ha had low available K. Pieterse and Rethman (2002) opined that increasing nitrogen fertilizer would reduce the available potassium and other nutrients in the soil due to the increased plant uptake.

5.3. EXPERIMENT III: CUTTING HEIGHT MANAGEMENT IN HYBRID NAPIER GROWN UNDER RAINFED CONDITION

Planting was done on 27-06-2013 using rooted slips and the plants established well. The growth was rather slow during the initial periods and later the growth was fast. After the cessation of rainfall, during the summer periods, the crop growth rate became slow as evidenced by various observations given in the results section. However, clump mortality was not observed. The first harvesting was done at 75 days after planting for all the treatments. Over a period of two years, there were nine harvests.

Cutting height management had significant effects on yield attributing factors such as tiller and leaf production of hybrid napier cultivars and produced substantial changes in fodder yield too. However, cutting height management could not produce significant effects on other morpho- physiological characters and nutritive quality but substantial changes in regrowth rate and stem fibre content were observed. Tessema *et al.* (2010) reported that cutting height management has no substantial effect on plant height, leaf elongation, and expansion of napier grass, but cutting at higher plant height helps in early elongation of stem.

5.3.1. Morpho- physiological responses

The data on plant height, leaf length, and width are given in Table 74 to Table 79 .Seasonal variation in plant height, leaf length, and width were noticed. In the first year, maximum plant growth was observed in the first harvest and decreased towards the final harvest. However, on receipt of premonsoon showers, plant growth recuperated. Due to the receipt of sufficient amount of rainfall, the peak in growth was observed in the second and the fourth harvest for the second year. The time allowed for growth and the receipt of sufficient amount of rainfall and soil nutrition helped favourable growth during the first harvest in all the treatment plots.

Among the cultivars, 'DHN-6' had maximum plant height, leaf length, and width during the periods of sufficient rainfall, and the cultivars 'Suguna', 'CO-3' and 'CO-4' had comparable growth attributes in almost all seasons. 'PTH' had the least leaf length and width during all the seasons.

Tillering and leaf production are substantially influenced by defoliation activities (Assuero and Tognetti, 2010). Defoliation activates lateral meristems on removal of apical meristems which favours new flushes (de Lana Sousa *et al.*, 2013). For viable fodder production and persistence of tropical forages, the threshold level of cutting fluctuates among plant genotypes and the removal of basal meristem during defoliation affect the persistence of plants (Humpherys, 1981).

The data pertaining to the number of tillers and leaves per clump are given in Table 80, Table 81, Table 82, Table 83and Fig.24. Both tiller production and leaf production in hybrid napier were significantly influenced by cutting height management and cultivars. In both years, tiller production and leaf production showed an increasing trend towards the final harvest. During the summer periods, tiller decline was noticed, but with the onset of premonsoon showers, regeneration was observed. Maximum number of tillers and leaves were produced when cut at 20 cm height and were much reduced when plants were cut at 5 cm height. In general, among the cultivars, 'PTH' showed maximum number of tillers and 'DHN-6' the minimum, which reflected in leaf production too.

However, in the second year, cutting height management had no significant effect on tiller production, except at the second harvest. This could be due to the self-thinning process taken place at higher tiller density. Tillering in grasses will not continue for long as increasing tiller density interrupt further tillering by delaying the bud development into tillers without affecting the phyllochron (Casal *et al.*, 1986). Similarly, intensive defoliation, especially in summer periods deprive the emerging tillers and leaf primordia in bunch grasses (Gittins *et al.*, 2010) like napier grass and its hybrids (Manyawu *et al.*, 2003) which might negatively affect tiller production resulting in tiller decline.

According to grass physiologists, cutting at higher plant height induce more basal buds and assist in higher tiller production. Persistence of more number of tillers from previous harvests at higher cutting heights is the source contributor of fodder yield in the later regrowth (Wong, 1991). Defoliation at ground level reduces the nearest carbon source for tiller development, thereby, the existing tillers and leaf growth deprive the basal bud for carbohydrates and suppress tillering in grasses (Gautier *et al.*, 1999).

The substantial changes in leaf production was reflected in leaf area index. Leaf area index of hybrid napier cultivars at different cutting heights are given in Table 84 and Table 85. Harvesting of various cultivars at different heights had considerable influence on leaf area index of hybrid napier. The highest LAI was noticed in plants when harvested at 20 cm height. During both years, LAI attained the highest value at second harvests. In general, among the cultivars, maximum LAI was observed in 'Suguna' and the least in 'PTH'.

Even though substantial changes in LAI was noticed, not much influence of cutting height was noticed on LAR, LWR, SLW, and leaf-stem ratio. However, it varied between the cultivars. In general, LAR and LWR values increased towards the final harvests in both years, since the dry weight of plants decreased towards the summer periods (Table 86 to Table 89).

Specific leaf weight of hybrid napier cultivars at different cutting heights are presented in Table 90 and Table 91. During the course of experiment, the crop

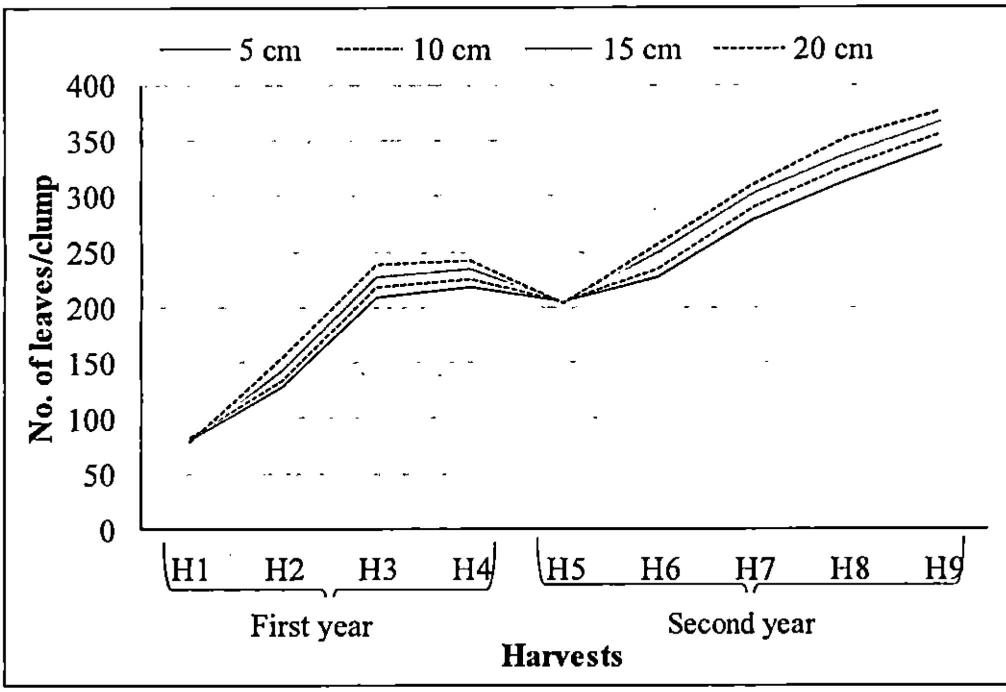

Fig. 24. Effect of cutting height management on leaf production in hybrid napier during various harvests

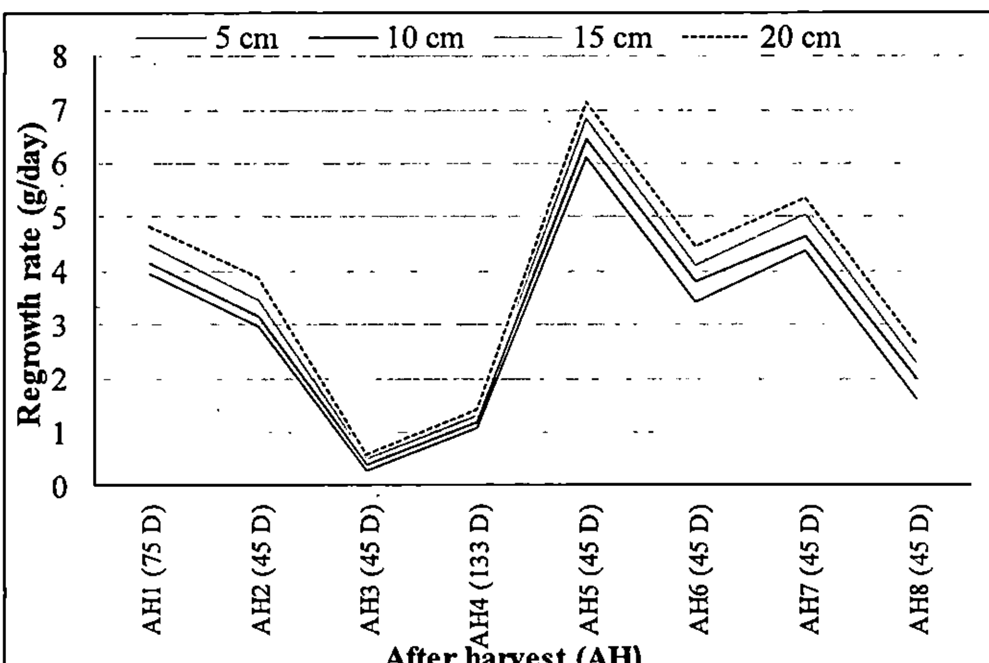

Fig. 25. Effect of cutting height management on regrowth rate in hybrid napier after each harvest (* D –days)

showed the highest SLW at the fourth harvest of the second year since the crop had the lowest leaf area at that time. Among the cultivars, 'PTH' recorded maximum SLW and showed reduced LAI at all harvests.

The data on leaf to stem ratio are presented in Table 92 and Table 93. Cutting at varying heights did not have significant effects on leaf to stem ratio of hybrid napier but the ratio varied between the cultivars. Interactions were absent. During both years, the highest leaf to stem ratio was recorded at the third harvests. In general, 'CO-3', CO-4' and 'Suguna' had comparable leaf to stem ratios recording maximum values. The least was observed in 'PTH'. The ratio increased towards the final harvest since the proportion of stem decreased as the stem development was negatively affected with continued soil moisture deficit towards the summer seasons.

Regarding regrowth rate, significant differences among cultivars were noticed when harvested at different cutting heights. Interaction effects of cutting height and cultivars were also evident (Table 94 and Table 95).

Hybrid napier showed maximum regrowth rate when harvested at 20 cm height and showed a declining trend when harvested at lower cutting heights (Fig.25). The highest regrowth rate was attained after the first harvest in both years of study and started decreasing towards the final harvests. In general, 'CO-3', 'CO-4' and 'Suguna' had comparable regrowth rate and showed the maximum. Similarly, regrowth rate of 'DHN-6' and 'PTH' were comparable; however, regrowth was rather poor in both cultivars.

After the final harvest in the first year, the crop showed an increasing trend in regrowth rate on receipt of premonsoon showers and reached its peak after the first harvest of the second year. However, regrowth rate decreased after the second harvest, and on receipt of north east monsoon, an increasing trend was noticed, but thereafter, it decreased.

Wijitphan *et al.* (2009) observed that napier grass harvested at 30 cm height had faster regrowth compared to those harvested at 0 cm because, low level cutting removes a large part of photosynthetic tissues, which takes longer time for regrowth than higher levels of harvest (Wadi *et al.*, 2004). Therefore, elevation in cutting height helps to maintain the regrowth vigour of napier grass during summer (de Lana Sousa *et al.*, 2012).

5.3.2. Fodder production

Fodder yield of hybrid napier cultivars was significantly influenced by cutting height management. Both fresh and dry fodder yield increased with increasing cutting height. All the cultivars included in the study had the highest fodder yield when harvested at 20 cm height. Substantial reduction in yield was noticed with decreasing cutting heights.

Because the crop had maximum number of tillers, leaves, LAI, and regrowth rate at higher cutting heights, fodder production increased with increasing cutting height. In napier, cutting at 20 cm increases fodder yield than cutting at 5 cm (Tekletsadik *et al.*, 2004). This is clearly evident from the seasonal trend lines of dry matter yield and regrowth rate. The dry matter yield and regrowth rate had comparable trend lines as shown in Fig.27 and Fig.25 At higher cutting heights, there would be supplementary amount of residual leaf area, and hence, the recuperation and dry matter production in plants depend on its photosynthetic capacity, rate of emergence of new foliage, and the subsequent carbon assimilation rate (Ryle and Powell, 1975).

There were four harvests in the first year and five in the second year. Fodder yield was higher during the second year. In the first year, the crop had higher fodder yield at the first harvest, thereafter, decreased towards the final harvest.

There were no harvests after the fourth harvest, as crop growth stunted due to cessation of rainfall during the summer months. However, on receipt of premonsoon showers, the crop growth recuperated and showed an increasing trend in yield. In the second year, maximum fodder yield was recorded at the second harvest. Again, the yield declined at the third harvest but with the onset of north east monsoon, crop yield increased at the fourth harvest. Thereafter, the yield reduced and no further harvests could be taken due to cessation of rainfall. The seasonal variation in tiller density affects LAI and fodder production in napier grass (Carvalho *et al.*, 2007).

The cultivars included in the study differed significantly with respect to fodder yield (Fig. 26). Among them, 'Suguna' had the highest yield, however, it was on par with the performance of 'CO-3' and 'CO-4' as shown in Table 96 to Table 99. This could be attributed to the higher similar regrowth rate (Table 94 and Table 95) and LAI (Table 84 and Table 85) of cultivars 'Suguna', 'CO-4' and 'CO-3'. The lowest yielder was 'PTH'.

In napier grass, the general recommendation is to harvest the crop at 15 cm to 30 cm, which produce the highest fodder yield (Wandera, 1997). In napier grass, maintaining high sward height promotes early stem elongation and dry matter accumulation, which help in early recuperation of growth and benefits in better light interception and higher forage production (Nascimento *et al.*, 2012).

5.3.3. Nutritive value and quality

The data on nutrient content of hybrid napier cutivars at different cutting heights are given in Table 100 to Table 106. Cutting height management did not show any significant effects on nutrient contents studied but significant effects were noticed in crude fibre content of stem. Crude fibre content also varied between the cultivars.

As reported by many researchers, the cutting height has substantial effect only on fibre content of napier grass. It seems cutting height has no significant effect on crude protein content of napier grass and its hybrids (Wijitphan *et al.*, 2009; Tessema *et al.*, 2010).

Crude fibre content of stems increased with decreasing the cutting height and maximum was recorded in cultivars when harvested at 5 cm height. Normally, the crop harvested at lower height contain more fibrous stubble portions along with

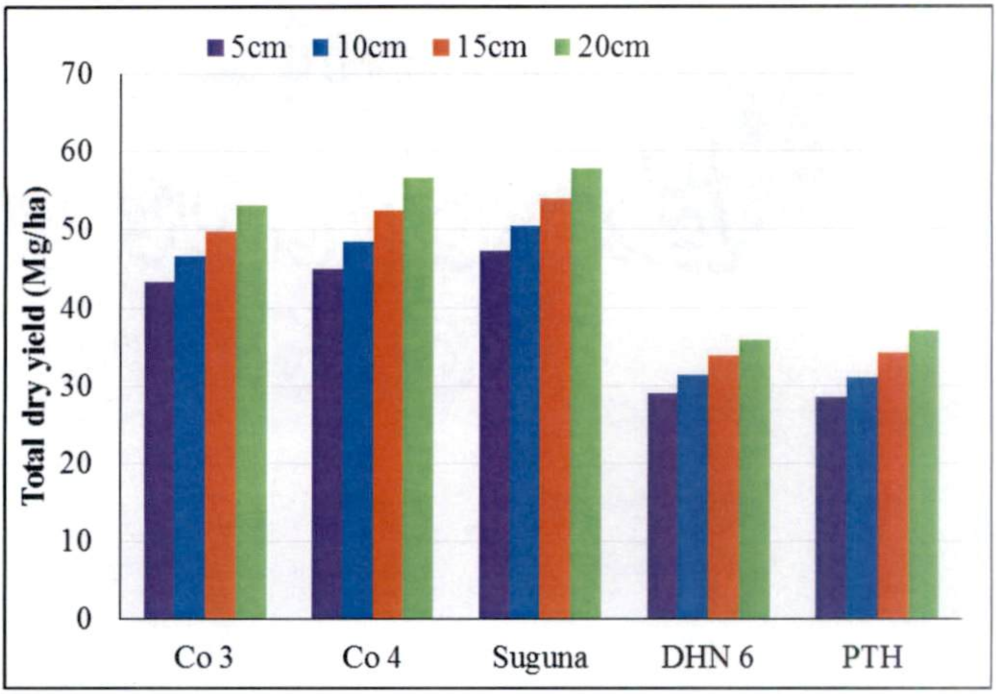

Fig. 26. Effect of cutting height management on total dry yield of hybrid napier cultivars

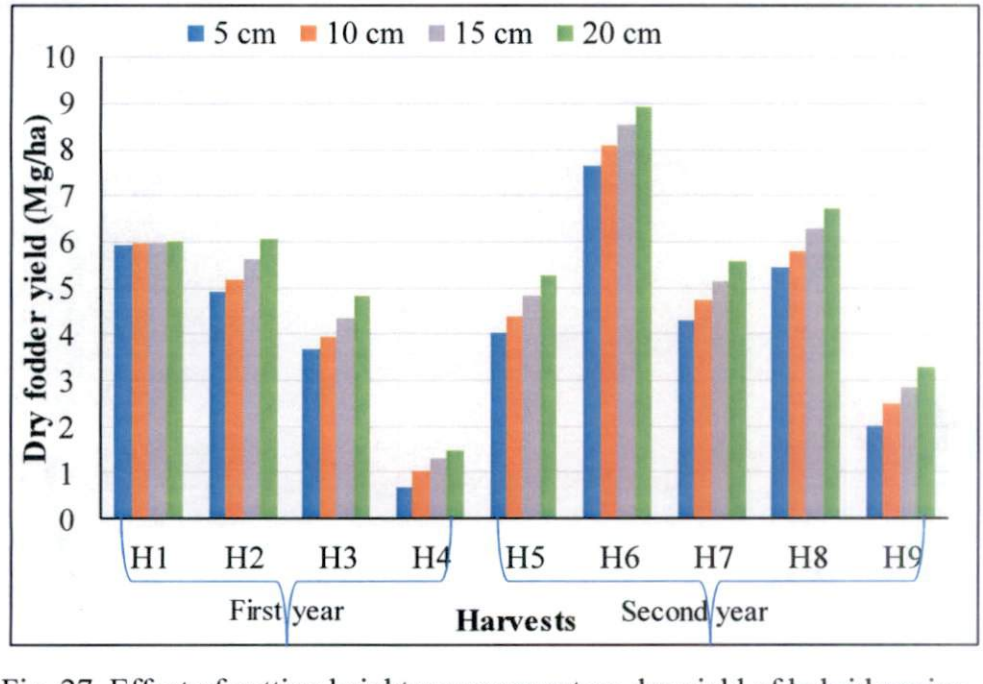

Fig. 27. Effect of cutting height management on dry yield of hybrid napier at each harvest

new flushes; however, harvesting at higher plant height excludes the lower stubble portions, which are highly fibrous.

The crude fibre content also varied between the cultivars. During the first year, in leaves, 'PTH' had the highest content of crude fibre. Interaction was absent. With respect to stem content, the value decreased from 35.07 per cent at 5 cm of cutting height to 27.90 per cent at 20 cm of cutting height. In the second year, 'PTH' and 'CO-4' had the highest content in leaves, and for the stems, the content ranged between 27.82 per cent at 20 cm of cutting height for 'DHN-6' to 35.10 per cent at 5 cm of cutting height for 'Suguna'.

Among the cultivars, crude protein content in 'CO-3', 'CO-4', 'Suguna' and 'PTH' were comparable as these trends were evident in the case of nitrogen content also. All the cultivars had more than 11 per cent crude protein. Similarly, all the cultivars had more than 2 per cent crude fat content except for 'PTH' in their leaves and more than 1 per cent in their stems. The NFE was more in leaves of 'DHN-6' and 'PTH'. Since, 'DHN-6' showed the lowest fibre content and 'PTH' the lowest ether extract, higher values were reflected in the final fraction, the NFE content.

Among the nutrient elements, 'PTH' showed the highest phosphorous content. Potassium content of almost all the cultivars were comparable with each other except 'DHN-6'. None of the cultivars had less than 0.2 per cent of Ca and Mg in their leaves and stems, only exception was 'PTH'.

5.4. CONCLUSION

The findings generated from the present experiment have implications for Kerala where land and water are scarce resources for fodder production. From the two years of shade study, it is obvious that shading reduces fodder yield of hybrid napier. The cultivars 'CO-3', 'CO-4', 'Suguna', 'IGFRI-3' and 'DHN-6' yielded more than 90 Mg/ha of fresh fodder per year under rainfed conditions in shade from the second year onwards. However, among the cultivars tested 'Suguna' and 'CO-3' fared better than others under all levels of shade. Therefore, these two can be grown without much yield reduction where the intercrops receive at least 50 per cent of the incoming solar radiation. This yield is appreciably higher when compared to guinea grass, a commonly recommended shade tolerant grass in coconut gardens which gives 80-100 Mg/ha of fresh fodder per year under irrigated conditions.

From the second experiment, 'Nitrogen nutrition and cutting frequency in hybrid napier under rainfed condition' it could be inferred that as the nitrogen use efficiency was higher at 200 kg/ha N compared to the other levels, a fertilizer dose of 200 kg/ha N is satisfactory under rainfed situations. Nitrate accumulation was also less at this rate. Considering the quality and quantity attributes, cutting at 45 days interval after the first harvest (75 days after planting) may be the best.

In view of cutting height management, under rainfed situation, cutting at 20 cm seems to be the satisfactory as the highest yield was obtained at higher cutting heights. The cultivars 'CO-3', 'CO-4', 'Suguna', 'IGFRI-3' and 'DHN-6' gave higher yield compared to the lowest yielder 'PTH' and no clump mortality was noticed in any of the selected cultivars. The results indicate that these cultivars are suitable for areas without irrigation in Kerala.

5.5. FUTURE LINE OF WORK

The present research project was to compare the prospects of growing hybrid napier under rainfed situations. These aspects, especially shade tolerance, cutting height, cutting interval and nitrogen management need to be studied under irrigated condition too as the crop responses may not be the same under irrigated and rainfed situations. Similarly, various spacing and harvesting intervals can be tried under shaded situations for compensating the yield reduction under reduced light. Antagonistic effects of higher doses of nitrogen on other elements such as K, P, Ca, Mg and micronutrients can also be considered. Since cutting at higher plant heights expose most of the roots after a long period, a study can be planned to incorporate various combinations of cutting management practices including cutting height and interval under different seasons.

Summary

6. SUMMARY

Three field experiments were conducted over a period of two years during 2013-2014 and 2014-2015 at the Agronomy Research Farm of Kerala Agricultural University, Vellanikkara to assess the feasibility of introducing hybrid napier under tree crop based farming system and to find out optimum nitrogen levels and harvesting management practices suitable for rainfed conditions. The experiments were (1) Shade tolerance of hybrid napier cultivars; (2) Nitrogen nutrition and cutting frequency in hybrid napier grown under rainfed condition; and (3) Cutting height management in hybrid napier grown under rainfed condition. A brief summary of the three experiments are given in this chapter.

EXPERIMENT I: SHADE TOLERANCE OF HYBRID NAPIER CULTIVARS

The planting was done on 3rd July 2013 using rooted slips at a spacing of 60 cm X 60 cm and the design of the experiment was split plot in RBD. There selected cultivars included in the study were CO-3, CO-4, Suguna, IGFRI-3, DHN-6, and PTH.

The first harvest was done at 75 days after planting and subsequent harvests at 45 days intervals. There were nine harvests over a period of two years (four in the first year and five in the second year). Observations on various parameters were recorded just before the harvests and these were analysed using suitable statistical tools. Growth parameters, chlorophyll content, light/ PAR interception and fodder yield were recorded. Proximate analysis and analysis of plant parts for nutrient contents and antinutritional factors were also done.

Shading had significant effect on morpho-physiological and yield response of hybrid napier cultivars and the performance of cultivars varied under different shade levels. In both years, increasing shade levels had a facilitating effect on plant height, leaf length, leaf width, leaf area index, leaf area ratio, leaf weight ratio, leaf-stem ratio, chlorophyll content, and light/PAR interception. However, number of tillers, number of leaves, specific leaf weight, and fodder yield were significantly reduced under shade.

Morpho- physiological responses

The crop showed comparatively higher plant height, leaf length and width when grown under 50 per cent shade. Among the cultivars, 'Suguna' showed maximum plant height and leaf length in most of the harvests whereas 'DHN-6' showed maximum leaf width. However, shading reduced tillering and leaf production of hybrid napier. During the experiment 'PTH' produced the highest number of tillers (87.33 tillers /clump) and leaves (554.33 leaves/clump) in full sunlight.

Leaf area index, leaf area ratio, leaf – stem ratio and leaf weight ratio increased with increasing shade levels and attained the maximum at 50 per cent shade. The crop had the highest LAI in the second harvest of the second year at 50 per cent shade and during which 'CO-3' (15.80) and 'Suguna' (15.70) showed maximum values. In general, the cultivars 'Suguna' and 'CO-3' had higher leaf- stem ratios. Specific leaf weight, however, decreased with increasing shade levels.

The chlorophyll content increased with increasing shade. Similarly, chlorophyll b to chlorophyll a ratio increased with increasing shade. Among the cultivars, 'DHN-6' grown under 50 per cent shade had the highest content and chlorophyll b to chlorophyll a ratio. The highest total chlorophyll content obtained was 3.83 mg/g of fresh leaf weight and the chlorophyll b to a ratio was 0.42.

Light regime within plants

Light and PAR interception increased with increasing leaf area. Among all the cultivars, more light and PAR interceptions were observed in 'Suguna' and 'CO-3' at 50 per cent shade level. The highest light interception values observed for 'Suguna' and 'CO-3' were 94.24 per cent and 93.13 per cent while the corresponding PAR interceptions were 84.84 per cent and 81.83 per cent. However, PAR transmission to the lower canopy layers reduced with increasing shade.

Fodder production

For the estimation of fresh fodder yield, the harvested produce from each plot was immediately weighed and weight was expressed in Mg/ha. Dry weight was recorded by randomly selecting five plants from each plot and by drying them at 80 ± 5 °C for 24 hours until constant weight was achieved. From this dry matter per cent was worked out for computing the dry fodder yield from fresh fodder yield. The yield was expressed in Mg/ha.

The highest yield was recorded during the first harvest for the first year and the second harvest during the second year, which coincided with the periods of south west monsoons. Later on, declining trend was noticed towards the final harvest. A slight increase in yield was noticed in the eighth harvest (fourth harvest of second year) than the previous harvest due to the receipt of rainfall, during the period. The highest fodder yield was recorded during the second year as the crop attained maximum number of tillers and leaves by the second harvest.

Fodder yield was significantly reduced under shade. In general, among the cultivars, 'Suguna' was superior in fodder yield in both years of study followed by CO-3 and the least by 'PTH'. Considering the interaction effect, in the first year, under full sunlight, 'Suguna' (111.34 Mg/ha/yr) and 'CO-3' (108.31 Mg/ha/yr) were on par. The same trend was also noticed under 25 per cent shade level. In the second year, under full sunlight, annual yield of 'CO-4' (159.39 Mg/ha) and 'Suguna' (154.62Mg/ha) were almost similar in performance. Under 25 and 50 per cent shade levels, 'CO-3' compared equally well with 'Suguna', fresh fodder yield being 132.92 and 124.98 Mg/ha for Suguna and 130.34 and 120.49 Mg/ha for 'CO-3'.

The dry fodder yield followed the same trend as that of fresh fodder yield. In full sunlight, in the first year, the highest yield was recorded by 'Suguna' (20.93 Mg/ha) followed by 'CO-3' (19.72 Mg/ha). Under 25 and 50 per cent shade, 'Suguna' recorded the highest dry fodder yield of 18.26 and 17.52 Mg/ha respectively followed by 'CO-3'. During the second year, under full sunlight, 'CO-4' (31.88Mg/ha) recorded the highest dry fodder yield followed by 'Suguna'

(29.06Mg/ha). Under 25 and 50 per cent shade, 'Suguna' recorded the highest dry fodder yield of 24.99 Mg/ha and 23.50 Mg/ha respectively followed by 'CO-3' (23.73 Mg/ha and 21.92 Mg/ha respectively).

In general, the relative yields of hybrid napier under 25 per cent and 50 per cent shade with full sunlight as base level were about 83 per cent and 73 per cent. However, when base level was raised to 25 per cent, the relative yield was about 88 per cent.

Nutritive value and quality

Plant samples were collected from each replication, just before third (first year) and fourth (second year) harvests; leaves and stems were separated, chopped, air dried and oven dried at 80 ± 5^{0}C for 24 hours till constant weight was achieved. The samples after grinding were used to find out the percentage content of nitrogen, phosphorus, potassium, calcium, magnesium and the five fractions of proximate analysis - crude protein, crude fibre, total ash, ether extract, and nitrogen free extract of leaves and stems. Percentage content of antinutritional factor –oxalate of both leaves and stems corresponding to Kharif, Rabi and Summer also were analysed in the harvested produce collected from harvests coinciding the respective seasons of both years. The samples collected after the heavy premonsoon showers were used for plant analysis corresponding to summer season. Significant effects of shade were noticed on nutritive value and quality of leaves and stems. Almost all the nutrients except crude fibre were higher in leaves compared to stems.

Among the cultivars, crude protein content and nitrogen content were higher in 'IGFRI-3,' followed by 'CO-3', 'CO-4', and 'Suguna'. Crude fibre content decreased with increasing shade. The NFE was more than 50 per cent in leaves compared to stems and content increased with increasing shade. The ash content decreased with increasing shade. 'Suguna', 'CO-3' and 'CO-4' had higher ash content and were comparable with each other.

Among the cultivars studied, 'PTH' had the highest phosphorous content. The potassium content of almost all the cultivars were comparable with each other. In general, all the cultivars included in the study had more than 0.2 per cent of Ca and Mg in their leaves and stems.

Leaves showed more oxalate content than stems. Substantial increase in oxalate content with increasing shade was noticed in cultivars. The safe limits of less than 4 per cent were surpassed only during the periods of luxurious growth in leaves. Among the cultivars, 'IGFRI-3' had the highest oxalate content in both leaves and stems. All other cultivars were similar in oxalate contents.

EXPERIMENT II: NITROGEN NUTRITION AND CUTTING FREQUENCY IN HYBRID NAPIER GROWN UNDER RAINFED CONDITION

The experiment was laid out in factorial randomised block design and planting of 'CO-3' was done on 20th June 2013 using rooted slips at a spacing of 60 cm X 60 cm uniformly in all the plots. The first harvesting was done at 75 days after planting for all the treatments. Over a period of two years, there were 12, 9, and 7 harvests respectively for 30 days, 45 days and 60 days of cutting frequencies. The assigned doses of nitrogen fertilizer (0 kg/ha, 100 kg/ha, 200 kg/ha, 300 kg/ha and 400 kg/ha) were applied in three splits as basal and after each harvest coinciding with periods of rainfall.

Cutting frequency and nitrogen nutrition had significant effects on morpho-physiological and yield responses of hybrid napier. In both years, increasing cutting intervals and nitrogen nutrition had facilitating effect on plant growth, yield, and yield attributes.

Morpho- physiological responses

Throughout the experiment, delayed harvesting with increasing nitrogen fertilizer showed higher plant height, leaf length, and leaf width. Over a period of two years, maximum plant height, leaf length, and leaf width were recorded in the second harvest of the second year for plants harvested at 60 days interval and fertilized with 400 kg/ha N.

During the initial stages of plant growth, tiller production and leaf production were less and a gradual increase was observed towards the final harvests. However, after the final harvest of the first year, tiller decline was noticed until the first harvest of the second year due to dearth of soil moisture during summer periods. Increasing nitrogen nutrition and cutting intervals had facilitating effect on leaf and tiller production.

Leaf area index (LAI) increased with delayed harvesting and increasing nitrogen levels. Higher LAI (more than 10) was attained at the second harvest in both years. LAI of the crop decreased towards final harvests in both years. Leaf area ratio (LAR) and Leaf weight ratio (LWR) decrease with delayed harvesting and increasing nitrogen nutrition. Similarly, the leaf- stem ratio decreased with increasing cutting intervals at higher levels of nitrogen. However, the specific leaf area (SLW) increased with increasing cutting interval and nitrogen nutrition. The significant effects of nitrogen nutrition, however, was lost towards the summer season as the effect was masked by lack of soil moisture.

Fodder production

Both fresh and dry fodder yield were recorded. During the first year, there were five, four, and three harvests respectively for 30 days, 45 days, and 60 days of cutting intervals. In the second year, there were seven, five and four harvests for the corresponding cutting intervals. There were no harvests after January for the first year and after December for the second year.

Compared to the first year, total fodder yield was higher in the second year. In the first year, maximum yield was obtained for the first harvest. However, when fertilized with 400 kg/ha N and harvested at 60 days interval, the crop had the highest yield in the second harvest compared to the first.

Significant changes in fresh and dry fodder yield were noticed with increasing nitrogen levels with delayed harvest. The crop produced the highest fresh and dry fodder yield when fertilized with 400 kg/ha N and harvested at 60 days intervals (175.34 Mg/ha and 31.91 Mg/ha).

Nutritive value and quality

The percentage content of nitrogen, phosphorus, potassium, calcium, magnesium and the five fractions of proximate analysis - crude protein, crude fibre, total ash, ether extract, and nitrogen free extract of leaves and stems were detrimental. Percentage content of antinutritional factors –oxalate and nitrate of both leaves and stems corresponding to Kharif, Rabi and Summer also were analysed in the harvested produce collected from harvests coinciding with the respective seasons of both years. The samples collected after the heavy premonsoon showers were used for plant analysis corresponding to summer season. Nitrogen nutrition and cutting frequencies affected the nutritive quality of hybrid napier.

Crude protein content in plants increased with increasing nitrogen levels. However, the content decreased with delayed harvesting. At 30 days harvest, with 400 kg/ha N, leaves had more than 14 per cent crude protein and stems more than 12 per cent. With delayed harvesting at 60 days of cutting frequency with 400 kg/ha N, the crop had more than 12 per cent and 11 per cent crude protein in leaves and stems.

Crude fibre content in plants increased with delayed harvesting but decreased with increasing nitrogen nutrition. However, the crop did not show more than 32 per cent crude fibre in stems even at lower dose of nitrogen with delayed harvesting. Crude fat content increased with increasing nitrogen levels; however, the content remained unchanged at all cutting intervals. The nitrogen free extract was the lowest at 45 days of harvest and the maximum was observed at 30 days of harvest. The content decreased with increasing nitrogen levels but again increased at higher levels of nitrogen. The ash content decreased with plant maturity but no significant effect was noticed with increasing nitrogen level.

In the present experiment, delayed harvesting reduced the content of phosphorus, potassium, calcium, and magnesium, and these reductions ultimately lowered total ash content with increasing cutting interval. There were no change in total ash, phosphorus, and potassium content with increasing nitrogen levels.

The status of antinutritional factors like oxalate and nitrate accumulation was also studied from representative samples during Kharif, Rabi and Summer harvests. In general, there were not much effects of cutting frequencies on oxalate contents. However, significant influence of cutting frequency was noticed in nitrate content. Both oxalate and nitrate content increased with increasing nitrogen levels.

In general, compared to leaves, stems had lesser nitrate content. Exceptions were noticed when the content reached or exceeded the safe limit of 1000 ppm. The nitrate content increased with increasing nitrogen level. The crop had the highest nitrate content in the first year Kharif season. The effect of cutting interval on nitrate content varied depending on the weather conditions.Throughout the experiment, the crop had not accumulated higher nitrogen content but exemptions were noticed only under certain situations only.

Nitrogen use efficiency

There were significant effects of nitrogen nutrition and cutting frequency on nitrogen use efficiency of hybrid napier. The highest efficiency of 47.92 kg dry fodder per kilogram N applied was recorded at 45 days of harvest with 200 kg/ha N. For all cutting frequencies, maximum efficiency was recorded under 200 kg/ha N. When fertilized with 100 kg/ha N and 200 kg/ha N, maximum efficiency was recorded at 45 days of harvest. For higher doses, NUE decreased on delaying the harvest.

Soil analysis

Soil analysis was done before and after the experiment. The organic carbon content increased after the experiment but the available N, P and K in soil declined after the experiment.

Soil analysis before the experiments indicated that the soil is high in all the available nutrients. Significant changes in soil organic carbon content was noticed with increasing cutting frequency and nitrogen levels. Interaction effect was also observed. After the experiment, all the plots showed more than 1 per cent of soil organic carbon. The content of available nutrients in soil increased with increasing cutting frequencies but a declining trend was noticed with increasing nitrogen levels. The highest content of organic carbon was observed in plots not fertilized with nitrogen but harvested at 60 days of cutting frequency. The least organic carbon was noticed in plots fertilized with 400 kg/ha N and harvested at 30 days intervals.

Available nitrogen content, decreased with increasing harvesting intervals and decreasing nitrogen levels. The highest content was noticed in plots treated with 400 kg/ha N and harvested at 30 days interval.. At 45 days and 60 days of cutting intervals, there were no changes in available nitrogen content of soil at higher doses of nitrogen, i.e., 200 kg/ha N, 300 kg/ha N and 400 kg/ha N.

Similarly, the available phosphorous content in soil decreased with increasing cutting intervals and increasing nitrogen levels. Maximum P was observed in unfertilized nitrogen plots but harvested at 30 days interval. When harvested at 45 days and 60 days of cutting frequencies, there were no changes in available P content of soil at higher doses of nitrogen, i.e., at 300 kg/ha N and 400 kg/ha N.

The available K content in the soil decreased with increasing cutting intervals and increasing nitrogen levels. The highest available K was observed in unfertilized nitrogen plots which were harvested at 30 days interval. K availability in plots treated with 400 kg/ha N were comparable at 30 days and 45 days of cutting frequencies.

EXPERIMENT III: CUTTING HEIGHT MANAGEMENT IN HYBRID NAPIER GROWN UNDER RAINFED CONDITION

The experiment was laid out in factorial randomised block design. Planting of five cultivars ('CO-3', 'CO-4', 'Suguna', 'DHN-6' and 'PTH') were done on 27th June 2013 using rooted slips. The growth was rather slow during the initial periods and later the growth was fast. During the summer periods, the crop growth rate became slow but clump mortality was not observed. The first harvesting was done at 75 days after planting for all the treatments. Over a period of two years, there were nine harvests.

Cutting height management had significant effects on yield attributing factors such as tiller and leaf production of hybrid napier cultivars which, in turn, produced substantial changes in fodder yield too. However, cutting height management could not produce significant effects on other morpho- physiological characters and nutritive quality. However, substantial changes in regrowth rate and stem fibre content were observed.

Morpho- physiological responses

Seasonal variation in plant height, leaf length, and width were noticed. In the first year, maximum plant growth was observed in the first harvest and decreased towards the final harvest. However, on receipt of premonsoon showers, plant growth recuperated. Due to the receipt of sufficient amount of rainfall, the peak in growth was observed in the second and the fourth harvest for the second year. The time allowed for growth and the receipt of sufficient amount of rainfall and soil nutrition helped favourable growth during the first harvest in all the treatment plots.

Among the cultivars, 'DHN-6' had maximum plant height, leaf length, and width during the periods of sufficient rainfall, and the cultivars 'Suguna', 'CO-3' and 'CO-4' had comparable growth attributes in almost all seasons. 'PTH' had the least leaf length and width during all the seasons.

Both tiller production and leaf production in hybrid napier were significantly influenced by cutting height management and cultivars. In both years, tiller production and leaf production showed an increasing trend towards the final harvest. During the summer periods, tiller decline was noticed, but there were no clump mortality. With the onset of premonsoon showers, regeneration was observed. Maximum number of tillers and leaves were produced when cut at 20 cm height and were much reduced when plants were cut at 5 cm height. In general, among the cultivars, 'PTH' showed maximum number of tillers and 'DHN-6' the minimum, which reflected in leaf production too.However, in the second year, cutting height management had no significant effect on tiller production, except at the second harvest.

Harvesting hybrid napier at different heights had considerable influence on leaf area index. The highest LAI was noticed in plants when harvested at 20 cm height. During both years, LAI attained the highest value at second harvests. In general, among the cultivars, maximum LAI was observed in 'Suguna' (16.60 at 20 cm) and the least in 'PTH' (5.34 at 5 cm).

Although substantial changes in LAI was noticed, cutting height has not much influnce on leaf area ratio (LAR), leaf weight ratio (LWR), specific leaf weight (SLW), and leaf-stem ratio. In general, LAR and LWR values increased towards the final harvests in both years. During the course of experiment, the crop showed the highest SLW at the fourth harvest of the second year since the crop had the lowest leaf area at that time. Among the cultivars, 'PTH' recorded maximum SLW but showed reduced LAI at all harvests.

Cutting at varying heights did not have much effects on leaf to stem ratio of hybrid napier although the ratio varied between the cultivars. Interactions were absent. During both years, the highest leaf to stem ratio was recorded at the third harvests. In general, 'CO-3', CO-4' and 'Suguna' had comparable leaf to stem ratios recording maximum values. The least was observed in 'PTH'. The ratio increased towards the final harvest.

Regarding regrowth rate, significant differences among cultivars were noticed when harvested at different cutting heights. Interaction effects of cutting height and cultivars were also evident. Hybrid napier showed maximum regrowth rate when harvested at 20 cm height and showed a declining trend when harvested at lower cutting heights. The highest regrowth rate was attained after the first harvest in both years of study and started decreasing towards the final harvests. In general, 'CO-3', 'CO-4' and 'Suguna' had comparable regrowth rate and showed the maximum. Similarly, regrowth rate of 'DHN-6' and 'PTH' were comparable; however, regrowth was rather poor in both cultivars.

After the final harvest in the first year, the crop showed an increasing trend in regrowth rate on receipt of premonsoon showers and reached its peak after the first harvest of the second year. However, regrowth rate decreased after the second harvest, and on receipt of north east monsoon, an increasing trend was noticed, but thereafter, it decreased.

Fodder production

Fodder yield of hybrid napier cultivars was significantly influenced by cutting height management. Both fresh and dry fodder yield increased with increasing cutting height. All the cultivars included in the study had the highest fodder yield when harvested at 20 cm height.

The cultivars included in the study differed significantly with respect to fodder yield. Among them, 'Suguna' had the highest yield, however, it was on par with the performance of 'CO-3' and 'CO-4'. The lowest yielder was 'PTH'. In the first year 'Suguna' and 'CO-3' had comparable total fresh fodder yields at 20 cm, 120.44 Mg/ha and 118.69 Mg/ha respectively and were superior to other cultivars. However, in the second year 'CO-4' had the highest total fresh yield (184.31 Mg/ha at 20 cm) and followed by 'Suguna' (181.43 Mg/ha).

Nutritive value and quality

The percentage content of N, P, K, Ca and Mg, and proximate analysis of both leaves and stems were analysed. Cutting height management did not show any significant effects on nutrient contents studied but significant effects were noticed in crude fibre content of stem. Crude fibre content of stems increased with decreasing the cutting height and maximum was recorded in cultivars when harvested at 5 cm height.

The crude fibre content also varied between the cultivars. During the first year, in leaves, 'PTH' had the highest content of crude fibre. Interaction was absent. With respect to stem content, the value decreased from 35.07 per cent at 5 cm of cutting height to 27.90 per cent at 20 cm of cutting height. In the second year, 'PTH' and

'CO-4' had the highest content in leaves, and for the stems, the content ranged between 27.82 per cent at 20 cm of cutting height for 'DHN-6' to 35.10 per cent at 5 cm of cutting height for 'Suguna'.

Among the cultivars, crude protein content in 'CO-3', 'CO-4', 'Suguna' and 'PTH' were comparable. All the cultivars had more than 11 per cent crude protein. Similarly, all the cultivars had more than 2 per cent crude fat content except for 'PTH' in their leaves and more than 1 per cent in their stems. The NFE was more in leaves of 'DHN-6' and 'PTH'. 'PTH' showed the highest phosphorous content. Potassium content of almost all the cultivars were comparable with each other except 'DHN-6'. All the cultivars had less than 0. 2 per cent of Ca and Mg in their leaves and stems.

Conclusion

The findings generated from the present experiment have implications for Kerala where land and water are scarce resources for fodder production. From the two years of shade study, it is obvious that shading reduces fodder yield of hybrid napier. The cultivars 'CO-3', 'CO-4', 'Suguna', 'IGFRI-3' and 'DHN-6' yielded more than 90 Mg/ha of fresh fodder per year under rainfed conditions in shade from the second year onwards. However, among the cultivars tested 'Suguna' and 'CO-3' fared better than others under all levels of shade. Therefore, these two can be grown without much yield reduction where the intercrops receive at least 50 per cent of the incoming solar radiation. This yield is appreciably higher when compared to guinea grass, a commonly recommended shade tolerant grass in coconut gardens which gives 80-100 Mg/ha of fresh fodder per year under irrigated conditions.

From the second experiment, 'Nitrogen nutrition and cutting frequency in hybrid napier under rainfed condition' it can be inferred that as the nitrogen use efficiency was higher at 200 kg/ha N compared to the other levels, a fertilizer dose of 200 kg/ha N is satisfactory under rainfed situations. Nitrate accumulation was also less at this rate. Considering the quality and quantity attributes, cutting at 45 days interval after the first harvest (75 days after planting) may be the best.

In view of cutting height management, under rainfed situation, cutting at 20 cm seems to be the satisfactory as the highest yield was obtained at higher cutting heights. The cultivars 'CO-3', 'CO-4', 'Suguna', 'IGFRI-3' and 'DHN-6' gave higher yield compared to the lowest yielder 'PTH' and no clump mortality was noticed in any of the selected cultivars. The results indicate that these cultivars are suitable for areas without irrigation in Kerala.

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* Originals not seen

Appendices

APPENDIX -I

Weekly mean surface air temperature, relative humidity, wind speed, sunshine hours, rainfall and rainy days at COH Vellanikkara from May 07 2013 to 30 June 2015 (latitude 10 ^{0} 31' N, longitude 76 ^{0} 13' and Altitude 40.29 MSL)

Month	Week No.	Date from to		Surface air temperature (⁰C)		Relative Humidity (%)		Windspeed (km/h)	Mean sunshine hours (h/day)	Rainfall (mm/week)	Rainy days
				max.	min.	Morning	Evening				
May 2013	19	7	13	34.3	25.8	92	58	2.6	2.6	0	0
	20	14	20	34.4	25.1	89	55	3.1	5.5	6.4	1
	21	21	27	34	24.6	92	61	2.4	5.3	5.7	1
	22	28	3-Jun	29.9	23.5	96	79	1.8	1.6	210.8	5
Jun	23	4	10	29.4	22.8	95	79	1.7	1.2	149.2	6
	24	11	17	28.6	22.3	97	87	2.2	1.1	302.5	7
	25	18	24	27.5	23	98	86	1	0.5	284.1	7
	26	25	1-Jul	28.6	22.9	96	83	1.1	0.8	172.2	6
Jul	27	2	8	28.6	22.8	97	85	1.9	0.9	247.5	7
	28	9	15	28.4	22.8	97	85	1.7	0.7	172.7	7
	29	16	22	27.5	22.7	97	90	1.4	0.2	276.8	7
	30	23	29	28.5	22.3	96	79	2	0.3	207.8	7
	31	30	5-Aug	28.9	22.8	96	81	3	1.6	185.8	6
Aug	32	6	12	29	23.5	96	72	2.4	3.6	89.9	2
	33	13	19	29.9	23.1	96	71	1.8	3.6	37.2	6
	34	20	26	30	22.5	97	69	1.9	6	20.5	4
	35	27	2-Sep	31.9	23.2	94	68	1.7	6.2	0.4	0
Sep	36	3	9	29.8	22	96	75	1.2	3.5	66.2	4
	37	10	16	29.4	22.1	96	79	1.9	2.7	158.4	5
	38	17	23	29.1	22.7	96	76	2.3	2.5	104.3	5
	39	24	30	31	21.6	93	69	1.3	6.2	10.4	2
Oct	40	1	7	30.9	21.9	96	62	1.7	5.8	17.8	2
	41	8	14	30.7	22.6	96	69	2.2	6.3	60.1	3

	42	15	21	30.8	23.1	96	72	1.8	5	150.6	5
	43	22	28	29.6	23	97	77	1.4	2.7	117.1	5
	44 -	29	4-Nov	32.8	24	89	62	2.3	7.1	29.8	2
Nov	45	5	11	32.4	24.1	76	54	5.6	7.9	0	0
	46	12	18	31.8	23.2	87	63	2.6	4.8	61.3	3
	47	19	25	32.9	23.9	94	63	1.8	5.7	13.2	1
	48	26	2-Dec	33.1	24	92	60	1.9	6.1	6.3	1
Dec	49	3	9	32.3	22.4	81	44	3.6	7.2	0.5	0
	50	10	16	32.4	22.5	87	51	3.3	6.6	0	0
	51	17	23	31.4	21.8	77	43	7	9.6	0	0
	52	24	31-Dec	31.3	22.1	66	39	7.7	9.1	0	0

Month	Week	Date		Surface air temperature (^0C)		Relative Humidity (%)		Wind speed (km/h)	Mean sunshine hours (h/day)	Rainfall (mm/week)	Rainy days
		From	To	Max	Min	Morning	Evening				
Jan. 2014	1	1-Jan	7	32.6	22.4	74	34	5.8	9.3	0.0	0
	2	8	14	32.8	23.1	68	37	6.3	8.1	0.0	0
	3	15	21	33.2	23.7	63	37	5.8	8.8	0.0	0
	4	22	28	32.5	23.3	63	38	8.8	9.3	0.0	0
	5	29	4-Feb	33.7	22.3	60	33	7.8	9.9	0.0	0
Feb	6	5	11	35.1	21.0	74	28	3.9	9.8	0.0	0
	7	12	18	33.6	22.6	89	51	4.2	7.4	0.0	0
	8	19	25	35.0	24.3	70	38	5.3	7.5	0.0	0
	9	26	4-Mar	35.2	24.6	78	42	3.9	8.7	0.0	0
Mar	10	5	11	35.1	25.1	71	38	4.9	7.2	0.0	0
	11	12	18	37.4	22.7	66	18	5.2	9.7	0.0	0
	12	19	25	37.3	24.7	84	44	2.7	8.5	0.0	0
	13	26	1-Apr	38.1	24.3	81	31	2.9	8.9	0.0	0
Apr	14	2	8	36.3	25.9	87	55	2.6	7.1	0.7	0
	15	9	15	34.5	24.3	90	58	2.1	5.1	40.0	2
	16	16	22	35.2	25.8	89	56	2.4	8.4	3.5	1
	17	23	29	35.2	26.5	89	61	2.1	4.9	14.6	1
	18	30	6-May	35.0	25.0	85	59	3.2	5.6	68.4	1
May	19	7	13	31.5	25.1	91	73	2.4	4.3	215.1	3
	20	14	20	33.2	25.0	91	79	2.3	7.6	0.0	0
	21	21	27	33.4	25.2	91	63	2.1	5.6	0.0	0
	22	28	3-Jun	32.7	25.2	93	68	2.3	5.4	55.0	2
Jun	23	4	10	30.4	24.5	92	81	2.1	3.1	161.4	5
	24	11	17	30.7	23.8	96	75	2.1	2.4	79.1	6
	25	18	24	30.5	24.2	97	79	2.8	1.2	142.9	6
	26	25	1-Jul	31.1	24.6	95	72	2	4.6	95.7	4
Jul	27	2	8	30.8	23.5	93	70	2.2	4.4	22.8	3
	28	9	15	28.1	22.8	97	85	2.1	0.2	243.9	7

	29	16	22	29.2	22.8	95	84	2.1	1.5	182.5
	30	23	29	29.8	23.1	97	81	1.9	0.7	166.1
	31	30	5-Aug	28.0	23.4	97	84	1.8	0.3	303.1
Aug	32	6	12	28.4	22.5	97	79	1.5	0.4	136.1
	33	13	19	30.6	23.8	97	69	2.2	4.9	6.1
	34	20	26	31.0	23.6	94	74	2.1	5.4	128.2
	35	27	2-Sep	29.2	23.0	98	78	2.2	1.3	203.0
Sep	36	3	9	29.8	23.0	97	74	1.8	3.4	47.6
	37	10	16	30.9	23.3	97	66	2.3	7.4	22.0
	38	17	23	31.5	23.5	94	65	2.4	7.3	1.8
	39	24	30	33.6	23.6	89	68	2.3	6.1	90.6
Oct	40	1	7	32.4	23.7	93	71	1.7	4.4	59.2
	41	8	14	31.2	23.8	96	73	1.3	3.8	59.9
	42	15	21	32.2	23.9	90	63	4	5.5	32.0
	43	22	28	31.8	23.7	91	68	1.7	4.9	67.4
	44	29	4-Nov	32.0	23.1	95	66	1.6	4.4	20.5
Nov	45	5	11	32.5	23.2	95	64	1.7	5.5	15.6
	46	12	18	32.2	23.4	81	60	5.8	7.8	55.3
	47	19	25	31.4	23.5	76	54	4.8	5.2	0.0
	48	26	2-Dec	30.3	22.4	68	54	4.7	2.3	0.0
Dec	49	3	9	32.3	21.9	76	50	4.9	8.5	0.0
	50	10	16	32.4	23.8	82	54	4.7	6.4	7.8
	51	17	23	31.5	24.2	80	59	8.2	5.4	0.0
	52	24	31-Dec	31.6	23.3	78	52	3.9	5.0	1.6

Month	Week	Date		Surface air temperature (^0C)		Relative Humidity (%)		Wind speed (km/h)	Mean sunshine hours (h/day)	Rainfall (mm/week)	Rainy days
		From	To	Max	Min	Morning	Evening				
Jan.2015	1	1-Jan	7	32.5	21.5	90	47	2.7	8.0	0.0	0
	2	8	14	32.0	21.3	72	39	5.7	8.7	0.0	0
	3	15	21	32.4	22.1	66	41	5.9	9.0	0.0	0
	4	22	28	32.9	23.0	73	38	7.1	9.3	0.0	0
	5	29	4-Feb	32.9	23.7	66	40	8.6	9.2	0.0	0
Feb	6	5	11	33.6	23.2	69	36	7.5	8.3	0.0	0
	7	12	18	35.2	23.5	83	37	4.0	9.1	0.0	0
	8	19	25	35.0	22.2	66	30	5.1	9.6	0.0	0
	9	26	4-Mar	34.6	23.6	86	49	3.0	6.7	0.0	0
Mar	10	5	11	35.4	24.5	81	45	3.3	8.2	0.4	0
	11	12	18	35.8	24.8	78	41	4.3	7.9	71.6	2
	12	19	25	35.8	25.1	89	46	2.8	8.4	0.0	0
	13	26	1-Apr	36.6	25.9	84	43	3.0	7.8	5.6	1
Apr	14	2	8	34.6	25.6	91	60	2.4	6.6	0.0	0
	15	9	15	34.1	24.5	85	64	2.6	6.1	23.8	1
	16	16	22	33.8	24.1	90	66	2.4	7.0	19.8	4
	17	23	29	33.2	24.2	88	65	2.2	7.3	72.6	2
	18	30	6-May	33.7	24.5	91	66	2.0	7.7	47.2	2
May	19	7	13	32.5	24.0	92	71	1.6	3.3	120.0	5
	20	14	20	32.2	24.6	92	72	1.8	2.8	81.0	3
	21	21	27	33.3	25.8	93	64	1.4	6.3	0.0	0
	22	28	3-Jun	32.6	24.9	89	65	1.6	5.1	14.8	2
June	23	4	10	32.3	24.1	92	73	1.4	3.9	44.5	3
	24	11	17	30.4	23.4	95	75	1.1	1.0	160.6	6
	25	18	24	30.5	24.3	93	83	2.2	0.3	196.8	7
	26	25	1-Jul	30.3	23.6	96	81	1.5	1.8	228.6	7

APPENDIX II. Schedule of field experiments

Sl. No		Event	Date				
			Experiment I	Experiment II			Experiment III
				30 DAH	45 DAH	60 DAH	
1	First year	Planting	03/07/2013	20/06/2013	20/06/2013	20/06/2013	27/06/2013
2		First harvest	16/09/2013*	03/09/2013*	03/09/2013*	03/09/2013*	10/09/2013*
3		Second harvest	31/10/2013*	03/10/2013	18/10/2013*	02/12/2013*	25/10/2013*
4		Third harvest	16/12/2013	02/11/2013*	02/12/2013	01/01/2014	09/12/2013
5		Fourth harvest	29/01/2014	02/12/2013	16/01/2014	-	23/01/2014
6		Fifth	-	01/01/2014	-		-
7		Dormant stage	29/01/2014 to 06/06/2014	01/01/2014 to 04/06/2014	16/01/2014 to 04/06/2014	01/01/2014 to 04/06/2014	23/01/2014 to 05/06/2014
8	Second year	First harvest	06/06/2014*	04/06/2014*	04/06/2014*	04/06/2014*	05/06/2014*
9		Second harvest	21/07/2014*	04/07/2014	19/07/2014*	02/08/2014*	20/07/2014*
10		Third harvest	04/09/2014*	02/08/2014*	02/09/2014*	01/10/2014*	03/09/2014*
11		Fourth harvest	19/10/2014	01/09/2014	17/10/2014	30/11/2014	18/10/2014
12		Fifth harvest	03/12/2014	01/10/2014*	01/12/2014	-	02/12/2014
13		Sixth harvest	-	31/10/2014	-	-	-
14		Seventh harvest	-	30/11/2014	-	-	-

DAH- Days after preceding harvest ; * top dressing with 1/3 dose of nitrogen on next day

SHADE TOLERANCE, NITROGEN NUTRITION, AND HARVEST MANAGEMENT IN HYBRID NAPIER UNDER RAINFED CONDITION

by

SAVITHA ANTONY
(2012-21-102)

ABSTRACT OF THE THESIS
Submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
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2016

ABSTRACT

Hybrid napier, an inter-specific cross between bajra and napier, is a popular fodder grass because of its high yield potential and quality. Three field trials were conducted during 2013–2015 with the objectives of assessing shade tolerance of selected hybrid napier cultivars, finding out optimum nitrogen levels and harvesting frequency, and studying the influence of different cutting heights on regrowth and mortality of major cultivars under rainfed condition.

The performance of six cultivars of hybrid napier(CO-3, CO-4, Suguna, IGFRI-3, DHN-6 and PTH) at three different shade levels (0 per cent, 25 per cent and 50 per cent) were studied under rainfed condition. Increasing shade levels had a facilitating effect on plant height, leaf length, leaf width, leaf area index, leaf area ratio, leaf weight ratio, leaf- stem ratio, chlorophyll content and PAR interception, whereas, number of tillers, number of leaves, specific leaf weight, and fodder yield were reduced under shade. 'Suguna' had the highest fodder yield followed by 'CO-3' and 'CO-4'. Shade also affected the nutritive value and quality of leaves and stems. Oxalate content in plants increased with increasing shade and 'IGFRI-3' had the highest content.

The effect of nitrogen levels (0, 100, 200, 300, and 400 kg/ha) and three cutting intervals (30, 45, and 60 days) were tested on hybrid napier cultivar 'CO-3'. Cutting frequency and nitrogen affected plant growth, yield, and yield attributes. Delayed harvesting reduced fodder quality. Crude protein, crude fat, Ca, Mg, oxalate, and nitrate contents increased with increasing nitrogen levels while total ash, K and P contents remained unaffected. The nitrogen use efficiency (NUE) decreased with increasing cutting intervals and nitrogen doses. The highest NUE was recorded at 45 days cutting interval and with 200 kg/ha N. Soil organic carbon content increased after the experiment but available N, P, and K declined.

The experiment to study the effect of different cutting heights (5, 10, 15, and 20 cm) on regrowth and mortality of major cultivars (CO-3. CO-4, Suguna, DHN-6 and PTH) revealed that cutting height management affected yield attributing factors such as tiller and leaf production and fodder yield. The fodder yield increased with increasing cutting height. Hybrid napier showed maximum regrowth rate when harvested at 20 cm height and showed a declining trend when harvested at lower cutting heights. The cultivars 'CO-3', 'CO-4' and 'Suguna' had comparable regrowth rate.

The results from the present investigation have implications for Kerala where land and water are scarce resources for fodder production. As 'Suguna' and 'CO-3' performed better than other cultivars under shade, these two can be grown where the intercrops receive at least 50 per cent of the incoming solar radiation. Applying 200 kg/ha nitrogen and cutting at 20 cm height at 45-60 days interval seem to be satisfactory for hybrid napier under rainfed condition.