PERFORMANCE OF HYBRID NAPIER CULTIVARS UNDER RAINFED CONDITIONS

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by

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(2010-11-103)

THESIS

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DECLARATION

I, hereby declare that the thesis entitled **"Performance of hybrid napier cultivars under rainfed conditions"** 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.

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We, the undersigned members of the advisory committee of **Ms. Savitha Antony (2010-11-103)** a candidate for the degree of **Master of Science in Agriculture**, with major field in Agronomy, agree that the thesis entitled **"Performance of hybrid napier cultivars under rainfed conditions"** may be submitted by **Ms. Savitha Antony (2010-11-103)** in partial fulfilment of the requirement for the degree.

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Introduction

1. INTRODUCTION

Livestock rearing is an important subsidiary and complimentary farming activity widely prevalent among small farmers of Kerala, especially as part of the homestead farming system. However, the livestock census data from 1996 to 2007 showed a drastic decline in cattle population from 3.396 million to 1.74 million (GOK, 2011). The factors attributed to this drastic decline in population are manifold such as the scarcity of cheap and quality fodder, rapid increase in the price of feed and feed ingredients, influx of cheap and low quality milk and other livestock products from neighbouring states, indiscriminate slaughter of animals, naive animal production potential, non availability of good genetic stock, threat from contagious diseases, diminishing grazing lands, and urbanization (KLDB, 2012). Among these, availability of cheap and quality feed is a major issue. The problem of feed availability in Kerala is acute because of several constraints. Reports regarding the availability of fodder in the state depict an alarming gap between demand and supply. Availability of land for fodder cultivation in the state is very low due to fragmentation and shifts in cropping patterns from food crops to cash crops. The land classified as ‘permanent pastures and grazing lands’ are just 228 ha in Kerala. Similarly, the area under fodder cultivation in Kerala is also low; it was only 4830 ha during 2009-10. It is estimated that the present fodder availability from all these sources together is only 5.1 million tonnes when the total requirement is 23.2 million tonnes (Anita *et al.*, 2011).

Because of the constraints on fodder, farmers use many feed materials including various crop wastes such as rice straw, banana pseudostems and leaves, coconut leaves, pineapple waste, cocoa waste and leaves of many trees including jack fruit and erythrina, grazing facilities along road side, railway line and canal bunds contribute significantly to the forage availability of cattle maintained by small and marginal farmers. However, most of these are generally poor in nutrients. Even these traditional resources are under threat. For example, there is drastic reduction in the availability of straw for feeding the cattle due to the rapid decline in the area under rice. All these constraints have forced a considerable proportion of dairy farmers to switch over to other enterprises. It is imperative that some urgent measures are needed to arrest the decline in livestock population and to revive the dairy sector. The best alternative is to address the shortage of feed resources by producing nutrient rich, high yielding, but less resource intensive fodder crops.

Hybrid napier is an introduced fodder grass, which has gained popularity among dairy farmers. Compared to other introduced grasses, this grass is well adapted to the agro climatic situations of Kerala, because of its wide adaptability, quick growth, ease of establishment, palatability, high nutritive quality, herbage yield, persistence and good response to fertilizers. However, most hybrid napier cultivars express high yield potential only when grown under irrigation. This limitation inhibits its cultivation especially among resource poor farmers. In recent years, several new cultivars were released and are becoming popular among farmers. Although Kerala is blessed with about 2960 mm of annual rainfall, majority of farmers in the midlands and high ranges face water shortage during summer months, a major constraint in establishing irrigation facilities. Farmers who are unable to establish irrigation facilities are in search of fodder crops that can be grown entirely dependent upon rainfall.

Although *ad-hoc* package of practices recommendations are given for cultivars like Pusa Giant Napier, Gajaraj, NB-5, NB-6, NB-21, NB-35, Suguna, and Supriya (KAU, 2007), most farmers prefer to grow new cultivars having high yield potential such as CO-3, CO-4, and KKM-1. Cultivars like IGFRI-3, IGFRI-7, DHN-6 and PTH (*Pennisetun* trispecific hybrid) are also being cultivated by several farmers under irrigated conditions. As water and electricity for pumping are limiting factors for irrigation, it is desirable to examine the suitability of growing popular cultivars entirely dependent on rainfall. It is hoped that by conducting a comparative evaluation of the newly released cultivars of hybrid napier under rainfed situations, promising cultivars among them could be recommended to the farmers. The present investigation was planned with the following main objectives.

1. Evaluate the performance of popular cultivars of hybrid napier under rainfed conditions.
2. Assess the quality parameters of the cultivars included in the study.

Review of Literature

2. REVIEW OF LITERATURE

Hybrid napier is a popular cultivated fodder grass among livestock farmers of Kerala. It is an inter-specific cross between bajra (*Pennisetum glaucum* (L.) R.Br.) and napier grass (*Pennisetum purpureum* Schum.) Bajra or pearl millet is a coarse annual bunch grass widely grown in Asia and Africa primarily for grain. In the American continent, it is usually grown for feed and forage (Gupta and Mhere, 1997; Faruqui *et al.*, 2009). Napier grass, a native of Rhodesia (now Zimbabwe) in South Africa, is a persistent and high yielding forage grass widely grown in the tropics and sub-tropics. It is a tall clumped grass with thick growth, earning the name 'elephant grass'. The name 'napier grass' is given in honour of Col. Napier, who first drew the attention 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 has high forage value as green fodder or hay and holds great promise for cultivation in the high rainfall areas as well as irrigated areas. It is one of the most promising and high yielding fodder grass giving high dry matter yield that surpasses most tropical grasses (Humpherys, 1994; Skerman and Riveros, 1990). It can be effectively used in developing new multicut, high forage yielding hybrids to overcome the fodder deficit periods by crossing it with pearl millet and to boost up fodder production (Bhatti *et al.*, 1985).

With the popularization of the interspecific hybrids (2n=21), bajra (2n=14) X napier (2n=28) and napier X bajra, importance of napier as a cultivated fodder grass declined. The perennial and heavy tillering characteristics along with deep root system and multicut habit of napier grass have been combined with faster growth habit, leafiness and high quality of bajra, and the napier x bajra hybrid was evolved. 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). Bajra and napier species readily inter cross and the hybrids are more vigorous than the parent species and highly sterile (Gupta and Mhere, 1997; Burton, 1944). In India, majority of area under cultivation of this grass is in the states of Tamil Nadu, Karnataka, Andhra Pradesh, Odisha, Maharastra, and Gujarat (Vijayakumar *et al.*, 2009).

A review of literature on various aspects included in the present study such as growth, growth analysis, fodder production, cultivars, nutritive value and quality, nutrient uptake, and water stress is presented in this chapter. Similar works on other grasses are also included in this review wherever the literature on hybrid napier is insufficient.

2.1. Characteristics of hybrid napier

Hybrid napier is a sterile triploid (2n=21), and therefore, does not produce seeds. This feature is an advantage as it prevents the grass from becoming a weedy menace. In the tropics, napier hybrids behave as perennials with higher yields and better forage quality than either parents (Powell and Burton, 1966). The dry matter yields of hybrids were comparable with common napier and its selections. They produce more tillers and leaves with bulk of fodder and grow faster than their parents (Gupta and Mhere, 1997). Thomas (2008) reported that 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, and drought resistant.

According to Faruqui *et al.* (2009), hybrid napier cultivars are well adapted to a wide range of soils except water logged soils. It is widely distributed in sub-tropical regions of Asia, Africa, Southern Europe and America. In India, it is mainly cultivated in Punjab, Haryana, UP, Bihar, Madhya Pradesh, Orissa, Gujarat, West Bengal, Assam, Andhra Pradesh, Kerala and Tamil Nadu. The grass grows throughout the year in tropics. 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). Anarase and Amolic (2007) reported that the hybrids are resistant to major pests and diseases.

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.

As the seeds are sterile, it is established from setts, cuttings, rooted slips, or splits and usually cultivated in irrigated areas (Pahuja and Joshi, 2007; Thomas, 2008). Hybrids are with high dry matter yield with high leaf percentage, high nitrogen content in stem, high stem digestibility, and wide adaptability (Pritchard, 1971). Hybrid napier is mostly planted for cut and carry systems, and not for long-term grazed pastures. It is also used for hedgerows and living fences, but roots may compete with adjacent crop. Young growth makes good hay, which can be fed as hay or pellets. It also makes good silage, although inferior to maize and sorghum. Sometimes, hybrid napier grass is also used as a windbreak in horticultural crops and orchards.

Hybrid napier is considered as a soil-restoring crop, as grass leaves the soil richer in organic matter (Gangaiah, 2008). According to Pahuja and Joshi (2007), its inclusion in arable crop rotations to an optimum level not only increases the yield of crops but also improves the soil structure, water retention, resistance to erosion, and productivity. It is gaining importance as they provide year round supply of fodder to cattle (Dwivedi *et al.*, 2007). Pandey and Roy (2011) have reported that hybrid napier grows fast and produce high herbage yield but stems are hard and less persistent. The grass once planted will survive for three years with continuous and regular supply of fodder and cost of production is almost half that of single- cut crops. The fodder production per unit area and time is approximately double than conventional fodders.

2.2 Growth and growth parameters

Watkins and Lewy-Van Severen (1951) reported that in El Salvador that enjoys tropical climate the period of the lowest growth in grasses is from February to May, and the maximum is from June to November and this trend is very much similar for all forage grasses.

According to Singh *et al.* (1995), leafiness can be used as an indicator of yield and nutritive value. Leaf number and leaf area per plant and per tiller are indications of leafiness, and this characteristic is closely correlated with yield and digestibility. Leaf length is the morphological characteristic most highly correlated with yield (Malaviya, 1999).

Leaf area index (LAI) is an important parameter, which is used to compare leaf area per unit area of land. It is the number of complete layers of leaves displayed by crop expressed as an average for the whole crop (Hunt, 1978). Gardner *et al.* (1985) suggested LAI of 8-10 for forage crops under favorable conditions to maximize light interception, where total biomass, not economic yield, is the objective. Kumar *et al.* (2011) observed LAI of 3.91-20.79 for hybrid napier under rain fed condition.

Net assimilation rate (NAR) is a measure of the average photosynthetic efficiency of leaves. It is the net gain of assimilate or dry matter accumulation per unit leaf area per unit time. Gardner *et al.* (1985) suggested that as the plant grows and LAI increases, more and more leaves become shaded, causing a decrease in NAR as the growing season progresses.

Relative growth rate (RGR) is the dry weight increase in a time interval in relation to its initial weight. According to Gardner *et al.* (1985), RGR of crop plants begins slowly just after germination, peaks rapidly soon afterwards and then falls off. Praveen (2007) reported that NAR and RGR of both Guinea and Potha grass declined during summer due to leaf senescence but improved on receipt of rains due to vigorous plant growth.

Leaf area ratio (LAR) is a measure of relative leafiness of a plant. It is the ratio between the area of leaf lamina or photosynthesizing tissue and the total respiring plant tissue or total plant biomass. Praveen (2007) observed that LAR of fodder grasses increased during initial three months and showed a decreasing trend with aging of plant.

Leaf to stem ratio is a qualitative character affecting the palatability and consequently animal intake. Soumya (2011) reported leaf: stem ratio of 0.6 to 0.9 for hybrid napier cultivars. The cultivar CO-4 has a leaf-stem ratio of 0.71 (Vijayakumar *et al.*, 2009). Fleischer (1987) reported a decrease in leaf: stem ratio with stand stage.

Gardner *et al.* (1985) suggested that shoot: root ratio can reflect one type of tolerance to drought stress. They also suggested that S-R ratio is influenced by genetic and environmental factors. Panwar and Bhardwaj (1999) reported S-R ratio of 1.66 for napier grass.

2.3. Fodder production potential

The rate of fodder production is a function of tiller production and leaf growth (Ryle, 1970; Selvi and Subramanian, 1993). Praveen (2007) observed that plant height, tiller number and leaf number directly influence the yield of fodder. Barbbar (1985) reported that the green fodder yield per plant was positively correlated with number of tillers per plant, number of leaves per plant and stem weight per plant. According to Sotomayour-Rios *et al.* (1972), tillering ability and forage volume shows the highest correlation with yield. Thomas *et al.* (2007) observed that plant height, leaf area, number of tillers and crude protein contributed either directly or indirectly to the green forage and dry matter yield. Premaratne and Premalal (2006) stated that the grass is endowed with quick regeneration capacity and under proper management practice together with correct application of fertilizer, irrigation in drought spells, cutting at suitable height and interval, the crop could be maintained up to 4-5 years with maximum profit. With liberal dressing of fertilizers, hybrid napier is expected to yield 40 Mg of dry matter, 6000 kg of crude protein and about 2000 kg of extractable protein from one hectare in a year in India (Gore *et al.*, 1974).

In an experiment conducted by Sheng (1983) during 1979-82 in Taiwan, five lines of *P. purpureum* X *P. americanum* were compared with napier grass cv. A146. The hybrid line 7001 yielded more fresh forage than napier grass, while three lines gave 10 percentage higher dry matter yields than napier grass. The hybrids had smooth leaves and leaf sheaths while those of napier grass bore hairs. The hybrids had higher crude protein and crude fibre contents than napier grass.

Under irrigated condition in the tropics, hybrid napier can provide green fodder throughout the year and yields on an average 200-400 Mg/ha depending on the cultivar and region (Thomas, 2008). Kumar *et al.* (2011) reported an average of three harvests per year under rainfed condition from the cultivar CO-3. According to Kaur and Chaudary (2010), hybrid napier shows luxuriant growth during monsoon season and provides 270-280 Mg/ha from 6-8 cuts.

Senthilkumar *et al.* (2010) stated that hybrid napier could produce fresh matter yield of 475-500 Mg/ha per year with improved agronomic practices.

Gupta and Mhere (1997) reported that during the dry periods some cultivars of hybrid napier continue to grow and produce dry matter yield of 600 kg/ha per cut. The dry matter yield was higher during rainy season. The leaf and tiller production was suppressed under moisture stress, or low temperatures and radiation (Muldoon and Pearson, 1977). They also observed that under favorable conditions, dry weight and leaf area responses were linear.

2.4. Cutting interval

Yield, in general, increases when the interval of cutting is increased (Watkins and Lewy-Van Severen, 1951). According to Ramasamy *et al.* (1993), green fodder yield showed a diminishing trend with the progressive increase in the number of cuttings. In hybrid napier cultivar ABPN-1, the green and dry fodder yields increased with increasing cutting interval from 30-60 days (Devi *et al.*, 2007). Increasing the harvest interval reduces the number of tillers but increases the size of grass leaves (Wilman and Asiegbu, 1982).

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).

According to Bhatti *et al.* (1985), higher yield at closer spacing is due to higher number of tillers per unit area, tiller height as well as leaf area and number of leaves per tiller. The yield of herbage increased with decrease in cutting frequency (Aleem and Noor, 1979). 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 a comparative trial conducted by Ibrahim *et al.* (2008) at the Animal Production Research Institute, Egypt, crude protein content and dry matter percentage of hybrid napier was higher than napier grass or pearl millet at 100 and 150 cm heights. With increase in plant height, crude fibre and acid detergent fibre percentage increased but crude protein percentage decreased, while the neutral detergent fibre percentage and acid detergent fibre percentage of pearl millet, napier grass and its hybrids were nearly similar.

In hybrid napier, Singh and Joshi (2002) obtained the highest green forage and crude protein yield with cutting at six week interval, while dry matter content and digestible dry matter yield increased with increase in cutting interval from 5 to 7 weeks. 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. In trials conducted by Tomer *et al.* (1974) with hybrid napier cv. 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.

2.5. Main cultivars of hybrid napier

Researchers under SAUs and ICAR system have released many cultivars of hybrid napier suited to specific regions, which differ widely in terms of green forage yield, dry matter and crude protein yield. Genotype is the most prominent factor which affects yield (Schank *et al.*, 1993; Cuomo *et al.*, 1996) followed by edaphic and climatic factors and management practices (Chaparro *et al.*, 1995; Chaparro *et al.*, 1996).

In hybrid napier, CO-1 and CO-2 are two earlier cultivars released from TNAU, Coimbatore suitable for black soils under irrigated ecosystem (Das *et al.*, 2000). The cultivar CO-2 was developed through interspecific cross between bajra-PT 8369 and napier- FD 488 followed by clonal selection. It has been recommended for cultivation in South India for cattle feeding. It provides 350.00 Mg/ha of green fodder (Pandey and Roy, 2011).

The influence of CO-3, an immensely popular and heavy yielding type, in making hybrid napier a preferred grass among dairy farmers is a well accepted fact. It was produced from bajra PT 1697 and napier grass. It is suitable for red loamy soil areas and for sheep and goat feeding in addition to cattle feeding. The cultivar CO-3 is recommended for cultivation in South India under irrigated condition. It flowers late in the season and has dark green leaves. It has high leaf stem ratio making it highly palatable for animals (Pandey and Roy, 2011). CO-3 gave an average green fodder yield of 393.60 Mg/ha per year during station trials conducted in Tamil Nadu during 1991-92 and a maximum yield of 514.00 Mg/ha at Pudupalayam in Salem District as part of Adaptive Research Trials. The dry matter yield averaged 65.00 Mg/ha per year and the crude protein yield averaged 5.40 Mg/ha per year, which are higher than the respective values for CO-1 and CO-2. The oxalic acid content is lower in CO-3 than in CO-1 and CO-2 (Fazlullahkhan *et al.*, 1996). The cultivar CO-3 is superior in quality in terms of leafiness, broader and softer leaves, and high leaf: stem ratio and very high fodder yield.

Vijayakumar *et al.* (2009) reported that the cultivar CO-3 is characterized by light green densely hairy leaves with white midrib. Leaf margins are serrated with an average leaf length of 80-95 cm and leaf width of 3.0-4.2 cm. The number of leaves per clump varies from 300-400 with leaf: stem ratio of 0.60. It is having a plant height of 300-360 cm at flowering and stem girth of 5.0 cm and the number of tillers per clump vary from 25-30. They also reported fresh fodder and dry matter yield of 325.50 Mg/ha, 62.10 Mg/ha respectively in a year with dry matter percentage of 19.10 from CO-3 cultivar.

Premaratne and Premalal (2006) reported that on an average CO-3 provides green fodder of 5–8 kg/plant from a single cutting or 250-350 Mg/ha annually, and the grass is superior in terms of higher tillering capacity, forage yield, regeneration capacity, leaf to stem ratio, crude protein content, resistance to pest and diseases and free from adverse factors. It can supply year-round quality fodder without concentrates for cattle. The grass contains 18-20 percent dry matter, 15–16 percent crude protein, 9.8–12.8 percent ash, 34-37 percent crude fibre and 74–78 percent neutral detergent fibre on dry matter basis. High crude protein content is one of the distinctive features of this grass.

From a study on the relative performance of seven bajra napier hybrid grasses, it was concluded that CO-3 was the best suitable hybrid grass for the coastal lowlands of Karaikal as compared to IGFRI-3, IGFRI-7, IGFRI-10, CO-4, KKM-1 and PBN-223 in terms of growth, green fodder yield and economics (Chellamuthu *et al.*, 2011).

The cultivar CO (CN) 4 is another high yielding and nutritious hybrid napier developed at the Department of Forage Crops, Center for Plant Breeding and Genetics, TNAU, Coimbatore and released for cultivation in 2008. It is found to tiller profusely and yield more than previous varieties (Velayudham *et al.*, 2011). It is an interspecific cross between fodder bajra-CO-8 and napier grass-FD-461 which is well adapted to soil and climatic conditions of Tamil Nadu and is highly palatable with high biomass, high leaf: stem ratio, soft stem and more protein (Vijayakumar *et al.*, 2009). They also reported that it is highly preferred by milch animals, goat and sheep. It registered a mean green fodder yield of 368 Mg/ha, which was 33 percent higher yield over CO-3. It is possible to take seven cuttings per year. It has erect plant habit with 4-5 m plant height at flowering. It is characterized by non lodging profuse tillers (30-40 tillers/clump), soft juicy stem with a brix value of 3.4 and stem girth of 5.6 cm, dark green leaves with bright white mid rib, serrated leaf margins with an average leaf length of 110-115 cm and leaf width of 4-5 cm. A uniform and visible white powdery coating on the stem is a distinguishing feature of this cultivar. Green, conspicuous arial roots encircling each node provide quick regeneration capacity. Number of leaves per clump is from 400 to 450 with leaf: stem ratio of 0.71. Under station trials conducted at TNAU, 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.

KKM-1 is another cultivar released from TNAU during January 2000 as a non lodging fodder hybrid specially suited for red soil areas of southern parts of Tamil Nadu. It is a cross between bajra- IP 15507 and napier grass- FD 429. It recorded an average green fodder yield of 288 Mg /ha in trials conducted in Killikulam, during 1991-92 to 1996-97, with a dry matter production of 16.4 Mg/ha. It is highly leafy with long and soft leaves and possesses quick regeneration capacity, and low oxalate content compared to CO-2 and CO-3 (Das *et al.*, 2000).

Suguna and Supriya are two cultivars developed at College of Agriculture, Vellayani, under the AICRP on Forage Crops and released for cultivation during 2006. Suguna is a derivative of cross between Composite 9 and FD 431. It is a semi-perennial, multicut fodder grass, which yields 260 Mg/ha of green fodder. Both cultivars are recommended for cultivation in southern districts of Kerala (Pandey and Roy, 2011). Suguna differs from other cultivars in having pale green leaf sheath with purplish pigmentation. It is having high yield potential of 283.70 Mg/ha with high quality fodder (KAU, 2007). Supriya was developed through inter specific hybridization of TNSC 4 and FD 471followed by clonal selection. It yields 270.00 Mg/ha of green fodder. It bears pale green leaves with small hairs on both sides (KAU, 2007).

The cultivar IGFRI-3 (Swetika) was developed at Indian Grassland and Fodder Research Institute, Jhansi by crossing napier grass and bajra (PSB-2). The cultivar was notified for cultivation in north and central zones of the country. It is a profuse tillering type, erect with narrow upright leaves with quick regeneration ability and have thin stems like guinea grass. It is tolerant to frost and low temperature and is suitable for low pH conditions. It has field resistance to *Helminthosporium* blight and gave an average yield of 70-80 Mg/ha green fodder and 18 Mg/ha dry fodder (Pandey and Roy, 2011). Faruqui *et al.*(2009) reported green fodder potential of 90-160 Mg/ha for IGFRI-3 and found highly suitable for inter cropping in central, north east and north hill region due to its erect growth habit, high tillering and leafiness. It has been reported that IGFRI -3 is a superior, shade tolerant cultivar exhibiting high green fodder yield, dry fodder yield, tillering potential and persistence (IGFRI, 2000).

The cultivar IGFRI-7 is suitable for hilly, sub-humid and sub-temperate areas of India. It yields 140-170 Mg/ha of green fodder (Gangaiah, 2008). Among the hybrids tested 'IGFRI 7' was superior to 'CO 2' and 'PBN 16' in relation to green forage yield (Ramamurthy, 2002).

DHN-6 (Sampoorna) is a cultivar developed at IGFRI Regional Research Station, Dharwad, through interspecific hybridization of IPM 14188 (Bajra line) and FD 184 (napier line) followed by clonal selection. AICRP trials conducted at IGFRI regional station Dharwad revealed that the cultivar DHN-6 is superior in terms of yield (IGFRI, 2002). The cultivar is recommended for cultivation in Karnataka state under irrigated conditions. It has low oxalic acid content (1.9 %) and yields 120.00-150.00 Mg/ha green fodder from 6-8 cuts (Pandey and Roy, 2011). Sridhar *et al.* (2008), reported that the cultivar produced green fodder yield of 182.40 Mg/ha and dry matter yield of 73.10 Mg/ha with relatively high palatability. It is also resistant to *Helminthosporium* leaf spot and rust disease.

PTH (*Pennisetum* trispecific hybrid) is the result of crossing between three species (*Pennisetum glaucum*, *P. purpureum* and *P. squamulatum*. The trispecific hybrid is a perennial and morphologically intermediate to the three species (Dujardin and Hanna, 1985). It is recommended for cultivation under rainfed conditions (Biradar *et al.*, 2008). It acquired softness from bajra, high yield potential from napier grass and drought tolerance from *P. squamulatum*. In field experiments conducted at IGFRI Regional Research Centre, Dharwad on utilization of bunds for fodder production, the cultivars PTH and IGFRI-3 are found suitable in terms of fodder production and tussock diameter. PTH grass established very well and recorded 4-6 kg of green fodder per cut per metre length of bund (IGFRI, 1999).

PBN-16 is a cultivar recommended for cultivation in Punjab, Maharashtra and Karnataka (Gangaiah, 2008). In a field experiment conducted by Manjunath *et* *al.* (2002) during 1999-2001 to evaluate the performance of grass-legume forage mixtures for intercropping in coconut, hybrid napier PBN-16+Centro combination recorded significantly superior mean total forage yield of 82.57 t/ha per year.

The cultivars recommended for cultivation in Kerala are Pusa Giant Napier, Gajaraj, NB-5, NB-21 and NB-25. Suguna and Supriya, the cultivars released during 2006 are also recommended for cultivation (KAU, 2007). Although not recommended, the cultivars such as CO-2, CO-3, CO-4, KKM-1, and DHN-6 are also under cultivation in many parts of Kerala.

2.6. Effect of nutrients

Nitrogen fertilizers significantly affect the nutritional quality of grasses (Mohammad, 1981). According to Havlin *et al.* (2003), with enhanced nitrogen application, carbohydrates are converted into proteins, more protoplasm is formed and because protoplasm is highly hydrated, a more succulent fodder results. From a study by Chellamuthu *et al.* (2000), it was observed that combined application of biofertilizers (*Azospirillum* and phosphobacterium) together with 75 percentage of recommended nitrogen and phosphorous fertilizers increased plant height, number of tillers per plant, and green and dry fodder yields slightly compared with 100 percentage of recommended NP and no biofertilizers. 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 224.20-237.20 Mg/ha in 10 cuts compared with 162.98 Mg without NPK. The highest average green and dry fodder yields of 100.8 and 28.0 Mg/ha respectively were achieved with 30 kg N and intercropping with legumes like cowpea and berseem at a row spacing of 1.0 m (Bhagat *et al*., 1992).

Forage production of all grasses increased with nitrogen fertilizer increments and hybrid napier at 120 kg/ha N yielded 32 Mg/ha dry matter (Pandey *et al*., 2011). 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. Walmsley and Sargeent (1978) reported that nitrogen application above 170 kg/ha did not affect forage yield of napier grass.

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 and with the increase in the level of fertilization. Plant height (155.80 cm), fresh fodder yield (102.73 Mg/ha) and dry matter yield (17.03 Mg) increased with nitrogen rate up to 90 kg with high economic returns but tillering was unaffected by fertilizers (Gupta, 1995).

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. 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). Malarvizhi and Rajamannar (2001) reported that the integrated use of sewage irrigation and nitrogen recorded the highest green fodder yield and dry matter yield from bajra napier hybrid.

2.7. Nutritive value and quality

Nutritive value of fodder crops decides the ability to provide the nutrients required by an animal for its maintenance, growth and reproduction. It is assessed in terms of energy availability, protein content, minerals, vitamins and freedom from anti-nutritional factors. Proximate analysis devised by Weende Experiment Station in Germany is made use of for assessing nutritive value, which involves five fractions- crude protein (CP), crude fibre (CF), nitrogen free extract (NFE), ether extract (EE) and ash (Thomas, 2008). Islam *et al.* (2003) suggested that napier grass varieties differ widely in terms of botanical fractions and nutritive value, which may have important implications on intake and productivity of animals. Cultivars differ widely in terms of nutritive value (Soumya, 2011). She compared eight cultivars and observed that crude protein content in different cultivars ranged from 6.14 to 13.83 percent, crude fibre 27.56 to 37.68 percent, crude fat 1.79 to 2.82 percent, nitrogen free extract 41.33 percent to 45.22 percent, total ash 11.62 to 13.90 percent, phosphorus content 0.16 to 0.20 percent, potassium content 1.64 to 2.14 percent, calcium content 0.42 to 0.43 percent, magnesium content 0.48 to 0.54 percent and oxalate content 1.20 to 4.19 percent.

Crude protein content gives an approximate value of protein content in the forages. According to Humpherys (1978), for dairy cows, the feed ingested should have at least 1.1 percent nitrogen (crude protein-6.88%) for maintenance, 1.6 percent (crude protein-10%) for beef production and 1.9 percent (crude protein-11.88%) for dairy cows. Hybrid napier, in general, contains about 10.2 percent crude protein (Thomas, 2008). Vijayakumar *et al.* (2009) reported that the cultivar CO-3 had an average crude protein content of 10.5 percent and crude protein yield of 6.52 Mg/ha, whereas the cultivar CO-4 had a crude protein yield of 8.71 Mg/ha with an average crude protein percentage of 10.71. With cultivar CO-3, Elanchezhian and Reddy (2009) obtained 21.4 percent dry matter when analysed at green stage and contained 10.38 percent crude protein. Premaratne and Premalal (2006) reported higher crude protein content of 15-16 percent when harvested at correct stage for CO-3. Velayudham *et al.* (2011) reported crude protein, crude protein yield and crude fibre varying from 7.53 - 8.34 percent, 3.12 – 3.89 Mg/ha and 27.95–28.06 percent, respectively for CO-4. The cultivar KKM-1 showed crude protein content varying from 9.36 percent to 10.28 percent (Pahuja and Joshi, 2007). Sridhar *et al.* (2008) reported that the cultivar DHN-6 was rich in crude protein content (13.2 %) with a relatively high crude protein yield of 4.53Mg/ha.

Bhatti *et al.* (1985) observed that crude protein, nitrogen free extract, ether extract and ash contents of napier grass were more in herbage of younger plants which were more succulent and lesser crude fibre contents than the more aged plants. According to Wilsie *et al.* (1940), protein content of napier grass decreased as harvest interval was lengthened. Cameron and Lachance (1970) reported that dry matter, protein and fibre digestion coefficients were higher for early cut and lower for late cut herbages. Rakkiyappan and Krishnamoorthy (1982) reported that fresh fodder yield, dry matter yield, acid detergent fibre, neutral detergent fibre, acid detergent lignin and silica contents increased while leaf:stem ratio and crude protein content decreased with plant growth.

Application of nitrogen increased both forage and crude protein yields (Reddy and Naik, 1999). Increasing nitrogen rates increased the average crude protein content of hybrid napier from 8.41 to 9.90 percent and oxalic acid contents from 2.29 to 2.85 percent in eight cuts (Govindasamy and Manickam, 1989). The crude protein content of hybrid napier cv. Pusa Giant decreased with delay in cutting intervals, but crude protein yield was the highest when cut at 50-days interval (Tomer *et al.*, 1974) and 45 days in case of NB-21 and BN-2, respectively (Mani and Kothandaramanan, 1981).

Fibre is essential for rumination. Grasses in general contain more crude fibre than legumes. According to Thomas (2008), a part of crude fibre is digestible. When harvested at correct stage, CO-3 grass contains 9.8 – 12.8 % ash, 34 – 37 % crude fibre and 74 – 78 % neutral detergent fibre on dry matter basis (Premaratne and Premalal, 2006). Vijayakumar *et al.* (2009) reported that hybrid napier cultivar CO-4 had a lower crude fibre (28.1 %) and higher total ash content (17.52 %) compared to that of cultivar CO-3 (30.5 % and 16.17 %). Vincente – Chandler *et al.* (1959) noticed increased fibre content by increasing nitrogen doses in napier grass and guinea grass.

Cutting interval is likely to affect crude fibre content. Mohammad *et al.* (1988) observed that at 30, 45 and 60 days cutting interval, crude fibre content in napier grass was 25.1, 30 and 32.7 percent, respectively. Higher crude fibre in plants harvested after longer intervals was due to maturation of grass (Vincente – Chandler *et al.*1959; Miller *et al.*, 1961).

Ether extract gives an estimate of crude fat content of fodder. According to Fernandes *et al.* (2007), in rainy season, hybrid napier grass contains crude fat content of 2.68 percent. Premaratne and Premalal (2006) reported that crude fat content of hybrid napier cultivars CO-3 and NB-21 ranged from 6.2-6.9 percent and 5.7-6.2 percent, respectively. Senthilkumar *et al.* (2010) found that the cultivar CO-3 on an average contains 4.24 percent crude fat.

Nitrogen free extract (NFE) represents the digestible carbohydrates present in feed. Soumya (2011) found that NFE in leaves ranged from 41.33 percent to 44.82 percent and that of stem varied from 42.14 percent to 45.22 percent.

Ash content gives an indication of minerals present in the sample. Vincente – Chandler *et al.* (1959) observed that mineral content of tropical grasses decreased markedly with length of harvest interval. Calcium and phosphorus contents of perennial grasses ranged from 0.49 to 0.51 and 0.36 to 0.40 percent, respectively (Singh *et al*, 2001). Hybrid napier cultivar CO-3 on an average contains 9.8-12.8 percent of ash (Premaratne and Premalal, 2006). They also found that hybrid napier contains 0.42-0.47 percent potassium, 0.11-0.17 percent calcium and 0.21 to 0.36 percent magnesium.

Chatterjee and Das (1989) reported phosphorus content of guinea grass, napier grass and para grass as 0.15, 0.4 and 0.8 percent, respectively. Rathore and Vijay (1977) found that with nitrogen application phosphorous content of grass decreased. Thangamuthu *et al.* (1974) noticed that application of phosphorous had no effect on crude protein content but increased the phosphorous content of forages. Bosworth *et al. (*1980) reported that potassium content of grasses varied from 2.0–3.2 percent at flowering stage. Fernandes *et al.* (2007) observed that the average content of phosphorous and calcium was 0.26 and 0.61 percent, respectively during rainy season. The ash content of napier grass varied from 13.4 percent to 15.3 percent when harvested at 30, 45 and 60 days interval (Mohammed *et al.*, 1988).

Garg *et al.* (2008) observed that paddy straw, a major dry roughage available for feeding dairy animals, was low in Ca (0.11 %), P (0.09 %), S (0.11 %), Cu (1.79 ppm) and Zn (11.69 ppm), whereas hybrid napier as green fodder was a good source of Ca (0.43 %), Mg (0.34 %), Cu (13.83 ppm), Mn (74.52 ppm) and Fe (1379 ppm). According to Nasker *et al.* (2003), hybrid napier is moderate to good source of Ca, Cu, Zn and Mn and very good source of Fe.

Oxalate is a common constituent of plants. However, many forage plants sometimes accumulate oxalate as soluble or insoluble form to potentially toxic level (Rahman *et al.*, 2006); soluble oxalate forms with sodium, potassium and ammonium ions, and insoluble oxalate forms with calcium, magnesium and iron ions (Savage *et al.*, 2000). Soluble oxalate content in napier grass was correlated with potassium ion concentration, while insoluble oxalate content was correlated with calcium and magnesium concentrations (Rahman *et al.*, 2008).

Kipnis and Dabush (1988) reported that in hybrid napier, oxalate levels in the leaves were higher than in stems compared to napier grass and napier grass accumulated more oxalate in stem portions. They also noticed that oxalate levels decreased in both plants with advancing maturity. Kaur *et al.* (2009) noticed that in hybrid napier, leaves accumulated higher concentration of oxalate (3.82 %) compared to stems (1.95 %). Rahman *et al.* (2009) reported that in napier grass clipping increased oxalate concentration and oxalate levels declined as harvest interval increased. According to Vijayakumar *et al.* (2009), oxalate content in CO-4 was less (2.48 %) compared to CO-3 (2.51 %).

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 as 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 a decreasing trend and insoluble oxalate content showed an increasing trend with increased rate of calcium application.

2.8. Water stress on fodder production

Water stress imposed during crop growth drastically affects growth ultimately leading to a massive loss in yield and quality (Govindarajan *et al.*, 1996). Stand density, soil moisture and soil fertility are the other factors positively correlated with forage yield (Sotomayour-Rios *et al.*, 1972). Praveen (2007) reported that dry matter accumulation in guinea grass and potha grass was higher during rainy season and lower during summer because of moisture stress. According to Gardner *et al.* (1985), moisture stress during the vegetative stage results in development of smaller leaves, which reduce LAI and result in less light interception by the crop. Root elongation and dry weight are not affected as much as leaf area, stem elongation and dry weight. According to Bade *et al.* (1985), water stress in tropical grasses reduces yield, slows cell enlargement and stem elongation, and reduces leaf area and shoot: root ratio.

Tekletsadik *et al.* (2004) observed that the protein percentage in dwarf napier was higher during the wet season compared to summer. Tudsri and Kangsanor (1994) showed that under severe water stress, cutting of dwarf napier grass caused death of all plants and no regrowth was observed after dewatering. Water stress affected the above ground biomass of bajara napier hybrids NB-2 and CO-1 but not affected the below ground biomass as water stress stimulated root growth (Manoharan and Paliwal, 1997).

Relative turgidity of leaves is a good indication of water deficit in plants, which is usually measured as relative leaf water content (RLWC) (Thomas, 2010). It was reported that plants having 75-85 percent RLWC exhibited visible wilting symptoms (Gardner and Ehlig, 1965). Maxwell and Redmann (1978) observed that relative water content in a xeric grass, *Agropyron dasystachyum* decreased from 90 percent to 75 percent when the leaf water potential dropped from near 0 bars to about -28 bars. In the case of rice, RLWC dropped down to 33 percent before the crop permanently wilted (Tomar and Ghildyal, 1973).

Materials and Methods

3. MATERIALS AND METHODS

A field experiment was conducted during the year 2011-2012 to evaluate the performance of hybrid napier cultivars under rainfed conditions. Comparisons were made with eleven cultivars of hybrid napier. The details of the materials used and the methods adopted for the study are reported in this chapter.

3.1. General details

Experiment site

The experiment was conducted at the Agronomy Research Farm of College of Horticulture, Kerala Agricultural University. Geographically, the area is situated at 10^0 31'N latitude and $76^0$13'E longitude and at an altitude of 40.3m above mean sea level.

Soil

The soil of the experiment site is sandy clay loam in texture (Order: Ultisol). Pysico-chemical properties of the soil are given in the Table 1.

Climate

The weather data recoded during the cropping period (June 2011 to May 2012) are given in Appendix I and graphically presented in Fig.1 and Fig.2.

3.2. Crop husbandry

Field operations

The selected area for the experiment was ploughed; stubbles removed, leveled and laid out into plots as per the lay out plan (Fig.3).

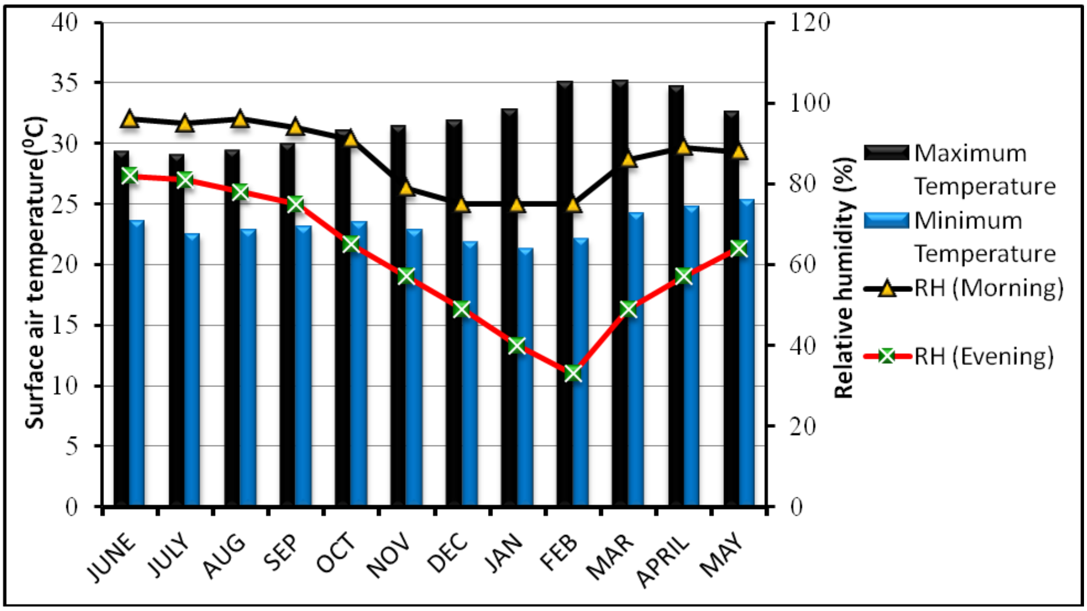

Fig.1.Temperature and relative humidity during the crop period (June 2011 to May 2012) at Vellanikkara, Thrissur

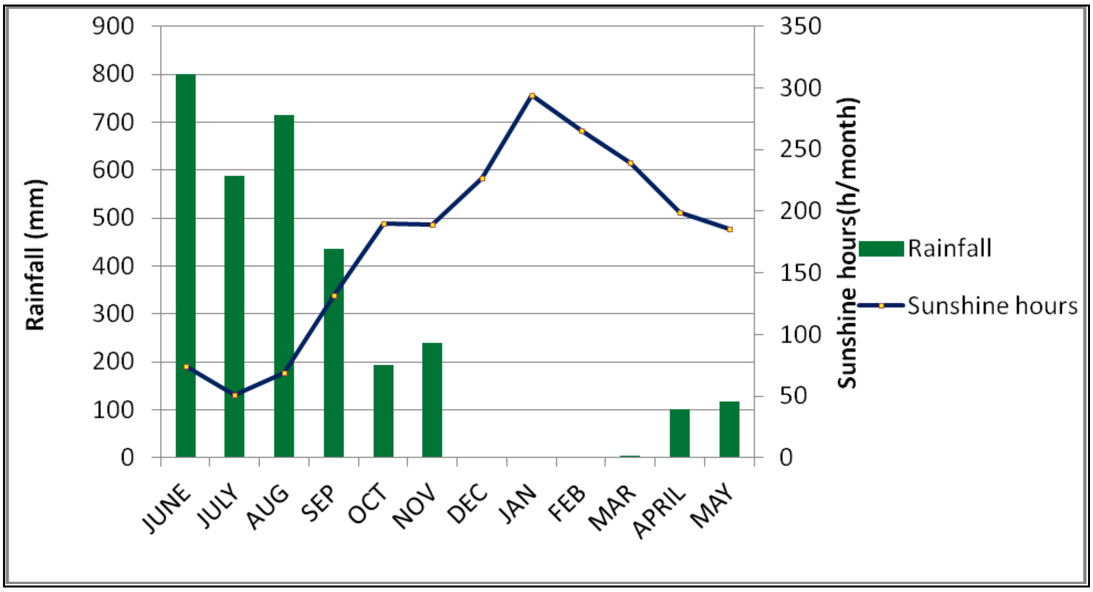

Fig.2.Rainfall and sunshine hours during the crop period (June 2011 to May 2012) at Vellanikkara, Thrissur

Planting

Rooted slips were collected from eleven cultivars of hybrid napier being maintained in the Agronomy farm, College of Horticulture, Vellanikkara. The slips were planted at one slip each at a spacing of 60 cm X 60 cm during June.

Manures and fertilizers

During land preparation, farm yard manure @ 25Mg/ha was applied uniformly and incorporated well into the soil. Fertilizer recommendation followed was 200:50:50 kg N, P_2O_5 and K_2O /ha respectively as per the package of practices recommendations, Kerala Agricultural University (KAU, 2007). One-third of N and entire recommended P_2O_5 and K_2O were applied basally as Urea (46% N), Mussorie Rock Phosphate (20% P_2O_5) and Muriate of Potash (60% K_2O) respectively. The remaining quantity of N was applied in two split doses at one-third dose each one week after first and second harvests.

After cultivation

Gap filling was done 10 days after planting of slips to maintain required plant population. Intercultivation and weeding was done at the time of fertilizer application.

Plant protection

Pseudomonas spraying @ 10g/litre was done to manage the incidence of blast disease during October- November.

Harvesting

The first harvest was done at 75 DAP (days after planting) and the subsequent cuts were taken at 45 days interval. No more harvesting was done after the fourth harvest because of cessation of growth and stunting due to summer. Two rows at one end were left for destructive sampling, and harvesting was done leaving one row as border row from all sides.

3.3. Experiment details

The layout of the experimental field is given in Fig.3. The details of the experiment are as follows:

Design: RBD

Plot size: 20.16m^2 (4.8m x4.2 m)

Replications: 3

Spacing: 60cm x 60cm

Treatments: 11 cultivars of hybrid napier

1. CO-2 2. CO-3 3. CO-4 4. KKM-I 5. Suguna 6. Supriya
7. IGFRI-3 8. IGFRI-7 9. DHN-6 10. PTH 11. PBN-16

Table 1. Physico-chemical properties of soil

Particulars	*Content*	*Method used*
Particle size composition		
Coarse sand (%)	30.90	Robinson international pipette method (Piper, 1942)
Fine sand (%)	26.30	
Silt (%)	19.64	
Clay (%)	23.16	
Field capacity (%)	20.00	Pressure membrane apparatus (Richards, 1947)
Permanent wilting point (%)	11.00	
Chemical composition		
pH	5.30	1: 2.5 soil water ratio Beckman glass electrode (Jackson,1958)
Organic C (%)	1.43	Walkley and Black method (Jackson,1958)
Available N (kg/ha)	485.00	Alkaline permanganate method (Subbiah and Asijah,1956)
Available P (kg/ha)	24.00	Ascorbic acid reduced molybdophosphoric blue colour method (Watnabe and Olsen,1965)
Available K (kg/ha)	239.40	Neutral normal ammonium acetate extractant flame photometry (Jackson,1958)

N

R_3		R_2		R_1	
T4	**T1**	**T5**	**T2**	**T2**	**B**
T11	**B**	**T10**	**T1**	**T9**	**T1**
T10	**T3**	**T7**	**T3**	**T8**	**T6**
T9	**T6**	**T11**	**T6**	**T10**	**T5**
T8	**T2**	**T9**	**T4**	**T11**	**T4**
T7	**T5**	**T8**	**B**	**T7**	**T3**

4.8 m

4.2 m

R_1, R_2, R_3 - Replications

T_1 - CO-2 T_2 - CO-3 T_3 – CO-4 T_4 - KKM-1 T_5 – Suguna T_6-Supriya

T_7 - IGFRI-3 T_8 - IGFRI-7 T_9 - DHN-6 T_{10} – PTH T_{11} - PBN-16 B - Bulk

Fig. 3. Layout of field experiment

3.4. Details of observations

Main observations recorded were growth parameters, green and dry fodder yield, nutrient content and uptake, proximate analysis, soil moisture status and relative leaf water content of leaves. Observations on growth parameters were taken 45days after planting (DAP) and at every harvest starting from the first harvest at 75 DAP of the crop. Plants were selected randomly from each plot. Based on the growth observations, derived variables such as Leaf Area Index (LAI), Leaf Area Ratio (LAR), Net Assimilation Rate (NAR), Relative Growth Rate (RGR), Leaf: Stem ratio and Shoot: Root ratio as detailed by Hunt(1978) and Gardner *et al.*(1985) were calculated.

Table 2. Schedule of harvests

Sl.No.	**Event**	**Date**
1	Planting	07/06/2011
2	First harvest	20/08/2011
3	Second harvest	04/10/2011
4	Third harvest	17/11/2011
5	Fourth harvest	01/01/2012

3.5. Biometric Observations

At 45 days interval, three plants were selected randomly from each plot and observations on the following growth characters were taken.

Plant height

The plant height in cm was recorded from the base of the plant to the tip of the top most leaf during each observation.

Number of tillers

The number of tillers per plant was counted from three different plants randomly selected and the mean was worked out.

Number of leaves

The number of leaves per plant was counted from three different plants randomly selected and the mean was worked out.

Length of leaves

For taking leaf measurements, completely opened and matured fourth leaf from the top was fixed as index leaf. Length of leaves in cm was measured from the base of leaves to the leaf tip and recorded.

Width of leaves

Width of leaves in cm was measured at the middle portion of the index leaf.

3.6. Growth analysis

Different growth indices were worked out as below (Gardner *et al.*, 1985).

Leaf area index (LAI)

Leaf area index is the ratio of leaf area to ground area. The leaf area was calculated using the software CompuEyeLSA (Bakr, 2005) from the randomly selected plants.

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

Leaf area ratio (LAR)

Leaf area ratio, a measure of 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.

$$\text{Leaf area ratio (LAR)} = \frac{(La_2 - La_1)\ (\ln W_2 - \ln W_1)}{(\ln La_2 - \ln La_1) \times (W_2 - W_1)} \quad dm^2/g$$

Where, La_1 and La_2 are total leaf area at time t_1 and t_2; W_1 and W_2 is total dry weight at time t_1 and t_2.

Net Assimilation rate (NAR)

Net assimilation rate gives an indication of the net gain of assimilate per unit of leaf area and time. It is defined as the increase in dry weight of plant per unit leaf area per unit time.

$$\text{Net Assimilation rate (NAR)} = \frac{(W_2-W_1)\ (\ln La_2-\ln La_1)}{(t_2-t_1)(La_2-La_1)} \qquad g/dm^2/day$$

Where, La_1 and La_2 are total leaf area at time t_1 and t_2 and W_1 and W_2 are total dry weights during the same period.

Relative growth rate (RGR)

Relative growth rate is defined as the dry weight increase in a time interval in relation to initial weight and expressed in g/g/day.

$$\text{Relative growth rate (RGR)} = \frac{(\ln W_2-\ln W_1)}{(t_2-t_1)}$$

Where, W_1 and W_2 are total dry weight at time t_1 and t_2 days.

Leaf: stem ratio

It is the ratio of total leaves to stem portions of plant. Stems and leaves were separated from the plant and the dry weights recorded separately. From this, leaf: stem ratio was worked out.

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

Shoot: root ratio

The plants was uprooted and separated into stems and roots, dry weights recorded separately. From this, shoot: root ratio was worked out.

$$\text{Shoot: root ratio} = \frac{\text{Dry weight of shoot}}{\text{Dry weight of root}}$$

3.7. Fodder yield

Green fodder yield

Green fodder yield from each plot was recorded immediately after cutting and the yield of green fodder in Mg/ha was calculated for each plot.

Dry fodder yield

Five plants were selected randomly after each harvest and the plants from each plot were initially weighed, air dried and oven dried (80 ± 5^0C) for 24 hours till constant weight was achieved and dry weight was recorded. Driage was worked out from this and dry fodder yield in Mg/ha was calculated from green fodder yield.

3.8. Proximate analysis

Plant samples from all the treatments were collected at third harvest; 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 calcium, magnesium, oxalate content 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 nitrogen, phosphorus and potassium of both leaves and stems were noted at 75 DAP, 120 DAP and 165 DAP at the time of first, second and third harvests.

Crude protein

The nitrogen content in the plant 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 sample.

Crude fibre

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

Total ash

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

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).

Nitrogen free extract

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

3.9. Nutrient content and uptake

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.

Potassium

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

Calcium and Magnesium

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

Oxalate content

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

Nutrient uptake

The nutrient uptake was calculated during 75 DAP, 120 DAP and 165 DAP at the time of first, second and third harvests. The product of dry matter yield and nutrient content was calculated to obtain the nutrient uptake by the plant.

3.10. Soil moisture content

During the summer months, soil moisture content at 15cm and 45cm was recorded using thermo-gravimetric method. The soil samples were collected with a soil tube in airtight aluminum containers. Then the samples were weighed and oven dried at 105^0C for 24 hours until all the moisture was driven off. The cans were taken out and cooled at room temperature and weighed again. The difference in weight gives the weight of soil moisture in the samples and expressed as percentage.

$$Pw = \frac{Wm - Wd}{Wd} \times 100$$

Where, Pw- percentage of soil moisture by weight; Wm- weight of moist sample and Wd- weight of oven dry sample.

3.11. Relative leaf water content (RLWC)

Relative leaf water content is the appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit. It estimates the current water content of the sampled leaf tissue relative to the maximal water content it can hold at full turgidity. The RLWC of the leaves samples was estimated during summer months as suggested by Barrs (1986)**.** Mid- leaf sections measuring 7cm from fully opened fourth leaf was taken. Each sample was immediately weighed to get the fresh weight and hydrated to full turgidity for four hours. After four hours, the samples were taken out, dried of any surface moisture quickly and lightly with filter paper, and immediately weighed to obtain fully turgid weight. The samples were oven dried at 80^0C for 24 hours and weighed to determine dry weight.

$$RLWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.12. Mortality of clumps

Observation on completely dried clumps were taken on 5-5-2012 after the receipt of a few premonsoon showers after waiting for regeneration, if any, and expressed as percentage of completely dried clumps.

3.13. Data analysis

Analyses of variance were performed on all data collected using the statistical package, 'MSTAT' (Freed, 1986). Duncan's multiple range test (DMRT) was used to compare means (Duncan, 1955; Gomez and Gomez, 1984).

Plate 1. General view of experimental field at 30 days after planting

Plate 2. Hybrid napier cultivar – CO - 2

Plate 3. Hybrid napier cultivar – CO - 3

Plate 4. Hybrid napier cultivar – CO - 4

Plate 5. Hybrid napier cultivar – Suguna

Plate 6. Hybrid napier cultivar – Supriya

Plate 7. Hybrid napier cultivar – KKM - 1

Plate 8. Hybrid napier cultivar – IGFRI - 3

Plate 9. Hybrid napier cultivar – IGFRI - 7

Plate 10. Hybrid napier cultivar – DHN - 6

Plate 11. Hybrid napier cultivar – PTH

Plate 12. Hybrid napier cultivar – PBN – 16

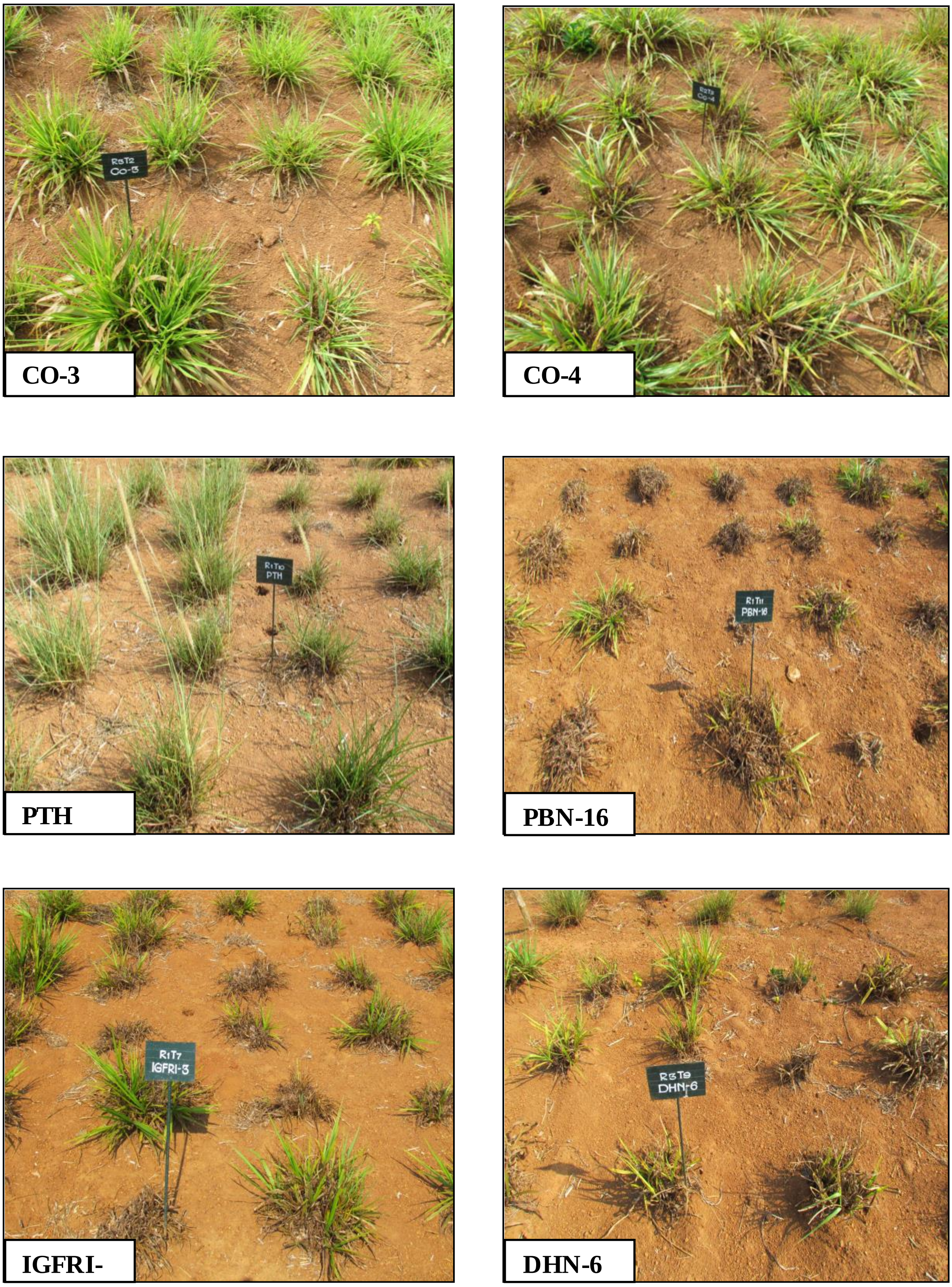

Plate 13. Midsummer mortality of clumps

Results

4. RESULTS

A field experiment to compare various aspects of growth, fodder production potential and nutritive value of eleven different cultivars of hybrid napier under rainfed conditions was conducted during 2011-2012 at Agronomy Farm, College of Horticulture, Vellanikkara. The cultivars included in the study were CO-2, CO-3, CO-4, KKM-1, Suguna, Supriya, IGFRI-3, IGFRI-7, DHN-6, PTH and PBN-16.

Rooted slips of hybrid napier were planted at a spacing of 60 cm X 60 cm on 7-6-2011. Single slips were planted at each hill. Bud regeneration was observed within 7-10 days after planting. The plant growth was almost uniform, the leaves started emerging from 15-20 days after planting, and tillering was observed within one month after planting.

The first harvest was done at 75 days after planting (DAP) and subsequent harvests were done at 45 days interval. Observations recorded at 45 DAP, 75 DAP, 120 DAP, 165 DAP and 210 DAP were used to compute various values. Towards the end of first harvest (75 DAP), the cultivars CO-2 and PTH flowered. However, in the later harvests, no cultivars showed flowering behavior.

4.1 Biometric observations

4.1.1. Plant height

The plant height of cultivars at 45 DAP and different harvests are presented in Table 3 and Fig. 4. All the cultivars showed maximum height during the first harvest, among which CO-2 was the tallest with 295.78 cm followed by IGFRI-7(285.22 cm) and the least was recorded by IGFRI-3 (169.89 cm) and PBN-16 (174.00 cm) which were on par. Plants showed an increase in height up to the second harvest, and thereafter a decreasing trend was noticed. At 45 DAP, CO-2, CO-3 and PTH were on par with 123.00 cm, 120.10 cm and 120.78 cm respectively. Supriya (74.39 cm) and IGFRI-3 (75.00 cm), which were on par, showed the lowest height. At the time of the second harvest again, CO-2 (242.66 cm) showed maximum plant height followed by CO-3 (206.33 cm) and the least was recorded by PBN-16 (137.00 cm). During the third harvest, KKM-1(185.32 cm) attained the first position and the last by PBN-16 (91.89 cm). During the fourth harvest, Suguna (75.94 cm) and KKM-1 (75.34 cm) showed the highest plant height (on par) and the lowest height was recorded by IGFRI-3 (44.57 cm). The mean height of plants over four harvests was the highest for CO-2 (190.16 cm) and the lowest for PBN-16 (116.25 cm).

Table 3. Plant height of hybrid napier cultivars at each harvest (cm)

Harvests		H1	H2	H3	H4	Mean
(Days)	45DAP	75DAP	120DAP	165DAP	210DAP	
CO-2	123.00^{a}	295.78^{a}	242.66^{a}	155.44^{b}	66.77^{cd}	190.16^{a}
CO-3	120.11^{a}	245.33^{d}	206.33^{b}	155.23^{b}	66.23^{d}	168.28^{d}
CO-4	100.67^{c}	245.89^{d}	189.00^{e}	131.10^{c}	53.78^{f}	154.94^{f}
KKM-1	104.22^{c}	229.39^{e}	193.67^{d}	185.32^{a}	75.34^{a}	170.93^{c}
Suguna	79.56^{e}	201.11^{f}	170.44^{h}	118.82^{ef}	75.94^{a}	141.58^{g}
Supriya	74.39^{f}	200.22^{f}	177.33^{g}	126.68^{cd}	69.33^{c}	143.39^{g}
IGFRI-3	75.00^{f}	169.89^{g}	142.55^{i}	103.22^{g}	44.57^{h}	115.06^{h}
IGFRI-7	103.00^{c}	285.22^{b}	199.44^{c}	155.12^{b}	72.44^{b}	178.06^{b}
DHN-6	113.67^{b}	268.56^{c}	174.22^{gh}	122.56^{de}	51.07^{g}	154.10^{f}
PTH	120.78^{a}	282.94^{b}	184.67^{f}	114.99^{f}	50.80^{g}	158.35^{e}
PBN-16	86.06^{d}	174.00^{g}	137.00^{j}	91.89^{h}	62.10^{e}	116.25^{h}

*In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.1.2. Number of tillers

Number of tillers per clump at 45DAP and different harvests is presented in Table 4 and Fig. 5. During the initial stages of the experiment, tiller production was less, then gradually increased and again decreased towards the end of the experiment. At 45DAP, PTH(19.89) and IGFRI-3(19.56) were on par and produced the maximum number of tillers followed by CO-3(17.00), PBN-16(16.12) and KKM-1(16.00) which were on par. Tiller production was minimum in CO-2(8.44) and CO-4(8.67). During the first harvest (75DAP), PTH(23.11), CO-3(21.67) and

IGFRI-3 (21.55) recorded the maximum number of tillers and they were on par, while CO-2 (9.67) and CO-4 (10.00) produced the lowest number of tillers, which were on par. In the second harvest, KKM-1 (33.01) and PBN-16 (35.55) produced the maximum number of tillers and were on par. During the second harvest also, tiller production was consistently low in the cultivars CO-2 (13.78) and CO-4 (13.11) and were on par with Supriya (16.43) and DHN-6 (15.21).

Table 4. Number of tillers per clump of hybrid napier cultivars at each harvest

Harvests		H1	H2	H3	H4	Mean
(Days)	45DAP	75DAP	120DAP	165DAP	210DAP	
CO-2	8.44[d]	9.67[d]	13.78[e]	35.56[f]	42.11[h]	25.28[h]
CO-3	17.00[b]	21.67[a]	29.33[b]	44.89[e]	53.02[f]	37.23[e]
CO-4	8.67[d]	10.00[d]	13.11[e]	43.12[e]	47.17[g]	28.35[g]
KKM-1	16.00[b]	17.88[b]	33.01[a]	42.48[e]	63.54[d]	39.23[d]
Suguna	11.67[c]	14.78[c]	17.56[cd]	57.42[d]	56.43[e]	36.55[e]
Supriya	12.33[c]	15.77[bc]	16.43[de]	60.32[d]	70.00[c]	40.63[d]
IGFRI-3	19.56[a]	21.55[a]	20.67[c]	100.34[a]	76.00[b]	54.64[b]
IGFRI-7	12.11[c]	15.22[bc]	18.22[c]	69.29[c]	69.33[c]	43.02[c]
DHN-6	12.67[c]	15.67[bc]	15.21[de]	43.78[e]	47.00[g]	30.42[f]
PTH	19.89[a]	23.11[a]	27.33[b]	93.00[b]	121.24[a]	66.17[a]
PBN-16	16.12[b]	17.67[b]	35.55[a]	66.44[c]	54.57[ef]	43.56[c]

***** In a column, means followed by common letters do not differ significantly at 5% level by DMRT

During the third harvest, IGFRI-3 (100.34) produced the maximum number of tillers and the least was observed in CO-2 (35.56). In the fourth harvest, PTH produced maximum number of tillers (121.24) and the minimum was recorded by CO-2 (42.11). The average number of tillers was found to be the highest for PTH (66.17) followed by IGFRI-3 (54.64). The lowest mean number of tillers was recorded in CO-2 (25.28).

4.1.3. Number of leaves

Number of leaves per clump in different cultivars of hybrid napier at 45 DAP and at the different harvesting stages are presented in Table 5 and Fig. 6. A progressive increase in number of leaves was observed with maturity of the plant during the course of investigation. At 45 DAP, the cultivar IGFRI-3 showed the maximum number of leaves followed by CO-3 and PBN-16. In the later stages, however, PTH showed the maximum number of leaves and CO-2 the least. The mean number of leaves was also maximum for PTH (433.38) followed by IGFRI-3 (350.42). The lowest number of leaves was in CO-2 (167.99).

Table 5. Number of leaves per clump of hybrid napier cultivars at each harvest

Harvests		H1	H2	H3	H4	Mean
(Days)	45DAP	75DAP	120DAP	165DAP	210DAP	
CO-2	70.00^{h}	125.09^{i}	104.55^{h}	227.33^{i}	215.00^{i}	167.99^{j}
CO-3	155.11^{b}	195.44^{b}	216.66^{b}	273.43^{g}	266.10^{f}	237.91^{fg}
CO-4	122.22^{e}	133.33^{h}	139.22^{g}	274.78^{g}	247.73^{g}	198.77^{i}
KKM-1	117.11^{f}	178.45^{d}	207.56^{c}	254.00^{h}	314.89^{cd}	238.72^{f}
Suguna	140.78^{d}	157.73^{f}	164.00^{f}	318.78^{f}	302.47^{e}	235.74^{g}
Supriya	147.33^{c}	177.56^{d}	167.43^{e}	319.96^{f}	305.00^{de}	242.49^{e}
IGFRI-3	176.56^{a}	185.22^{c}	192.56^{d}	575.89^{b}	448.01^{b}	350.42^{b}
IGFRI-7	95.43^{g}	155.22^{f}	162.89^{f}	376.56^{d}	320.00^{c}	253.67^{d}
DHN-6	122.22^{e}	143.44^{g}	167.67^{e}	325.89^{e}	237.11^{h}	218.53^{h}
PTH	117.11^{f}	227.45^{a}	254.00^{a}	633.46^{a}	618.63^{a}	433.38^{a}
PBN-16	152.22^{b}	167.33^{e}	218.44^{b}	404.88^{c}	303.00^{e}	273.41^{c}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.1.4. Length of leaves

The data pertaining to the leaf length in eleven cultivars of hybrid napier at 45DAP and at different harvests are presented in Table 6. In general, the length of leaves of most of the cultivars was maximum during the first harvest, which showed a decreasing trend towards the final harvest. At 45 DAP, PTH showed the maximum leaf length, but was on par with CO-3 and IGFRI-7, and the least was recorded by KKM-1 and PBN-16, which were on par with Supriya and IGFRI-3.

Table 6. Leaf length of hybrid napier cultivars at each harvest (cm)

Harvests (Days)	45DAP	H1 75DAP	H2 120DAP	H3 165DAP	H4 210DAP	Mean
CO-2	55.33^{cd}	72.77^{g}	67.67^{g}	71.21^{de}	44.20^{d}	63.96^{d}
CO-3	64.55^{ab}	117.61^{a}	120.00^{a}	86.56^{b}	53.78^{a}	94.46^{a}
CO-4	56.45^{c}	90.56d^{e}	93.77^{d}	79.00^{c}	48.66^{bc}	77.99^{c}
KKM-1	50.29^{e}	100.83^{c}	83.67^{e}	98.00^{a}	53.01^{ab}	83.88^{b}
Suguna	56.22^{c}	87.11^{e}	100.22^{c}	70.32^{e}	53.57^{a}	77.81^{c}
Supriya	52.39^{de}	92.67^{d}	111.22^{b}	75.77^{cd}	51.00^{ab}	82.66^{b}
IGFRI-3	53.44^{cde}	76.33^{fg}	77.78^{ef}	58.72^{f}	35.87^{fg}	62.18d^{e}
IGFRI-7	63.28^{ab}	106.78^{b}	81.33^{ef}	75.67^{cd}	42.10^{de}	76.47^{c}
DHN-6	62.67^{b}	98.95^{c}	101.44^{c}	70.54^{e}	39.33^{ef}	77.57^{c}
PTH	66.26^{a}	76.78^{f}	76.11^{f}	51.56^{g}	34.90^{g}	59.84^{e}
PBN-16	51.55^{e}	78.22^{f}	70.22^{g}	56.77^{f}	45.97^{cd}	62.79^{d}

*In a column, means followed by common letters do not differ significantly at 5% level by DMRT

During the first harvest, maximum leaf length was recorded by CO-3 (117.61cm) and the least by CO-2 (72.77cm) that was on par with IGFRI-3 (76.33cm). During the second harvest too, CO-3 showed the maximum leaf length and the least by CO-2 and PBN-16 (on par). In the third harvest, KKM-1 recorded the maximum leaf length and PTH recorded the least. During the final harvest, CO-3 and Suguna showed the maximum leaf lengths followed by KKM-1 and Supriya (on par). The lowest was noticed for PTH, which was on par with IGFRI-3. In general, the maximum leaf length was recorded by CO-3(94.46cm) followed by

KKM-1(83.88cm) and the least by PTH(59.84cm) and IGFRI-3(62.18cm), which were on par.

4.1.5. Leaf width

The data on the leaf width are presented in Table 7. In general, maximum leaf width was recorded at the time of the first harvest, and thereafter a diminishing trend was noticed. At 45 DAP, maximum leaf width was recorded by CO-2 and CO-4 which was on par with CO-3, KKM-I and DHN-6 and the lowest was recorded by PTH which was on par with IGFRI-3.

Table 7. Leaf width of hybrid napier cultivars at each harvest (cm)

Harvests		H1	H2	H3	H4	Mean
(Days)	45DAP	75DAP	120DAP	165DAP	210DAP	
CO-2	3.84^{a}	3.99^{ab}	3.57^{a}	2.80^{b}	1.80^{a}	3.04^{a}
CO-3	3.24^{abc}	3.56^{abc}	2.97^{bc}	2.22^{c}	1.43^{abc}	2.54^{bc}
CO-4	3.77^{a}	4.04^{a}	3.31^{ab}	3.32^{a}	1.67^{ab}	3.08^{a}
KKM-1	2.91^{abc}	3.56^{abc}	2.55^{cd}	2.42^{bc}	1.17^{cd}	2.40^{c}
Suguna	2.78^{bc}	3.18^{cd}	2.30^{d}	2.20^{c}	1.47^{abc}	2.29^{c}
Supriya	2.70^{bc}	3.22^{bcd}	2.60^{cd}	2.00^{cd}	1.63^{ab}	2.36^{c}
IGFRI-3	2.38^{cd}	2.58^{d}	2.23^{d}	1.70^{de}	0.95^{d}	1.87^{d}
IGFRI-7	2.78^{bc}	3.33^{abcd}	1.67^{e}	1.45^{e}	1.13^{cd}	1.92^{d}
DHN-6	3.43^{ab}	3.95^{abc}	2.93^{bc}	2.39^{bc}	1.40^{bc}	2.67^{b}
PTH	1.53^{d}	1.52e	0.97^{f}	0.76^{f}	0.53^{e}	0.95^{e}
PBN-16	2.64^{bc}	3.28^{abcd}	2.43^{d}	2.20^{c}	1.63^{ab}	2.39^{c}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Just before the first harvest (75 DAP), maximum leaf width was recorded by CO-4, which was on par with CO-2, CO-3, KKM-1, IGFRI-7, DHN-6 and PBN-16, but the cultivar PTH recorded the lowest leaf width. At the time of the second harvest, maximum leaf width was observed in CO-2, which was on par with CO-4 and the least by PTH. In the third harvest, the maximum leaf width was noticed in CO-4. PTH followed the same trend as before in subsequent harvests in having the narrow leaves. During the last harvest, the maximum leaf width was observed in CO-2, which was on par with CO-3, CO-4, Suguna, Supriya and PBN-16. When considering the mean, CO-4 and CO-2 had maximum leaf widths and PTH, the lowest.

4.2. Growth analysis

4.2.1. Leaf area index (LAI)

The leaf area index of different cultivars of hybrid napier calculated from leaf area noted at 45 DAP and just before each harvests are presented in Table 8. In general, the cultivars showed the maximum LAI at the third harvest stage and decreased towards the fourth harvest. The cultivar CO-3 had consistently high LAI. At 45 DAP, the LAI was maximum in CO-3, CO-4 and PTH and were on par with DHN-6. The least was recorded by PBN-16, which was on par with Suguna. During the first harvest, the maximum LAI was noticed in CO-3 and Suguna and the least was observed in KKM-1 and IGFRI-3, which were on par with CO-2 and PBN-16. At the time of the second harvest, the lowest LAI was noticed in KKM-1. During the third harvest, LAI was the highest in CO-3 and Suguna and the lowest in DHN-6. In the final harvest, the lowest LAI was noticed in IGFRI-3, and the highest in CO-3.

Table 8. Leaf area index (LAI) of hybrid napier cultivars at each harvest

Harvests		**H1**	**H2**	**H3**	**H4**
(Days)	**45DAP**	**75DAP**	**120DAP**	**165DAP**	**210DAP**
CO-2	1.55^{d}	7.66^{cde}	8.26^{f}	11.40^{cd}	3.03^{de}
CO-3	2.30^{a}	11.92^{a}	15.61^{a}	19.56^{a}	5.29^{a}
CO-4	2.32^{a}	8.16^{cd}	13.63^{b}	12.38^{bc}	3.83^{c}
KKM-1	1.80^{c}	7.18^{e}	6.42^{g}	9.71^{de}	4.52^{b}
Suguna	1.15^{ef}	12.15^{a}	9.69^{e}	20.35^{a}	3.20^{b}
Supriya	1.52^{d}	9.13^{b}	11.48^{cd}	12.05^{bc}	4.52^{b}
IGFRI-3	1.35^{de}	6.92^{e}	12.30^{c}	8.75^{e}	2.53^{f}
IGFRI-7	1.93^{bc}	8.36^{bcd}	8.53^{f}	13.51^{b}	3.89^{c}
DHN-6	2.17^{ab}	9.02^{b}	9.79^{e}	7.02^{f}	2.87^{e}
PTH	2.21^{a}	8.44^{bc}	10.64^{de}	9.83^{de}	2.95^{de}
PBN-16	0.97^{f}	7.58^{de}	12.10^{c}	11.26^{cd}	4.32^{b}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.2.2. Leaf area ratio (LAR)

The data pertaining to the leaf area ratio in different cultivars of hybrid napier at different intervals are presented in Table 9. The maximum LAR was recorded at the time of the third harvest, and thereafter, a diminishing trend was noticed. At 45 DAP, maximum LAR was observed in Supriya and the least was noticed in Suguna, which was on par with CO-2, CO-4, KKM-1, IGFRI-3, IGFRI-7 and PBN-16. During the first harvest, Suguna had the maximum LAR and CO-2 the least. In the second harvest, maximum LAR was noticed in IGFRI-3 and the least in KKM-1. At the time of the third harvest, the highest LAR was observed in Supriya and the lowest in PTH. In the final harvest, Co-3 had the maximum LAR and DHN-6 had the lowest.

Table 9. Leaf area ratio (LAR) of hybrid napier cultivars at each harvest(dm^2/gm)

Harvests		H1	H2	H3	H4
(Days)	45DAP	75DAP	120DAP	165DAP	210DAP
CO-2	1.760^{de}	1.170^{i}	1.210^{h}	1.863^{i}	1.560^{g}
CO-3	1.970^{c}	1.917^{c}	1.720^{c}	2.433^{de}	2.193^{a}
CO-4	1.740^{de}	1.447^{f}	1.577^{d}	2.553^{b}	1.720^{e}
KKM-1	1.667^{de}	1.530^{e}	0.947^{i}	2.243^{f}	1.783^{c}
Suguna	1.117^{e}	2.380^{a}	1.550^{e}	2.520^{c}	1.753^{d}
Supriya	2.413^{a}	2.147^{b}	1.840^{b}	2.620^{a}	1.870^{b}
IGFRI-3	1.723^{de}	1.690^{d}	1.980^{a}	2.090^{g}	1.560^{g}
IGFRI-7	1.743^{de}	1.273^{h}	1.220^{h}	2.403^{e}	1.697^{f}
DHN-6	1.770^{d}	1.393^{g}	1.533^{ef}	1.953^{h}	1.417^{h}
PTH	1.643^{de}	1.377^{g}	1.353^{g}	1.760^{j}	1.680^{f}
PBN-16	1.663^{de}	1.387^{g}	1.520^{f}	2.103^{g}	1.753^{d}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.2.3. Net assimilation rate (NAR)

Net assimilation rate computed for all the eleven cultivars of hybrid napier at different intervals are presented in Table 10. For most of the cultivars, higher NAR was observed at the second harvest stage and thereafter a decreasing trend was noticed. By the third and fourth harvests, the difference in NAR between cultivars narrowed and at the fourth harvest, there was no significant difference between the cultivars. At 45DAP, CO-4 and PTH recorded the highest values and Supriya, the lowest. During the first harvest stage, CO-2 and PBN-16 recorded the highest NAR and the least was observed in CO-3, which was on par CO-4, KKM-1, Suguna, Supriya, IGFRI-3, DHN-6 and PTH. At the time of the second harvest, KKM-1 had the highest NAR and the least was noticed in IGFRI-3, which was on par with CO-3, Suguna, Supriya and DHN-6. During the third harvest, CO-2 and PTH showed the highest NAR and were on par, and CO-4 and Supriya had the least, while they were on par with all cultivars except for CO-2 and PTH.

Table 10. Net assimilation rate of hybrid napier cultivars (g/dm^2/day) at each harvest

Harvests		H1	H2	H3	H4
(Days)	45DAP	75DAP	120DAP	165DAP	210DAP
CO-2	0.041^{abc}	0.064^{a}	0.100^{b}	0.063^{a}	0.059^{a}
CO-3	0.040^{abc}	0.035^{c}	0.073^{def}	0.050^{ab}	0.046^{a}
CO-4	0.047^{a}	0.041^{c}	0.080^{de}	0.043^{b}	0.055^{a}
KKM-1	0.046^{ab}	0.039^{c}	0.130^{a}	0.048^{ab}	0.054^{a}
Suguna	0.028^{bc}	0.038^{c}	0.076^{def}	0.048^{ab}	0.051^{a}
Supriya	0.025^{c}	0.040^{c}	0.064^{ef}	0.041^{b}	0.051^{a}
IGFRI-3	0.040^{abc}	0.040^{c}	0.059^{f}	0.051^{ab}	0.056^{a}
IGFRI-7	0.044^{abc}	0.059^{ab}	0.099^{bc}	0.048^{ab}	0.056^{a}
DHN-6	0.046^{ab}	0.050^{abc}	0.077^{def}	0.053^{ab}	0.066^{a}
PTH	0.050^{a}	0.045^{bc}	0.092^{bcd}	0.066^{a}	0.052^{a}
PBN-16	0.037^{abc}	0.064^{a}	0.082^{cde}	0.053^{ab}	0.055^{a}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.2.4. Relative growth rate (RGR)

Relative growth rate of different cultivars of hybrid napier are presented in Table 11. The maximum RGR was noticed during the second harvest, and thereafter, a decreasing trend was observed. The RGR values of cultivars did not differ significantly in the second, third and final harvests. At 45DAP, the highest value was recorded by PTH followed by CO-4 and DHN-6. Suguna showed the lowest value. During the first harvest, Suguna had the highest RGR and CO-4 the least, however, the difference between the cultivars were insignificant.

Table 11. Relative growth rate of hybrid napier cultivars (g/g/day) at each harvest

Harvests		**H1**	**H2**	**H3**	**H4**
(Days)	**45DAP**	**75DAP**	**120DAP**	**165DAP**	**210DAP**
CO-2	0.071^{abc}	0.085^{abc}	0.121^{a}	0.117^{a}	0.091^{a}
CO-3	0.078^{abc}	0.068^{cdef}	0.126^{a}	0.122^{a}	0.094^{a}
CO-4	0.080^{ab}	0.051^{f}	0.125^{a}	0.110^{a}	0.093^{a}
KKM-1	0.07^{abc}	0.055^{ef}	0.123^{a}	0.108^{a}	0.097^{a}
Suguna	0.060^{c}	0.090^{a}	0.118^{a}	0.122^{a}	0.089^{a}
Supriya	0.061^{bc}	0.085^{abc}	0.117^{a}	0.109^{a}	0.095^{a}
IGFRI-3	0.069^{abc}	0.067^{cdef}	0.117^{a}	0.107^{a}	0.087^{a}
IGFRI-7	0.077^{abc}	0.077^{abcd}	0.122^{a}	0.114^{a}	0.095^{a}
DHN-6	0.080^{ab}	0.070^{bcde}	0.119^{a}	0.104^{a}	0.093^{a}
PTH	0.082^{a}	0.060^{def}	0.124^{a}	0.115^{a}	0.088^{a}
PBN-16	0.063^{bc}	0.088^{ab}	0.124^{a}	0.113^{a}	0.096^{a}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.2.5. Leaf-stem ratio

The data pertaining to the leaf to stem ratio of different cultivars of hybrid napier are presented in Table 12. At 45 DAP, Supriya recorded the highest leaf-stem ratio closely followed by Suguna and IGFRI-3, which were on par. During the first harvest also, Supriya recorded the highest followed by CO-3, KKM-1 and IGFRI-3 which were on par. In the second harvest, CO-3 had the highest leaf-stem ratio followed by Supriya and IGFRI-3. At the time of the third harvest, again Supriya recorded the highest leaf-stem ratio followed by Suguna. During the final harvest, Suguna showed the maximum leaf-stem ratio. In general, the lowest leaf- stem ratio was shown by CO-2 in all the harvests although in the third harvest it was just above PTH and IGFRI-7 (but was on par). Considering the mean values CO-3, Suguna and Supriya were found to be superior and they were on par, CO-2 had the least leaf to stem ratio, on par with PTH.

Table 12. Leaf: stem ratio of hybrid napier cultivars at each harvest

Harvests		H1	H2	H3	H4	Mean
(Days)	45DAP	75DAP	120DAP	165DAP	210DAP	
CO-2	1.72^{c}	0.51^{c}	0.63^{e}	1.71^{ef}	1.35^{e}	1.05^{d}
CO-3	1.94^{bc}	1.40^{ab}	1.53^{a}	3.16^{b}	2.53^{b}	2.16^{a}
CO-4	1.85^{c}	0.61^{c}	1.00^{cd}	2.73^{c}	2.05^{c}	1.60^{b}
KKM-1	1.74^{c}	1.34^{ab}	0.60^{e}	2.11^{de}	2.41^{b}	1.61^{b}
Suguna	2.37^{ab}	1.18^{b}	1.23^{bc}	3.53^{ab}	3.32^{a}	2.32^{a}
Supriya	2.44^{a}	1.72^{a}	1.37^{ab}	3.71^{a}	1.99^{c}	2.20^{a}
IGFRI-3	2.35^{ab}	1.47^{ab}	1.37^{ab}	1.98^{e}	1.95^{c}	1.70^{b}
IGFRI-7	1.71^{c}	0.64^{c}	0.60^{e}	1.40^{f}	1.97^{c}	1.15^{c}
DHN-6	1.76^{c}	0.74^{c}	1.03^{cd}	1.83^{e}	1.34^{e}	1.24^{c}
PTH	1.66^{c}	0.69^{c}	0.83^{de}	1.30^{f}	1.65^{d}	1.12^{cd}
PBN-16	1.99^{bc}	1.21^{b}	1.20^{bc}	2.46^{cd}	1.47^{de}	1.59^{b}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.2.6. Shoot-root ratio

Shoot to root ratio of different cultivars of hybrid napier at different intervals are presented in Table 13. At 45DAP, PBN-16 recorded the highest shoot-root ratio followed by CO-3 and the least in CO-4. During the first harvest, PTH recorded the highest value followed by CO-3, which were on par with IGFRI-7 while IGFRI-3 showed the lowest. In the second harvest KKM-1 recorded the highest value while IGFRI-3 and IGFRI-7 the least. At the time of the third harvest, PTH showed the highest ratio while CO-2, Suguna and PBN-16(on par) the lowest and they were on par with CO-3, KKM-1, Supriya and DHN-6. During the final harvest, DHN-6 had the highest ratio and the least by Suguna, which was on par with CO-4, IGFRI-3, IGFRI-7 and PBN-16. Based on the mean values, the cultivars CO-3 and PTH had the highest shoot to root ratio, while IGFRI-3 had the least.

Table 13. Shoot: root ratio of hybrid napier cultivars at each harvest

Harvests		H1	H2	H3	H4	Mean
(Days)	45DAP	75DAP	120DAP	165DAP	210DAP	
CO-2	22.18[d]	17.27[b]	11.81[f]	4.97[e]	6.24[b]	10.07[cd]
CO-3	36.92[ab]	18.22[ab]	23.06[b]	5.48[de]	6.33[b]	13.27[a]
CO-4	17.26[e]	16.79[b]	11.80[f]	7.80[b]	4.69[cd]	10.27[cd]
KKM-1	11.93[f]	10.41[c]	27.36[a]	6.16[cde]	5.39[bc]	12.33[b]
Suguna	21.04[de]	9.81[cd]	16.45[de]	4.72[e]	4.20[d]	8.79[e]
Supriya	20.91[de]	9.78[cd]	19.54[c]	5.71d[e]	6.36[b]	10.35[c]
IGFRI-3	19.77[de]	7.85[d]	6.49[g]	6.80[bcd]	5.13[cd]	6.57[f]
IGFRI-7	18.63[de]	18.18[ab]	6.92[g]	7.41[bc]	4.75[cd]	9.32[de]
DHN-6	33.89[b]	9.91[cd]	15.39[e]	5.93[cde]	8.83[a]	10.02[cd]
PTH	29.27[c]	20.09[a]	17.67[d]	12.01[a]	5.74[bc]	13.88[a]
PBN-16	37.85[a]	16.09[b]	22.71[b]	4.69[e]	5.07[cd]	12.14[b]

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.3. Fodder production potential

4.3.1. Green fodder yield

Green fodder yield of hybrid napier cultivars from each harvest is presented in Table.14. In all, four harvests were obtained under rainfed conditions starting from June to May. The highest green fodder yield was obtained from the first harvest, and thereafter a decreasing trend in yield was noticed. During the first harvest, DHN-6 recorded the highest green fodder yield of 82.71 Mg/ha and the lowest was recorded by IGFRI-3 (31.38 Mg/ha). In the second harvest, CO-3 recorded the highest green fodder yield of 62.45Mg/ha and IGFRI -3, the lowest green fodder yield of 28.26 Mg/ha. During the third harvest, CO-3 and Suguna gave the highest green fodder yield of 39.54 Mg/ha each while IGFRI-3 (18.52 Mg/ha) recorded the lowest yield and was on par with DHN-6, KKM-1, Supriya and IGFRI-7. During the final harvest, CO-3 (6.75Mg/ha) and PBN-16 (6.85 Mg/ha) recorded the highest green fodder yield and they were on par with KKM-1, Supriya and IGFRI-7 while the lowest green fodder yield was recorded by DHN-6 (3.89Mg/ha). Among the cultivars, CO-3 recorded the highest total green fodder yield of 173.30 Mg/ha/yr and the lowest from IGFRI-3 (84.79 Mg/ha/yr). DHN-6 recorded total green fodder yield of 151.62 Mg/ha/yr and attained the second position.

Table 14. Green fodder yield of hybrid napier at each harvest (Mg/ha)

Cultivars	H1	H2	H3	H4	Total
(Days)	75DAP	120DAP	165DAP	210DAP	
CO-2	45.22[d]	41.00[bc]	31.44[b]	6.07[b]	123.74[cde]
CO-3	64.58[b]	62.45[a]	39.54[a]	6.75[a]	173.30[a]
CO-4	52.31[c]	43.80[bc]	24.61[cd]	5.33[c]	126.05[cd]
KKM-1	54.41[c]	36.23[d]	21.11[de]	6.58[ab]	118.34[de]
Suguna	47.28[d]	40.61[c]	39.54[a]	5.01[cd]	132.44[c]
Supriya	49.80[cd]	36.41[d]	21.78[de]	6.57[ab]	114.56[e]
IGFRI-3	31.38[e]	28.26[e]	18.52[e]	4.68[d]	84.79[f]
IGFRI-7	62.17[b]	33.36[d]	22.20[de]	6.40[ab]	124.13[cde]
DHN-6	82.71[a]	44.65[b]	20.36[e]	3.89[e]	151.62[b]
PTH	49.72[cd]	43.31[bc]	24.63[cd]	4.84[cd]	122.50[cde]
PBN-16	47.18[d]	42.94[bc]	26.59[c]	6.85[a]	123.55[cde]

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.3.2. Dry fodder yield

Dry fodder yield of hybrid napier cultivars at each harvest are presented in Table 15. There was a decrease in dry fodder yield from the second harvest onwards. CO-3 recorded the highest annual dry fodder yield of 23.90 Mg/ha followed by CO-2 (22.65 Mg/ha), which were on par while IGFRI-3 recorded the lowest yield of 15.00Mg/ha. In the first harvest, CO-2 (9.04 Mg/ha) recorded the highest dry matter production followed by IGFRI-7 (8.70 Mg/ha) while KKM-1 (5.44 Mg/ha) recorded the lowest and was on par with Suguna and Supriya. During the second harvest, maximum dry matter production was recorded by CO-3 (8.12 Mg/ha) followed by CO-4 but were on par and the lowest was recorded by IGFRI-

3(5.37 Mg/ha) which was on par with Suguna, Supriya and DHN-6. During the third harvest, CO-3 and Suguna obtained the highest dry fodder yield of 6.72 Mg/ha. The lowest was obtained for DHN-6 (3.05 Mg/ha) which was on par with Supriya, KKM-1 and IGFRI-3. At the time of final harvest, KKM-1 had the highest dry matter production of 2.17 Mg/ha followed by PBN-16 and Supriya. The lowest dry fodder yield was recorded for IGFRI-3 (1.41 Mg/ha) and PTH (1.50 Mg/ha).

Table 15. Dry fodder yield of hybrid napier at each harvest (Mg/ha)

Cultivars	H1	H2	H3	H4	Total
Days	**75DAP**	**120DAP**	**165DAP**	**210DAP**	
CO-2	9.04^{a}	6.56^{d}	5.35^{b}	1.70^{ef}	22.65^{ab}
CO-3	7.10^{cd}	8.12^{a}	6.72^{a}	1.95^{cd}	23.90^{a}
CO-4	6.80^{cd}	7.88^{ab}	3.94^{de}	1.92^{cd}	20.54^{cde}
KKM-1	5.44^{e}	6.88^{cd}	3.59^{ef}	2.17^{a}	18.09^{g}
Suguna	5.68^{e}	5.69^{e}	6.72^{a}	1.55^{fg}	19.64^{ef}
Supriya	5.48^{e}	5.46^{e}	3.72^{ef}	2.04^{abc}	16.68^{h}
IGFRI-3	4.71^{f}	5.37^{e}	3.52^{ef}	1.41^{g}	15.00^{i}
IGFRI-7	8.70^{ab}	6.67^{d}	4.66^{c}	1.98^{bcd}	22.01^{bc}
DHN-6	8.27^{b}	5.81^{e}	3.05^{f}	1.83^{de}	18.96^{fg}
PTH	7.46^{c}	7.36^{bc}	4.93^{bc}	1.50^{g}	21.25^{bcd}
PBN-16	6.60^{d}	7.30^{bc}	4.52^{cd}	2.12^{ab}	20.55^{de}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.4. Proximate analysis and quality

Plant samples from all the treatments were collected at third harvest and were used to find out oxalate content and the five fractions of proximate analysis - crude protein, crude fibre, total ash, ether extract and nitrogen free extract of leaves and stems separately.

4.4.1. Crude protein

The data pertaining to crude protein content of leaves and stems are given in Table 16 and Table 17. In general, crude protein content of leaves was higher than stems. There were significant differences between cultivars with respect to crude protein. The cultivars IGFRI-3, CO-3, KKM-1, DHN-6 and PBN-16 were almost equal in terms of crude protein content of leaves (13.54 % -14.17 %). The lowest values were obtained for CO-2, CO-4, Suguna and IGFRI-7, which were on par (10.73 % -11.52 %). The cultivar CO-3 had the highest crude protein content in stem (9.58 %) followed by IGFRI-3 (9.17 %), and they were on par. Among the cultivars tested, PTH (6.15 %) and Supriya had the lowest crude protein content in stem.

4.4.2. Crude fibre

The crude fibre content of hybrid napier cultivars are given in Table16 and Table 17. In general crude fibre content of stems was more than that of leaves. In the leaves, maximum crude fibre (31.05 %) was recorded in (IGFRI-7) followed by PTH (29.65 %). The lowest crude fibre content was in CO-2 (25.43 %) followed by Supriya (25.55 %). In the stems, the highest content was observed in IGFRI-7 (36.22 %) followed by CO-2 (34.75 %) and the least was recorded in Supriya.

Table 16. Proximate analysis of hybrid napier leaves (%) at third harvest

Cultivar	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
CO-2	11.52^{c}	25.43^{d}	2.30^{b}	51.88^{a}	8.87^{ab}
CO-3	14.06^{a}	26.92^{cd}	2.30^{b}	47.02^{e}	9.70^{a}
CO-4	11.46^{c}	27.22^{cd}	2.80^{a}	49.26^{bcde}	9.27^{ab}
KKM-1	13.23^{ab}	28.50^{bc}	2.32^{b}	47.19^{de}	8.77^{b}
Suguna	11.50^{c}	26.67^{cd}	1.85^{cd}	51.20^{ab}	8.87^{ab}
Supriya	12.50^{b}	25.55^{d}	1.77^{de}	50.62^{abc}	9.57^{ab}
IGFRI-3	14.17^{a}	26.62^{cd}	2.16^{bc}	49.52^{abcd}	7.53^{c}
IGFRI-7	10.73^{c}	31.05^{a}	1.47^{e}	49.22^{bcde}	7.53^{c}
DHN-6	13.54^{a}	26.18^{d}	2.37^{b}	51.34^{ab}	6.57^{d}
PTH	12.50^{b}	29.65^{ab}	1.67^{de}	48.68^{cde}	7.50^{c}
PBN-16	13.54^{a}	28.42^{bc}	1.92^{cd}	47.39^{de}	8.73^{b}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.4.3. Total ash

The data pertaining to the total ash content of leaves and stems of various hybrid napier cultivars are given in Tables16 and 17. In general, total ash content of the leaves was higher than the stems. There were significant differences between cultivars with respect to total ash content. Total ash content of leaves was the highest in CO-3 (9.75 %) followed by CO-2, CO-4, Suguna and Supriya. The lowest ash content was recorded in PTH (7.5 %) but it was on par with IGFRI-3 and IGFRI-7. Total ash content of stems ranged from 5.20 per ent (PTH) to 8.47 percent (Supriya). PTH was on par with DHN-6 while CO-2, CO-3, CO-4 and Suguna were on par with Supriya.

Table 17. Proximate analysis of hybrid napier stems (%) at third harvest

Cultivar	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Total ash
CO-2	8.33^{bc}	34.75^{ab}	1.41^{ab}	47.44^{d}	8.07^{abc}
CO-3	9.58^{a}	28.62^{de}	1.26^{bcd}	52.21^{b}	8.33^{ab}
CO-4	7.08^{de}	28.98^{de}	1.38^{abc}	54.29^{ab}	8.27^{ab}
KKM-1	8.19^{bc}	33.67^{b}	1.17^{bcd}	49.58^{cd}	7.40^{c}
Suguna	7.92^{cd}	29.87^{cd}	1.34^{abcd}	53.01^{d}	7.87^{abc}
Supriya	6.67^{e}	28.03^{e}	1.10^{d}	55.73^{a}	8.47^{a}
IGFRI-3	9.17^{ab}	31.48^{c}	1.58^{a}	51.73^{bc}	6.03^{d}
IGFRI-7	7.71^{cd}	36.22^{a}	1.13^{cd}	48.81^{b}	6.13^{d}
DHN-6	8.52^{bc}	31.50^{c}	1.42^{ab}	53.06^{b}	5.50^{de}
PTH	6.15^{e}	34.33^{b}	1.10^{d}	53.22^{b}	5.20^{e}
PBN-16	8.54^{bc}	30.12^{cd}	1.35^{abcd}	52.49^{b}	7.50^{bc}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.4.4 Ether extract

The data pertaining to crude fat content of leaves and stems of hybrid napier are given in Tables 16 and 17. The crude fat content of the leaves was higher than the stems. There were significant differences between cultivars with respect to crude fat. Crude fat content of leaves ranged from 2.80 percent (CO-4) to 1.47 (IGFRI-7) percent. IGFRI-7 was on par with PTH. Crude fat content of stems ranged from 1.10 percent (Supriya and PTH) to 1.58 percent (IGFRI-3). CO-3, KKM-1, Suguna, IGFRI-7 and PBN-16 were on par with Supriya and PTH while IGFRI-3 was on par with CO-2, CO-4, Suguna, DHN-6 and PBN-16.

4.4.5. Nitrogen free extract

Nitrogen free extract of leaves and stems of hybrid napier cultivars are given in Tables.16 and 17. Nitrogen free extract of the leaves was more than the stems. There were significant differences between cultivars with respect to nitrogen free extract. In the leaves, the content ranged from 47.02 percent (CO-3) to 51.88 percent (CO-2).CO-2 was on par with Suguna, Supriya and IGFRI-3 where as CO-3 was on par with CO-4, KKM-1, IGFRI-7, PTH and PBN-16. In the stems, nitrogen free extract ranged from 53.01 percent (Suguna) to 55.73 percent (Supriya). CO-4 was on par with Supriya. CO-2 and KKM-1 was on par with Suguna

Table 18. Oxalate content (%) of hybrid napier cultivars

Cultivars	Oxalate content of leaves	Oxalate content of stem
CO-2	2.87^{d}	3.77^{b}
CO-3	3.60^{ab}	3.13^{cde}
CO-4	2.40^{e}	2.90^{def}
KKM-1	2.97^{d}	3.43^{bc}
Suguna	3.63^{a}	4.13^{a}
Supriya	3.53^{ab}	2.83^{ef}
IGFRI-3	3.80^{a}	2.97^{def}
IGFRI-7	3.50^{ab}	2.70^{f}
DHN-6	3.17^{cd}	2.83^{ef}
PTH	2.91^{d}	3.30^{cd}
PBN-16	3.30^{bc}	3.10^{cdef}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.4.6. Oxalate content

Oxalate content of leaves and stems of different cultivars of hybrid napier are presented in Table.18. There was not much difference between the oxalate content of leaves and stems. Suguna (3.63 %) and IGFRI-3 (3.80 %) showed the highest oxalate content in leaves followed by CO-3 (3.60 %) and IGFRI-7 (3.50 %), which were on par. CO-4 leaves showed the lowest oxalate content. In the case of stems, the highest oxalate content was observed in Suguna (4.13 %) and the lowest in IGFRI-7 (2.70 %), which was on par with CO-4, Supriya, IGFRI-3, DHN-6 and PBN-16.

4.5. Nutrient composition

Percentage content of nitrogen, phosphorus and potassium of both leaves and stems were noted at 75 DAP, 120 DAP and 165 DAP at the time of first, second and third harvests. Composition of calcium and magnesium were noted at 165 DAP (third harvest).

Table 19. Nitrogen content of hybrid napier leaves at each harvest (%)

Cultivar	H1	H2	H3	Mean
CO-2	2.067^{ab}	2.067^{bc}	1.833^{d}	1.989^{cde}
CO-3	2.233^{a}	2.267^{a}	2.250^{ab}	2.250^{a}
CO-4	2.133^{ab}	2.067^{bc}	1.833^{d}	2.011^{cd}
KKM-1	2.017^{b}	2.233^{ab}	2.100^{bc}	2.117^{b}
Suguna	1.983^{b}	2.200^{ab}	1.827^{d}	2.003^{cde}
Supriya	2.260^{a}	2.200^{ab}	2.000^{c}	2.153^{b}
IGFRI-3	2.267^{a}	2.267^{a}	2.267^{a}	2.267^{a}
IGFRI-7	2.050^{ab}	1.957^{c}	1.733^{d}	1.914^{de}
DHN-6	2.000^{b}	2.100^{abc}	2.167^{ab}	2.089^{bc}
PTH	1.577^{c}	2.133^{abc}	2.000^{c}	1.903^{e}
PBN-16	1.967^{b}	2.200^{ab}	2.167^{ab}	2.111^{b}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.5.1. Nitrogen

Nitrogen content of hybrid napier cultivars is given in Tables 19 and 20. In general, the leaves contained more nitrogen than stems and nitrogen content was higher during the second harvest. Nitrogen percentage of leaves ranged from 1.577 to 2.267 and that of stems ranged from 0.983 to 2.267. In the first harvest, IGFRI-3, Supriya and CO-3 showed the maximum values and PTH the lowest. IGFRI-3 showed supremacy and consistency in terms of nitrogen content in all the three harvests (2.267 %), but was on par with CO-3. In the case of stems, during the first harvest, CO-3 (2.033 %) had the highest nitrogen content and was superior to all other cultivars, and PTH had the lowest content (1.077 %).

Table 20. Nitrogen content of hybrid napier stems at each harvest (%)

Cultivar	H1	H2	H3	Mean
CO-2	1.550^{b}	1.823^{a}	1.333^{bc}	1.569^{b}
CO-3	2.033^{a}	1.760^{ab}	1.533^{a}	1.775^{a}
CO-4	1.517^{b}	1.400^{c}	1.133^{de}	1.350^{cd}
KKM-1	1.167^{cd}	1.433^{c}	1.310^{bc}	1.303^{d}
Suguna	1.517^{b}	1.533^{bc}	1.267^{cd}	1.439^{bcd}
Supriya	1.717^{b}	1.250^{cd}	1.067^{e}	1.344^{cd}
IGFRI-3	1.460^{bc}	1.343^{c}	1.467^{ab}	1.423^{bcd}
IGFRI-7	1.693^{b}	1.467^{c}	1.233^{cd}	1.464^{bc}
DHN-6	1.150^{cd}	1.377^{c}	1.363^{bc}	1.297^{d}
PTH	1.077^{d}	1.017^{d}	0.983^{e}	1.026^{e}
PBN-16	1.550^{b}	1.517^{bc}	1.367^{bc}	1.478^{bc}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

During the second harvest, nitrogen content of leaves ranged from 1.957 (IGFRI-7) to 2.67 percent (IGFRI-3 and CO-3). CO-3 and IGFRI-3 were on par with other cultivars except for CO-2 and IGFRI-7. In the third harvest, nitrogen content of leaves ranged from 1.827 percent (Suguna) to 2.67 percent (IGFRI-3). IGFRI-3 was on par with CO-3, DHN-6 and PBN-16 while Suguna was on par with CO-2 and CO-4. Nitrogen content of stems ranged from 0.983 percent (PTH) to 1.533 percent (CO-3). CO-3 was on par with IGFRI-3, but PTH was on par with CO-4. Considering the mean values, with respect to nitrogen content of leaves, IGFRI-3 (2.267 %) and CO-3 (2.250 %) were superior while IGFRI-7 (1.914 %) the lowest scorer. In general, CO-3 was superior to all other cultivars based on nitrogen content (1.775 %) and PTH was inferior to others (1.026 %).

4.5.2. Phosphorous

Phosphorous content of hybrid napier cultivars is given in Tables 21 and 22. In general, phosphorous content was high in the third harvest. Phosphorous content was maximum in leaves compared to stems.

Table 21. Phosphorus content of hybrid napier leaves at each harvest (%)

Cultivar	H1	H2	H3	Mean
CO-2	0.157^{fg}	0.187^{c}	0.250^{ab}	0.198^{cde}
CO-3	0.213^{b}	0.200^{bc}	0.234^{ab}	0.216^{bc}
CO-4	0.193^{cd}	0.200^{bc}	0.210^{ab}	0.201^{bcde}
KKM-1	0.180^{de}	0.143^{d}	0.210^{ab}	0.178^{f}
Suguna	0.157^{fg}	0.227^{a}	0.270^{a}	0.218^{ab}
Supriya	0.160^{fg}	0.223^{a}	0.233^{ab}	0.206^{bcd}
IGFRI-3	0.147^{g}	0.193^{c}	0.217^{ab}	0.186^{ef}
IGFRI-7	0.183^{de}	0.203^{bc}	0.197^{b}	0.195^{def}
DHN-6	0.173^{ef}	0.213^{ab}	0.243^{ab}	0.210^{bcd}
PTH	0.203^{bc}	0.193^{c}	0.247^{ab}	0.214^{bc}
PBN-16	0.233^{a}	0.227^{a}	0.243^{ab}	0.234^{a}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

The content of P in leaves ranged from 0.143 percent to 0.270 percent, while that of stems ranged from 0.123 percent to 0.233 percent. At the time of first harvest, phosphorus content of leaves ranged from 0.147 percent (IGFRI-3) to 0.233 percent (PBN-16). Suguna, PBN-16 and Supriya were the top scorers with on par values (0.223 % to 0.227 %). In the case of stems, maximum phosphorous content at the second harvest was noted in CO-3 and IGFRI-3(0.163 %) and the lowest in CO-2 and KKM-1(0.133 %). Phosphorous content of leaves in the third harvest ranged from 0.197 percent (IGFRI-7) to 0.270 percent (Suguna). All the cultivars except IGFRI-7 were on par with Suguna. During the third harvest, phosphorus content of stems ranged from 0.140 percent (CO-4) to 0.233 percent (CO-2). Supriya and CO-3 were on par with CO-2. Considering the mean values of all the three harvests, with respect to phosphorus content of leaves PBN-16(0.234 %) was superior and the lowest scorer was KKM-1(0.178 %). In the case of stems, PBN-16 was superior(0.191 %) and the lowest scorer was Suguna(0.135 %). In general, PBN-16 was superior to all other cultivars in terms of phosphorus content.

Table 22. Phosphorus content of hybrid napier stems at each harvest (%)

Cultivar	H1	H2	H3	Mean
CO-2	0.130[ef]	0.133[c]	0.233[a]	0.165[b]
CO-3	0.140[cde]	0.163[a]	0.220[ab]	0.174[ab]
CO-4	0.157[bc]	0.137[c]	0.140[e]	0.144[cd]
KKM-1	0.147[bcde]	0.133[c]	0.143[e]	0.141[cd]
Suguna	0.123[f]	0.137[c]	0.143[e]	0.135[d]
Supriya	0.133[def]	0.137[c]	0.220[ab]	0.163[b]
IGFRI-3	0.140[cdef]	0.163[a]	0.197[c]	0.167[b]
IGFRI-7	0.140[cdef]	0.147[abc]	0.147[e]	0.145[cd]
DHN-6	0.150[bcd]	0.143[bc]	0.173[d]	0.156[bc]
PTH	0.163[b]	0.150[abc]	0.203[bc]	0.172[b]
PBN-16	0.207[a]	0.160[ab]	0.207[bc]	0.191[a]

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.5.3 Potassium

Potassium content of hybrid napier cultivars is presented in Tables 23 and 24. Potassium content was higher in the second harvest compared to other harvests. Potassium content of leaves was higher compared to stems. During the first harvest potassium content of leaves ranged from 1.600 percent (CO-4) to 2.433 percent (PTH). The highest potassium content was observed in PTH and CO-2 which were on par. K content of stems ranged from 1.400 percent (CO-4) to 2.133 percent (Supriya). In the second harvest, potassium content of leaves ranged from 1.800 percent (DHN-6) to 2.400 percent (PTH) while that of stems ranged from 1.383 percent (CO-4) to 1.887 (PBN-16) percent.

Table 23. Potassium content of hybrid napier leaves at each harvest (%)

Cultivar	H1	H2	H3	Mean
CO-2	2.400^{a}	2.267^{ab}	1.960^{ab}	2.209^{a}
CO-3	2.267^{ab}	2.283^{ab}	1.900^{ab}	2.150^{a}
CO-4	1.600^{c}	1.867^{cd}	2.000^{a}	1.822^{b}
KKM-1	2.000^{b}	1.867^{cd}	1.510^{c}	1.792^{b}
Suguna	2.300^{ab}	2.200^{ab}	2.067^{a}	2.189^{a}
Supriya	2.267^{ab}	2.233^{ab}	1.867^{ab}	2.122^{a}
IGFRI-3	2.167^{ab}	2.367^{ab}	2.100^{a}	2.211^{a}
IGFRI-7	2.150^{ab}	2.100^{bc}	1.500^{c}	1.917^{b}
DHN-6	2.067^{ab}	1.800^{d}	1.643^{bc}	1.837^{b}
PTH	2.433^{a}	2.400^{a}	1.990^{a}	2.275^{a}
PBN-16	2.313^{ab}	2.333^{ab}	2.143^{a}	2.263^{a}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 24. Potassium content of hybrid napier stems at each harvest (%)

Cultivar	H1	H2	H3	Mean
CO-2	1.633^{cd}	1.800^{ab}	1.433^{bcd}	1.622^{cdef}
CO-3	2.067^{ab}	1.700^{ab}	1.700^{ab}	1.822^{ab}
CO-4	1.400^{d}	1.383^{b}	1.667^{ab}	1.483^{f}
KKM-1	1.700^{bcd}	1.667^{ab}	1.177^{d}	1.514^{ef}
Suguna	1.900^{abc}	1.600^{ab}	1.333^{cd}	1.611^{cdef}
Supriya	2.133^{a}	1.667^{ab}	1.517^{bc}	1.772^{abc}
IGFRI-3	1.717^{bcd}	1.633^{ab}	1.700^{ab}	1.684^{bcde}
IGFRI-7	1.850^{abc}	1.693^{ab}	1.367^{cd}	1.637^{cdef}
DHN-6	1.900^{abc}	1.433^{ab}	1.467^{bc}	1.600^{def}
PTH	2.067^{ab}	1.800^{ab}	1.357^{cd}	1.741^{abcd}
PBN-16	1.933^{abc}	1.887^{a}	1.857^{a}	1.892^{a}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

During the third harvest, potassium content of leaves ranged from 1.500 percent (IGFRI-7) to 2.143 percent (PBN-16). The highest scorers on par with PBN-

16 were IGFRI-3, Suguna, CO-4 and PTH. Potassium content of stems ranged from 1.177 (KKM-1) to 1.857 percent (PBN-16). The mean values suggest that the cultivars PTH, PBN-16, IGFRI-3, Supriya, Suguna, CO-3 and CO-2 are similar in potassium content of leaves. However, in the case of stems, PBN-16 was superior to others.

4.5.4. Calcium

Calcium content of hybrid napier estimated at the third harvest is presented in Table 25. The leaves had higher calcium content than the stems. In the leaves, calcium content ranged from 0.143 percent (DHN-6) to 0.267 percent (CO-2). The calcium content of stems ranged from 0.100 percent (PTH) to 0.207 percent (CO-3 and CO-4). However, CO-3, CO-4, CO-2 and Suguna were on par.

Table 25. Ca and Mg content of hybrid napier leaves and stems at thirdharvest(%)

Cultivar	Ca		Mg	
	Leaves	Stems	Leaves	Stems
CO-2	0.267^{a}	0.197^{a}	0.223^{bcd}	0.200^{cde}
CO-3	0.213^{ab}	0.207^{a}	0.260^{abc}	0.213^{c}
CO-4	0.237^{ab}	0.207^{a}	0.253^{bc}	0.233^{ab}
KKM-1	0.197^{bc}	0.167^{b}	0.207^{cd}	0.190^{de}
Suguna	0.203^{bc}	0.200^{a}	0.313^{a}	0.243^{a}
Supriya	0.233^{ab}	0.150^{bc}	0.283^{ab}	0.217^{bc}
IGFRI-3	0.223^{ab}	0.137^{cd}	0.217^{cd}	0.207^{cd}
IGFRI-7	0.197^{bc}	0.140^{c}	0.223^{cd}	0.170f
DHN-6	0.143^{c}	0.103^{ef}	0.187^{d}	0.187ef
PTH	0.180^{bc}	0.100^{f}	0.203^{cd}	0.147g
PBN-16	0.183^{bc}	0.120^{de}	0.260^{abc}	0.203^{cde}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.5.5. Magnesium

Magnesium content of hybrid napier cultivars at the third harvest is presented in Table 25. The leaves had higher magnesium content than stems. In the leaves, Mg content ranged from 0.187 percent (DHN-6) to 0.313 percent (Suguna) and that of stems ranged from 0.147 percent (PTH) to 0.243percent (Suguna). The highest Mg content was observed in Suguna in both leaves and stems. The lowest scorer was DHN-6.

4.6. Nutrient uptake

The nutrient uptake was calculated during the first, second and third harvests. The product of dry matter yield and nutrient content was calculated to obtain the nutrient uptake by the plant. The data regarding the nutrient uptake is given in Tables 26, 27 and 28. Nutrient uptake was higher during the first harvest. In the first harvest, the highest nitrogen uptake was noticed in CO-2 (153.98 kg/ha), IGFRI-7 (150.14 kg/ha) and DHN-6 (144.05 kg/ha) while PBN-16(14.61 kg/ha) recorded the highest phosphorous uptake.

Table26. Nutrient uptake by hybrid napier cultivars at first harvest (kg/ha)

Cultivar	N	P	K
CO-2	153.98^{a}	12.57^{bc}	171.23^{a}
CO-3	128.67^{b}	12.97^{b}	155.01^{b}
CO-4	117.01^{c}	11.60^{c}	100.38^{e}
KKM-1	98.38^{d}	9.02^{d}	101.88^{e}
Suguna	101.83^{d}	8.03^{d}	120.16^{d}
Supriya	100.48^{d}	8.23^{d}	121.46^{d}
IGFRI-3	85.57^{e}	6.78^{e}	93.41^{e}
IGFRI-7	150.14^{a}	13.65^{ab}	171.17^{a}
DHN-6	144.05^{a}	13.23^{b}	163.01^{ab}
PTH	129.30^{b}	13.40^{b}	165.31^{ab}
PBN-16	118.64^{bc}	14.61^{a}	141.42^{c}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Potassium uptake had the same trend as nitrogen uptake. with respect to CO-2 (171.23 kg/ha) and IGFRI-7 (171.17 kg/ha). During the second and third harvest, CO-3 (167.81kg/ha and 139.68 kg/ha respectively) showed the highest nitrogen uptake. In terms of P uptake, during the second harvest, the top scorer was CO-3

(15.14 kg/ha). In the third harvest, Suguna, PBN-16 and CO-3 were on par. In the case of K uptake, PTH (160.94 kg/ha) was on par with CO-3 (167.86 kg/ha) and PBN-16 (159.02 kg/ha). In the third harvest, Suguna was on par with CO-3 with respect to phosphorous and potassium uptake.

Table 27. Nutrient uptake by hybrid napier cultivars at second harvest (kg/ha)

Cultivar	N	P	K
CO-2	125.80^{c}	10.98^{d}	137.63^{b}
CO-3	167.81^{a}	15.14^{a}	167.86^{a}
CO-4	136.64^{b}	13.61^{b}	130.67^{bc}
KKM-1	119.31^{cd}	9.60^{f}	123.24^{cd}
Suguna	108.13^{def}	10.90^{de}	111.81^{de}
Supriya	98.26^{f}	10.46^{def}	110.64^{e}
IGFRI-3	100.83^{ef}	9.79^{ef}	112.45^{de}
IGFRI-7	110.08^{def}	12.10^{c}	129.60^{bc}
DHN-6	101.28^{e}	10.68^{def}	95.57^{f}
PTH	112.24^{de}	13.10^{bc}	160.94^{a}
PBN-16	137.93^{b}	14.86^{a}	159.02^{a}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 28. Nutrient uptake by hybrid napier cultivars at third harvest (kg/ha)

Cultivar	N	P	K
CO-2	88.17^{c}	13.04^{b}	94.42^{b}
CO-3	139.68^{a}	15.52^{a}	124.51^{a}
CO-4	64.78^{de}	7.53^{de}	75.22^{cd}
KKM-1	66.20^{de}	6.76^{e}	50.31^{e}
Suguna	114.51^{b}	16.27^{a}	128.07^{a}
Supriya	66.67^{de}	8.53^{d}	66.32^{d}
IGFRI-3	70.28^{de}	7.38^{de}	69.14^{d}
IGFRI-7	71.05^{de}	8.19^{de}	67.31^{d}
DHN-6	57.49^{e}	6.78^{e}	48.27^{e}
PTH	76.79^{cd}	11.23^{c}	84.50^{bc}
PBN-16	87.49^{c}	10.52^{c}	93.14^{b}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.7. Soil moisture content during summer months (%)

Soil moisture content observed from December to March from two depths, 0-15cm and 15-45cm, at monthly interval is shown in Table 29. Between the months, higher soil moisture content was observed during December. Thereafter, a decrease in soil moisture content was noticed until the receipt of summer showers in March. There was not much variation between the plots.

Table 29. Soil moisture content (SMC) during summer months (%)

Month	Dec		Jan		Feb		Mar	
Depth(cm)	15	45	15	45	15	45	15	45
CO-2	7.97	9.30	3.77	5.40	1.63	4.83	4.43	6.93
CO-3	7.47	9.20	3.40	5.17	1.33	3.77	5.62	7.27
CO-4	8.30	8.87	3.97	6.03	2.37	4.53	4.43	6.84
KKM-1	7.73	9.07	3.27	4.83	2.50	4.43	5.65	7.57
Suguna	7.43	9.97	3.70	5.93	2.33	4.38	5.17	6.88
Supriya	8.40	9.77	3.30	5.77	2.83	5.20	5.52	8.03
IGFRI-3	8.17	9.78	3.80	5.97	2.54	4.81	4.70	7.07
IGFRI-7	7.53	8.97	3.43	5.83	2.65	4.27	4.97	7.51
DHN-6	7.33	9.53	3.23	4.50	1.83	4.33	4.77	7.04
PTH	6.67	8.33	3.93	5.67	1.97	4.27	4.49	6.90
PBN-16	7.40	9.47	4.83	5.97	1.90	5.37	5.21	7.65

4.8. Relative Leaf Water Content (RLWC)

The data on RLWC recorded at monthly intervals starting from December after the cessation of rains are presented in Table 30. Plants showed the highest RLWC in December and there was a decreasing trend up to February but again an increasing trend was observed in March. In December, PTH recorded the highest RLWC and the lowest was noticed in DHN-6. The cultivars CO-2, CO-3, KKM-1, Supriya and PBN-16 showed the highest RLWC in January. DHN-6 recorded the lowest value. In February, CO-3 recorded the highest RLWC, followed by Supriya and the lowest by PTH. In March, maximum RLWC was noticed in Supriya and CO-3. The lowest was noticed in IGFRI-3.

Table 30. Relative leaf water content during summer months(%)

Cultivars	Dec	Jan	Feb	Mar
CO-2	90.98^{de}	89.90^{a}	82.20^{c}	88.11^{ab}
CO-3	91.43^{de}	91.27^{a}	91.23^{a}	91.56^{a}
CO-4	90.58^{de}	87.70^{abc}	85.70^{b}	89.61^{ab}
KKM-1	93.93^{bc}	89.97^{a}	86.03^{b}	90.20^{ab}
Suguna	92.72^{bcd}	88.70^{ab}	86.10^{b}	90.78^{ab}
Supriya	92.28^{cde}	88.98^{a}	88.17^{ab}	91.73^{a}
IGFRI-3	90.63^{de}	84.87^{bcd}	87.48^{b}	78.67^{d}
IGFRI-7	95.07^{ab}	87.77^{abc}	85.87^{b}	89.02^{ab}
DHN-6	89.87^{e}	83.80^{d}	80.83^{cd}	87.46^{b}
PTH	96.37^{a}	84.33^{cd}	78.37^{d}	83.91^{c}
PBN-16	93.85^{abc}	90.43^{a}	86.93^{b}	88.61^{ab}

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4.9. Mortality of clumps

After the fourth harvest in January, no more harvest could be conducted because of inhibited growth as a result of drought. Some clumps dried completely due to dryness. During March, 3.50 mm of rainfall and in April 101.90 mm of rainfall were received enough to allow regeneration of clumps. Observation on completely dried and non-regenerated clumps were taken on 5-5-2012 and presented in Table 31 and Fig. 8, expressed as percentage of completely dried clumps. The data given in Table 31 shows that all the clumps of CO-3, CO-4 and PTH survived the dry periods. Only 3.33 percent clumps dried in Suguna and 6.67 percent in Supriya. Maximum mortality of clumps was noticed in PBN-16 with 52.50 percent loss of clumps followed by IGFRI-3 (33.33%), DHN-6 (25 %), CO-2 (22.50 %) and KKM-1 (17.50 %). Other cultivars were able to withstand moderate drought and showed less than 25 percent drying.

Table 31. Percentage of completely dried clumps

Cultivars	Percentage of completely dried clumps
CO-2	4.791^{bc} (22.50)
CO-3	0.707^{f} (0.00)
CO-4	0.707^{f} (0.00)
KKM-1	4.215^{c} (17.50)
Suguna	1.756^{ef} (3.33)
Supriya	2.644^{de} (6.67)
IGFRI-3	5.731^{b} (33.33)
IGFRI-7	3.064^{d} (9.17)
DHN-6	5.046^{bc} (25.00)
PTH	0.707^{f} (0.00)
PBN-16	7.279^{a} (52.50)

* In a column, means followed by common letters do not differ significantly at 5% level by DMRT

*$\sqrt{x+0.5}$ transformed values, original values with in parentheses

Discussion

5. DISCUSSION

A field experiment to compare the performance of eleven cultivars of hybrid napier grown under rainfed conditions was conducted during the period 2011-2012 at the Agronomy Farm of College of Horticulture, Vellanikkara. The results obtained from the experiment reported in the previous chapter are discussed based on available literature.

5.1. Growth analysis

Planting was done on 7-6-2011 using slips separated from old clumps. All the cultivars established well and showed proportionate increase in growth. The growth was rather slow in the first few weeks but later the crop growth was fast. However, after the cessation of rainfall by November, growth rate decreased and some cultivars even died because of the severity of summer. The cultivars that survived in a dormant condition during summer utilizing the residual soil moisture regenerated after the receipt of a few premonsoon showers.

Plant height is considered as a varietal character which is genetically controlled, but modified by a lesser extent due to environment. Plant height was maximum at the time of first harvest (75 DAP) probably because of the interplay of all the favourable conditions such as enough soil moisture, sunshine and soil fertility. The time allowed for growth was also higher (75 days) compared to subsequent harvests (45 days). Increasing the harvest interval increases plant height in hybrid napier (Singh and Joshi, 2002). It could be seen from Table 3 and Fig.4 that the cultivars differed significantly in height. During the first and second harvests, CO-2 showed maximum plant height but later KKM-1 showed dominance in height. The plants showed decrease in height towards the later part of the experiment due to cessation of rainfall and moisture stress. Water deficit is likely to affect the two vital processes of growth, namely, cell division and cell enlargement and according to Begg and Turner (1976), cell enlargement is more affected resulting in poor growth. The general belief is that growth is suspended during moisture stress and resumed upon its elimination (Arnon, 1975). The average height was comparatively higher for CO-2 while IGFRI-3 had the minimum (Fig.4). Cook *et al.* (2005) reported the height of hybrids ranging from 2m to 3.5m. In the present experiment, the cultivar CO-2 attained 295.80cm height at the first harvest time.

The rate of fodder production is a function of tiller production and leaf growth (Ryle, 1970; Selvi and Subramanian, 1993). Number of tillers and leaves are considered as genetic characters modified by the environment. The genetic control of axillary branching was reported in cereals such as rice, wheat and oats by Gardner *et al.* (1985). During the initial stage of the experiment, tiller production was less, then gradually increased, but decreased by the final harvest. Low tiller production during the initial stages can be attributed to the difficulty in establishment and slow growth and gradual increase was probably because of the interplay of all the favourable conditions such as enough soil moisture, sunshine, and soil fertility, and formation of more number of axillary buds after each harvest. The gradual decrease in tillers during later stages of harvests can be attributed to the stress developed during summer months. Busso *et al.* (1989) reported that water availability and defoliation stimulated more axillary buds

The control of tillering in grasses is the contribution of genetic and physiological factors and their interaction with environmental factors (Assuero and Tognetti, 2010). As presented in Table 4 and Fig.5, the average number of tillers was maximum for PTH followed by IGFRI-3. PTH is recommended for cultivation under rainfed conditions (Biradar *et al.*, 2008). IGFRI-3 is a profuse tillering type, erect with narrow upright leaves with quick regeneration ability and has thin stems like guinea grass (Pandey and Roy, 2011).

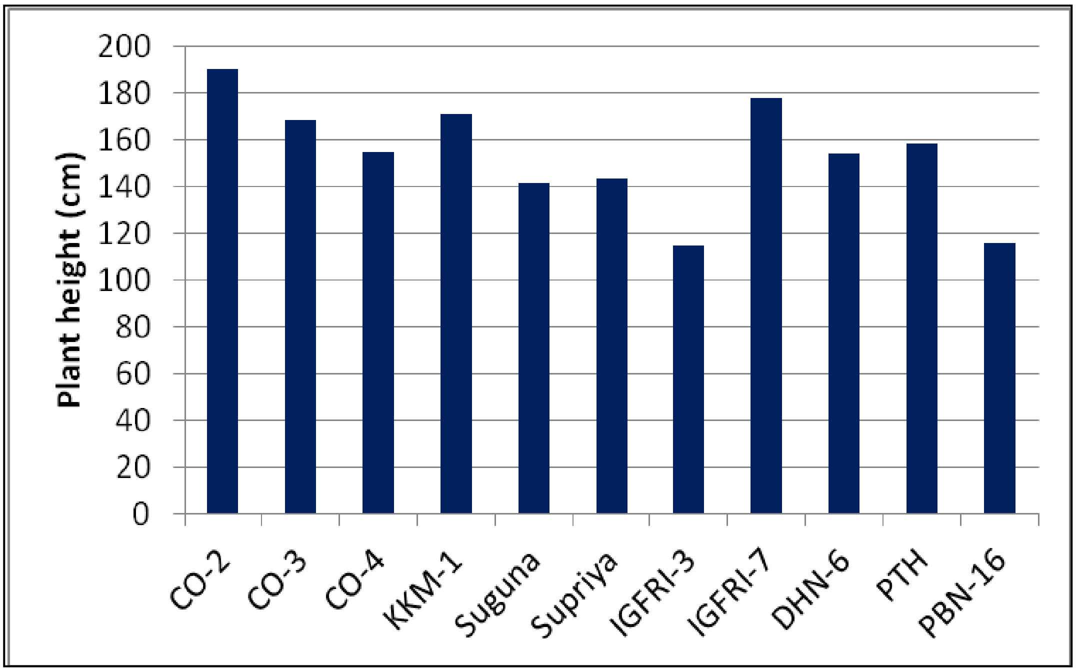

Fig. 4. Mean plant height of hybrid napier cultivars

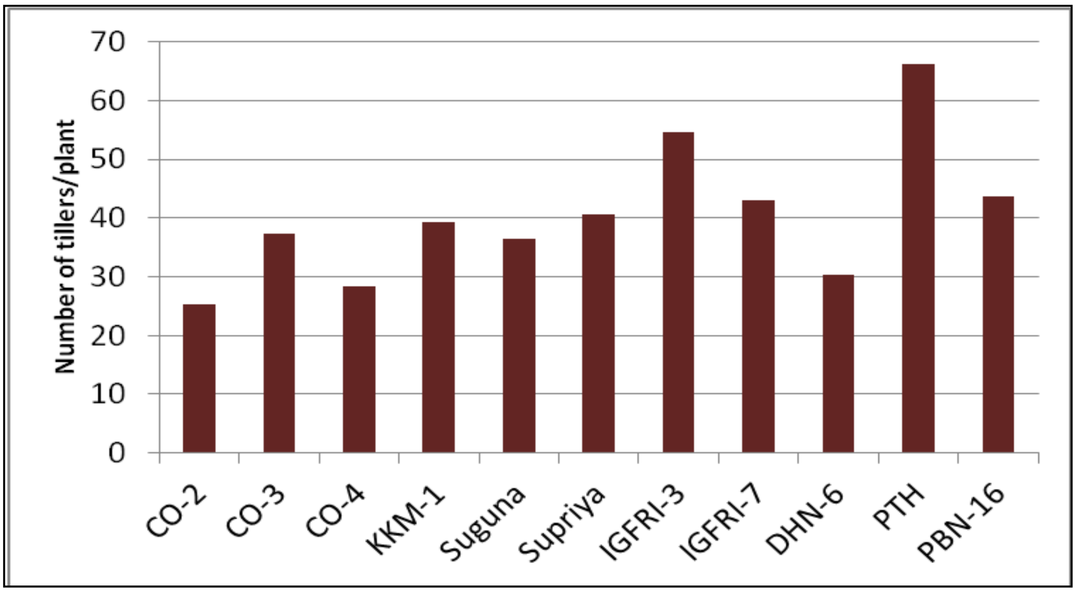

Fig. 5. Mean number of tillers/plant in hybrid napier cultivars

As reported by Singh *et al.* (1995), leafiness can be used as an indicator of yield and nutritive value. Leaf number and leaf area per plant and per tiller are indications of leafiness, and this characteristic is closely correlated with yield and digestibility. In the present experiment, plants showed an increase in the number of leaves throughout the experiment except for the last harvest (Table 5). This can be attributed to the production of more number of tillers after each harvest and the favourable environmental conditions prevailed during monsoon months. The decrease in leaf number during final harvest was probably due to decrease in growth and tiller production as a result of deficit in rainfall and soil moisture. Gardner *et al.* (1985) stated that in non irrigated condition, leaf growth was greater when moisture was available naturally.

Leaf production was found to be the maximum for PTH, followed by IGFRI-3 and the lowest in CO-2. This is because of the high tillering character of PTH and IGFRI-3 and low tillering in CO-2 (Table 5 and Fig.6) In the opinion of Humpheries and Wheeler (1963) leaf number and size in plants are characters which are affected by genotype and environment.

Leaf length is a morphological characteristic most highly correlated with yield (Malaviya, 1999). Leaf length and width also showed a similar trend as that of leaf number. Bade *et al.* (1985) reported that water stress retarded cell enlargement and stem elongation, and reduced leaf area. The mean leaf length was found to be maximum in CO-3 and minimum in PTH (Table 6) Leaf width was higher in CO-2 and CO-4 (Table 7 and Fig.8) and PTH had the least followed by IGFRI-3 and IGFRI-7.

Leaf area is one of the factors which contribute to fodder production (Thomas *et al.* 2007). In the present study, leaf area index varied from 0.97 to 20.35 depending on stages of observations and cultivars. Kumar *et al.* (2011) observed LAI of 3.91-20.79 for hybrid napier cultivar CO-3 under rainfed condition. The cultivars showed low LAI during initial stage because leaf length, leaf width and number of leaves were less at that time. There was a rapid increase in leaf area index during June to August which can be attributed to the rapid increase in number

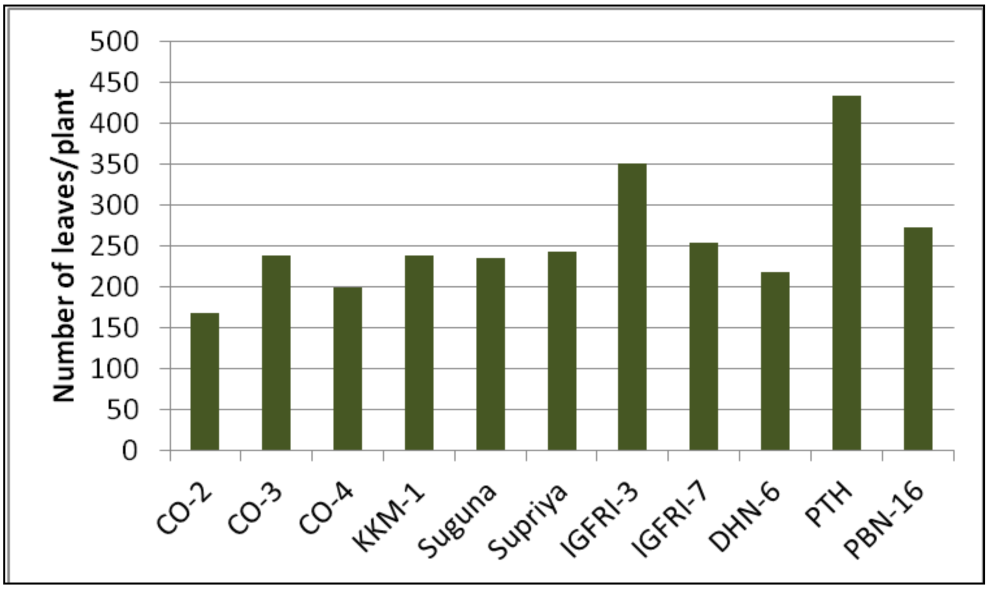

Fig. 6. Mean number of leaves/plant in hybrid napier cultivars

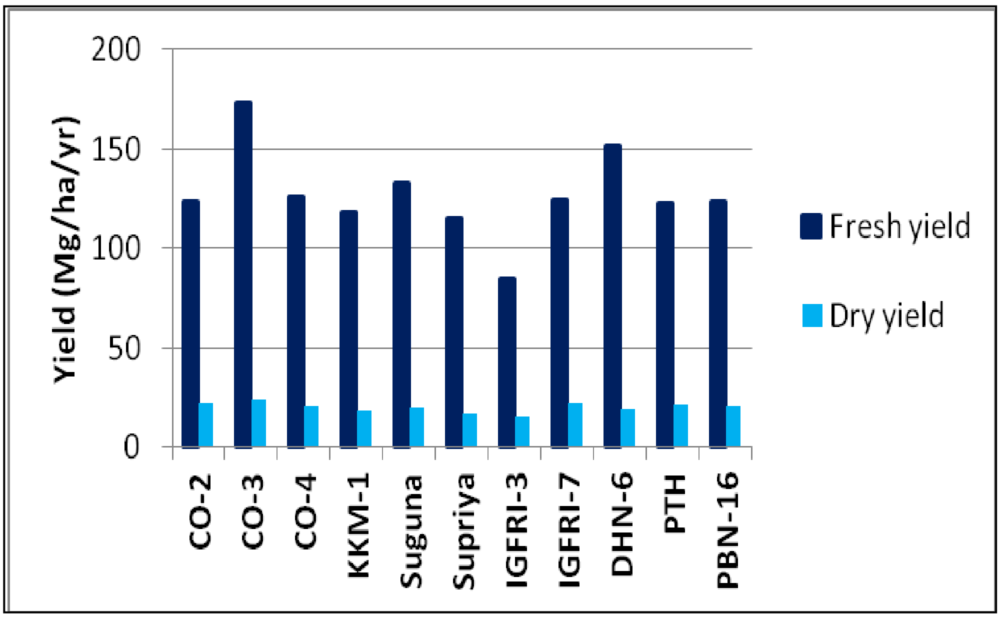

Fig. 7. Total green and dry fodder yield of hybrid napier cultivars

of leaves, leaf length and leaf width. Maximum leaf area index was shown at the third harvest stage as the number of leaves was more at the time of third harvest. A decrease in LAI was observed during the last harvest probably due to the decrease in leaf number and leaf area as a result of water stress developed in summer. The cultivar CO-3 showed the highest LAI throughout the period because CO-3 recorded the maximum leaf length and leaf width.

Variation in total leaf area may result from changes in leaf number or in leaf size. Leaf number depends on the number of growing points, the length of time during which leaves are produced, the rate of leaf production during the period and the life of leaves. 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 (Arnon, 1975). A steep decline in LAI was reported by several workers in crops when leaf water potential decreased. This indicates that modest changes in evaporative condition or the soil water supply will have a considerable influence on leaf growth. Low leaf water potential also causes the loss of existing area (Arnon, 1975; Begg and Turner, 1976).

In the present study, life of leaves is fixed to the cutting interval of 45 days. Reduction in LAI during the later harvests is mainly due to moisture stress. The leaves of a plant are the main organs of photosynthesis and LAI is the best measure of the capacity of a crop for producing dry matter (Arnon, 1975). Lower photosynthetic efficiency which was evident from low LAI might be a major reason for the poor growth and low fodder yield during the fourth harvest.

Leaf area ratio (LAR) is a measure of relative leafiness of a plant. LAR also showed a similar trend as in case of LAI (Table 9). LAR was maximum at the third harvest stage because LAI was maximum at third harvest. Higher proportion of leaf area contributes to substantial increase in LAR of plants (Hunt, 1978).

Net assimilation rate (NAR) and relative growth rate (RGR) were higher during the second harvest and decreased at the time of the final harvest as depicted in Table 10, because there was a decrease in plant dry weight due to moisture stress by the final harvest. Water stress affects the most important physiological determinants of yield- canopy architecture, photosynthesis and partitioning of assimilates (Balasimha, 1999). NAR decreased by the third harvest because LAI was maximum at the third harvest stage. As the plant grows and LAI increases more and more leaves become shaded, causing a decrease in NAR as the growing season progress (Gardner *et al.* 1985).

Leaf to stem ratio is a qualitative character affecting the palatability and consequently animal intake. Often, it is a genetic character. In the case of hybrid napier, leaf to stem ratio varied considerably between cultivars as evident from Table 12. Comparatively higher leaf: stem ratio was shown by CO-3, Suguna and Supriya. This can be attributed to the higher leaf dry weights compared to other cultivars. The supremacy of CO-3 in terms of high leaf to stem ratio making it highly palatable for animals has already been reported (Pandey and Roy, 2011).

Shoot to root ratio is also a genetic character and the cultivars differed substantially (Table 13). CO-3 and PTH gave the highest values and IGFRI-3 the lowest. Shoot- root (S-R) ratio has physiological significant as it can reflect tolerance to drought. As Gardner *et al.* (1985) stated although S-R ratio is under genetic control, it is strongly influenced by environment. Shoot: root ratio decreased in the third and fourth harvest because moisture stress reduced the above ground dry weight. Gardner *et al.* (1985) stated that moisture stress during the vegetative stage results in development of smaller leaves, which reduce LAI and result in less light interception by the crop. Root elongation and dry weight were not affected as much as leaf area, stem elongation and dry weight. In other words, water deficiency has a relatively greater effect on top growth than root growth. According to Bade *et al.* (1985), water stress in tropical grasses slows cell enlargement and stem elongation, and reduces leaf area and shoot: root ratio and finally yield. Water stress affected the above ground biomass of bajra napier hybrids, NB-2 and CO-1, but not affected the below ground biomass as water stress stimulated root growth (Manoharan and Paliwal, 1997).

5.2. Fodder production

The data on green and dry fodder yields under rainfed conditions are given in Table 14 & 15 and Fig.7. Four harvests were taken under rainfed conditions.

Kumar *et al.* (2011) reported an average of three harvests per year under rainfed conditions from the cultivar CO-3 at Kollam, Kerala. Among the four harvests, the highest green and dry fodder yields were obtained in the first harvest, and thereafter, a decreasing trend was noticed. After the fourth harvest, no harvesting could be done as there was stunting and drying of plants due to drought in summer months. Water stress imposed during crop growth drastically affects growth ultimately leading to a massive loss in yield and quality (Govindarajan *et al.*, 1996).

Higher yield during the first harvest can be attributed to the interplay of all the favourable conditions such as sufficient soil moisture, sunshine and soil fertility. The time allowed for growth was also higher (75 days) compared to subsequent harvests (45 days). Yield, in general, increases when the interval of cutting is increased (Watkins and Lewy-Van Severen, 1951).

The green and dry fodder yields of hybrid napier cultivars ranged from 84.79 Mg/ha to 173.00 Mg/ha and 15.00 Mg/ha to 23.90 Mg/ha respectively (Table 14 and 15 and Fig.7). Gupta and Mhere (1997) reported that during the dry periods some cultivars of hybrid napier continued to grow and produced dry matter yield of 600kg/ha per cut.

Genotype is the most prominent factor which affects yield (Schank *et al.*, 1993; Cuomo *et al.*, 1996) followed by edaphic and climatic factors and management practices (Gardner *et al.*, 1985; Chaparro *et al.*, 1995; Chaparro *et al.*, 1996). Among the cultivars, CO-3 recorded the highest total green (173.30Mg/ha) and dry (23.90 Mg/ha) fodder yields. The lowest green and dry fodder yields were recorded by IGFRI-3 (84.79 Mg/ha and 15.00 Mg/ha). The higher yields of CO-3 can be attributed to higher leaf length, LAI, LAR, NAR, RGR, leaf:stem ratio, shoot: root ratio and the ability to withstand drought, which is evident from zero percent mortality of clumps and high RLWC. Premaratne and Premalal (2006) reported that CO-3 yields an average green fodder of 5–8 kg/plant from a single cutting or 250-350 Mg/ha annually, and the grass is superior in terms of higher tillering capacity, forage yield, regeneration capacity, leaf to stem ratio, crude protein content, resistance to pest and diseases and free from adverse factors.

DHN-6 (151.62 Mg/ha/yr) followed CO-3 (173.30 Mg/ha/yr) in terms of green fodder yield. During the first harvest, DHN-6 recorded the highest green fodder yield (82.71Mg/ha). Soumya (2011) reported that under irrigated condition DHN-6 gave green fodder yield of 283.31 Mg/ha/yr. This proves that DHN-6 can perform better under good management provided there is enough soil moisture.

The third highest yielder was Suguna with 132.44 Mg/ha. As it survived drought with very little mortality (3.33%), it can also be recommended for rainfed areas. The fourth rank in total yield was shown by CO-4 (126.05 Mg/ha/yr). This also seems to be a good cultivar for rainfed condition as it showed zero mortality during drought.

Pandey and Roy (2011) reported that IGFRI-3 (Swetika) is a cultivar suitable for cultivation in north and central zones of the country and under north Indian conditions, it gave an average yield of 70-80 Mg/ha/yr green fodder and 18 Mg/ha/yr dry fodder. Faruqui *et al.* (2009) reported green fodder potential of 90-160 Mg/ha/yr for IGFRI-3. Although it's total yield in the present experiment was 84.79 Mg/ha/yr, it was the lowest yielder from among the eleven cultivars, probably, it may be used in grass-legume mixture under irrigated condition as it is short, narrow stemmed and profuse tillering with high crude protein content. As per Thomas (2008), short, leafy bunch grasses are highly preferred for a successful good grass-legume mixture in the pasture as they reduce competition for light.

5.3. Nutritive value and quality

Plant samples from all the treatments were collected at the third harvest and were used to find out calcium, magnesium, oxalate content and the five fractions of proximate analysis - crude protein, crude fibre, total ash, ether extract and nitrogen free extract. Percentage content of nitrogen, phosphorus and potassium of both leaves and stems were estimated at 75 DAP, 120 DAP and 165 DAP at the time of first, second and third harvests respectively.

Crude protein content gives an approximate value of protein content in the forages. Significant differences were noticed between cultivars with respect to crude protein content because there were significant differences in nitrogen content among the cultivars. In general, the percentage content of crude protein was higer in leaves than stems. In the leaves, the content ranged from 10.73 percent to 14.17 percent. Among the cultivars IGFRI-3 had the highest score (14.17%) on par with CO-3 (14.06 %), DHN-6 (13.54 %) and PBN-16 (13.54 %). In stems, the crude protein content ranged from 6.15 percent (PTH) to 9.58 percent (CO-3). Vijayakumar *et al.* (2009) reported that the cultivar CO-3 had an average crude protein content of 10.5 percent and crude protein yield of 6.52 Mg/ha, whereas the cultivar CO-4 had a crude protein yield of 8.71 Mg/ha with an average crude protein percentage of 10.71. Fernandes *et al.* (2007) reported that during rainy season, hybrid napier grass contain an average crude protein content of 9.91 percent. When crude protein content of both leaves and stems are considered, IGFRI-3 (14.17% and 9.17%) and CO-3 (14.06% and 9.58%) seems to be superior compared to others.

In general, crude fibre content of stems was more than the leaves and showed significant differences between the cultivars. In the leaves, the content ranged from 25.43 percent (CO-2) to 31.05 percent (IGFRI-7). In the stems, IGFRI-7 showed the highest value (36.22 %) and Supriya the lowest (28.03 %). Pandey and Roy (2011) reported that hybrid napier grass has crude fibre content of 30.50 percent.

Total ash, ether extract and NFE were found to be higher in leaves than stems and showed significant differences between the cutivars. The total ash content of leaves ranged from 7.50 percent (PTH) to 9.70 percent (CO-3) and that of stems ranged from 5.20 percent (PTH) to 8.47 percent (Supriya). Crude fat content of leaves ranged from 2.80 percent (CO-4) to 1.47 percent (IGFRI-7). In the stems, crude fat content ranged from 1.10 percent (Supriya and PTH) to 1.58 percent (IGFRI-3). Nitrogen free extract of leaves ranged from 47.02 percent (CO-3) to 51.88 percent (CO-2).

Cultivars differ widely in terms of nutritive value (Soumya, 2011). She compared eight cultivars under irrigated conditions and observed that crude protein content in different cultivars ranged from 6.14 to 13.83 percent, crude fibre 27.56 to 37.68 percent, crude fat 1.79 to 2.82 percent, nitrogen free extract 41.33 percent to 45.22 percent, total ash 11.62 to 13.90 percent, phosphorus content 0.16 to 0.20

percent, potassium content 1.64 to 2.14 percent, calcium content 0.42 to 0.43 percent, magnesium content 0.48 to 0.54 percent and oxalate content 1.19 to 4.19 percent. When harvested at correct stage, CO-3 grass contains 9.8 – 12.8% ash, 34 – 37% crude fibre and 74 – 78% neutral detergent fibre on dry matter basis (Premaratne and Premalal, 2006).

In the present experiment, in general, all the cultivars exhibited lower ash content. The lower ash content can be attributed to the lower content of minerals especially calcium and magnesium.

All the nutrient elements studied (N, P, K, Ca and Mg) were higher in leaves than stems (Tables 19 to 25). Nitrogen and potassium contents were higher in the second harvest, but phosphorus content was higher in the third harvest. The nutrient contents were lower at the first harvest, probably due to higher length of harvest interval (75 DAP) compared to the subsequent harvests (45 DAP). As stated earlier (section 5.2) fodder yield was the highest during the first harvest suggesting a dilution effect on nutrients. Vincente – Chandler *et al.* (1959) observed that mineral content of tropical grasses decreased markedly with length of harvest interval.

Kipnis and Dabush (1988) reported that in hybrid napier, oxalate levels in the leaves were higher than in stems. Kaur *et al.* (2009) noticed that in hybrid napier, leaves accumulated higher concentration of oxalate (3.82%) compared to stems (1.95%). In most of the cultivars barring CO-2, CO-4, KKM-1, Suguna and PTH, leaves exhibited higher oxalate content compared to stems (Table 18). In the leaves, oxalate content ranged from 2.40 percent (CO-4) to 3.63 percent (Suguna) and in stems, oxalate content ranged from 2.70 percent (IGFRI-7) to 4.13 percent (Suguna). High oxalate content will interfere with calcium uptake in animals; therefore, cultivars with low oxalate are prefered.

5.4. Nutrient uptake

The uptake of nutrients is a function of biomass production and nutrient content. The highest nutrient uptake was recorded during the first harvest because the biomass production was higher in the first harvest compared to other harvests (Tables 26, 27 and 28). During the first harvest, cultivars CO-2, IGFRI-7, DHN-6, PBN-16 recorded the highest nutrient uptake. In the second and third harvests, CO-3, PBN-16, PTH and Suguna had the highest nutrient uptake.

5.5 Soil moisture content

Soil moisture content was observed after the cessation of rain from December to March, from two depths, 0-15cm and 15-45cm at monthly intervals. Soil moisture content was higher in the lower 15-45 cm layer than 0-15cm layer (Table 29), indicating that besides transpiration, losses due to evaporation from the soil surface were also considerable. A decrease in soil moisture content was noticed until the receipt of summer showers in March. Gardner (1968) reported that root mass and their activity were important for soil moisture extraction. Soil moisture and soil fertility are the factors, which are positively correlated with forage yield (Sotomayour-Rios *et al.*, 1972).

5.6. Relative leaf water content

Relative leaf water content (RLWC) is an indication of water deficit in plants. The data on RLWC were recorded at monthly intervals from December after the cessation of rain and presented in Table 30. Plants showed the highest RLWC in December and thereafter a decreasing trend was noted upto February, but again it increased in March because of the receipt of a few premonsoon showers. The decreasing trend in RLWC in summer can be attributed to the low soil moisture content, low relative humidity and high temperature which prevailed during summer months. During the summer months, Supriya and CO-3 recorded the highest RLWC and the lowest in IGFRI-3.

RLWC of leaves ranged from 78.37 percent to 96.37 percent. It was reported that plants having less than 75-85 percent RLWC exhibited visible wilting symptoms (Gardner and Ehlig, 1965). Kirnak *et al.* (2001) reported that in eggplant, water stress caused significant decrease in chlorophyll content and relative leaf water content. Higher the RLWC higher will be the drought tolerance ability.

5.7. Mortality of clumps.

Mortality of clumps is an indication of the susceptibility of cultivars to drought. Table 31 gives the percentage of clumps dried even after giving time for regeneration. Maximum mortality of clumps was noticed in PBN-16 with 52.50 percent loss of clumps followed by IGFRI-3 (33.33%), DHN-6 (25%), CO-2 (22.50%) and KKM-1 (17.50%). It is evident from Fig. 8 and Table 31 that CO-3, CO-4 and PTH survived the dry periods. This is because of the highest shoot: root ratio of cultivars after the cessation of rain.

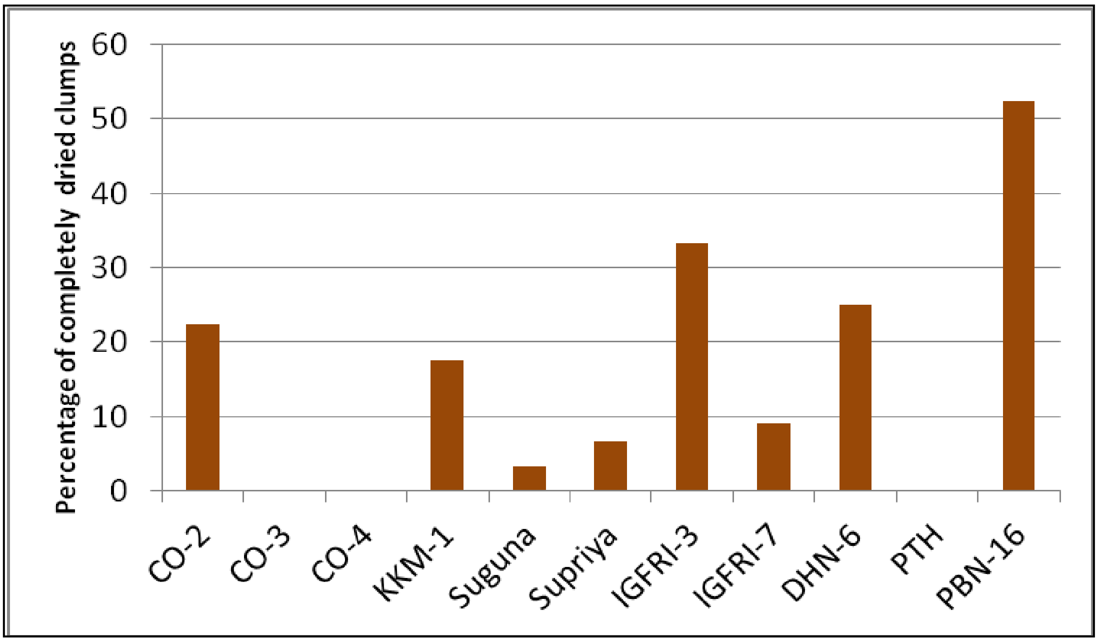

Fig. 8. Percentage of completely dried clumps in hybrid napier cultivars

5.8. Conclusion

From the above discussion we can infer that CO-3 is superior to all other cultivars with respect to yield, nutritive value and the ability to withstand drought, hence highly suited for rainfed cultivation. As the mortality of clumps was zero for CO-4 and PTH, these cultivars can also be recommended for rainfed areas, in addition to CO-3. Other cultivars like Suguna, Supriya and IGFRI-7 may be recommended for Southern Kerala where distribution of rainfall is maximum and even. It may also be grown with life saving irrigation during summer months. Although DHN-6 showed 25% mortality of clumps during summer, as it out yielded other cultivars, it may be suitable under well managed fodder cultivation with irrigation. Although IGFRI-3 was the lowest yielder from among the eleven cultivars, probably, in grass- legume mixture under irrigated conditions it may be used as it is short, narrow stemmed and profuse tillering with high crude protein content.

5.9. Future line of work

Only one year data could be taken in the present experiment. For confirmation of the findings the experiment may be repeated for 2-3 years. The shade tolerance ability of hybrid napier cultivars shall also be evaluated to fit them in to various farming systems. Information on digestibility and palatability of superior cultivars must be generated. Most of the new hybrids are heavy yielders and there is an urgent requirement to study the relationship between high yield and nutrient depletion from the soil. Similarly, the present recommendation on NPK, 200: 50: 50 kg/ha, seems to be inadequate and may need revision. Another need is simultaneous evaluation of hybrid napier cultivars under irrigated and rainfed conditions. The effect of cutting height on midsummer mortality of clumps may also be investigated. Optimum soil and plant management practices to improve Ca and Mg content in hybrid napier grown in acidic soils may also be considered.

Summary

6. SUMMARY

A field experiment was conducted during 2011-2012 at the Agronomy Farm of College of Horticulture, Vellanikkara to evaluate the performance of hybrid napier cultivars under rainfed condition. The main objectives of the experiment were to select the most suitable cultivars under rainfed condition and to assess the nutritive quality of the cultivars included in the study.

The experiment was laid out in randomized block design with three replications. The treatments comprised of eleven different cultivars of hybrid napier; CO-2, CO-3, CO-4, KKM-1, Suguna, Supriya, IGFRI-3, IGFRI-7, DHN-6, PTH and PBN-16. Rooted slips of hybrid napier were planted at a spacing of 60 cm X 60 cm on 7-6-2011.

The first harvest was taken at 75 days after planting (DAP) and subsequent harvests at 45 days interval. Main observations recorded were growth parameters, green and dry fodder yield, nutrient content and uptake, proximate analysis, soil moisture status, relative leaf water content of leaves and mortality of clumps.

Observations on growth parameters were taken 45 days after planting (DAP) and at every harvest starting from the first harvest at 75 DAP of the crop. Leaves, stems and roots of randomly selected plants were separated and dry weights were recorded separately. Based on the growth observations and dry weights, derived variables such as leaf area index (LAI), leaf area ratio (LAR), net assimilation rate (NAR), relative growth rate (RGR), leaf: stem ratio and shoot: root ratio were calculated. Analyses of variance were performed on all data collected using the statistical package, ‘MSTAT’. Duncan’s multiple range test (DMRT) was used to compare means. The present investigation came out with the following findings.

Growth and growth analysis

The growth was rather slow in the first few weeks, but later the crop growth was fast. However, after the cessation of rainfall by November, growth rate decreased and some cultivars even dried because of the severity of summer. There were significant differences between the cultivars with respect to plant height, number of tillers/clump, number of leaves/clump, leaf width, leaf length, leaf area index, net assimilation rate, relative growth rate, leaf area ratio, leaf: stem ratio and shoot: root ratio.

The plants, in general, showed maximum plant height at the time of first harvest (75 DAP). Plant height decreased towards the later part of the experiment. During the initial stage of the experiment, tiller production was less, then gradually increased, but decreased in the final harvest. Plants showed an increase in the number of leaves throughout the experiment except for the last harvest. Leaf length and width also showed similar trend as that of leaf number.

Leaf area index in hybrid napier varied from 0.97 to 20.35 depending upon the stage of observations and cultivars. All the cultivars showed low LAI during initial stages. There was a rapid increase in leaf area index during June to August. The cultivars showed maximum leaf area index at the third harvest stage. A decrease in LAI was observed during the last harvest. LAR also showed a similar trend as in the case of LAI. LAR was maximum at the third harvest stage. Although there were significant differences between the cultivars with respect to net assimilation rate and relative growth rate during the initial stages of growth, the differences between the cultivars were quite narrow towards the later stages of harvests. Higher leaf: stem ratio was shown by CO-3, Suguna and Supriya. Shoot: root ratio decreased in the third and fourth harvest.

Based on growth parameters and growth analysis, it is concluded that CO-2 attained the maximum plant height and leaf width while PTH recorded the maximum number of tillers per clump and maximum number of leaves per clump. The highest leaf length, leaf area index, leaf: stem ratio and shoot: root ratio was shown by CO-3.

Fodder production

Green fodder yield from each plot was recorded immediately after cutting and expressed in Mg/ha. Five plants were selected randomly after each harvest and the plants from each plot were initially weighed, oven dried at 80 ± 5^{0}C for 24 hours till constant weight was achieved and dry weight was recorded. From this, yield of dry fodder in Mg/ha was calculated.

Only four harvests could be made and the last was in January. Green and dry fodder yield were maximum during the first harvest, and thereafter, a decreasing trend in yield was noticed. In summer, no harvesting was done due to stunting and drying of plants. CO-3 recorded the highest green fodder yield throughout the experiment; hence CO-3 outyielded other cultivars under rainfed condition. DHN-6 followed CO-3 as it attained the highest green fodder yield during the first harvest; however, in subsequent harvests a decrease in green fodder yield was noticed. IGFRI-3 was the lowest yielder.

Nutritive quality and nutrient uptake

Nutritive values of the cultivars included in the study were assessed based on proximate analysis, elemental composition and the presence of oxalate content. Plant samples from all the treatments were collected at third harvest; leaves and stems were separated, chopped, dried in hot air oven at 80 ± 5^{0}C for 24 hours till constant weight was achieved. The samples after grinding were used to find out calcium, magnesium, oxalate content 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 nitrogen, phosphorus and potassium of both leaves and stems were noted at 75 DAP, 120 DAP and 165 DAP at the time of first, second and third harvests.

Analyses of data on nutritive value and oxalate content showed significant differences among the cultivars. In general, nutritive value of leaves was higher than stems. When crude protein content of both leaves and stems are considered, CO-3 (14.06% and 9.58%) and IGFRI-3 (14.17% and 9.17%) seems to be superior compared to others. Crude fibre content of stems was more than the leaves and showed significant differences between the cultivars. Crude fibre content was higher in leaves and stems of IGFRI-7 compared to others.

In terms of nutritional quality, CO-3 was found superior to other cultivars as the percentage content of crude protein, crude fibre, total ash, ether extract, nitrogen free extract, nitrogen, phosphorus, potassium, calcium and magnesium was either high or balanced in CO-3 compared to other cultivars. Oxalate content, an antinutritive factor, was found to be the highest in leaves and stems of Suguna. Nutrient uptake was higher in the first harvest, and in general, CO-3 had the highest rate of nutrient removal.

Soil moisture content, relative leaf water content and mortality of clumps

Soil moisture content was observed from December to March from two depths, 0-15 cm and 15-45 cm at monthly intervals. The highest soil moisture content was observed during December; thereafter, a decrease in soil moisture content was noticed until the receipt of summer showers in March. There was not much variation between the plots.

The data on relative leaf water content (RLWC) was recorded at monthly intervals starting from December after the cessation of rains. Plants showed higher RLWC in December and there was a decreasing trend up to February, but again an increasing trend was observed in March. In summer, maximum RLWC was noticed in Supriya and CO-3 and the lowest was noticed in IGFRI-3.

Observation on completely dried clumps were taken on 5-5-2012 after the receipt of a few premonsoon showers and expressed as percentage of clumps dried completely. All the clumps of CO-3, CO-4 and PTH survived the dry periods and maximum mortality of clumps was noticed in PBN-16, followed by IGFRI-3, DHN-6, CO-2 and KKM-1.

Conclusion

It was concluded that CO-3 is superior to all other cultivars with respect to yield, nutritive value and the ability to withstand drought, and hence, CO-3 is highly suited for rainfed cultivation. Since there was no mortality of clumps for CO-4 and PTH, these cultivars can also be recommended for rainfed areas. Although DHN-6 showed 25 percent mortality of clumps during summer, as it outyielded other cultivars during the rainy period, it may be suitable for areas with well distributed and plentiful rainfall.

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Appendices

APPENDIX-I

Weekly mean surface air temperature (^{0}C), relative humidity (%), wind speed(km/h), sunshine hours (hrs/day) and rainfall (mm/week), at COH, Vellanikkara from June 2011 to May 2012 (Latitude $10^{0}31'$N, Longitude $76^{0}13'$ and Altitude 40.29MSL)

Month	Week No.	Surface air temperature (^{0}C)		Relative Humidity (%)		Wind speed (km/h)	Sunshine Hours (h/day)	Rainfall (mm/week)
		Max.	Min.	Morning	Evening			
June	23	29.60	24.00	95	86	2.5	1.9	211.50
	24	28.50	23.70	95	86	2.3	2.0	205.60
	25	30.40	23.40	96	76	3.1	3.9	122.00
	26	29.90	23.10	96	79	2.3	3.2	86.40
	27	30.40	23.20	94	94	2.1	4.0	19.10
July	28	29.00	23.30	94	94	2.4	2.3	16.20
	29	28.30	22.40	96	83	2.5	0.7	218.20
	30	28.50	22.90	96	83	2.0	1.1	132.80
	31	28.50	22.60	96	86	1.7	0.6	231.00
Aug	32	29.20	22.50	97	80	2.2	1.7	216.70
	33	30.20	22.90	96	74	2.3	3.0	20.80
	34	29.60	22.80	94	73	2.7	3.6	62.50
	35	28.80	23.30	95	85	2.8	0.9	286.90
	36	30.00	23.10	95	79	2.0	2.7	131.90
Sep	37	28.90	22.80	96	79	2.3	2.4	174.80
	38	30.20	23.40	94	71	2.0	4.6	34.20
	39	31.60	23.10	91	63	2.5	9.1	0.50
	40	32.30	23.30	91	58	2.80	9.5	0.00
Oct	41	32.40	23.40	92	62	2.30	6.2	5.90
	42	32.30	23.70	92	69	1.90	5.1	94.30
	43	31.70	23.30	89	71	5.00	5.0	87.40
	44	30.70	23.30	90	69	2.90	2.8	192.80
Nov	45	31.70	22.00	84	54	3.20	7.3	34.20
	46	32.40	22.00	80	48	4.70	9.3	0.00
	47	30.70	23.90	63	54	9.20	6.8	3.50
	48	31.50	23.80	87	64	3.40	3.8	11.90
Dec	49	32.10	22.80	82	51	4.40	8.5	0.00
	50	32.50	23.90	73	46	8.00	8.9	0.00
	51	31.00	23.50	62	44	9.80	6.1	0.00

Month	Week No.	Surface air temperature (^0C)		Relative Humidity (%)		Wind speed (km/h)	Sunshine Hours (h/day)	Rainfall (mm/week)
		Max.	Min.	Morning	Evening			
	52	31.70	20.10	81	50	4.40	6.4	2.40
Jan	01	32.10	21.60	84	44	5.80	8.50	0.00
	02	33.30	22.60	81	44	5.50	9.50	0.00
	03	32.00	20.20	71	31	6.00	9.10	1.00
	04	32.60	20.80	67	34	7.80	9.90	1.00
Feb	05	32.50	22.30	66	39	8.80	9.20	1.00
	06	34.70	23.00	78	41	4.90	8.60	1.00
	07	35.10	22.50	83	38	4.50	8.80	1.00
	08	35.90	21.00	74	22	4.80	9.20	1.00
Mar	09	35.60	22.20	78	39	4.30	7.30	1.00
	10	33.80	23.20	89	50	3.40	7.90	0.00
	11	36.00	25.00	85	49	4.00	7.90	2.50
	12	35.20	24.40	83	45	3.10	6.90	0.00
April	13	35.80	24.90	86	52	3.50	8.80	1.00
	14	35.10	24.20	90	52	3.70	8.10	8.40
	15	35.80	24.80	87	52	3.40	6.90	0.00
	16	35.40	25.10	84	57	3.60	3.50	7.60
May	17	33.20	24.70	93	66	3.20	5.30	79.10
	18	32.40	25.30	89	64	3.00	5.30	6.80

PERFORMANCE OF HYBRID NAPIER CULTIVARS UNDER RAINFED CONDITIONS

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by

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(2010-11-103)

ABSTRACT OF THE THESIS

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Department of Agronomy

COLLEGE OF HORTICULTURE

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ABSTRACT

Hybrid napier, an inter-specific cross between bajra (*Pennisetum glaucum* (L.) R. Br.) and napier (*Pennisetum purpureum* Schum.) is a popular fodder grass with high nutritive value and herbage yield. Hybrid napier cultivars perform well under irrigated condition but their performance under rainfed condition is not evaluated. A field experiment was conducted at the College of Horticulture, Vellanikkara to evaluate the performance of 11 popular cultivars under rainfed conditions—CO-2, CO-3, CO-4, KKM-1, Suguna, Supriya, IGFRI-3, IGFRI-7, DHN-6, PTH and PBN-16.

Slips were planted at a spacing of 60 cm X 60 cm in June, and growth, fodder yield and nutrient uptake were studied at 45 days interval. The first harvest was taken at 75 days after planting and subsequent harvests at 45 days interval. The cultivars differed significantly in various parameters such as plant height, tillers/plant, leaves/plant, leaf width, leaf length, leaf area index, net assimilation rate, relative growth rate, leaf area ratio, leaf: stem ratio and shoot: root ratio.

Four harvests were made, the last being in January. Green and dry fodder yield were maximum during the first harvest, thereafter, yield decreased. In summer, no harvesting was done due to stunting and drying of plants. Among the eleven cultivars evaluated, CO-3 recorded the highest green fodder yield followed by DHN-6.

Nutritive values and oxalate content showed significant differences among the cultivars. Crude protein content was maximum in CO-3 and IGFRI-3. In general, CO-3 showed supremacy over other cultivars in terms of overall nutritional quality. Oxalate content, an antinutritive factor, was found to be the highest in Suguna.

Nutrient uptake was higher in the first harvest, and CO-3 had the highest nutrient removal. In summer, maximum RLWC was noticed in Supriya and CO-3,

and the lowest in IGFRI-3. All the clumps of CO-3, CO-4 and PTH survived the dry periods and maximum mortality was noticed in PBN-16 followed by IGFRI-3, DHN-6, CO-2 and KKM-1.

The study revealed that CO-3 is superior to all other cultivars with respect to yield, nutritive value and the ability to withstand drought, and hence, CO-3 is highly suited for rainfed cultivation. Since there was no mortality of clumps for CO-4 and PTH, these cultivars can also be considered. Although DHN-6 showed 25 percent mortality of clumps during summer, as it outyielded other cultivars during rainy period, it may be suitable for areas with well distributed rainfall.