FODDER PRODUCTION TECHNOLOGY UNDER LIGHT AND MOISTURE STRESS SITUATIONS

by

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(2011 - 21 - 102)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"FODDER PRODUCTION TECHNOLOGY UNDER LIGHT AND MOISTURE STRESS SITUATIONS"** 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.

Vellayani,

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Certified that this thesis entitled **"FODDER PRODUCTION TECHNOLOGY UNDER LIGHT AND MOISTURE STRESS SITUATIONS"** is a record of research work done independently by Ms. Anita, M.R. (2011-21-102) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

%	-	per cent
°C	-	degree Celsius
ADF	-	acid detergent fibre
BCR	-	Benefit Cost Ratio
CD (0.05)	-	critical difference at 5 % level
cm	-	centimeter
cv.	-	cultivar
CPE	-	cumulative pan evaporation
CID	-	carbon isotope discrimination
DAS	-	days after sowing
DMP	-	dry matter production
DMY	-	dry matter yield
DW	-	dry weight
et al.	-	and co-workers/co-authors
Fig.	-	Figure
FYM	-	farm yard manure
FW	-	fresh weight
g	-	gram
g ha^{-1}	-	gram per hectare
ha	-	hectare
i.e.	-	that is
IW	-	irrigation depth

K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	kilogram
kg ha^{-1}	-	kilogram per hectare
LAI	-	leaf area index
m	-	metre
mg	-	milligram
mg g^{-1}	-	milligram per gram
mm	-	millimetre
m^2	-	square metre
MOP	-	Muriate of potash
MPa	-	mega pascal
MSL	-	mean sea level
N	-	Nitrogen
NS	-	non significant
P	-	Phosphorus
pH	-	negative logarithm of hydrogen ion concentration
POP	-	package of practices
q ha^{-1}	-	quintal per hectare
RBD	-	randomized block design
Rs ha^{-1}	-	Rupees per hectare
RWC	-	relative water content
SE	-	standard error

SLA	-	specific leaf area
$t\ ha^{-1}$	-	tonnes per hectare
TW	-	turgid weight
viz.	-	namely
WUE	-	water use efficiency

Introduction

1. INTRODUCTION

In India, cattle population which dominates the livestock sector is estimated around 187.38 million, which is about 14 per cent of the world cattle population. Though the per capita availability of milk is low compared to world average, substantial increase in this regard was attained over a period of 10 years, from 213 to 252 gm day^{-1}. In spite of India's position as the highest producer of milk, productivity per animal is very poor. At the national level, it is only 987 kg $lactation^{-1}$ when compared to the world average of 2038 kg $lactation^{-1}$. The poor productivity per animal has been mainly attributed to inadequate availability and poor quality of fodder.

In India, Kerala State has the highest percentage of cross bred animals with higher genetic potential for milk production. But the average yield of cow day^{-1} is only 7.508 kg milk and the total milk productions do not meet the requirement of the state. A weak feed and fodder base is a major factor hindering the full expression of the increased genetic potential created in the state.

A serious drawback of sustainable livestock production system in Kerala is the inadequate seasonal distribution of fodder production. The quantity and quality of herbage available in the lean dry months from January to May is very low. Therefore it is imperative to develop a fodder production system that increases the availability and improves the quality of herbage in the dry summer months.

Intensive fodder production system based on grasses is increasingly becoming important to the dairy farmers of Kerala. Dry matter yield of the grass is generally low due to poor soil fertilization regimes and erratic rainfall. The fodder is productive during the wet season and the nutritive value is generally low and does not meet the animal requirements throughout the year. It contains low to moderate crude protein (CP) content (6-12 %) during the wet season, but declines to less than 5 % during the dry period. Below a critical level of 6-8 % CP in cattle diet, digestibility and voluntary intake of forages are likely to be reduced (Humphreys, 1991). The major challenge is to overcome the inadequate quantity and quality of these cultivated fodders. Use of fertilizers to improve yield and commercial concentrates as livestock supplements to enhance nutritive value is limited due to inability of farmers to purchase them.

Inclusion of fodder legumes in the fodder production system is the most efficient way to increase herbage production and quality (Mwangi et al., 2005) and the most economic feed supplement than the commercial concentrates (Njarui *et al.*, 2004). Legume in fodder grass production system would not only provide a nitrogen source to promote grass growth but enhance the quality of feed. Legumes benefit grasses by contributing Nitrogen is contributed to the soil through atmospheric fixation, decay of dead root nodules or mineralization of shed leaves. The inclusion of a legume in Napier grass based diet has shown to improve animal performance in terms of milk production because of their high nutrient contents (Muinga *et al.*, 1992). Thus combining grasses with legumes capable of improving protein content of the overall ration clearly has nutritional and financial potential.

Fodder cowpea (*Vigna unguiculata* L. Walp) is a legume inherently more tolerant to drought than other fodder legumes (Fatokun *et al.*, 2009) and considered as a crop capable of improving sustainability of livestock production through its contribution in improving seasonal fodder productivity and nutritive value. It has shade tolerance, quick growth and rapid ground covering ability. Summer cowpea irrigated according to a schedule based on IW/CPE ratio of 0.8 recorded the maximum dry matter production (Subramaniam *et al.*, 1993) and plant height (Kher *et al.*, 1994). Fodder cowpea varieties CO-5, COFC- 8, UPC - 618, UPC-622, Bundel Lobia-1 are high yielding and suitable for cultivation in Kerala (Rajasree 1994; Lakshmi *et al.*, 2007; Gayathri, 2010). It is the most widely cultivated fodder legume in areas where rainfall is scanty and soils are relatively infertile. Most households that keep livestock raise fodder cowpea as an intercrop with other crops and fodder cowpea forms an integral component of crop livestock farming system (Singh and Tarawali, 2011).

Development of compatible persistent grass legume mixtures could alleviate acute seasonal livestock feed deficiency in dry seasons. The major problem in grass fodder cowpea mixtures is the low legume plant density and shading of cowpea by grasses. To overcome this problem, cropping systems using optimum cowpea densities and different crop combinations are to be standardized. Perennial fodder grasses like hybrid napier and guinea grass are widely accepted by the dairy farmers all over Kerala as these grasses are well adapted to tropical conditions with potential for higher yields per unit area and shade tolerance. Grass legume mixtures yielded as much or more drymatter than grasses alone and showed better seasonal distribution of forage production than grasses alone and were superior to grasses in forage quality during summer (Posler *et al.*, 1993).

The dairy homesteads of Kerala are mostly experiencing light stress of varying intensities. Poor adaptation of many improved fodder crops/ varieties in shade environment limits fodder production in homesteads and shade affects persistence, yield and quality of understory forages. Evaporative demand is greatly reduced in the shaded environment and soil water availability for the pasture will be maintained at a higher level than in open through the combined effect of less evaporation from soil and lower transpiration rates of the pasture. *V. unguiculata* grows well in shade and is useful as a component crop of silvipastoral systems (Bazil, 2011). Keeping this in view, the present study was taken up with the following objectives.

1. To identify drought tolerant varieties of fodder cowpea suitable for the dry summer months.
2. To evaluate the performance of fodder cowpea in varying proportions of mixtures with hybrid napier and guinea grass which are the popular fodder grasses of Kerala, for improving the quantity, quality and economics of fodder production under open and shaded situations during the lean dry months.

Review of Literature

2. REVIEW OF LITERATURE

2.1. EFFECT OF SOIL MOISTURE STRESS LEVELS ON THE PERFORMANCE OF FODDER CROPS

2.1.1. Effect of Soil Moisture Stress Levels on Growth Characters

2.1.1.1. Plant Height

Reduction in plant height was observed in coastal bermuda grass (*Cynodon dactylon* (L.)) and kleingrass "75" (*Panicum coloratum* L.) in water stressed conditions (Bade *et al.*, 1985). Nair (1989) recorded maximum plant height with irrigation at IW/CPE ratio of 0.5 in Stylosanthes. Fening *et al.* (2009) recorded a decrease in the plant height in three fodder legumes such as *Lablab purpureus*, *Stylosanthes guianensis* and *Centrosema pubescens* with increase in water stress levels. Purbajanti *et al.* (2012) also recorded a decrease in plant height in guinea grass and napier grass under water stress conditions. Haffani *et al.* (2013) conducted an experiment to find out the effects of water stress (100% FC, 80% FC, 60% FC and 40% FC) on the growth of three forage legume species namely *Vicia narbonensis, Vicia sativa* and *Vicia villosa* and reported that plant height decreased with increase in irrigation stress levels.

2.1.1.2. Number of Branches per Plant

Gosse *et al.* (1982) and Hall (1993) reported that the stressed plants presented smaller stems than not stressed plants in *Medicago sativa*. According to Brown and Taner (1983), when leaves expansion was reduced by water deficit, elongation of all internodes was also reduced in *M. sativa*. The rate of tiller number was slower in water stressed ryegrass (Barker *et al.*, 1985). Reduction in number of tillers was observed in coastal bermuda grass (*C. dactylon* (L.)) and kleingrass "75" (*P. coloratum* L.) in water stressed conditions (Bade *et al.*, 1985). Nair (1989) recorded maximum number of branches in Stylosanthes at IW/CPE ratio of 0.75.

Gallegos and Shibata (1989) and Oussalem (1998) reported that the number of branches was significantly affected by water deficit in *Phaseolus vulgaris*. The number of internodes was too affected by water stress, which induced a slowing in the development of branches. Chebouti and Abdelguerfi (2004) reported that number of primary branches in *M. orbicularis, M. aculeata* and *M. truncatula* declined significantly under the influence of water deficiency. The reduction was 17.0% for *M. truncatula*, 16.4% for *M. orbicularis* and 31.4% for *M.aculeata*, compared with non-stressed treatments. Purbajanti *et al.* (2012) reported a reduction in tiller number in guinea grass and napier grass under water stressed conditions.

2.1.1.3. Leaf: Stem Ratio

Nair (1989) reported that irrigation treatment IW/CPE ratio of 1.00 recorded maximum leaf to stem ratio in Stylosanthes. In Lucerne and other legume species, water stress increased the leaf:stem ratio with the result of improved quality but drastically reduced yield (Dehabadi *et al.* 1994).

Hajibabae *et al.* (2012) recorded an increase in leaf to stem ratio with increase in water stress levels in 14 corn forage hybrids (*Zea mays* L.). Due to higher decrement of dry stem weight (46%) in comparison to leaf dry weight (28%) in the treatment of irrigation after 130 mm evaporation, leaf to stem ratio increased under stress conditions.

2.1.1.4. Root Growth

The morphological plasticity which resulted in a preferential development of the roots was often concomitant with the tolerance to water deficit stress (Slama *et al.,* 2008; Yousfi *et al.,* 2010). Bingchang *et al.* (2007) reported an increase in root/shoot ratio in three forage legumes such as *V. narbonensis, V. sativa* and *V. villosa* under water stress. Fening *et al.* (2009) reported that under water stress conditions there was decrease in root dry weight in lablab and Stylosanthes and the decrease was more in Stylosanthes. However, in Centrosema there was increase in the root dry weight under mild and moderate water stress and under severe water stress there was no significant difference in root dry weight in this species.

Achten *et al.* (2010) indicated in *Jatropha curcas* subjected to a severe water stress that the plant falls its leaves and accumulates more dry matter in roots. Boutraa (2010) reported that water stress significantly reduced root dry weight at 80 % FC more than that at 50 % and 30 % FC treatments. Hayatu and Mukhtar (2010) reported a variation of 3.7 % to 73.7 % in root biomass in seven fodder cowpea genotypes. He also reported a variation of 27.3 % to 26.3 % in root-shoot ratio in these genotypes.

Slama *et al.* (2011) compared the root:shoot ratio of eight *M. sativa* cultivars and reported that it increased significantly in all the cultivars subjected to water stress. Haffani *et al.* (2013) reported a decrease in root dry matter with increase in water stress levels in *V. narbonensis, V. sativa* and *V. villosa*. All these species exhibited an increased root-shoot ratio under water stressed conditions.

2.1.2. Effect of Soil Moisture Stress Levels on Yield

2.1.2.1. Green Fodder Yield

In an experiment conducted by Segui *et al.* (1984) in Cuba, the correlation between yield and irrigation was tested in 100 cultivars of guinea grass (*P. maximum*). The crop was grown under two moisture regimes *viz.*, irrigated and rainfed. No remarkable yield differences was found between irrigated and rainfed treatments. Nair (1989) reported that the irrigation at IW/CPE ratio of 0.75 gave the higher green fodder yield in Stylosanthes during the two years of study. Contrasting results were obtained by Khistaria *et al.* (1991) in fodder sorghum. Significantly higher fodder yields were obtained in irrigated treatments than the unirrigated control.

The study carried out by Peterson *et al.* 1992 in four perennial forage legumes *viz.*, alfalfa (*M. sativa*), birds foot trefoil (*Lotus comiculatus*), cicer milk vetch (*Astragalus cicer* L.) and red clover (*Trifolium pratense*) showed that the total yield of biomass was reduced by a maximum of 46% in birds foot trefoil and by a minimum of 25.4% in alfalfa under water stressed conditions.

Similarly the study carried out by Sheaffer *et al.* (1992) in four perennial forage grasses viz., reed canary grass (*Phalaris arundinaceae*), orchard grass (*Dactylis glomerata*), smooth brome grass (*Bromus inermis*) and timothy (*Phleum pratense*) showed that the total yield of biomass was reduced by a maximum of 49% in reed canary grass under water stress conditions. The smooth brome grass exhibited more tolerance to drought with a reduction of only 11.63 % in total biomass.

Srivastava and Bhatnagar (1995) noted that in Uttar Pradesh hills a single irrigation of 50mm during April-May boosted the yield of pastures by 45.32 %. The yield was improved by 101 % when the irrigation depth was 200mm. Chebouti and Abdelguerfi (2004) also reported a reduction in forage yield (leaves+stems) significantly in case of water shortage in three *M. sativa* cultivars. Hajibabaee *et al.* (2012) reported that highest yield was obtained in normal irrigation and the yield reduced as the water stress increased in 14 corn (*Z. mays* L.) forage hybrids. Purbajanti *et al.* (2012) reported that the green forage yield reduced significantly with increase in water stress levels in guinea grass and napier grass.

2.1.2.2. Dry Fodder Yield

Pitman *et al.* (1981) reported decrease in dry matter yield of Klein grass grown under comparable degrees of constant water stress. According to Bade *et al.* (1985), water stress reduced dry matter yields by 31 and 44 % in Bermuda grass (*C. dactylon* (L.)) and Klein grass "75" (*P. coloratum* L.) respectively. Irrigation @ 90 per cent field capacity was found to increase the dry matter yield of tropical pastures by 37 per cent (Herrera *et al.*, 1985). In *Setaria* *sphacelata,* highest annual dry matter yield was obtained when grown under irrigated conditions. Dry fodder yields were high at 50 mm CPE and 100 mm CPE irrigation levels (Muldoon, 1986). Nair (1989) reported that the irrigation level IW/CPE 0.75 gave the higher dry fodder yield during the two years of study.

Mansfield *et al.* (1990) also reported the enhancement of dry fodder yields by irrigation in perennial grasses. Irrigation during drier spring period increased the dry matter yield of perennial grasses by 109 per cent, but, irrigation during cool dry period had little effect on dry matter yield.

Fening *et al.* (2009) reported a decrease in shoot dry weight in three forage legumes *viz., C. pubescens, L. purpureus* and *S. guinansis* under water stressed conditions. Slama *et al.* (2011) compared the response patterns of eight cultivars of *M. sativa* to water stress and the results showed that the shoot dry matter of all cultivars decreased with increase in water stress levels. The water deficit reduced the accumulation of the dry matter in some forage legumes (Akmal *et al.,* 2011).

Hajibabaee *et al.* (2012) conducted an experiment to find out the effect of water stress on growth and yield of 14 corn (*Z. mays* L.) forage hybrids. The results showed that highest yield was obtained in normal irrigation and the yield reduced as the water stress increased. Haffani *et al.* (2013) reported a reduction in shoot dry matter in three forage legumes *viz., V. narbonensis, V. sativa* and *V. villosa* under water stressed conditions.

2.1.3. Effect of Soil Moisture Stress Levels on Physiological Characters

2.1.3.1. Leaf Area Index

Water stressed rye grass has smaller, thicker and shorter leaves, a slower rate of leaf expansion and slower leaf appearance (Jones *et al.,* 1980). Bade *et al.* (1985) reported a reduction in leaf area during water stress condition in coastal Bermuda grass (*C. dactylon* (L.)) and Klein grass "75" (*P. coloratum* L.).

Ritchie (1987) reported no difference of LAI between forages irrigated normally and forages under drought stress condition during growth season but the only difference in LAI between normal irrigation and drought condition were observed at the end of growing season in which plants under stress condition lost leaf area earlier. The main effect of water stress on *Medicago arborea* was the reduction of leaf area, which has a direct consequence in limitation of the water losses by stomatal and cuticular transpiration which was mentioned by Noitsakis *et al.* (1991) and Blum (2005).

The leaf area reduction is considered as a criterion of adaptation to the drought (Masinde *et al.,* 2006). The leaf area of three forage legume species namely, *V. narbonensis, V. sativa* and *V. villosa* reduced significantly with increase in water stress levels (Fening *et al.*, 2009). Boutraa (2010) reported that highest leaf area was recorded under the moderate water stress level (50 % FC) compared with that of control (80 % FC) and severe water stress level (30 % FC).

Hayatu and Mukhtar (2010) reported a reduction in leaf area of seven fodder cowpea genotypes when subjected to water stress situations. The decrease of the leaf area in the presence of the water deficit resulted in a reduction of the dry matter accumulation (Martinielli and De silva, 2011). According to Hajibabaee *et al.* (2012), leaf area index of 14 corn (*Z. mays* L.) forage hybrids decreased with increase in water stress levels.

2.1.3.2. Specific Leaf Area

Samson and Helmut (2007) reported that water deficit reduced significantly the total leaf area and total dry matter in fodder cowpea. According to Hayatu and Mukhtar (2010), the specific leaf area showed an increased response both under moderate and severe water stress situations in seven fodder cowpea genotypes.

2.1.3.3. Leaf Weight

Chebouti and Abdelguerfi (2004) reported that leaf weight reduced by 48.0 % in *Medicago orbicularis,* 55.7 % in *M. truncatula* and 60.1 % in

M. aculeate when subjected to water stress. Hajibabaee *et al.* (2012) reported that water stress caused a significance in leaf dry weight in 14 corn (*Z. mays* L.) forage hybrids.

2.1.3.4. Relative Water Content

It has been reported that water stress had no effects on RWC in tolerant *Phaseolus acutifolius*, while RWC decreased in sensitive *P. vulgaris* (Turken *et al.*, 2005). Several studies have reported the decrease of RWC under severe water deficit conditions in *M. sativa* cultivars (Mohsenzadeh *et al.*, 2006; Slama *et al.*, 2008; Nunes *et al.*, 2008; Yousfi *et al.*, 2010).

Contrary to severe water stress conditions, mild drought has no effects on RWC in *M. sativa* cultivars (Nunes *et al.*, 2008). In addition to the severity of stress, plant response to water deficit stress was variety-dependent. The analysis of the response of water stress on the RWC in the leaves of eight cultivars of *M. sativa* by Slama *et al.* (2011) showed that relative water content was 30 % to 40 % for plants under normal irrigation (100% FC) conditions whereas for plants under water stressed conditions (33 % FC), it was 10 % to 23 %.

2.1.3.5. Leaf Water Potential/Osmotic Potential

Leaf expansion in Harding grass (*Phalaris aquatica*) ceased at leaf water potential of -1.5MPa with no osmotic adjustment, but continued to -2.8MPa when turgor was maintained (Sambo, 1981). Decline in osmotic potential of more than 1 MPa during periods of drought occur in many cool season grasses (Sambo and Aston, 1985). Jaafari (1993) showed that the osmotic adjustment is a criterion of selection to characterize the tolerant varieties of plants to water deficit stress. This adaptive mechanism includes traits, which promote the maintenance of high tissue water content, as well as those for promoting tolerance to low water availability (Moinuddiu *et al.*, 2005; Cattivelli *et al.*, 2008; Chaves *et al.*, 2010).

Jefferson and Cutforth (2005) reported that alfalfa (*M. sativa*) and crested wheat grass (*Agropyron cristatum* L. Gaertn.) exhibited different responses to water stress. Crested wheat grass exhibited very low water potentials during midday water stress, which is indicative of tissue tolerance to low water potential and very low turgor. Alfalfa exhibited apparent osmotic adjustment to maintain leaf turgor during mid-day water stress. Slama *et al.* 2011 reported a decrease in leaf osmotic potential in all the cultivars of *M. sativa* when subjected to water deficit stress.

2.1.3.6. Stable Isotope Discrimination ($_{13c}$) Studies

Low available soil moisture produced tissues of low carbon isotope discrimination. Decreasing soil moisture during dry periods decreased leaf conductance and intercellular CO_2 levels, which in turn lowered carbon isotope discrimination (Farquhar and Richards, 1984; Johnson *et al.*, 1990).

Ebdon and Kopp (2004) reported that Carbon Isotope Discrimination (Δ) was not always reliable in assessing WUE, but the turf performance of Kentucky Blue grass under drought was correlated with Δ. Low Δ values were associated with less wilt and leaf firing, suggesting that Δ may be a useful selection criterion for superior performance under limiting soil moisture.

Sima *et al.* (2011) reported that the variation of the isotope compostion for $_{13\ c}$ are higher in C_3 than in C_4 plants. They analysed that the $_{13c}$ values were typical values for C_3 species and ranged between -24.2% (*Festuca pratensis*) and -29.4% (*Lolium corniculatus*).

According to Ray and Townsend (2013), carbon isotope discrimination was positively correlated with forage yield and forage maturity among the nine alfalfa cultivars under water stress conditions.

2.1.3.7. Water Use Efficiency

In a field study with *P. maximum*, *C. ciliaris* and *C. dactylon*, *C. nlemfuensis*, water consumption during dry season was found to be increasing with irrigation. The water use of grasses were maximum from the 0-40 cm layer of soil (Herrera *et al.*, 1985). A summary report of alfalfa water use efficiency from eight locations in the USA indicated that it produced 15.2 ± 2.10 kg $ha^{-1}mm^{-1}$ (Sheaffer *et al.*, 1988). Highest WUE for the lower IW/CPE ratio of 0.5 was reported in Stylosanthes by Nair (1989). In California, irrigated alfalfa WUE was reported to be 23.2 kg $ha^{-1}mm^{-1}$ (Grimes *et al.*, 1992).

Sasani *et al.* (2002) reported that WUE increased with higher levels of water stress in forage pearl millet. Jefferson and Cutforth (2005) reported that dryland alfalfa had 30% higher water use efficiency than crested wheat grass (*A. cristatum* L. Gaertn.). A significant difference between the fodder cowpea genotypes for WUE under water stress was reported by Ahmed and Suliman (2010).

Hayatu and Mukhtar (2010) reported that fodder cowpea genotypes showed a varied response in water use efficiency under water stress conditions and it varied from 8 % to 135.3 %. In a study conducted by Purbajanti *et al.* (2012), water use of guinea grass and napier grass reduced with increase in moisture stress levels. However, the percentage reduction was less in napier grass compared to that of guinea grass. Volesky and Berger (2012) reported that warm-season annual grasses such as foxtail (*Setaria italica*) and pearl millet (*Pennisetum glaucum*), sudan grass (*Sorghum bicolor*) and sorghum-sudan grass hybrids are the most water use efficient plants used for forage. Forage legume *M. lupulina* showed a higher WUE than *T. repens* under strong drought stress (Kuchenmeister, 2013).

2.1.4. Effect of Soil Moisture Stress Levels on Biochemical Aspects

2.1.4.1. Chlorophyll Content

Sanchez *et al.* (1983) reported that water stress reduced cholorophyll levels, stomatal conductance and photosynthesis in two forage maize genotypes.Water stress entailed a decrease of the quantity of chlorophyll in leaves of two perennial forage grasses such as *Poa pratensis* L. and *F. arundinaceae*, Schrab (Fu and Huang, 2001). Tayeb (2006) reported a reduced total chlorophyll content in leaves of two *V. faba* cultivars under water stress conditions. Drought stress imposed during vegetative growth significantly decreased chlorophyll a, chlorophyll b and total chlorophyll content in three forage chickpea cultivars (Mafakheri *et al.,* 2010). According to Hayatu and Mukhtar (2010), the total chlorophyll content of seven fodder cowpea genotypes decreased as the water stress increased. The decrease in chlorophyll content under drought stress has been considered a typical symptoms of pigment photooxidation and chlorophyll degradation (Anjum *et al.,* 2011). Chlorophyll is one of the major chloroplast components for photosynthesis (Rahdari *et al.,* 2012).

Haffani *et al.* (2013) compared the total chlorophyll content of three forage legumes namely *V. narbonensis*, *V. sativia* and *V. villosa* under three irrigation levels. The results showed that in all the three species, the chlorophyll content decreased significantly with increase in water stress levels. Hajibabaee *et al.* (2012) reported a reduction in leaf chlorophyll content with increase in water stress levels in 14 corn (*Z. mays* L.) forage hybrids. Jalalpoori (2013) reported that drought stress reduced the total chlorophyll content of alfalfa (vs. Nick Urban).

2.1.4.2. Proline Content

Accumulation of proline has been advocated as a parameter of selection for stress tolerance (Yancy *et al.,* 1982; Jaleel *et al.,* 2007). Bokhari and Trent (1985) reported that droughted tall fescue (*F. arundinaceae*) and western wheat grass had higher concentrations of proline than non-stressed plants. In maize primary root, the proline level increased as much as a hundred fold under a low water potential (Voetberg and Sharp, 1991). Frank (1994) found that proline concentration was higher at the highest water deficit (50% rainfall) in crested wheat grass (*A. cristatum* L. Gaertn). The free proline level also increased from 4 to 40 times in pea in response to water deficit stress (Franciso *et al.,* 1998).

It has been observed that there is higher proline content in drought tolerant forage sorghum as well as in *Phaseolus species* than in sensitive ones (Turken *et* *al.*, 2005). Proline accumulation is believed to play adaptive roles in plant stress tolerance (Verbruggen and Hermans, 2008). Mafakheri *et al.* (2010) reported an increase in proline content during drought stress in three varieties of fodder chickpea. Slama *et al.* (2011) reported a large variability in proline concentrations in eight cultivars of *M. sativa* during drought. It varied from 41.67 % to 823 % under water stress conditions. Rouched *et al.* (2013) studied the response patterns during water deficit stress of two forage species, *M. truncatula* and *Sulla carnosa.* Enzymatic assay revealed that in the two species, P5CS (delta-1-pyrroline-5 carboxylate synthase) activity was stimulated whereas that of PDH (Proline dehydrogenase) was inhibited under stress conditions.

2.1.5. Effect of Soil Moisture Stress Levels on Quality Aspects

2.1.5.1. Crude Protein Content

Higher protein content of 14.07% for higher IW/CPE ratio of 1.00 was reported in stylosanthes by Nair (1989). The study carried out by Peterson *et al.* (1992) in the four perennial forage legumes *viz.*, alfalfa (*M. sativa*), birds foot trefoil (*L. corniculatus*), cicer milk vetch (*Astragalus cicer* L.) and red clover (*T. pratense*) showed that drought had no consistent effect on the crude protein (CP) content in the forages. The results showed that during drought conditions the forages accumulated more CP in stem (8.3 % to 19.4 % increase) than in leaves whereas, the CP content in leaves reduced by 4.9 % to 15.10 %.

Similarly, the study carried out by Sheaffer *et al.* (1992) in four perennial forage grasses *viz.*, reed canary grass (*P. arundinaceae*), orchard grass (*D. glomerata*), smooth brome grass (*B. inermis*) and timothy (*P. pratense*) showed that there was increase in the concentration of CP in stems than in leaves under drought conditions and the increase was between 29.2 % to 58.5 %.

Barnett and Naylor (1996) found no significant differences in the amino acid and protein metabolism of two varieties of Bermuda grass during water stress and reported that amino acids were continually synthesized during the water stress treatments but protein synthesis was inhibited and protein content reduced. Sasani *et al.* (2002) reported that irrigation intervals (weekly irrigation interval, 11-day irrigation interval and 15-day irrigation interval) had significant effects on total protein and digestible crude protein in forage pearl millet. Crude protein values ranged from 225 g kg^{-1} DM for birdsfoot trefoil (*L. corniculatus*) to 274 g kg^{-1} DM for yellow alfalfa with no drought stress, and from 212 g kg^{-1} DM for birds foot trefoil to 278 g kg^{-1} DM for yellow alfalfa under water shortage (Kuchenmeister, 2013).

2.1.5.2. Crude Fibre Content

Neutral detergent fibre concentration in forages is the trait that seems to be most consistently affected by drought. The study carried out by Peterson *et al.* (1992) in the four perennial forage legumes *viz.*, alfalfa (*M. sativa*), birds foot trefoil (*L. comiculatus*), cicer milk vetch (*A. cicer* L.) and red clover (*T. pratense*) showed that the total neutral detergent fibre content in all the four species reduced under drought condition, the reduction being 7.8 % to 10.6 %.

Similarly the study carried out by Sheaffer *et al.* (1992) in four perennial forage grasses namely reed canary grass (*P. arundinaceae*), orchard grass (*D. glomerata*), smooth brome grass (*B.inermis*) and timothy (*P. pratense*) showed that total neutral detergent fibre content in all the four species decreased under drought condition and the decrease was between 5.4 % to 7.8 %.

The reduction of NDF and ADF concentration under strong stress supports the findings of Peterson *et al.* (1992) and Buxton (1996) that a delayed maturity under drought is associated with lower NDF and ADF concentrations.

Drought effects on NDF (including cellulose, hemicellulose and lignin) were stronger than for ADF (including cellulose and lignin) which was explained by the fact that the hemicellulose concentration, as a part of NDF, is more affected by drought than cellulose and lignin. The cell walls of monocots and dicots differ in their composition. The lignification of cell walls in dicots is stronger, but the concentration of hemicellulose is smaller (Buxton and Mertens, 1995; Ebringerova *et al.* 2005) resulting in higher NDF of grasses than of legumes (Buxton, 1996). A lower fibre concentration may lead to a higher herbage intake and to increase in digestibility of forage (Buxton, 1996). Sasani *et al.* (2002) reported that irrigation volume had significant effects on acid detergent fibre in forage pearl millet.

However, results on the effects of drought on hemicellulose concentrations are inconsistent in the literature; some authors have reported decreased hemicellulose concentrations under drought (Jiang *et al.,* 2012), while others reported increases (Hakimi, 2006). The ADF concentration in forage legumes such as birds foot trefoil (*L. comiculatus*), yellow alfalfa (*M. falcata* L.), sainfoin (*O. viciifolia*) and white clover (*T. repens*) is approximately 100 g kg^{-1} lower than that of NDF, while this difference is usually about 200 g kg^{-1} for forage grasses such as perennial ryegrass (Kuchenmeister, 2013).

2.1.6. Effect of Soil Moisture Stress Levels on Nutrient Content

2.1.6.1. Nitrogen Content

Many workers have reported different effects of water stress on nutrient concentrations of different plant species and genotypes.

Perterson *et al.* (1992) reported that nitrogen content in birds foot trefoil (*L. comiculatus*) and cicer milk-vetch (*A. cicer* L.) increased under water stress, whereas there was only meager increase in nitrogen content in alfalfa and red clover.

The study carried out by Sheaffer *et al.* (1992) in four perennial forage grasses *viz.*, reed canary grass (*P. arundinaceae*), orchard grass (*D. glomerata*), smooth brome grass (*B. inermis*) and timothy (*P. pratense*) showed that there was increase in the nitrogen content in stems than in leaves under drought conditions.

The high concentration of N in plants subjected to water stress is due to the fast accumulation of free amino acids that are not converted into proteins (Barnet and Naylor, 1996).

Viets (1972) generalized the opinion that moisture stress induces a definite increase in the N level in all grasses.

2.1.6.2. Phosphorus Content

A reduction in the quantity of phosphate in solution caused an equivalent reduction in the response of rye grass (*L. perenne* L.) to applied phosphate (Mouat and Nes, 1985). Watering the surface to field capacity twice a week led to a 50% reduction in phosphorus uptake by subterranean clover (*T. subterreneum* L.) compared with daily watering (Simpson and Pinkerton, 1989). There was an increase in the concentration of P in alfalfa (*M. sativa* L.) with decreasing moisture supply (Kidambi *et al.*, 1990). Veits (1999) generalized the opinion that moisture stress induces a definite decrease in the P level in all grasses.

The mean P content of *L. purpureus*, *S. guianensis* and *C. pubescens* decreased with decreasing soil moisture content and recorded 0.23% and 0.52% for 25% FC and 100% FC respectively (Fening *et al.,* 2009). Mild water stress situations had no effect on the accumulation of P in the root cells or in the xylem sap. However, the absorption of $H_2PO_4^-$ was severely inhibited when water stress was increased (Seyed *et al.,* 2012). Translocation of P to the shoots was severely restricted even at a relatively low water stress condition (Akinci and Losel, 2012).

2.1.6.3. Potassium Content

Viets (1972) generalized the opinion that moisture stress induced a definite reduction in level in all grasses. The plant content of K increased as moisture stress increased with the K content of *Stylosanthes*, *Lablab* and *Centrosema* increasing by 39, 30 and 26 % respectively for a moisture range from 100 to 25 % FC (Fening *et al.,* 2009). Decrease in potassium concentration was reported in many plant species due to membrane damage and disruption in ion homeostasis. Potassium deficient plant has lower resistance to water stress (Seyed *et al.,* 2012).

2.1.6.4. Calcium and Magnesium Content

It has been noted that an increased water stress condition of a growth medium not only depressed the uptake and solubility of nutrient elements but also increased Ca/K and Ca/P ratio in herbage (Nuttall, 1976). There was an increase in the concentration of Ca and Mg both in alfalfa and sainfoin (*O. viciifolia* Scop.) with decreasing soil moisture supply (Kidambi *et al.,* 1990). In forage maize plants grown with inadequate water, accumulation of N, P, K, Ca and Mg were 50, 40, 71, 91 and 65% respectively, of those found in plants grown with adequate water. 50 % decrease in plant Ca^{2+} content was reported in drought stressed maize leaves, while in roots Ca^{2+} concentration was higher (Seyed *et al.,* 2012).

2.1.7. Effect of Soil Moisture Stress Levels on Soil N, P, K Status

Soil water has a two-fold role in the nutrition of pasture plants. In general, drying of the soil should increase the concentration of a nutrient in solution as a result of reduction of solution volume (Mouat and Nes, 1985). The decrease in PO_4- P availability with water deficit may be due to decreased diffusive flux of nutrients during water stress (Schaff and Skogley, 1982). Reduction in water content of a soil increased the concentration of ammonium and nitrate in solution, but had no effect on the concentration of phosphate (Mouat and Nes, 1985).

Availability of K also followed the same trend and decreased with increasing water stress. Increase in diffusive K flux in the soil and the increased efficiency of applied K with increased soil moisture are reported by Zong and Brown (2000).

Availability of soil nutrients decreased with water deficit. Among the nutrients, PO_4- P, NH_4- N, K, Ca, Cu and Fe showed decreasing trend with increase in water stress (Singh and Singh, 2004). Unlike N, which moves freely over large distances in the soil solution, P and K can only move at most a few short millimeters in the soil solution, which causes these nutrients to become positionally unavailable to the crop when the soil dries up (Fernandez, 2012).

2.2. EFFECT OF VARIETIES ON THE PERFOMANCE OF FODDER CROPS

2.2.1. Effect of Varieties on Growth Characters

2.2.1.1. Plant Height

Significant differences for plant height of 18 cultivars of cowpea grown for forage were reported by Pal (1988). Genetic variability and correlation in cowpea was studied by Sharma *et al.* (1988) and the maximum genotypic coefficient of variation among 35 genotypes was seen for plant height. Jindal (1989) studied path coefficient analysis in fodder cowpea and reported that plant height was positively and significantly correlated among the varieties. High significant phenotypic and genotypic variances for plant height in fodder cowpea were reported by Roquib and Patnaik (1990). Siddique and Gupta (1991) worked out estimates of variability in cowpea and reported high genotypic and phenotypic coefficient of variation for plant height.

A considerable variation in plant height was reported by Radhika (2003) in 50 accessions of fodder cowpea. The results of an initial varietal trial on forage cowpea varieties showed that plant height of MFC-08-14, IL-1177, RR-3, IC-202762, Bundel Lobia-1 and UPC-5286 were 127.1 cm, 136.4 cm, 129.4 cm, 122.1 cm, 126.7 cm and 122.8 cm respectively (AICRP, 2009). In an advanced varietal trial conducted with forage cowpea varieties, results showed that plant height of UPC-801, UPC-802, Bundel Lobia-1 and UPC-5286 were 141.6 cm, 139.7 cm, 141.3 cm and 149.5 cm, respectively (AICRP, 2009).

In an initial varietal trial conducted with forage cowpea varieties, results showed that plant height of MFC-09-2, EC-548872-1, UPC-1101, IPOK-1/52-1, UPC-1102, BL-1 and UPC-5286 were 139.9 cm, 142.9 cm, 150.3 cm, 126.1 cm, 139.8 cm, 145.0 cm and 148.6 cm, respectively (AICRP, 2012). In an advanced varietal trial conducted with forage cowpea varieties, results showed that plant height of RR-3, MFC-09-1, BL-1 and UPC-5286 were 153.3 cm, 148.8 cm, 156.4 cm and 152.6 cm, respectively (AICRP, 2012). Haffani *et al.* (2013) reported a significant differences in plant height among the species of vicia, *viz.*, *V. narbonensis, V. sativa* and *V. Villosa*. Shekara *et al.* (2012) reported that among the different fodder cowpea genotypes *viz.* MFC 08-14, IL-117, UPC-5286, Bundel Lobia-1 and UPC-9202 tested, MFC 08-14 recorded significantly higher plant height.

2.2.1.2. Number of Branches

Significant differences for number of branches of 18 cultivars of cowpea grown for forage were reported by Pal (1988). Jindal (1989) studied path coefficient analysis in fodder cowpea and reported that characters such as number of branches, stem weight etc were positively and significantly correlated among themselves. In ricebean, Baisakh (1992) reported wide variation in the means of different genotypes for branches per plant. Aravindhan and Das (1995) based on correlation and path analysis using 59 genotypes of fodder cowpea reported that fodder yield was significantly and positively correlated with number of branches per plant. Hazra *et al.* (1996) observed significant variation in the characters, number of primary branches per plant and days to flowering in fodder cowpea.

High estimates of variability were observed for number of branches by Borah and Fazlullahkhan (2000) in fodder cowpea. High estimates of variability were recorded for all the characters except number of primary branches per plant in fodder cowpea (Radhika, 2003). Shekara *et al.* (2012) reported that, among the different cowpea genotypes viz., MFC 08-14, IL-117, UPC-5286, Bundel lobia-1 and UPC-9202 tested, MFC 08-14 recorded significantly more number of branches.

2.2.1.3. Leaf: Stem Ratio

Genetic variability and correlation studies were conducted in fodder lablab by Ushakumari and Chandrasekharan (1991) and reported that significant correlation was observed with dry weight of leaf and stem. Aravindhan and Das (1995) based on correlation and path analysis using 59 genotypes of fodder cowpea reported that fodder yield was significantly and positively correlated with leaf:stem ratio. High estimates of variability were observed for dry weight of leaves and dry weight of stem by Borah and Fazlullahkhan (2000) in fodder cowpea. Considerable variation for leaf:stem ratio was reported by Radhika (2003) in 50 accessions of fodder cowpea. The leaf:stem ratio had an average of 0.76. The range was from 0.4 exhibited by the accession EC 240744 and IFC 24094 to 1.2 by IFC 95102.

In an initial varietal trial conducted with forage cowpea varieties, results showed that L: S ratio of MFC-08-14, IL-1177, RR-3, IC-202762, Bundel Lobia-1 and UPC-5286 were 0.75, 0.72, 0.77, 0.71, 0.66 and 0.81 respectively. Also, in an advanced varietal trial conducted with forage cowpea varieties, results showed that L: S ratio of UPC-801, UPC-802, Bundel Lobia-1 and UPC-5286 were 0.71, 0.65, 0.68 and 0.72, respectively (AICRP, 2009). In an initial varietal trial conducted with forage cowpea varieties, results showed that leaf:stem ratio of MFC-09-2, EC-548872-1, UPC-1101, IPOK-1/52-1, UPC-1102, BL-1 and UPC-5286 were 0.75, 0.72, 0.74, 0.76, 0.76, 0.80 and 0.80, respectively (AICRP, 2012).

In an advanced varietal trial conducted with forage cowpea varieties, results showed that the leaf:stem ratio of RR-3, MFC-09-01, BL-1 and UPC-5286 were 0.74, 0.78, 0.71 and 0.83, respectively (AICRP, 2012). Shekara *et al.* (2012) reported that, among the different cowpea genotypes *viz.*, MFC 08-14, IL-117, UPC-5286, Bundel Lobia-1 and UPC-9202 tested, UPC-9202 recorded significantly more L:S ratio.

2.2.1.4. Root Growth

Hayatu and Mukhatar (2010) reported a varied response of seven cowpea genotypes in total root biomass. The variation ranged between 3.7 % to 73.7 % among the genotypes. The root shoot ratio also showed a varied response and it ranged from a minimum of 27.3 % in IT00835-45 genotype to a maximum of 263 % in IT96D-610 genotype. Haffani *et al.* (2013) reported significant variation in root dry matter and root shoot ratio among *V. narbonensis, V. sativa and V. villosa.*

2.2.2. Effect of Varieties on Yield

2.2.2.1. Green Fodder Yield

Variability studies in 50 diverse genotypes of cowpea conducted by Kumar and Mishra (1981) revealed that for green forage yield, environmental coefficient of variation exceeded genotypic variances. Genetic variability and correlation in cowpea was studied by Sharma *et al.* (1988) and the maximum genotypic coefficient of variation among 35 genotypes was seen for green forage yield. Jindal (1989) studied path coefficient analysis in fodder cowpea and reported that green fodder yield was positively and significantly correlated among themselves.

Considerable variation for green fodder yield was reported by Thaware *et al.* (1992) in 30 varieties of fodder cowpea. Aravindhan and Das (1995) observed a considerable variation in 59 genotypes of fodder cowpea regarding the green fodder yield.

High estimates of variation were observed for green fodder yield by Borah and Fazlullahkhan (2000) in fodder cowpea. Based on the variability studies in fodder cowpea, Manonmani *et al.* (2000) reported that green fodder yield recorded the highest variability. Considerable variations for green fodder yield was reported by Radhika (2003) in 50 accessions of fodder cowpea. The shoot biomass of seven cowpea genotypes ranged from 9.8 % to 50.7 % (Hayatu and Mukhtar, 2010).

In an initial varietal trial conducted with forage cowpea varieties showed that green forage yield of MFC-08-14, IL-1177, RR-3, IC-202762, Bundel Lobia-1, UPC-5286 and UPC-9202 were 177 q ha^{-1}, 189.3 q ha^{-1}, 159.1 q ha^{-1},165.0 q ha^{-1}, 174.6 q ha^{-1}, 174.9 q ha^{-1} and 171.7 q ha^{-1}, respectively (AICRP, 2009). In an advanced varietal trial conducted with forage cowpea varieties, results showed that green forage yield of UPC-801, UPC-802, Bundel Lobia-1 and UPC-5286 were 291.4 q ha^{-1}, 286.8 q ha^{-1}, 293.7 q ha^{-1} and 298.8 q ha^{-1}, respectively (AICRP, 2009).

In an initial varietal trial conducted with forage cowpea varieties, results showed that green forage yield of MFC-09-02, EC-548872-1, UPC-1101, IPOK-1/52-1, UPC-1102, BL-1 and UPC-5286 were 244.3 q ha^{-1}, 218.1 q ha^{-1}, 232.2 q ha^{-1}, 207.1 q ha^{-1}, 241.7 q ha^{-1}, 215.7q ha^{-1} and 251.3 q ha^{-1}, respectively (AICRP, 2012). In an advanced varietal trial conducted with forage cowpea varieties, results showed that green forage yield of RR-3, MFC-09-1, BL-1 and UPC-5286 were 269.8 q ha^{-1}, 304 q ha^{-1}, 247.9 q ha^{-1} and 288 q ha^{-1}, respectively (AICRP, 2012). Shekara *et al.* (2012) reported that, among the different cowpea genotypes viz., MFC-08-14, IL-117, UPC-5286, Bundel Lobia-1 and UPC-9202 tested, MFC 08-14 recorded significantly higher green forage yield.

2.2.2.2. Dry Fodder Yield

Variability studies in 50 diverse genotypes of cowpea conducted by Kumar and Mishra (1981) revealed that dry matter yield environmental coefficient of variation exceeded genotypic variances. Genetic variability and correlation in cowpea was studied by Sharma *et al.* (1988) and the maximum genotypic coefficient of variation among 35 genotypes was uses for dry matter yield. Aravindhan and Das (1995) based on correlation and path analysis using 59 genotypes of fodder cowpea reported that fodder yield was significantly and positively correlated with dry matter yield.

High estimates of variability were observed for dry fodder yield by Borah and Fazlullahkhan (2000) in fodder cowpea. Considerable variations for dry fodder yield was reported by Radhika (2003) in 50 accessions of fodder cowpea. In an initial varietal trial conducted with forage cowpea varieties showed that dry matter yield of MFC-08-14, IL-1177, RR-3, IL-202762, Bundel Lobia-1, UPC-5286 and UPC-9202 were 38.2 q ha^{-1}, 35.8 q ha^{-1}, 31.9 q ha^{-1}, 35.2 q ha^{-1}, 35.0 q ha^{-1}, 33.2 q ha^{-1} and 35.8 q ha^{-1}, respectively (AICRP, 2009). In an advanced varietal trial conducted with forage cowpea varieties, results showed that dry matter yield of UPC-801, UPC-802 Bundel Lobia-1 and UPC-5286 were 47.6 q ha^{-1}, 47.5 q ha^{-1}, 45.6 q ha^{-1} and 48.8 q ha^{-1} (AICRP, 2009).

In an initial varietal trial conducted with forage cowpea varieties results showed that dry forage yield of MFC-09-2, EC-548872-1, UPC-1101, IPOK-1/52-1, UPC-1102, BL-1 and UPC-5286 were 38.3 q ha^{-1}, 36.3 q ha^{-1}, 39.1 q ha^{-1}, 35.2 q ha^{-1}, 39.3 q ha^{-1}, 35.7 q ha^{-1} and 38.6 q ha^{-1}, respectively. Also, in an advanced varietal trial conducted with forage cowpea varieties, results showed that dry forage yield of RR-3, MFC-09-1, BL-1 and UPC-5286 were 50.2 q ha^{-1}, 53.8 q ha^{-1}, 46.7 q ha^{-1} and 52.2 q ha^{-1}, respectively (AICRP, 2012). Haffani *et al.* (2013) reported a varied response on shoot dry matter in three species of vicia namely *V. narbonensis, V. sativa* and *V. villosa.* Shekara *et al.* (2012) reported that, among the different cowpea genotypes *viz.*, MFC 08-14, IL-117, UPC-5286, Bundel Lobia-1 and UPC-9202 tested, MFC 08-14 recorded significantly higher dry fodder yield.

2.2.3. Effect of Varieties on Physiological Characters

Significant differences for leaf number and dry matter production of 18 cultivars of cowpea grown for forage were reported by Pal (1988). Significant phenotypic and genotypic variations for leaf area in fodder cowpea were reported by Roquib and Patnaik (1990). Aravindhan and Das (1995) based on correlation and path analysis using 59 genotypes of fodder cowpea reported that fodder yield was significantly and positively correlated with leaf area index and specific leaf yield. Backiyarani and Natarajan (1996) studied the variability on ten yield related characters in thirty four genotypes of fodder cowpea and observed high variability for leaf area index.

Rajasree and Pillai (2001) reported the fodder cowpea variety C-152 recorded higher LAI compared to other cowpea varieties, CO-5 and Karnataka local. Considerable variations for leaf area, leaf area index and leaf dry weight was reported by Radhika (2003) in 50 accessions of fodder cowpea. Hayatu and Mukhtar (2010) studied physiological responses of seven fodder cowpea genotypes and reported a significant variation in specific leaf area and water use efficiency among all the genotypes. A significant difference in leaf area among three vetch species namely *V. narbonensis*, *V. sativa* and *V. villosa* was reported by Haffani *et al.* (2013).

2.2.4. Effect of Varieties on Biochemical Aspects

Hayatu and Mukhtar (2009) studied the total chlorophyll content in seven cowpea genotypes and reported that the genotype IT 98K-205-8 recorded a higher chlorophyll content of 52.93 and a lower chlorophyll content was recorded by the genotype IT 98K-555-1.

The results of the analysis of chlorophyll content in three forage vetch species namely *V. narbonensis, V. sativa* and *V. villosa* revealed that chlorophyll content varied significantly among the species (Haffani *et al.*, 2013). Slama *et al.* (2011) reported a considerable variation in proline accumulation under different water stress treatments among eight *M. sativa* cultivars.

2.2.5. Effect of Varieties on Quality Aspects

2.2.5.1. Crude Protein Content

Aravindhan and Das (1995) based on correlation and path analysis using 59 genotypes of fodder cowpea reported that fodder yield was significantly and positively correlated with crude protein content. Correlation for fodder yield in cowpea was done by Srinivasan and Das (1996) and suggested that a desirable plant type for higher forage would be more number of larger leaves with high protein content. Considerable variation for protein content was reported by Radhika (2003) in 50 accessions of fodder cowpea

In an initial varietal trial conducted with forage cowpea varieties, results showed that crude protein yield of MFC-08-14, IL-1177, RR-3, IC-202762, Bundel Lobia-1 and UPC-5286 were 6.8 q ha^{-1}, 8.0 q ha^{-1}, 7.2 q ha^{-1}, 6.4 q ha^{-1}, 7.5 q ha^{-1} and 6.9 q ha^{-1}, respectively and crude protein content were 15.4 %, 15.9 %, 15.8 %, 15.3 %, 15.3 % and 15.5 %, respectively. Also, in an advanced varietal trial conducted with forage cowpea varieties showed that crude protein yield of UPC-801, UPC-802, Bundel Lobia-1 and UPC-5286 were 8.1 q ha^{-1}, 8.1 q ha^{-1}, 7.9 q ha^{-1} and 8.3 q ha^{-1}, respectively and crude protein content were 15.5 %, 15.5 %, 15.4 % and 15.8 %, respectively (AICRP, 2009).

In an initial varietal trial conducted with forage cowpea varieties, results showed that crude protein yield of MFC-09-2, EC-548872-1, UPC-1101, IPOK-1/52-1, UPC-1102, BL-1 and UPC-5286 were 8.6 q ha^{-1}, 8.4 q ha^{-1}, 9.9 q ha^{-1}, 6.6 q ha^{-1}, 9.4 q ha^{-1}, 7.0 q ha^{-1} and 9.2 q ha^{-1}, respectively and the crude protein content were 15.9 %, 15.9 %, 15.8 %, 15.9 %, 15.4 %, 16.1 % and 16.2 %, respectively (AICRP, 2012).

Advanced varietal trial conducted with forage cowpea varieties showed that crude protein yield of UPC-801, UPC-802, Bundel Lobia-1 and UPC-5286 were 8.1 q ha^{-1}, 8.1 q ha^{-1}, 7.9 q ha^{-1} and 8.3 q ha^{-1} respectively and crude protein content were 15.5 %, 15.5 %, 15.4 % and 15.8 %, respectively (AICRP, 2012). A field experiment was conducted to study the response of fodder cowpea genotypes (MFC 08-14, IL-117, UPC-5286, Bundel Lobia-1 and UPC-9202) and revealed that the genotype MFC 08-14 recorded a higher crude protein yield of 6.41q ha^{-1}compared to other genotypes (Shekara *et al.*, 2012).

2.2.5.2. Crude Fibre Content

Considerable variation for crude fibre content was reported by Radhika (2003) in 50 accessions of fodder cowpea. In an advanced varietal trial conducted with forage cowpea varieties, results showed that Acid Detergent Fibre of UPC-801, UPC-802, Bundel Lobia-1 and UPC-5286 were 49.3 %, 49.6 %, 51.2 % and 46.4 %, respectively and the Neutral Detergent Fibre were 56 %, 56.8 % 56.7 % and 54.7 %, respectively (AICRP, 2009).

In an initial varietal trial conducted with forage cowpea varieties, results showed that ADF of MFC-09-2, EC-548872-1, UPC-1101, IPOK-1/52-1, UPC-1102, BL-1 and UPC-5286 were 37.0 %, 40.8 %, 38.0 %, 41.7 %, 40.2 %, 39.2 % and 38.3 %, respectively and NDF were 55 %, 54.3 %, 53.2 %, 53.5 %, 53.3 %, 56.1 % and 53.8 %, respectively. Also, in an advanced varietal trial conducted with forage cowpea varieties, results showed that NDF of RR-3, MFC-09-1, BL-1 and UPC-5286 were 54.4 %, 54.6 %, 53.8 % and 54.8 % and the ADF were 45.6 %, 44.9 %, 44.0 % and 44.8 %, respectively (AICRP, 2012).

2.2.6. Effect of Varieties on N, P, K, Ca and Mg Content

Considerable variation for nutrient composition was reported by Thaware *et al.* (1992) in 30 varieties of fodder cowpea. Radhika (2003) reported considerable variation in N content in 50 accessions of fodder cowpea.

2.3. EFFECT OF SHADE ON THE PERFORMANCE OF FODDER CROPS

2.3.1. Effect of Shade on Growth Characters

2.3.1.1. Plant Height

Pillai (1986) recorded more height in guinea grass (*P. maximum*) and setaria grass (*S. sphacelata*) when grown under coconut shade than those grown in open area. East and Felker (1993) reported that under mature mesquite trees (shade), the height of four perennial grasses such as green panic (*P. maximum*), plains bristle grass (*S. leucophila*), canada wildrye (*E. Canadensis* L.) and virginia wildrye (*E. virginicus* L.) increased when compared with open canopies. Raymundo (1997) also reported an increase in plant height with increase in shade levels in six grasses and six legumes. Guinea grass (*P. maximum*) was taller in the shade, than in the full sunlight (Paez *et al.*, 1997) due to photosynthetic limitation.

In general, internode length increased for plants grown in shade compared to plants grown in full sun (Blanche, 1999). According to Buxton (2001) stem length is often greater for forages adapted to shade. Height of guinea grass varieties recorded significant increase as shade intensity increased (Anita, 2002). Baruch and Guenni (2007) reported an increase in plant height in three forage species viz., *Brachiaria brizantha*, *Brachiaria decumbens* and *Brachiaria dicyoneura* when grown under shade.

2.3.1.2. Number of Branches

There was reduction in tiller production in guinea grass (*P. maximum*) and setaria grass (*S. sphacelata*) when grown under coconut shade (Pillai, 1987). In a study by Wong (1993) with two tropical grasses, *Paspalum malacophyllum* and *Paspalum wettsteinii* under 20 per cent, 50 per cent and 100 per cent light transmission, the dominating influence of shade on inhibition of tiller production was obvious in both species. Total tiller number declined with shading, being the lowest in 20 per cent light transmission in both species. According to Kephart and Buxton (1996) shading often reduces tillering of forages. Shading often reduces tillering of forages and slows the growth rate of forages (Buxton, 2001).

Reduction in number of tillers was reported in six grasses and six legumes (Raymundo, 1997), perennial rye grass (Gautier *et al.*, 1999), guinea grass (Paez, 1997 and Anita, 2002), *B. brizantha*, *B. decumbens* and *B. dicyoneura* (Baruch and Guenni, 2007). Thirty seven per cent reduction and 63 % reduction in tiller number was recorded at 57 % and 29 % light transmission respectively in *B. brizantha* compared to that of 100 % light transmission (Guenni *et al.*, 2008).

Shading reduces tillering in three *Brachiaria* sp. viz., *B. decumbens, B. brizantha* and *B. dicyoneura* (Baruch and Guenni, 2007; Zootec, 2012).

2.3.1.3. Leaf: Stem Ratio

There are contradictory reports on the influence of shade on leaf stem ratio of forages. Mullakoya (1982) reported that shade levels had no significant effect on leaf/stem ratio of guinea grass (*P. maximum*) while Wong *et al.* (1985) reported increase in specific leaf area and leaf/stem ratios, particularly in shade tolerant species due to shading. Shading increased leaf/stem ratio of guinea grass (*P. maximum*) and Setaria grass *(S. sphacelata*) when grown under coconut shade (Pillai, 1986). Wilson *et al.* (1990) found an increase in the proportion of green leaf of a *Paspalum notatum* pasture under trees compared with that in the open pasture. Shading increases leaf:stem ratios particularly in shade tolerant species compared to plants grown in full sun (Wong, 1991).

Leaf:stem ratio was reduced significantly with increasing shade levels in guinea grass varieties (Anita, 2002). One way of having higher LA1 is by more biomass allocation to leaves. Both components of forage yield were equally affected by shade, so the leaf:stem ratio was not altered. Baruch and Guenni (2007) reported these results in Brachiaria species, including *B .decumbens.* Barro *et al.* (2012) reported that shading never affected mean leaf to stem ratio within pasture species *viz.*, *P. notatum, P. dilatum, P. regnelli* and *A. pinotoi.* Gomez et al. (2013) reported an increase in leaf:stem ratio with increase in shade levels in *B. decumbens* and a maximum L:S ratio of 1.6 was recorded at 30 % of irradiance.

2.3.1.4. Root Growth

Wong *et al.* (1985) reported reductions of root yield and increased shoot/root ratio, in shade-tolerant species. In *L. perenne* grass, due to shading, less photosynthate is made available for root growth (Gregory *et al.*, 1987). Wong (1991) reported reduction in leaf, stem, stubble and root production at low light in two shade tolerant grasses *viz., P. malacophyllum* and *P. wettsteinii.* He also reported that shading decreases root/shoot ratio in shade tolerant species. Shoot:root ratio was higher for tall fescue (*F. arundinacea* Schreb.) grown at low irradiance than for those grown at high irradiance (Allard *et al.*, 1991).

In spotted knap weed (*Centaurea maculosa* Lam.) the foliage, root and crown growth increased significantly under full, rather than half-light (Kennett *et al.*, 1992). Grasses in general respond to shade by increasing their leaf-area and shoot-to-root ratio to increase their surface area, while decreasing leaf blade thickness and shoot dry weight (Kephart *et al.*, 1992). Exposure to prolonged periods of shade causes most forages to modify proportioning of biomass among plant parts so that the potential for photosynthetic active radiation interception is maintained or increased and root growth is decreased (Kephart and Buxton, 1996). George (1996) reported a root volume of 44cm^3 and root/shoot ratio of 0.38 for guinea grass var. Hamil under coconut shade. Root-to-shoot ratio was higher in deep shade than in partial shade and full sun in *P. maximum* (Paez *et al.*, 1997).

Jacob (1999) reported that root length of congosignal (*B. ruziziensis*) was 30.56 cm and root weight was 35.36 g plant^{-1} when grown under coconut shade. Reduced light is associated with greater allocation of assimilates for leaf tissue development than roots as a mechanism of adaptation under shade (Cruz, 1997; Dias-Filho, 2000). Lowest levels of shade recorded significantly higher root volume of guinea grass varieties, whereas root shoot ratio was not influenced by shade levels (Anita, 2002). Guenni *et al.* (2008) reported that shoot : root ratio increased with increase in shade levels in three *Brachiaria* species *viz.*, *B. brizantha, B. decumbens* and *B. dictyoneura.*

2.3.2. Effect of Shade on Yield

2.3.2.1. Green Fodder Yield

Some grasses and legumes are more shade tolerant than others. When light transmission values fall below 40 or 50 per cent then production is severely reduced. In general herbage production and therefore carrying capacity is inversely proportional to light transmission values (Wong, 1991). Many sun species yielded well initially in shade habitat but did not persist under regular cutting or grazing (Kaligis and Sumolong, 1991). Bai *et al.* (1993) obtained a green fodder yield of 108 t ha^{-1} for guinea grass (*P. maximum*) and 100 t ha^{-1} for congosignal grass (*B. ruziziensis*) when grown in coconut gardens.

Kephat *et al.* (1992) and Kephart and Buxton (1993) found that imposing 63 per cent shade on perennial forage grasses like reed canary grass (*P. arundinacea*), orchard grass (*D. glomerata*), timothy grass (*P. pratense*), and smooth brome grass (*B. inermis*) reduced yield by 43 per cent. Productivity was found to be increasing with fertilizer application under shaded condition. *P. maximum* exhibited high water use efficiency and biomass accumulation in shaded condition (Kinyanario *et al.*, 1995). In general, yield of forages is linearly related to the amount of light available, provided that other factors affecting growth are not limiting. And in a coconut plantation with 50 per cent light transmission, the yield of *P. maximum* will be approximately 50 per cent of the yield achieved in full sunlight (Reynolds, 1995). Kephart and Buxton (1996) revealed that growth rates and herbage yield of forages decrease with increasing shade.

Many workers (Sharma *et al.*, 1996) have also reported yield reduction in forages in an agroforestry due to reduction in solar radiation availability. George (1996) recorded a green fodder yield of 58 t ha^{-1} for guinea grass (*P. maximum*) grown in coconut garden. The mean green forage production in alfalfa and orchard grass decreased significantly with increase in shade intensity (Varella et al., 2001).

Total green fodder yield in guinea grass varieties *viz.*, Hamil and Haritha was highest in open (100.31 t ha^{-1}) followed by 25 per cent shade (95.46 t ha^{-1}) and 50 per cent shade (67.21 t ha^{-1}) (Anita, 2002). Ladyman *et al.* (2003) recorded a drastic reduction in green fodder yield in forage legumes such as creeping alfalfa, alfalfa, Birds foot trefoil 'Norcen', Rhizomatous Birds foot trefoil, Alsike clover, Korean lespedeza and Crimson clover with decrease in irradiance. The fresh weight of stems and shoots reduced significantly with increase in shade levels in three *Brachiaria* sp. *viz., B. brizantha, B. decumbens* and *B. dictyoneura* in all the harvests (Guenni *et al.*, 2008).

The green fodder yield of forage species *viz., P. regnelliii, P. dilatatum, P. notatum* and *A. pintoi* reduced significantly under 0 %, 50 % and 30 % shade levels in two evaluation cycles (Barro *et al.*, 2012). The fresh biomass yield of *C. gayana* was found to be highest in the sunlight (859.0g) and lowest (48.70 g) under the shade (Aderinola *et al.*, 2012). Mimenza *et al.* (2013) also recorded a significant reduction in green forage yield in *B. brizantha* when grown underneath the crown of six tree species. *A. gayanus* cv. planattina and *P. maximum* cv. tanzania were higher in shaded environments rather than those in full sun (Oliveira *et al.*, 2013). Mishra *et al.* (2010) reported that the total biomass production in C. *ciliaris* in terms of fresh weight decreased under the tree canopies.

2.3.2.2. Dry Fodder Yield

Wilson *et al.* (1990) found 35 per cent increase in accumulated dry matter of *P. notatum* pasture under trees compared with that in the open pasture. When grown at 100 %, 40 % and 10 % sunlight, the dry matter yield of signal grass and guinea grass decreased significantly (Chen *et al.*, 1991). A study undertaken by Wong (1993) involving two tropical grasses *P. malacophyllum* and *P. wettsteinii* showed that shade depressed total dry matter production, proportional to the quantum of photosynthetic active radiation reduction. Perennial grasses such as green panic (*P. maximum*), plains bristle grass (*S. leucophila*), canada wildrye (*E. Canadensis* L.) and Virginia wildrye (*E. virginicus* L.) reduced under mature mesquite trees (shade) compared to outside canopies (open) in all the harvests (East and Felker, 1993).

Wilson (1996) reported a decrease in dry weight yield of tops in green panic, buffel, rhodes and spear grass when grown under shade. The mean dry matter production rate in alfalfa and orchard grass decreased significantly with increase in shade intensity (Varella et al., 2001). Ladyman *et al.* (2003) recorded a drastic reduction in dry matter production in forage legumes such as Creeping alfalfa (*M. sativa*), Alfalfa (*M. sativa),* Birds foot trefoil 'Noreen' (*Lotus corniculatus* L.), Rhizomatoms Birds foot trefoil (*Lotus corniculatus*), Alsike clover (*Trifolium hybridum*), Korean lespedeza (*Kummerowia stipulacea*) and Crimson clover (*Trifolium incarnatum*) with decrease in irradiance. The dry weight of stems and shoots reduced significantly with increase in shade levels in three *Brachiaria* sp. *viz.*, *B. brizantha*, *B. decumbens* and *B. dictyoneura* in all the harvests (Guenni *et al.*, 2008).

Cumulative forage dry matter yields of perennial ryegrass (*L. perenne* L.) and orchard grass (*D. glomerata* L.) averaged 2.14 and 1.27 t acre^{-1} under the younger and mature stands of Douglas-fir trees respectively, compared to the control (no trees) of 4.15 t acre^{-1} (Angima *et al.*, 2010). There is a positive association between photosynthetically active radiation and dry matter production in some forage grasses such as Brachiaria grass (*B. decumbens*), Marandu grass (*B. brizantha* cv. Marandu), Xaraes grass (*B. brizantha* cv. Xaraes), Mombaca grass (*P. maximum* cv.Tanzania) and Tifton 85 grass (*Cynodon sp.*cv. Tifton 85) (Silva *et al.*, 2012). The dry matter yield of forage species *viz.*, *P. regnellii, P. dilatatum, P. notatum* and *A. pintoi* reduced significantly under 0 %, 50 % and 80 % shade levels in two evaluation cycles (Barro *et al.*, 2012). The highest dry matter yield was observed when *C. gayana* was grown in the sunlight compared to the grass under the shade (Aderinola *et al.*, 2012). According to Kyriazopoulos (2012), the dry matter production of *D. glomerata* was not affected by shading, while that of *T. subterraneum* was drastically reduced.

The dry matter yield of the two forage grasses, *A. gayanus* cv. planaltina and *P. maximum* cv.tanzania was higher in shaded environment rather than those in full sun (Oliveria *et al.*, 2013). Mishra *et al.* (2010) reported that the total biomass production in *C. ciliaris* in terms of dry weight decreased under the tree canopies. On average of two years, *C. ciliaris* had produced 38 % reduction in dry matter yield under the tree canopies over the open grown grasses. Mimenza *et al.* (2013) also recorded a significant reduction in dry fodder yield of *B. brizantha* when grown underneath the tree crown of six tree species.

2.3.3. Effect of Shade on Physiological Characters

2.3.3.1. Leaf Area Index

Wilson *et al.* (1990) found an increase in the proportion of green leaf of a *P. notatum* pasture under trees compared with that in the open pasture. True shade tolerance in forage species is associated with a number of morphological and physiological adaptations of plants. These include higher leaf area ratios and specific leaf areas which in turn influence the efficiency of interception and use of radiation and therefore growth potential at low levels of radiation (Stur, 1991). Newly developed leaf blades of tall fescue (*F. arundinacea* Schreb.) had 56 or 77 % more leaf area at low irradiance than at full sunlight (Allard *et al.*, 1991).

The amount of carbohydrates that a plant can produce in a given time is dependent on the amount of sun's energy it can capture and convert to tissue. A plant maximizes radiation absorption by accumulating leaves (Ramus, 1995). Kephart and Buxton (1996) reported that shaded forage leaves are longer and thinner with higher water content than when grown in full sunlight. George (1996) reported a LAI of 5.2 for guinea grass (*P. maximum*) grown under coconut shade. The increase in LA is attributed to maximize light interception and changes in physiological processes to enhance the efficiency of carbon utilization (Evans and Seeman, 1996). Lin *et al.* (1999) reported that leaves of grasses grown at 50 % shade had a blade area that was 13 to 126 % larger than leaves grown in full sun. As the shade level increased to 80 % the blade area of most grasses was 19 to 220% greater than for plants grown under full sun.

Anita (2002) reported a significant influence of shade levels on LAI of guinea grass in all harvests. The LAI was found to be significantly higher at zero per cent shade level followed by 25 % and 50 % shade levels in first, second and fifth cuts is, an increase in shade resulted in an increase in LA. But in third and fourth cuts, significantly higher LAI was recorded at 25 per cent shade level. One way of having higher LAI is by more biomass allocation to leaves under shade. Baruch and Guenni (2007) reported similar results in three *Brachiaria* species, including *B. decumbens*. Guenni *et al.* (2008) reported a reduction in leaf area/plant in three *Brachiaria* sp *viz.*, *B. brizantha, B. decumbens* and *B. dictyoneura* at the end of regrowth period of 41 days with increase in shade levels. A maximum photosynthetic photon flux density was recorded (PPF=0.8) at LAI=3.4 in *B. decumbens* (Gomez et al., 2013).

2.3.3.2. Specific Leaf Area

Increased SLA under shade is a generalized response of grasses (including *B. brinzantha* and *B. decumbens*) (Wong *et al.*, 1985; Wilson *et al.*, 1990; Kephart *et al.*, 1992; Deinum *et al.*, 1996; Cruz, 1996; Cruz *et al.*, 1999; Dias Filho, 2000). Shade increased specific leaf area in the forage grasses such as buffalo grass (*Stenotaphrum secundatum*), mat grass (*Axenopus compressus*) and kikiyu grass (*Pennisetum clandestinum*) (Samarakoon *et al.*, 1990). At low irradiance, the leaves of tall fescue (*F. arundinacea* scrub) had 56 per cent or 77 % more leaf area (Allard *et al.,* 1991). This response has been attributed to the development of relatively large and their leaves due to decreased numbers of mesophyll cells per unit area increased internal air space and/or reduced cell size (Kephart *et al.*, 1992). Poez *et al.* (1994) reported that shaded leaves had a greater SLA than leaves produced in full sun in a forage grass, *P. maximum.* At decreasing light intensity, the leaves of *P. maximum* became wider and thinner having an average SLA of 353 cm^2 g^{-1} at 12 % PFD compared with 204 cm^2 g^{-1} when unshaded (Durr and Rangel, 2000).

Baruch and Guenni (2007) reported that decreased irradiance increased specific leaf area (SLA) in *B. brizantha, B. decumbens* and *B. dictyoneura*, but this was significant only in *B. brizantha, B. dictyoneura* had the lowest SLA readings. Guenni *et al.* (2008) reported an increase in specific leaf area in *B. brizantha, B. decumbens* and *B. dictyoneura* with increase in shade intensity. In *B. decumbens,* an increase of SLA (*ie*, 39-46 %) was observed with decreasing light intensity (Gomez et al., 2013). Here, leaf biomass reduction under decreasing light intensity was compensated by approximately 45 % increase in SLA.

2.3.3.3. Leaf Weight

A decrease in leaf weight in tall fescue due to shading was computed by Allard *et al.* (1991). Among 30 forage cultivars, only selected species have their leaf dry weight decreased when grown in shade compared to those grown in full sun (Lin *et al.,* 2001). Akhter *et al.* (2009) found that leaf weight was lower in shaded genotypes than in normal genotypes of garden pea (*Pisum sativum* L.). The maximum leaf weight was obtained from 100 % PAR level, which was closer with 75 % PAR level.

2.3.4. Effect of Shade on Biochemical aspects

2.3.4.1. Chlorophyll Content

Lower chlorophyll a/b ratios are typical of shade ecotypes and may enable more efficient absorption of light under shaded conditions due to the difference in the absorption spectra of chlorophyll a and b and the variance in light quality in the understorey (Young and Smith, 1980). Mullakoya (1982) reported that chlorophyll content increased with increase in shade intensity and the highest value was obtained at 75 per cent shade level in guinea grass (*P. maximum*) var. Mackuenii. Liu *et al.* (1984) suggested high chlorophyll a+b and low a/b ratio as a selection parameter for efficient photosynthesis at low light. Shade leaf chloroplasts (10 and 25 per cent of full sun) were larger and rich in thylakoids while sun leaf chloroplasts (50 and 100 per cent of full sun) showed poorly stacked grana. The increase in chlorophyll content under shaded conditions is an adaptive mechanism commonly observed in plants to maintain the photosynthetic efficiency (Attridge, 1990).

True shade tolerance in forage species is associated with higher chlorophyll densities (Stur, 1991). George (1996) recorded a chlorophyll content of 2.5 mg g^{-1} in guinea grass (*P. maximum*) grown under coconut shade. According to Evans and Seemann (1996) shade leaves have high chlorophyll per chloroplast. Chlorophyll content increased significantly with increase in shade levels in two guinea grass varieties *viz.*, Hamil and Haritha and the maximum chlorophyll content in all harvests was recorded at 50 % shade level (Anita, 2002).

Baruch and Guenni (2007) reported that chlorophyll content increased with increase in shade levels in three *Brachiaria* sp *viz.*, *B. brizantha*, *B. decumbens* and *B. dictyoneura* in all the harvests. The chlorophyll content and total chlorophyll of calopo (*Calopogonium muconoides*) increased under shade (Fanindi *et al.*, 2010). The two forage grasses, *A. gayanus* cv. 'planattina' and *P. maximum* cv. 'tanzania' recorded increase in the chlorophyll a content, but no change in chlorophyll b content under shade. The positive adaptation of cultivars in the shaded environments becomes promising in systems of integration of pastures with trees (Oliveira *et al.,* 2013).

2.3.5. Effect of Shade on Quality Aspects

2.3.5.1. Crude Protein Content

An increase in crude protein content was recorded with increasing levels of shade in guinea grass var. Mackuenii (Mullakoya, 1982). Crude protein content was more in guinea grass (*P. maximum*) grown under 45 per cent shade than that grown under open (Pillai, 1986). East and Felker (1993) reported an increase in crude protein content in four perennial grasses such as green panic (*P. maximum*), plains bristle grass (*S. leucophila*), canada wildrye (*E. Canadensis* L.) and virginia wild rye (*E. Canadensis* L.) when grown under mature mesquite trees (shade) compared to outside canopies (open). Kephart and Buxton (1993) found that crude protein content is much more responsive to shading than other quality characteristics of fodder. They found that 63 per cent shade increased crude protein concentration by 26 per cent in forage grasses like red canary grass, orchard grass, timothy and smooth brome grass. Crude protein concentration is usually greater in leaves and stem segments from the top of plant canopies than from the bottom. This has been attributed to shading within the plant canopy, which enhances senescence rates of bottom plant parts (Buxton and Fales, 1994).

George (1996) recorded a crude protein content of 8.8 per cent in guinea grass (*P. maximum*) grown under partially shaded condition. The crude protein concentration of orchard grass (*D. glomerata* L.) increased significantly with increase in shade levels whereas alfalfa showed a varied response (Varella et al., 2001). Forages grown under shaded conditions usually has higher crude protein concentrations than unshaded forages (Buxton, 2001). Crude protein content of guinea grass varieties *viz*., Hamila and Haritha enhanced with increase in shade levels (Anita, 2002).

The crude protein content and crude protein yield of forage grasses such as *P. regnelli, P. dilatatum* and *P. notatum* increased significantly with increase in shade levels whereas *A. pintoi* showed a reduction in crude protein content (Barro *et al*., 2012). In *C. gayana*, grown under shade the highest crude protein was in leaf (11.12 %) and least in stem (7.89 %) (Aderinola *et al*., 2012). Zootec (2012) reported that photosynthetically active radiation affects the crude protein content of grass like Brachiaria grass (*B. decumbens*), Maranda grass (*B. brizantha*cv. Marandu), Xaraes grass (*B. brizantha* cv.Xaraes), Mombaca grass (*P. maximum* cv. Tanzania) and Tifton 85 grass (*Cynodon sp.* cv. Tifton 85). Mimenza *et al.* (2013) reported an increase in crude protein content in *B. brizantha* when grown underneath tree crown of six tree species compared to that of open.

2.3.5.2. Crude Fibre Content

George (1996) recorded a crude fibre content of 31.9 percent for guinea grass (*P. maximum*) grown under partially shaded situation. Anita (2002) reported that crude fibre content reduced significantly with increased shade levels in guinea grass varieties Hamil and Haritha. Ladyman *et al.* (2003) reported an increase in the amount of neutral detergent fibre (NDF) and acid detergent fibre (ADF) content in seven forage legumes as light intensity decreased. Four natural grass species, *Axonopus compressus, Imperata cylindrica, C. dactylon* and *Pennisetum polystachyon* had highest acid detergent fibre (ADF) at 28 % light transmission and lowest acid detergent fibre at 64 % light transmission (Senanayake, 2005).

The average values of NDF and IVDMD (Invitro Dry matter digestibility) were 71.0 % and 54.8 % in the rainy season and 71.5 % and 51.3 % in the dry season, respectively in *B. decumbens* in silvipastoral system (Paciullo *et al.*, 2011). Shading increased the crude protein and acid detergent lignin content, but did not affect the acid detergent fibre and neutral detergent fibre content in *D. glomerata* and *T. subterraneum* (Kyriazopoulos *et al.*, 2012). The fibre fractions composition of *C. gayana* under sunlight and shade of both leaf and stem were studied by Aderinola *et al.* (2012) and reported that the percentage compositions of ADF and NDF in the stem were observed to be higher under shade and under sunlight than that of leaf.

Zootec (2012) reported that photosynthetically active radiation indirectly affected the neutral detergent fibre of Brachiaria grass (*B. decumbens*), Maranda grass (*B. brizantha* cv. Marandu), Xaraes grass (*B. brizantha* cv.Xaraes), Mombaca grass (*P. maximum* cv. Tanzania) and Tifton 85 grass (*Cynodon sp.* cv. Tifton 85). Mimenza *et al.* (2013) revealed that the neutral detergent fibre (NDF) content of *B. brizantha* reduced underneath the tree crown of six tree species compared to the open condition.

2.3.6. Effect of Shade on Nutrient Content

2.3.6.1. Nitrogen Content

George (1996) recorded a nitrogen uptake of 139 kg $ha^{-1}year^{-1}$ in guinea grass (*P. maximum*) under partially shaded situation. Jacob (1999) recorded a nitrogen uptake of 34.5 kg ha^{-1} in congosignal grass (*B. ruzizensis*) when grown under coconut shade. Cruz (1997) found that shade had no effect on the C and N influxes into the whole plant of *Dichanthium aristatum*, showing that the N absorption is regulated by the C assimilation. However, C and principally N, were preferentially allocated to the laminar under reduced irradiance. Under 100 % and 56 % of full sunlight, more N was allocated to the stubble component. Nitrogen content of six forage grasses increased with increasing levels of shade while legumes were generally not affected (Raymundo, 1997). Varella et al. (2001) reported a decrease in nitrogen production rate in alfalfa and orchard grass with increase in shade levels.

Addison (2003) conducted shade tolerance studies in 35 legume species and found that the highest concentrations of N were found in leaf produced under the 76 % and 84 % shade treatments, with a decline in plants grown under full sun. Baruch and Guenni (2007) reported an increase in leaf nitrogen concentration in *B. brizantha* and *B. decumbens* at 70 % irradiance whereas in *B. dictyoneura* N content was more at 40 % irradiance. The leaf nitrogen concentration of *B. brizantha, B. decumbens* and *B. dictyoneura* increased with increase in shade intensity both with and without N fertilization (Guenni *et al.*, 2008). Pandey *et al.* (2011) reported that N concentration in three grasses such as, guinea grass (*P. maximum*), para grass (*Brachiaria mutica*) and hybrid napier increased as N fertilizer level increased under coconut shade.

At 50 % and 30 % light transmission, forage N concentration was higher under fertilized plots than unfertilized plots in *B. decumbens* (Gomez et al., 2013). Nitrogen nutrition index (NNI) for three forage species *viz.*, *P. regnellii*, *P.*

dilatatum, P. notatum was maximum at 80 % shade level whereas, in *A. pintoi* it was highest at 0 % shade level (Barro *et al.*, 2012).

2.3.6.2. Phosphorus Content

Cruz *et al.* (1993) showed that phosphorus uptake and conversion efficiency of solar radiation were twice as high in *D. aristatum* grown under tree shade. This was due to the better water status of the grass leaves under shade due to a reduction in the evaporative demand on the grass due to the presence of the trees.

George (1996) recorded a phosphorus uptake of 24.4 kg $ha^{-1}yr^{-1}$ in guinea grass (*P. maximum*) var. Hamil when grown under coconut shade. Jacob (1999) recorded a phosphorus uptake of 4.76 kg ha^{-1} in congosignal grass (*B. ruziziensis*) when grown under coconut shade. In an experiment with shade tolerance of several forage species, Addison (2003) reported an increase in leaf phosphorus with shading in *C. pubescens, Desmodium uncinatum, Flemingia congesta, Neonotonia wightii*, while other species *viz.*, *Calopogonium mucunoids, D. intortum* and *D. heterophyllum* were found to have the greatest concentrations of leaf P under full sunlight.

2.3.6.3. Potassium Content

The fodder potassium content increased with shade intensity and the maximum value was noted under 75 per cent shade level in guinea grass (*P. maximum*) (Mullakoya, 1982). Watson *et al.* (1984) has found that the potassium content in grass and legume species increased significantly under shade than in full sunlight. He also found that the potassium content in marshall rye grass (*L. multiflorum*) grown under shade increased as shade intensity increased. The potassium content was 1.6 per cent under full sunlight whereas the potassium content was 2.1 per cent and 2.7 per cent under 50 per cent and 75 per cent shade, respectively. Pillai (1986) found that under shaded conditions, the requirement of potassium was more in guinea grass (*P. maximum*) compared to open. But the uptake was more in open area than in coconut garden. Wilson *et al.* (1990) found an increase in the proportion of potassium content of *P. notatum* pasture under trees compared with that in the open pasture. The total content of potassium in the forages tended to increase from open grass land to tree understorey (Belsky, 1992).

According to Mullen and Shelton (1996), the potassium concentration of buffalo grass (*S. secundatum*) was 2.47 % at 34 % light transmission, whereas at full sun, it was reduced to 1.55 %. George (1996) reported that the potassium uptake was 131 kg ha^{-1} for guinea grass (*P. maximum*) grown under partially shaded conditions. Jacob (1999) recorded a potassium uptake of 28.4 kg ha^{-1} for congosignal grass (*B. ruziziensis*) when grown under coconut shade.

2.3.6.4. Calcium and Magnesium Content

Blair *et al.* (1983) found that leaves of three common palatable southern deer browses-flowering dog wood (*Comus florida*), yaupon (*Ilex vomitoria*), Japanese honey suckle (*Lonicera japonica*) grown under shade have higher calcium content throughout the year especially in deep shaded leaves, but showed little difference in content between moderated shade or full sunlight. Lewis *et al.* (1983) reported that calcium in warm season forages was doubled when planted under slash pines. Pillai (1986) reported that calcium levels in two forages (guinea grass and setaria grass) grown under coconut shade were higher than in open. The total content of calcium in the forages tended to increase from open grass land to tree understorey (Belsky, 1992).

According to Mullen and Shelton (1996) the calcium and magnesium concentration of buffalo grass (*S. secundatum*) was more at 34 % light transmission, whereas at full sun, it was decreased. Calcium concentration decreased with increasing tree planting density of loblolly pine in forages, while magnesium did not respond to density treatments (Burner and Brauer, 2003).

2.3.7. Effect of Shade on Soil N, P, K Status

George (1996) reported that the NPK content of the soil with forage grasses under partially shaded situation was found to be 193 %, 27 % and 64 % respectively compared to grass in open area. According to Wilson (1996), soil humidity levels dropped more slowly in shaded soil than in soil in full sunlight, which enhanced microbial activity in the leaf litter, leading to a greater mineralization and nitrogen availability in the soil, resulting in the greater pasture dry matter production (Paciullo *et al.*, 2007; Guenni *et al.*, 2008).

Jacob (1999) reported that available N P K content of the grass cropped soil under partially shaded condition was found to be 207 %, 51 % and 99 % respectively of that under open area. The rates of litter and soil organic matter mineralization and nutrient availability to plants may be greater under trees, due to higher litter inputs, higher soil moisture levels and lower soil and air temperature (Menezes *et al.*, 2002). Organic carbon concentration at 30 cm depth was 5.6 % greater, and total N was 8.5 % greater, exchangeable K (52 %), calcium (26 %), magnesium (43 %), sodium (23 %), electrical conductivity (24 %) and pH (0.13 units) (Addison, 2003).

2.4. EFFECT OF GRASS-LEGUME MIXTURES ON THE PERFORMANCE OF FODDER CROPS

2.4.1.Effect of Grass-Legume Mixtures on Growth Characters

2.4.1.1. Plant height

Marchiol *et al.* (1992) observed an increase in plant height of soybean when intercropped with maize. Paired row planting of BN hybrid with fodder cowpea as inter crop recorded maximum plant height of BN Hybrid and the inter crop cowpea. Mean height of the BN hybrid increased significantly in presence of legume fodder cowpea intercrop (Jayakumar, 1997).

Different seed ratio significantly influenced plant height in maize, which was suppressed with an increased percentage of legume seed in combination (Ibrahim *et al.,* 2006). The plant height results can be relatively supported by other authors (Hong *et al.*, 1987; Ibrahim et al., 2006). According to them highest plant height was obtained with maize and cowpea seed combination of 75:25 (214.40 cm). In a field study conducted to assess the effect of grass and legume intercropping on the biomass yield, the mixture of guinea grass with rice bean significantly increased the height of grass (Ullah *et al.*, 2007). Kumari *et al.* (2008) reported that hybrid napier interplanted with drumstick recorded significantly higher plant height throughout the crop period.

Bakhashwain (2010) reported that plant heights were significantly affected by growth of rhodes grass alfalfa fodder mixtures. When the ratio of alfalfa increases in the mixture, the plant height significantly decreases. This might be as a result of the growth formation of rhodes grass and for the effects of competition for light. The plant height results can be competition for light. In grass-legume mixtures, maximum plant height (823 cm) was obtained by Oats+Vetch mixture followed by barley + Vetch mixture (70.23 cm) and wheat + vetch (68.78 cm) (Nadeem *et al.*, 2010). Ojo *et al.* (2013) reported that the plant height of guinea grass was highest (163.07 cm) when intercropping *P. maximum* var. Ntchisi with *L. purpureus* but not significantly different from the sole (165.87 cm).

2.4.1.2. Number of Branches

Jayakumar (1997) observed significantly more number of tillers in BN hybrid intercropped with legume under paired row planting. He observed that planting under paired row system produced more number of branches in fodder cowpea. Orak *et al.* (1999) reported higher number of tillers/branches and seed per plant in barley + vetch mixture. Canan and Orak (2002) reported higher number of branches/tillers in oats + vetch mixture. The fodder legumes stylosanthes cv.seca and siratro planted in double rows had no significant advantage over single rows and did not benefit the tiller number of the fodder grasses such as napier grass and giant panicum (Njarui *et al.*, 2007). Of the tested mixture, shaftal with oats and berseem with barley at relatively higher seeding rates were profitable combinations in tiller number/branch number (Azam *et al.*, 2008). The number of tillers clump^{-1} was higher in sole crop and reduction in number of tillers was observed when hybrid napier was inter-planted with drumstick (Kumari *et al.*, 2008).

In grass-legume mixtures, consistently higher number of tillers/branches was recorded in barley + vetch mixture at all successive crop growth stages followed by oats + vetch and wheat + vetch (Nadeem *et al.*, 2010). Maximum number of branches was obtained from the ratio of 100:0 (alfalfa was sown alone). Increasing the ratio of alfalfa over rhodes grass increased the number of branches per plant (Bakhashwain, 2010).

2.4.1.3. Leaf: Stem Ratio

Leaf to stem ratio is a significant parameters of forages. Higher stem contribution reduced forage intake and hence adversely affected forage quality. Jayakumar (1997) reported that growing fodder cowpea and lablab bean along with BN hybrid had no significant effect on leaf:stem ratio of the grass in a BN hybrid-legume intercropping system. Pure crop of BN hybrid recorded highest L:S ratio.

Shaftal with oats and berseem with barley at relatively higher seeding rates were profitable combinations for higher leaf:stem ratio (Azam *et al.*, 2008). In mixtures, maximum leaf ratio was noted in oats + vetch (0.85) followed by barley + vetch (0.73) mixture. The higher leaf stem ratio of oats + vetch mixture was the result of greater leaf weight and area in oats crop (Nadeem *et al.*, 2010).

2.4.2. Effect of Grass–Legume Mixtures on Yield

2.4.2.1. Green Fodder Yield

Angadi and Gumaste (1989) reported that intercropping of seven legumes in maize gave total fresh fodder yields of 61.06 to 67.95 t ha^{-1} compared with 60.52 t ha-^{1} for maize in pure stands. But Shahapurkar and Patil (1989) indicated that the maize yields were not significantly affected by intercropping it with cowpea. Gill *et al.* (1990) observed that hybrid napier planted in paired rows with subabul (1:1 ratio) gave the highest total fresh fodder yields compared with yield in pure stands or other mixed stands. Gangwar and Sharma (1994) found that intercropping of blackgram in maize recorded maximum green forage yield. Mureithi *et al.* (1995) showed a beneficial effect to Napier grass when grown together with leucaena. They recorded increased yield of Napier grass when planted adjacent to leucaena hedge rows than sole Napier grass or Napier grass growing away from leucaena. This contradicts the results of Mwangi (1999) who found out that intercropping Desmodium depressed green fodder yield of Napier grass but overall total yield (grass+legume) was higher.

Jayakumar (1997) concluded that the paired row planting produced maximum tonnage of green fodder yield (41.35 t ha^{-1}) in a BN hybrid-legume intercropping system. Green fodder yield increased to the tune of 7.814 t ha^{-1} due to fodder cowpea and lablab bean intercropping compared to pure crops. Choubey *et al.* (1997) reported that intercropping *B. brizantha* with *Vigna umbellata* gave the highest green fodder yield. Reddy and Naik (1999) revealed that hybrid napier intercropped with cowpea produced the highest mean green forage yield of 33.6 t ha^{-1}. Among the annual fodder legumes, cowpea was found to be the best intercrop for hybrid napier with a green fodder yield of 136.94 t ha^{-1} (Lakshmi *et al.* 2002). Canan and Orak (2002) reported that the mixture of vetch (25 %) and oats (75 %) were more productive than pure stand of vetch. A reduction in green fodder yield was observed by Gopalan *et al.* (2003) when pearl millet-napier grass hybrid was intercropped with *D. virgatus.* Sengul (2003) reported that legume mixtures such as sainfoin (*O. sativa*), alfalfa (*M. sativa* L.) with grass species such as binary grass (*A. elongatum*), crested wheat grass (*A. cristatum*) and smooth brome grass (*B. inermis*) gave higher green forage yield than the single crop. The combination of *C. pubescens* with the grasses (*B. ruziziensis* and *C. nlemfuensis*) recorded higher green fodder yields compared with the combination with other legumes (*S. guianensis, A. histris*) (Olanite *et al.*, 2004).

Katoch and Marwah (2006) reported that hybrid napier intrcropped with soybean in the *kharif* season, and oats, peas and sarson (*Brassica campestris* var.

sarson) in the *rabi* season produced the highest green biomass of 87.64 t ha^{-1}. According to Njoka-Njiru *et al.* (2006), the napier grass/seca intercrop had the highest total green forage yield but not significantly higher than napier grass/siratro intercrop. The highest yield of green fodder (68.30 t ha^{-1}) was obtained by sowing maize and cowpea in a ratio of 75:25 (Ibrahim *et al.*, 2006). On the basis of combined green fodder production, napier grass intercropped with seca was most productive while napier intercropped with siratro and *Panicum* intercropped with either seca and siratro showed similarity in green fodder production (Njarui *et al.*, 2007).

Azam *et al.* (2008) reported that shaftal with oats and berseem with barley at relatively higher seeding rates were profitable combinations for round the year seasonal production. Nadeem *et al.* (2010) reported that the highest green fodder yield (37.97 t ha^{-1}) was obtained in oats + vetch mixture followed by barley + vetch (24.38 t ha^{-1}). Khogali *et al.* (2011) reported that intercropping fodder maize with lablab bean (*L. purpureus*) reduced green fodder yield significantly in both seasons.

Albayrak *et al.* (2011) found significant differences in green fodder yield among the forage mixtures investigated. Sanifoin (*O. sativa* Lam) + bromegrass (*B. inermis* Leys) + crested wheat grass (*A. cristatum* L. Gaertn.) and sanifoin (*O. sativa* Lam.) + crested wheat grass (*A. cristatum* L. Gaertn.) mixtures gave the highest green fodder yield. Intercropping row ratio of cowpea (*V. unguiculata*) and *C. setigerus* in 2:1 resulted in significantly higher green fodder yield (13.02 and 14.08 t ha^{-1}) than other row ratios (1:1 and 1:2) (Meena and Mann, 2011). Green fodder yields of sorghum/maize cropping systems either sole sorghum or sorghum + cowpea in the ratio of 2:1 were equally good and significantly superior to rest of the systems (Surve *et al.*, 2012).

2.4.2.2. Dry Fodder Yield

In a trial conducted by Gill and Gangwar (1990) for the evaluation of intensive forage production system under guava plantation, pure crop of hybrid napier recorded maximum dry matter yield followed by hybrid napier + cowpea and guinea grass + cowpea. Intercropping *B. brizantha* with *V. umbellata* gave the highest dry matter yield (Choubey *et al.*, 1997). Dry fodder yield increased to the tune of 2.03 t ha^{-1} due to legume intercropping compared to pure crops in a BN hybrid legume intercropping system (Jayakumar, 1997).

Ezenwa and Akenora (1998) reported that Verano Stylo (*S. hamata*) mixtures with star grass (*C. nlemfuensis* var. nlemfuensis), guinea grass (*P. maximum*) and elephant grass (*P. purpureum*), yielded 13.8 t ha^{-1} $year^{-1}$ dry matter, and tropical kudzu (*Pueraria phaseoloides*) mixtures with guinea grass and elephant grass yielded 13.6 t ha^{-1} $year^{-1}$ dry matter. The mixture produced 22-154 % higher total dry matter yield than their respective sole grass. He also conducted that legume intercropping has favorable influence on dry matter production of grasses. Fodder cowpea was found to be the best intercrop for hybrid napier with a dry fodder yield of 50.10 t ha^{-1} (Lakshmi *et al.*, 2002).

In a field experiment conducted to determine the effect of intercropping perennial forage legumes like *S. hamata*, *C. pubescens* and *Glycine wighti* in pasture grasses *C. ciliaris*, *Chrysopogon fulvus* and *P. notatum* for sustainable fodder production, the fodder yield of the grasses was found to be increased by the legumes (Reddy *et al.,* 2004). In grass-legume mixture, among the legumes tried (*S. guianensis, A. histris, C. pubescens* and *Chamaecrista rotundifolia* the proportion of *C. pubescens* with the grasses (*B. ruzizizensis* and *C. nlemfuensis*) increased over the experimental period, so that, it had the highest yield (Olanite *et al.*, 2004).

Njoka-Njiru (2006) reported that the napier grass/seca intercrop had the highest total dry matter production but was not significantly higher than napier grass/siratro intercrop. The highest yield of dry matter (13.26 t ha^{-1}) was obtained by sowing fodder maize (*Z. mays* L.) and cowpea in a ratio of 75:25 (Ibrahim *et al.*, 2006). On the basis of combined dry matter production, napier grass/seca was more productive while napier intercropped with siratro and *Panicum* intercropped with either seca and sirato showed similarity in DM (Njarui *et al.,* 2007).

Shaftal (*Trifolium resupinatum* L.) with oats (*Avena sativa* L.) and berseem (*T. alexandrinum* L.) with barley (*Hordeum vulgare* L.) at relatively higher seeding rates were profitable combinations for higher dry fodder yield (Azam *et al.*, 2008).

Nadeem *et al.* (2010) found that in mixtures oats (*Avena sativa* L.) + vetch (*Vicia sativa* L.) ranked first in dry matter yields (9.28 t ha^{-1}) in all successive harvest followed by barley (*H. vulgare*) + vetch (*V. sativa* L.) (5.69 t ha^{-1}) and wheat (*Triticum aestivum*) + vetch (*V. sativa*) (5.22 t ha^{-1}). Albayrak *et al.* (2011) found significant differences in dry fodder yield among the forage mixtures investigated. Sainfoin (*O. sativa* Lam.) + brome grass (*B. inermis* Leys.) + crested wheat grass (*A. cristatum* L. Gaertn.) and sanifoin (*O. sativa* Lam.) + crested wheat grass (*A. cristatum* L. Gaertn.) mixtures gave the highest dry fodder yield (8.36 and 7.75 t ha^{-1}, respectively).

Intercropping row ratio of cowpea (*V. unguiculata*) and *C. setigerus* in 2:1 resulted in significantly higher dry fodder yield (3.25 and 3.44 t ha^{-1}) than other row ratios (1:1 and 1:2) (Meena and Mann, 2011). Dry fodder yields of sorghum/maize cropping systems either sole sorghum or sorghum + cowpea in the ratio of 2:1 were equally good and significantly superior to rest of the systems (Surve *et al.*, 2012). The highest total dry matter yields were obtained from the alfalfa (*M. sativa* L.) - smooth brome grass (*B. inermis* Leys.) mixture at 16.65 t ha^{-1} in 2009 and 16.00 t ha^{-1} in 2010 (Albayrak and Turk, 2013).

2.4.3. Effect of Grass–Legume Mixtures on Physiological Characters

2.4.3.1. Leaf Area Index

Lazaridou *et al.* (2012) reported that alfalfa - tall fescue mixture reduced significantly the LAI of alfalfa, which remained higher in tall fescue compared to alfalfa. According to Alalada *et al.* (2013), the increased biomass yield in *P.*

maximum when intercropped with *S. hamata* may be attributed to increase in leaf production, and increased rate of leaves extension which stimulated the greater light capture and hence photosynthesis and thus increased yield.

2.4.4. Effect of Grass–Legume Mixtures on Quality Aspects

2.4.4.1. Crude Protein Content

Crude protein, dry matter digestibility and NDF concentrations are used as measures of quality of fodder crops. Chelliah and Ernest (1994) concluded that growing sorghum and maize in mixture with cowpea and soybean in 1:1 and 2:1 row proportion produced more crude protein than their sole planting. In a hybrid napier-legume intercropping system maximum crude protein was obtained when the grass was grown under paired row system of planting. Legume intercropping resulted in maximum crude protein yield (Jayakumar, 1997). Tripathi *et al.* (1997) obtained higher content of crude protein when maize was intercropped with cowpea. Increase in crude protein content of napier grass associated with leguminous shrubs like calliandra and sesbania from 11.3 to 17.8 per cent was reported by Niang *et al.* (1998).

Reddy and Naik (1999) obtained a crude protein yield of 916.0 kg ha^{-1}, when hybrid napier was intercropped with cowpea. Papastylianou (1999) attributed this result to nitrogen transfer from legumes to the associated grass in mixture. Mapairwe *et al.* (2002) stated that intercropping fodder legumes with cereals generally resulted in higher crude protein than maize in pure stand. Enhancement in crude protein was observed by Gopalan *et al.* (2003) when pearl millet-Napier hybrid grass was intercropped with *D. virgatus*. Legume crude protein concentration in grass legume mixtures was higher than that in grasses (Olanite *et al.*, 2004). According to them *C. pubescens* in combination with *B. ruziziensis* contained the highest legume crude protein. For the grass components, *C. nlemfuensis* in combination with *A. histris* had the highest crude protein concentration for the first two grazing periods, but *B.ruziziensis* in combination with the same legume was highest for the dry season grazing in

December. Combining crude protein concentration with dry matter yield gave an estimate of the production of crude protein which was highest for the June grazing reflecting the high dry matter yield at that time.

Higher protein content was obtained in mixtures with forage sorghum (*Sorghum sp*) and Pearl millet (*Pennisetum glaucum*) intercropped with cowpea (*V. unguiculata*) and dolichos (*L. purpureus*) and generally there was lower protein production and content at matured stages (Boloko, 2004). Njoka-Njiru (2006) reported that napier grass (*P. purpureum*) intercropped with Siratro (*Macroptilium atropurpureum* cv.Siratro) and seca (*Stylosanthes Scabra* cv. Seca) had more crude protein (9.64-9.96 %) than sole Napier grass (8.14 %). The cowpea sown alone produced more crude protein (18.10 %) followed by 25:75 seed combination of cowpea - maize (15.9 %) and maize sown alone produced minimum crude protein (Ibrahim *et al.*, 2006).

Njoka-Njiru *et al.* (2006) observed that it was possible to produce high quality of livestock feed of higher nutritional quality by incorporating a legume in a fodder grass production system. The results indicated that there was a significant gain in crude protein content by inclusion of legumes like seca and siratro in napier grass thus improving the herbage value and digestibility.

Hybrid napier and its mixture with soybean had higher crude protein content, lower amounts of lignin and silica (Katoch and Marwah, 2006). Azam *et al.* (2008) reported that shaftal (*Trifolium resupinatum* L.) with oats (*A. sativa* L.) and berseem (*T. alexandrium* L.) with barley (*H. vulgare* L.) at relatively higher seeding rates increased the crude protein content. Adding rye grass (*L. multiflorum* Lam.) and alfalfa (*M. sativa* L.) could further improve both forage quality.

Intercropping fodder maize (*Z. mays*) with lablab bean (*L. purpureus*) significantly increased protein content and reduced crude fibre content, and then it increased nutritive value of maize + lablab mixture (Khogali *et al.*, 2011). According to Albayrak *et al.* (2011), binary and ternary mixtures of alfalfa (*M.

sativa L.) + grasses *viz*., brome grass (*B. inermis* Leys.), intermediate wheat grass (*A. intermedium* (Host). Beauv.), crested wheat grass (*A. cristatum* L. Gaertn.) had a higher crude protein content than sainfoin (*O. sativa* Lam.) + grasses mixtures. Crude protein content (12.07 and 12.33 %) was highest in case of 2:1 row ratio of cowpea and *C. setigerus* over other row ratios of 1:1 and 2:1 (Meena and Mann, 2011).

Ojo *et al.* (2013) reported that the crude protein (15.27 %) of the intercropped *P. maximum* var. Ntchisi and *L. purpureus* was the highest and the sole (6.87 %) was the least. According to Alalade *et al.* (2013), the crude protein was highest for the combination *P. maximum* intercropped with 3 rows of stylosanthes. The least value was obtained for sole *P. maximum* stand. Bakhashwain (2010) reported that crude protein content (%) of the dry fodder plants as an average of the two cuts revealed that the highest values were recorded from the 100 % alfalfa (17.17 %) and 75 % alfalfa + 25 % rhodes grass (16.94 %), while the lowest value was obtained from plants of 100 % rhodes grass (8.11 %).

2.4.4.2. Crude Fibre Content

Seresinhe and Pathirana (2000) reported a reduced NDF of guinea grass when intercropped with gliricidia. For the grass components, *C.nlemfuensis* in combination with *A. histris* had the lowest crude fibre oncentration (Olanite *et al.*, 2004). The level of fibre remained high but only the ADF content was significantly more in sole napier grass (*P. purpureum*)than napier grass grown with legumes, seca (*S. scabra* cv.Seca) and siratro (*M. atropurpureum* cv. Siratro) (Njoka-Njiru, 2006). Ibrahim *et al.* (2006) reported that maximum crude fibre (34.51 %) was recorded by sowing maize alone, which decreased to some extent with an increase of cowpea seed. Minimum crude fibre (32.73 %) was found in cowpea alone.

In grass/legume mixtures which involved grasses such as timothy grass (*P. pratense* L.), rye grass (*L. perenne* L.), meadow fescue (*F. pratensis* L.), kentucky blue grass (*P. pratensis* L.) and legumes such as red clover (*T. pratense* L.), alsike clover (*T. hybridum* L.), alfalfa (*M. sativa* L.), mixtures with red clover or alfalfa had the least neutral detergent fibre (NDF), averaging 418 and 429 g kg^{-1}, respectively. However, mixtures including white clover were initially low in NDF at 347 g kg^{-1} in first year but increased to 550 g kg^{-1} in third year as white clover composition declined in the sward (Kunelins *et al.,* 2006).

According to Bakhashawain (2010), crude fibre (%) was highest from 75 and 100 % Rhodes grass (17.99 and 17.3 %) respectively when combined with alfalfa. Intercropping fodder maize (*Z. mays*) with lablab bean (*L. purpureus*) significantly reduced crude fibre content and this increased nutritive value of maize (Khogali *et al.,* 2011). Binary and ternary mixtures of alfalfa (*M. sativa* L.) + grasses such as brome grass (*B. inermis* Leys.), intermediate wheat grass (*A. intermedium* (Host). Beauv.), crested wheat grass (*A. cristatum* L. Gaertn.) had lower ADF and NDF contents than sainfoin (*O. sativa* Lam.) + grasses mixtures (Albayrak *et al*., 2011).

When alfalfa (*M. sativa* L.) was grown in mixtures of four grasses, *D. glomerata* L., *F. pratensis* L., *P. pratensis* L. and *L. perenne* L, the crude fibre content of the fodder increased, when the percentage of participation of alfalfa in the fodder mixture decreased (Samuil *et al.,* 2012). According to Albayrak and Turk (2013), the legumes such as alfalfa (*M. sativa* L.) and red clover (*T. pratense* L.) in monoculture or in binary and ternary mixtures with grasses such as smooth brome grass (*B. inermis* Leys.), orchard grass (*D. glomerata* L.) and meadow fescue (*F. pratensis* Huds.) had lower NDF and ADF values than the grasses grown in monoculture. The red clover and alfalfa monocultures demonstrated the lowest NDF and ADF concentrations, followed by the red clover binary and termary mixtures and the alfalfa binary mixtures. Ojo *et al*., (2013) reported that the crude fibre content of sole *P. maximum* var. Ntchisi had higher value than that of intercropping *Panicum* with *L. purpureus*.

2.4.5. Effect of Grass–Legume Mixtures on the Nutrient Content

Legumes benefit the grass by contributing nitrogen to the soil through atmospheric N_2 fixation, decay of dead root nodules and mineralization of shed leaves. Seresinhe *et al.* (1994) has indicated that inclusion of legume in a pasture mixture stimulates the growth and increases the N uptake of grass. It was observed that closer planting geometry of legume with grass resulted into higher contents of these mineral in the *P. maximum*. This observation agrees with the result of Fischer and Barker (1996) that herb and leguminous species consistently have higher concentration of some important minerals than perennial grasses which when planted together are made available for the grasses uptake through the senescence and decay of leaf and rooting materials of the legumes.

In a study conducted by Jayakumar (1997) intercropping hybrid napier with lablab bean resulted in maximum uptake of N (113.10 kg ha^{-1}) and P (16.48 kg ha^{-1}). Saren and Jana (1999) reported that total NPK (nitrogen, phosphorus and potassium) uptake was higher in intercropped maize with pigeon pea than in pure stand of either crop.

Zimkova *et al.* (2002) evaluated grass (*L. perenne*, *F. pratensis, D. glomerata* and *P. pratense*) / legume (*T. repens* and *M. sativa*) mixtures and revealed that the chemical composition of both grass / *T. repens* and grass / *M. sativa* mixtures showed a sufficient concentration of N, P and Ca. The napier grass intercropped with legumes, seca (*S. scabra* cv. Seca) and siratro (*M. atropurpureum* cv. Siratro) had more N content than sole napier grass but for *P. maximum*, the effect of legume relative to control was not significant (Njoka-Njiru *et al*., 2006). However, the legumes did not influence the level of P, K and Ca. According to them, the level of P and Ca increased overtime, while K declined.

Intercropping fodder maize (*Z. mays*) with lablab bean (*L. purpureus*) did not affect mineral contents of calcium, magnesium and phosphorus, but increased potassium and nitrogen contents significantly (Khogali *et al.,* 2011). When alfalfa (*M. sativa* L.) was grown in mixtures of four grasses, *D. glomerata* L., *F.*

pratensis L., *P. pratensis* L. and *L. perenne* L., total nitrogen content of mixture increased with increasing the percentage of alfalfa, whereas phosphorus content increased with the decrease of the percentage of alfalfa. The potassium content of the fodder decreased in almost all fodder mixtures, but the calcium content was good in all the mixtures (Samuil *et al.*, 2012). The mineral contents (P, K, Ca, Mg) of *P. maximum* intercropped with *S. hamata* increased with increasing inter row spacing of the different legumes (Alalade *et al.*, 2013).

2.4.6. Effect of Grass–Legume Mixtures on Soil Characters

Higher content of N, P and K was recorded in plots where lablab bean was raised as an intercrop of BN hybrid than cowpea as intercrop (Jayakumar, 1997). Gil and Fick (2001) investigated soil N availability in monoculture and binary mixtures of alfalfa (*M. sativa*) or red clover (*T. pratense* L.) with eastern gamma grass (*Tripsacum dactyloides*) and found that soil organic N was three fold higher with alfalfa, red clover and gamma grass alfalfa mixture than with gamma grass in monoculture.

Zimkova *et al.* (2002) evaluated grass (*L. perenne, F. pratensis, D. glormerata* and *P. pratense*)/legume (*T. repens* and *M. sativa*) mixtures and revealed that the chemical composition of the soil confirmed a positive import of the grass/legume mixtures on soil. The soil organic carbon content, available N and P were improved when legume (*V. unguiculata*) and grass (*C. setigerus*) were grown in 2:1 row ratio and the increase was to the tune of 42.54, 37.64 and 69.17 % over than the initial content of these nutrients (Meena and Mann, 2011).

Materials and methods

3. MATERIALS AND METHODS

The present investigation entitled "Fodder production technology under light and moisture stress situations" was undertaken to identify drought tolerant varieties of fodder cowpea suitable for the dry summer months and their evaluation in mixtures with the popular fodder grasses of Kerala for improving the quantity, quality and economics of fodder production under open and shaded situation during the lean dry months. The materials used and methods adopted for the study are detailed below.

3.1. EXPERIMENTAL SITE

The experiment was conducted in the upland area of the Instructional Farm of College of Agriculture, Vellayani, Thiruvananthapuram. The farm is located at 8.5^0 N latitude and 76.9^0 E longitude at an altitude of 29 m above mean sea level.

3.2. SEASON AND CLIMATE

The experiment was conducted during the period from January 2012 to March 2014. The meteorological parameters such as rainfall, maximum and minimum temperature and evaporation rate recorded during the cropping period are given in the Appendix - I & II and graphically presented in Fig. 1 and Fig. 2. The abstract of the weather data is given in the Table 1.

Table 1. Abstract of the weather data during the experimental period (January 2012 to March 2014).

Weather elements	Range
Maximum temperature (^oC)	$28.3 - 33.3^0C$
Minimum temperature (^oC)	$19.2 - 26.1^0C$
Total rainfall (mm)	2835.4 mm
Relative humidity (%)	84.8 – 99.0%
Monthly evaporation (mm)	2 - 4.2 mm

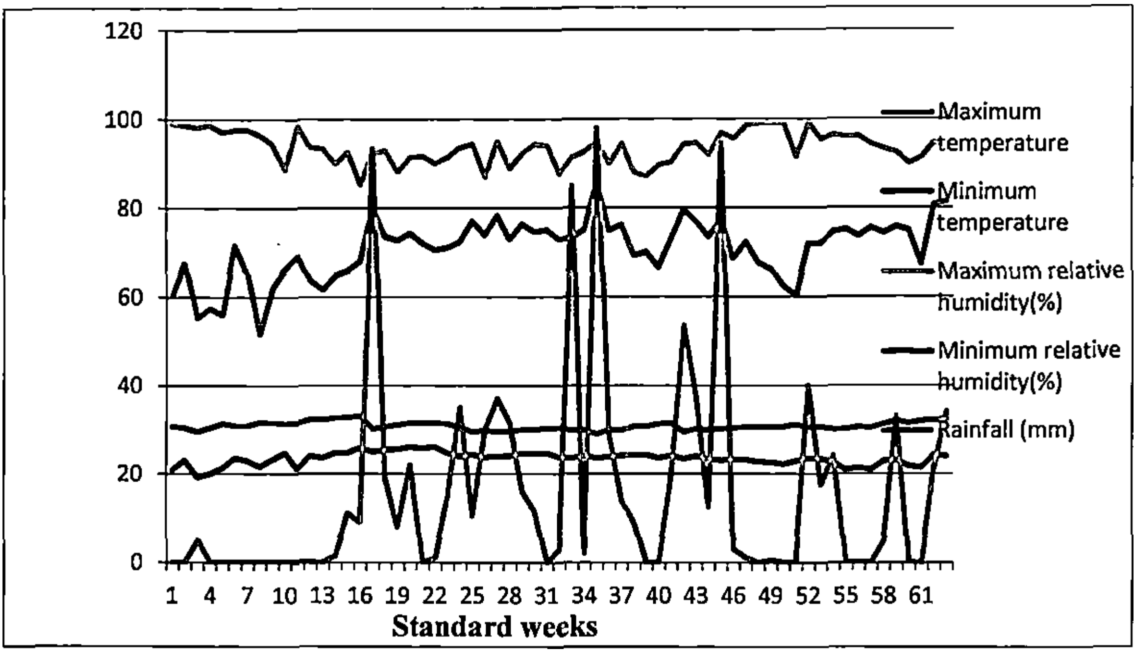


Figure 1. Weather data during the first year of experimentation

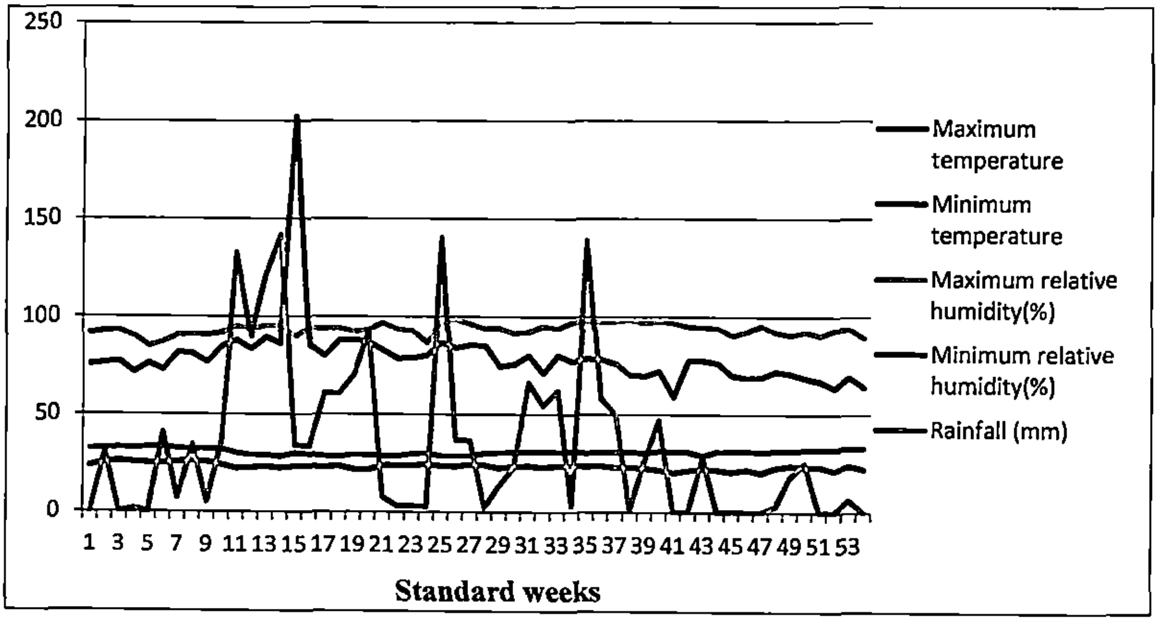


Figure 2. Weather data during the second year of experimentation

3.3. SOIL

The soil of the experimental site was red sandy clayloam (Oxisol, Vellayani series). Prior to the conduct of the experiment, composite soil samples were drawn from 0-15 cm depth and analyzed for physico-chemical properties. The data obtained is given in Table 2. The soil was low in available N and K and medium in available P with an acidic pH.

Table 2. Soil physico-chemical properties of the experiment site

S.No	Particulars	Mean value	Method used
A	Physical Properties		
1	Mechanical Composition		
	Coarse sand (percent)	16.70	Bouyoucos Hydrometer method (Bouyoucos, 1962)
	Fine sand(percent)	31.30	
	Silt (percent)	25.50	
	Clay (percent)	26.50	
2.	Bulk density (gcc^{-1})	1.375	Gupta and Dakshinamoorthi (1980)
3.	Water holding capacity(percent)	21.50	Gupta and Dakshinamoorthi (1980)
4.	Porosity (percent)	32.00	Gupta and Dakshinamoorthi (1980)
B	II. Chemical Properties		
1.	Soil reaction (pH)	5.1	pH meter with glass electrode (Jackson,1973)
2.	Organic carbon(percent)	0.53	Walkely and Black's method (Jackson,1973)
3.	Available nitrogen($kgha^{-1}$)	196	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
4.	Available P_2O_5($kg\ ha^{-1}$)	48.5	Bray's colorimetric method (Jackson,1973)
5.	Available K_2O ($kg\ ha^{-1}$)	95.3	Flame photometric method (Jackson,1973)

3.4. CROPS AND VARIETIES

3.4.1. Fodder Cowpea

Five fodder cowpea varieties viz., COFC-8, CO-5, UPC-618, UPC-622 and Bundel Lobia-1 were used for the investigation. The seeds of COFC-8 and CO-5 were obtained from Department of Forage crops, TamilNadu Agricultural University, Coimbatore. The seeds of UPC-618 and UPC-622 were obtained from Department of Plant Breeding, G.B. Pant University of Agriculture and Technology, PantNagar, Uttar Pradesh and the seeds of Bundel Lobia-1 was obtained from Indian Grass land and Fodder Research Institute, Jhansi.

3.4.2. Bajra Napier Hybrid

The BN hybrid variety Suguna, released from Kerala Agricultural University was used for study. Suguna is a profuse tillering variety with long broad leaves and pale green leaf sheath with purplish pigmentation, suitable for uplands in all seasons. Average yield of Suguna per year is 283 t ha^{-1}.

The stem cuttings of this variety required for the study was obtained from the Department of Agronomy, College of Agriculture, Vellayani.

3.4.3. Guinea Grass

Guinea grass variety Harithasree released from Kerala Agricultural University was used for the investigation. Harithasree was developed by clonal selection from JHGG-96-3. The stem is pubescent and leaf glaborous. It is free from pests and diseases. It is suitable for cultivation in uplands and homesteads of Kerala. It is a high tillering variety with dark green leaves. The average yield per year is 130-150 t ha^{-1}.

3.5. EXPERIMENTAL PROCEDURE

The project was undertaken as two investigations. Each investigation was undertaken as two separate experiments.

Investigation - I: Drought tolerance studies in fodder cowpea under open and shaded situations.

Investigation - II: Evaluation of grass-fodder cowpea mixtures under open and shaded situations

3.6. INVESTIGATION – I: DROUGHT TOLERANCE STUDIES IN FODDER COWPEA UNDER OPEN AND SHADED SITUATIONS.

3.6.1. Layout and Design

This investigation was conducted as two separate experiments, one in open and another in shaded situation (25-35 per cent shade). Shade intensity was measured using quantum sensor. Photosynthetic photon flux density (PPFD, μ mol m^{-2} s^{-1}) was measured by a quantum sensor (L1-250). The global radiation was measured by using pyranometer and radiometer. For standardization, all readings were taken in the middle of tree shade at 1 m height on a clear day within 45 minutes of solar noon. The relative shading for the PAR ranges were determined as SPAR = 100 x (1 - PAR/PARo) where o corresponds to the solar radiation measured in open. Light intensities in PAR was obtained by integration over the respective wavelength ranges of the solar radiation spectra (Oren-shanir et *al*., 2006).

Design: Split plot

Replication: 4

Plot size: 4m x 5m

Season: Summer 2012 (January 2012 – March 2012)

3.6.2. Treatments

The layouts of the experiments are given in Fig 3 and Fig 4. Overall views of the experimental sites are shown in Plate 1 & Plate 2.

Main plot: Soil moisture stress levels (M) – 4

M_1- Pre sowing irrigation + life-saving irrigation

M_2- Pre sowing irrigation + irrigation at IW/CPE ratio of 0.4

M_3- Pre sowing irrigation + irrigation at IW/CPE ratio of 0.6

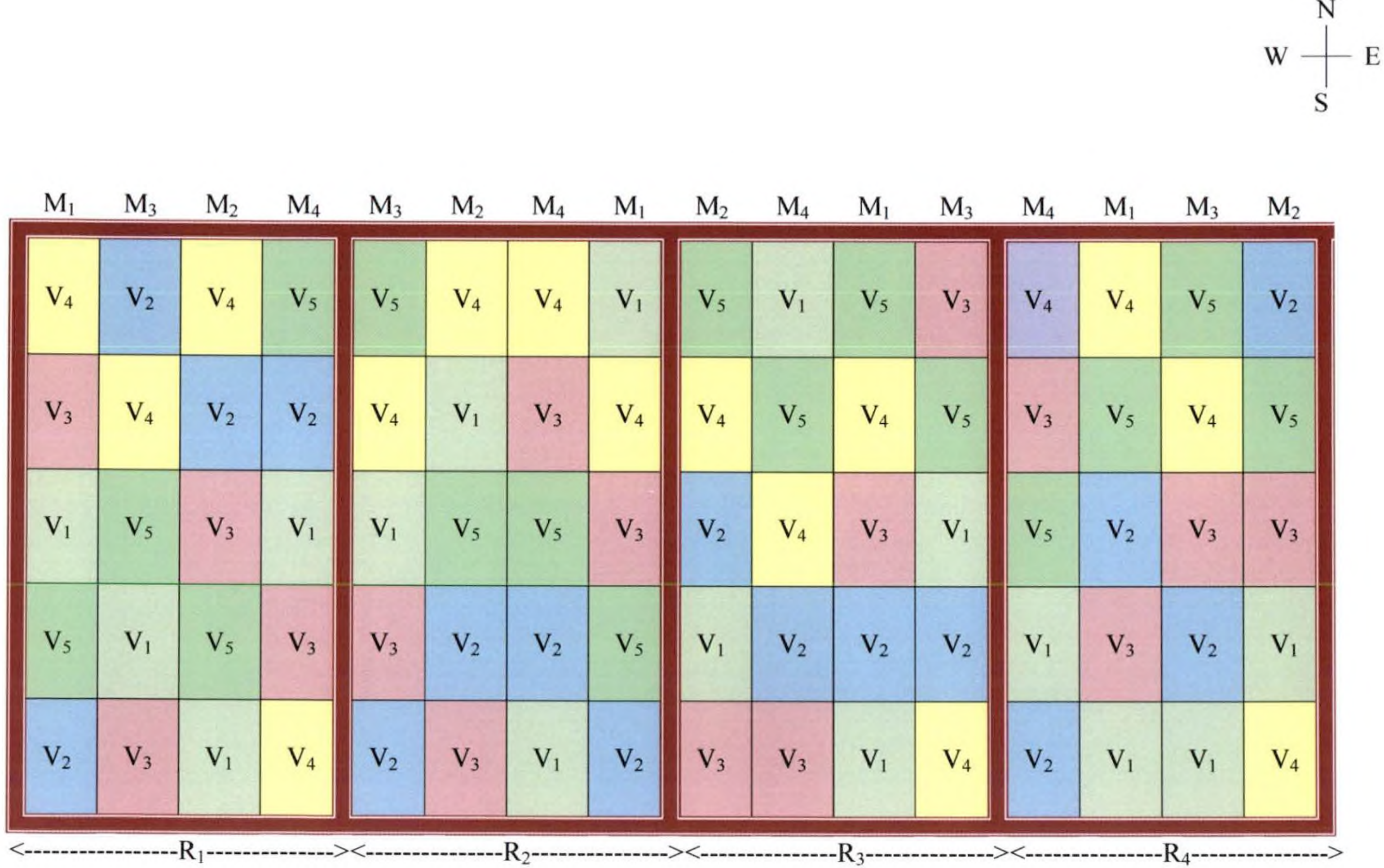


Figure 3. Layout of Investigation - I (open)

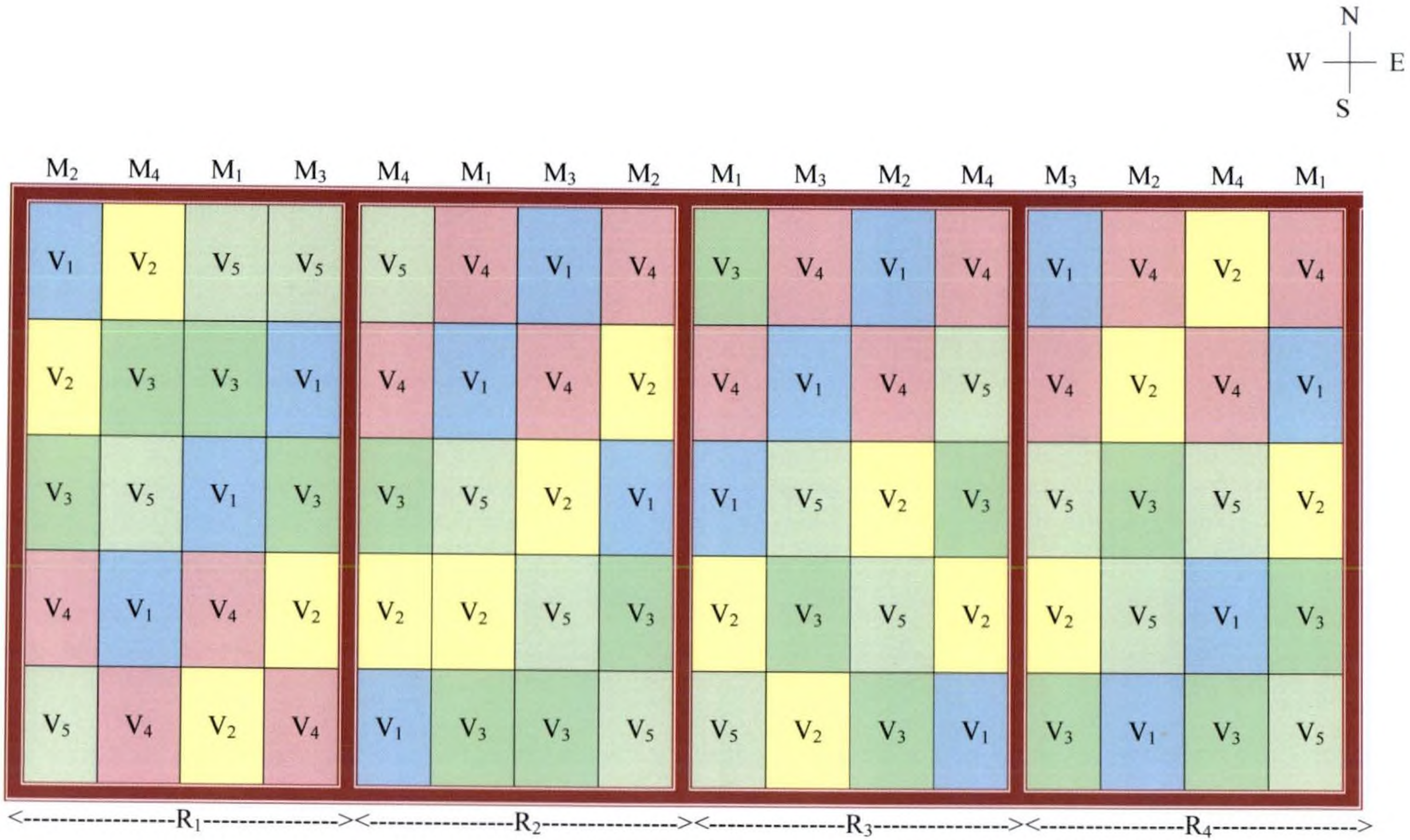


Figure 4. Layout of Investigation - I (shade)

Plate 1. General view of the experimental site in open (Investigation - I)

Plate 2. General view of the experimental site in shade (Investigation –I)

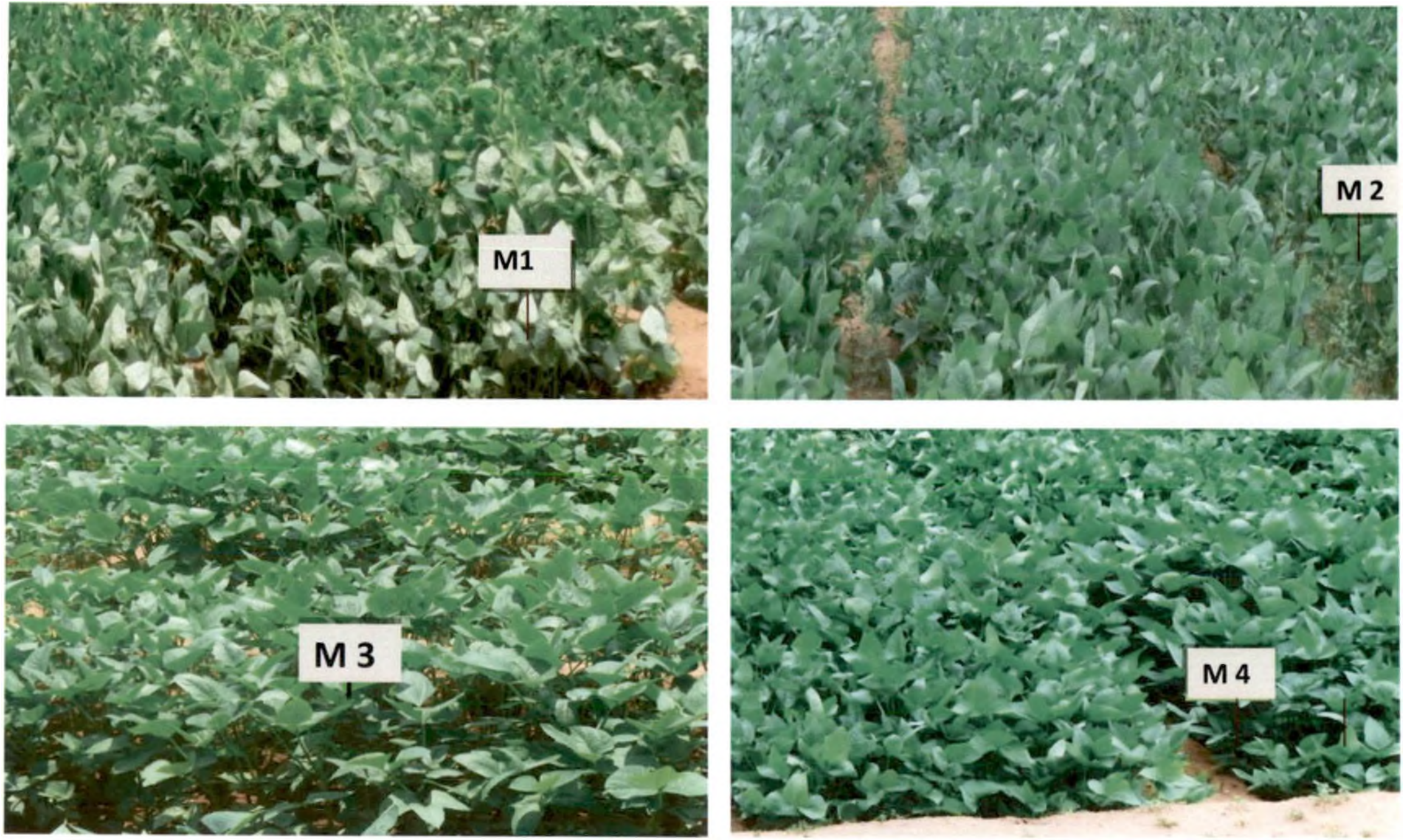


Plate 3. Soil moisture stress levels

CO-5

COFC-8

UPC-618

UPC-622

Bundel Lobia-1

Plate 4. Fodder cowpea varieties

M_4- Pre sowing irrigation + irrigation at IW/CPE ratio of 0.8

Sub plot: Fodder cowpea varieties (V) : 5.

V_1-UPC-618

V_2- UPC-622

V_3- Bundel lobia-1

V_4- COFC-8

V_5- CO-5

Treatment combinations: 20

The combinations of four soil moisture stress levels (M) and five fodder cowpea varieties (V) formed 20 treatment combinations.

M_1V_1	M_3V_1
M_1V_2	M_3V_2
M_1V_3	M_3V_3
M_1V_4	M_3V_4
M_1V_5	M_3V_5
M_2V_1	M_4V_1
M_2V_2	M_4V_2
M_2V_3	M_4V_3
M_2V_4	M_4V_4
M_2V_5	M_4V_5

3.6.3. Details of Cultivation

3.6.3.1. Field Preparation

The experimental area was cleared off weeds, ploughed twice, clodes broken, stubbles removed and the field was laid out into blocks and plots. The plots were dug and leveled. Check basin was made to supply irrigation as per the treatments.

3.6.3.2. Manuring and Fertilizer Application

FYM @ 10 t ha^{-1} was applied uniformly to all the plots at the time of final preparation of land. Entire dose of phosphorus was given as basal @ 30 kg ha^{-1}. Nitrogen @ 40 kg ha^{-1} and potassium @ 30 kg ha^{-1} were given in two equal splits, one as basal and one after one month of sowing.

3.6.3.3. Sowing

The fodder cowpea varieties as per treatments were sown at a spacing of 30 x 15cm @ 2 seeds $hole^{-1}$ on 14th January 2012 both in open as well as in shade (25-35 per cent).

3.6.3.4. After Care

Light inter cultivation and hand weeding were done at 15 days after sowing Thinning was done, one week after sowing and population was maintained. Plant protection measures were carried out as and when necessary.

3.6.3.5. Irrigation

Pre-sowing irrigation was given to all the plots uniformly. Uniform irrigation was given upto 10 DAS for germination and establishment. There after irrigation was given as per the treatments. Daily cumulative pan evaporation data was noted from USWB open pan evaporimeter. Based on the evaporation data and depth of irrigation, irrigation was given to the plots. The quantity of water applied to each plot in one irrigation was 600 litres. The daily rainfall and evaporation data along with the respective dates of irrigation are given in Appendix- III. The total amount of water received by each irrigation treatment is shown in Table 3a. Life-saving irrigation was given in treatment M_1.

1. Date of sowing : 14.01.2012
2. Period of irrigation for germination & establishment : 10days (14.01.2012 to 23.01.2012)
3. After 23.01.2012 irrigation was applied as per treatment.
4. IW/CPE = 0.8, CPE = 37.5 mm

5. IW/CPE = 0.6, CPE = 50 mm
6. IW/CPE = 0.4, CPE = 75 mm

Total number of days of irrigation for various irrigation treatments are as follows:

M_1: Life-saving irrigation - 2 days
M_2: IW/CPE = 0.4 - 2 days
M_3: IW/CPE = 0.6 - 3 days
M_4: IW/CPE = 0.8 - 4 days

Table 3a. Irrigation requirement of fodder cowpea during the cropping period

Treatment	Irrigation (mm)	Effective rainfall (mm)	Total amount of water received (mm)
Lifesaving irrigation	60	Nil	60
Irrigation at IW/CPE ratio of 0.4	60	Nil	60
Irrigation at IW/CPE ratio of 0.6	90	Nil	90
Irrigation at IW/CPE ratio of 0.8	120	Nil	120

3.6.3.6. Harvest

The fodder cowpea varieties were harvested on 13.03.2012 (60 DAS).

3.7. INVESTIGATION - II: EVALUATION OF GRASS-FODDER COWPEA MIXTURES UNDER OPEN AND SHADED SITUATIONS

3.7.1. Layout and Design

This investigation was conducted as two separate experiments, one in open and another in shaded situations (25-35 per cent shade). The treatments and other experimental details for both the experiments are the same.

Design: RBD

Replication: 3

Plot size: 3.6 m x 7.2 m

Season: From March 2012 to March 2013 & from March 2013 to March 2014.

The layouts of the experiments are given in Fig 5 & Fig 6. Overall views of the experimental sites are shown in Plate 5 and Plate 6.

Treatments:

Grasses - 2

G_1 – Hybrid napier (Suguna)

G_2 – Guinea grass (Harithasree)

Fodder cowpea varieties – 2

In experiment under open, V_1-COFC-8 & V_2-UPC-618.

In experiment under shade, V_1-COFC-8 & V_2-UPC-622.

Grass-legume row ratio - 3

R_1 – 1:1

R_2 – 1:2

R_3 – 1:3

Treatment combinations - 12

1. $G_1V_1R_1$
2. $G_1V_1R_2$
3. $G_1V_1R_3$
4. $G_1V_2R_1$
5. $G_1V_2R_2$
6. $G_1V_2R_3$
7. $G_2V_1R_1$
8. $G_2V_1R_2$
9. $G_2V_1R_3$
10. $G_2V_2R_1$
11. $G_2V_2R_2$
12. $G_2V_2R_3$

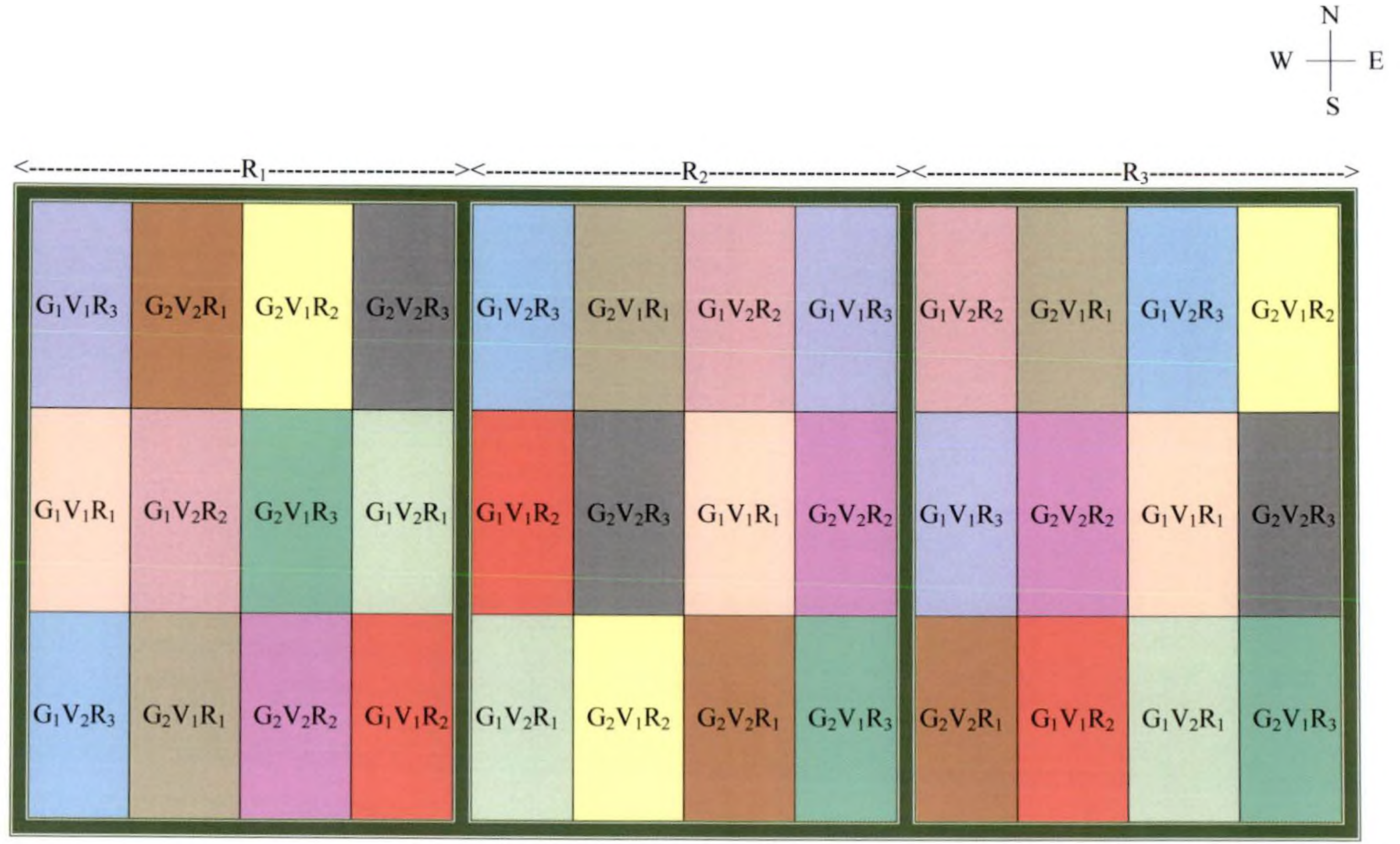


Figure 5. Layout of Investigation - II (open)

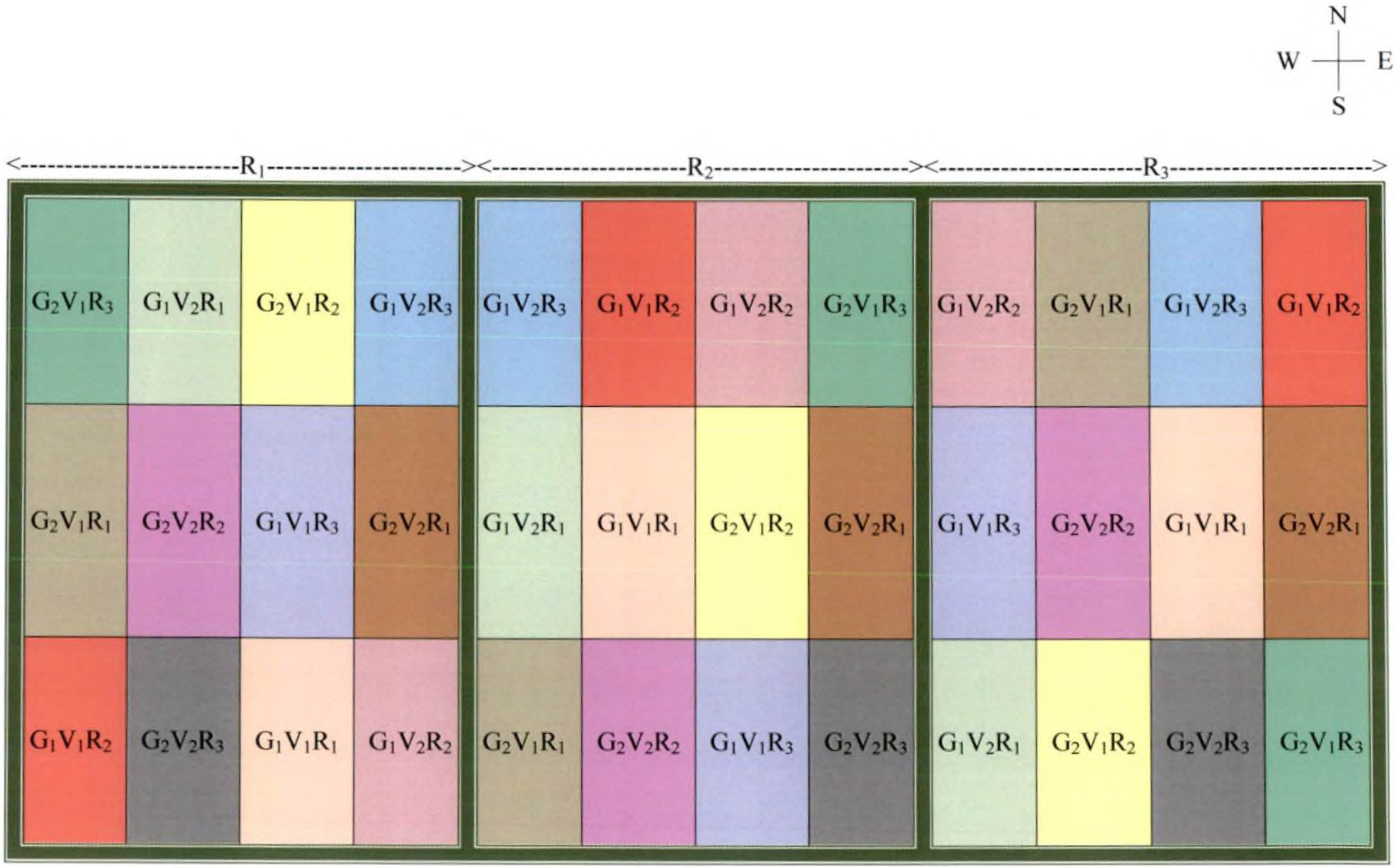
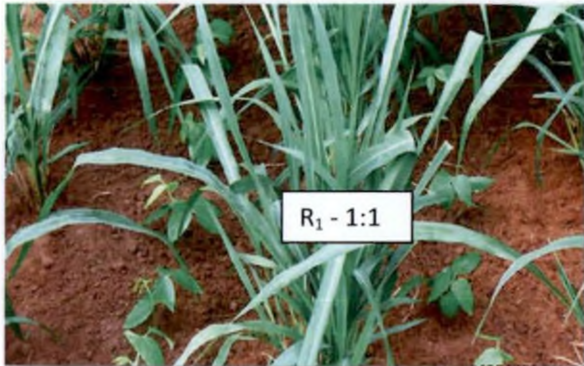


Figure 6. Layout of Investigation - II (shade)

Plate 5. General view of the experimental site – Investigation - II (open)

Plate 6. General view of the experimental site – Investigation - II (shade)



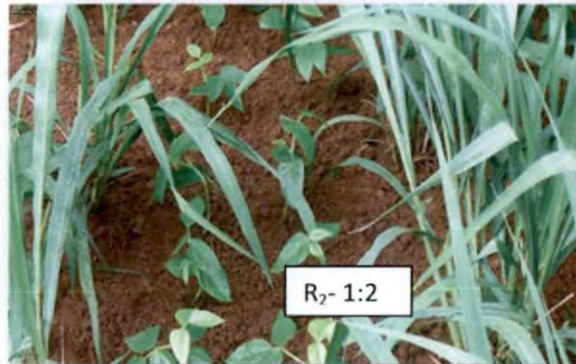


Plate 7. Grass legume row ratio

The varietal details of grass and cowpea varieties are shown Table 3b.

Table 3b. Varietal details of grass and cowpea varieties

Sl.No.	Fodder crops	Varietal details
1	Guinea grass cv. Harithasree	Released from KAU. Average yield: 130-150 t $ha^{-1}yr^{-1}$
2	Hybrid napier cv. Suguna	Released from KAU. Average yield: 283 t $ha^{-1}yr^{-1}$
3	Fodder cowpea cv. COFC-8	Released from TNAU. Average yield: 25-30 t ha^{-1} cut^{-1}
4	Fodder cowpea cv. UPC-622.	Released from G.B. Pant University Average yield: 32 t ha^{-1} cut^{-1}
5	Fodder cowpea cv. UPC-618.	Released from G.B. Pant University Average yield: 30 t ha^{-1} cut^{-1}

3.7.2. Details of Cultivation

3.7.2.1. Preparation of Land

The experimental area was ploughed twice, clodes broken, stubbles removed and the field was laid out into blocks and plots.

3.7.2.2. Manuring and Fertilizer Application

FYM @ 12 t ha^{-1} was applied in the trenches taken for planting BN hybrid and guinea grasses and well incorporated in the soil. FYM @ 10 t ha^{-1} was applied in the rows taken for planting fodder cowpea and incorporated in the soil. For grasses, entire dose of phosphorus and potassium was given as basal each @ 50 kg ha^{-1}. Nitrogen @ 200 kg ha^{-1} was given in two equal splits first as basal and second one month after planting. For fodder cowpea, entire dose of phosphorus and potassium was given as basal each @ 30 kg ha^{-1}. Nitrogen @ 40 kg ha^{-1} was given in two equal splits, first as basal and second one month after sowing.

3.7.2.3. Planting

Three noded stem cuttings (setts) of BN hybrid were planted in the channels @ 1 sett per hill, at a spacing of 60 cm x 60 cm. Slips of guinea grass were planted in the channels @ 2 slips per hill at a spacing of 60 cm x 30 cm.

Seeds of fodder cowpea were sown @ 2 seeds per hole at a spacing of 30cmx 15cm in between the rows of fodder grasses as per the treatments. In 1:1 row ratio, 1 row of fodder cowpea was sown in the interspaces of fodder grasses. In 1:2 ratio, 2 rows of fodder cowpea were sown in the interspaces of fodder grasses.In 1:3 row ratio, 3 rows of fodder cowpea were sown in the interspaces of fodder grasses.The same planting procedure was followed in both the experiments laid out under open and shade.

3.7.2.4. After Cultivation

Gap filling was done twenty days after planting in fodder grasses. Excess sprouts were removed retaining only two healthy and vigorous shoots on appropriate stages. Dried slips/setts of fodder grasses were removed and replaced with healthy ones according to the treatments. Thinning was done for fodder cowpea, one week after sowing and uniform population was maintained. Intercultivation and hand weeding operations were done at weekly intervals.

3.7.2.5. Irrigation

Uniform irrigation was given upto 2 WAS of fodder cowpea for establishment. There after based on the findings of Investigation-I, the plots in the open condition were irrigated at IW/CPE ratio of 0.8 whereas the plots in shaded condition were irrigated at IW/CPE ratio of 0.6. Measured quantities of water were given to the plots according to the treatments.

3.7.2.6. Harvest

Harvesting of grasses was done at a height of 15 cm from the base. Both grasses and cowpea were harvested on 21.05.2012 in the first year and on

15.05.2013 in the second year. After the harvest of grass-legume mixture, the experiment was continued as a pure grass crop and observations were recorded on yield.

3.8. OBSERVATIONS RECORDED

For fodder grasses growth observations of ten randomly selected BN hybrid and guinea grass plants in the net plot were recorded prior to harvest. Average of the observations were worked out and presented.

In case of fodder cowpea observations were taken from five randomly selected plants in the net plot at the time of harvest and their average was worked out and presented.

3.8.1. Biometric Observations

3.8.1.1. Plant Height

Height of fodder grasses and fodder cowpea were measured from the base of the plant to the tip of the longest leaf. Mean height was worked out and presented in cm.

3.8.1.2. Number of Tillers/Branches

The number of tillers clump^{-1} were counted in case of fodder grass at the time of harvest and recorded. The total number of branches of fodder cowpea in the selected observation plants of each plot were also recorded.

3.8.1.2. Leaf : Stem Ratio

The sample plants collected for recording dry matter production were separated into leaf and stem, dried, weighed and the leaf:stem ratio was then worked out on dry weight basis. The mean leaf: stem ratio was calculated.

3.8.1.3. Root Volume

Root volume was recorded by water displacement method as stated below. The roots of sample plants were washed free of adhering soil with a low jet of water. The roots are immersed in 1000 ml measuring cylinder containing water and the rise in water level was recorded. Displacement in volume of water is taken as a measure of the volume of the root measured.

3.8.1.4. Root : Shoot Ratio

Ratio of weight of dried roots and shoots of five plants were calculated and the mean value arrived.

3.8.1.5. Root Dry Weight

The roots of sample plants were washed free of adhering soil with a low jet of water. The roots were oven dried and dry weight was recorded.

3.8.1.6. Green Fodder Yield

The green fodder yield from the net plot area was recorded for six cuts in BN hybrid and seven cuts in guinea grass in the entire year and the total green fodder yield in t ha^{-1} was worked out for the entire year (for 1^{st} year and 2^{nd} year). In the case of fodder cowpea, a single harvest was done in summer season and the green fodder yield from the net plot area was recorded.

3.8.1.7. Dry Fodder Yield

The sample plants of grasses and fodder cowpea collected from each net plot on the day prior to harvest were sundried and then oven dried to a constant weight at 60^0 C. The dry matter content was computed from each treatment and dry fodder yield was worked out.

3.9. PHYSIOLOGICAL OBSERVATIONS

3.9.1. Dry Matter Production

Ten sample hills were uprooted from the net plot, washed, dried under sun, then oven dried at 60^0 C to constant weight and dry matter production expressed in t ha^{-1}.

3.9.2. Leaf Area Index

LAI was computed by using the length x width method suggested by Gomez (1972).

$$LAI = \frac{K\,(LxW)\ x\ \text{Number of leaves plant}^{-1}}{\text{Area occupied by the plant}}$$

Where, K= adjustment factor (0.75)

L = Leaf length (cm)

W = Leaf width (cm)

3.9.3. Specific Leaf Area

Third fully opened leaf from the top of 10 sample plants were selected. Leaf area was noted and kept in the oven at 60^0C for 2 days for taking dry weight.

$$SLA = \frac{\text{Leaf Area}}{\text{Leaf weight}}$$

3.9.4. Leaf Weight/Plant

Weight of total leaf from 10 sample plants were taken after drying the leaf for two days at 60^0C. This will give an estimation of assimilating surface area.

3.9.5. Relative Water Content

The method proposed by Weatherley (1950) which was later modified and described in detail by Slatyer and Barrs (1965) was used to determine relative water content expressed in percentage.

$$RWC\ (\%) = \frac{(FW\text{-}DW)}{(TW\text{-}DW)}\ X\ 100$$

FW – Fresh weight

DW – Dry weight

TW – Turgid weight

Third fully opened leaf of ten sample plants were taken from the net plot area. The fresh weight, turgid weight and oven dry weight were taken and from these values relative water content was calculated.

3.9.6. Leaf Water Potential

Leaf water potential of intact leaf of sample plants was measured by taking leaf punches/leaf discs and kept it in the vapour pressure osmometer.

3.9.7. Osmotic Potential

Third fully opened leaf of 10 sample plants were taken and ground with mortar and pistil. The juice of the leaves was filtered through Whattmann No.1 filter paper and the extract was collected. The extract was kept in a cuvette in vapour pressure osmometer and reading was taken directly from the instrument and expressed as m moles kg^{-1}.

3.9.8. Stable Isotope Discrimination ($_{13}C$) Studies

The carbon isotope discrimination ratio (CID) is $_{13}C$ /$_{12}C$ was determined for calculating the isotope discrimination. The third fully opened leaf of ten sample plants were collected and oven dried and ground and the samples were sent to the National Facility Department of Crop Physiology, UAS Bangalore for determining the CID ratio using IRMS (Isotope Ratio Mass Spectrophotometer).

3.9.9. Water Use Efficiency

Field water use efficiency was calculated by dividing the economical crop yield by the total quantity of water applied in the field (WR) and expressed in kg $ha^{-1}mm^{-1}$.

3.10. BIOCHEMICAL STUDIES

3.10.1. Chlorophyll Content

Total chlorophyll content was estimated from the fully opened second leaf from the top of ten sample plants by the method suggested by Arnon (1949). Total chlorophyll is expressed in mg $g^{-1}$of fresh weight of leaf.

$$\text{Total chlorophyll} = 8.02\ A_{663} + 20.20\ A_{645} \times \frac{V}{1000 \times W}$$

Where,

A = Absorbance at specific wave lengths

V = Final volume of chlorophyll extract in 80 % acetone

W = Fresh weight of tissue extracted in 80 % acetone.

3.10.2. Proline Content

Proline content was estimated from the fully opened second leaf from the top of ten sample plants by the technique suggested by Bates *et al.* (1973) and expressed in $\mu g\ g^{-1}$ fresh weight.

3.11. QUALITY STUDIES

3.11.1. Crude Protein

Crude protein content was calculated by multiplying the nitrogen content of plant by the factor 6.25 (Simpson *et al.*, 1965).

3.11.2. Crude Fibre

Crude fibre content was determined by A.O.A.C. method (A.O.A.C., 1975).

3.11.3. Crude Protein Yield

Crude protein yield was calculated by multiplying the crude protein content in plants and dry matter production and expressed in $t\ ha^{-1}$.

3.12. UPTAKE STUDIES

3.12.1. Uptake of Nitrogen

The nitrogen content was estimated by modified micro Kjeldal method (Jackson, 1973) and the uptake of nitrogen was calculated based on the content of this nutrient in plants and the dry matter produced. The values were expressed in $kg\ ha^{-1}$.

3.12.2. Uptake of Phosphorus

Phosphorus content was determined by Vanedomolybdo-phosphoric yellow colour method using spectro photometer (Jackson, 1973). Phosphorus uptake was calculated by multiplying the phosphorus content and dry weight of plants. The values were expressed in kg ha^{-1}.

3.12.3. Uptake of Potassium

The potassium content in the plant samples were estimated using Flame photometry (Jackson, 1973). The uptake was calculated based on potassium content in plants and dry matter production and expressed in kg ha^{-1}.

3.13. ANALYSIS OF SOIL BEFORE AND AFTER EXPERIMENT

A composite sample of soil was collected from the experimental field from a depth of 10-15 cm from each plot before the commencement of experiment. Similarly soil samples were also collected from each plot at the end of experiment. The samples were dried in shade, sieved by passing through a 2 mm sieve and were analyzed for available nitrogen, available phosphorus and available potassium content.

Available nitrogen content was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus content was estimated by Bray method (Jackson, 1973) and available potassium by neutral normal ammonium acetate method (Jackson, 1973).

3.14. ECONOMIC ANALYSIS

The economics of cultivation was worked out based on cost of cultivation and prevailing market price of the fodder. The net income and benefit: cost ratio were calculated as follows.

$$\text{Net income (Rs ha}^{-1}) = \text{Gross income} - \text{Total expenditure}$$

$$\text{Benefit : Cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.15. STATISTICAL ANALYSIS

Data relating to each character was analysed by applying the analysis of variance technique (ANOVA) as suggested by Panse and Sukhatme (1967).

Results

4. RESULTS

The experiment entitled "Fodder production technology under light and moisture stress situations" was undertaken at the Instructional Farm, College of Agriculture, Vellayani, during January 2012 to March 2014. The main objectives of the study were to identify drought tolerant varieties of fodder cowpea suitable for the dry summer months and their evaluation in mixtures with the popular fodder grasses of Kerala for improving the quantity, quality and economics of fodder production under open and shaded situations.

The study comprised two investigations. The first investigation, entitled "Drought tolerance studies in fodder cowpea under open and shaded situations" was conducted during the summer season (January to March) of 2012 as two separate experiments, one in open and another in shade. The second investigation on "Evaluation of grass fodder cowpea mixtures under open and shaded situations" was conducted during the summer season (March 2012 to March 2013) and (March 2013 to March 2014). Two best drought tolerant fodder cowpea varieties were selected based on the results of the first investigation. For evaluating the grass fodder cowpea mixtures, two separate experiments were conducted under open and shaded conditions. The results of the investigations are presented in the chapter.

INVESTIGATION– I: DROUGHT TOLERANCE STUDIES IN FODDER COWPEA UNDER OPEN AND SHADED SITUATIONS

4.1. BIOMETRIC OBSERVATIONS

4.1.1. Plant Height

The results on the effect of treatments (soil moisture stress levels and varieties) with respect to the plant height of fodder cowpea under open and shaded condition are presented in Table 4 & 5.

In open, plant height showed significant difference for various soil moisture stress and varietal treatments. The plant height was significantly higher (100.83 cm) when irrigated at IW/CPE ratio of 0.8 (M_4) followed by irrigation at IW/CPE ratio of 0.6 (M_3). The least plant height was recorded by life saving irrigation (M_1) which was on par with irrigation at IW/CPE ratio of 0.4 (M_2). Among the varieties, COFC-8 (V_4) recorded higher plant height (101.36 cm), which was on par with that of UPC-618 (V_1). The plant height of UPC- 622 (V_2) (99.30 cm) was on par with that of Bundel lobia-1 (V_3) (98.71 cm). None of the interactions were significant.

Under 25-35 % shade, significantly higher plant height (102.89 cm) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4), which was on par with irrigation at IW/CPE ratio of 0.6 (M_3). The least plant height (98.44 cm) was recorded by irrigation at IW/CPE ratio of 0.4 (M_2) which was on par with lifesaving irrigation (M_1) (98.48 cm). Among the varieties, COFC-8 (V_4) recorded higher plant height of 102.31cm. The plant height of 104.98 cm recorded for m_3v_2 (UPC-622 irrigated at IW/CPE ratio of 0.6) was significantly higher which was on par with m_3v_4 (104.43 cm), m_4v_4 (104.35 cm), m_4v_3 (103.70 cm) and m_4v_2 (103.68 cm).

4.1.2. Number of Branches

The perusal of the data on number of branches presented in Table 4 & 5 showed that soil moisture stress levels and varieties had significant effect on number of branches in open condition. Significantly higher number of branches (4.57) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4), followed by IW/CPE ratio of 0.6 (M_3) (4.22) and life saving irrigation (M_1) which was on par with IW/CPE ratio of 0.4 (M_2). Among the varieties, COFC-8 (V_4) produced significantly more number of branches (4.79), followed by UPC-622 (V_2) (4.33). The least number of branches was produced by CO-5 (V_5). The interaction effect between soil moisture stress levels and varieties was significant and m_4v_4

Table 4. Effect of soil moisture stress levels and varieties on plant height, number of branches and leaf: stem ratio of fodder cowpea

Treatments	Plant height (cm)		Number of branches		Leaf: stem ratio	
	Open	Shade	Open	Shade	Open	Shade
Soil moisture stress levels (M)						
M_1- Life saving	97.98	98.48	3.70	2.98	0.90	0.94
M_2- IW/CPE = 0.4	98.34	98.44	3.80	3.08	0.94	0.94
M_3- IW/CPE = 0.6	100.14	102.49	4.22	3.23	1.09	0.94
M_4- IW/CPE = 0.8	100.83	102.89	4.57	3.23	1.09	1.01
SEm (±)	0.397	0.340	0.075	0.086	0.001	0.002
CD(0.05)	0.636	0.544	0.121	NS	NS	NS
Varieties (V)						
V_1 - UPC 618	99.30	100.54	3.85	3.40	0.90	0.93
V_2 - UPC 622	100.06	101.09	4.33	3.20	1.08	0.95
V_3-Bundel lobia-1	98.71	100.48	4.03	2.99	1.00	0.94
V_4 - COFC -8	101.36	102.31	4.79	3.52	1.18	1.05
V_5 - CO-5	97.16	98.42	3.37	2.54	0.86	0.90
SEm (±)	0.449	0.475	0.086	0.082	0.092	0.002
CD(0.05)	0.639	0.675	0.123	0.117	0.131	NS

Table 5. Interaction effect of soil moisture stress levels and varieties on plant height, number of branches and leaf: stem ratio of fodder cowpea

Treatments	Plant height (cm)		Number of branches		Leaf: stem ratio	
	Open	Shade	Open	Shade	Open	Shade
M x V						
m_1v_1	99.10	99.40	3.32	3.23	0.85	0.92
m_1v_2	97.60	97.63	4.15	2.97	0.96	0.95
m_1v_3	97.23	97.80	3.57	2.82	0.82	0.92
m_1v_4	100.10	100.93	4.5	3.43	1.12	1.02
m_1v_5	95.88	96.63	2.80	2.46	0.77	0.88
m_2v_1	98.60	98.88	3.40	3.36	0.80	0.93
m_2v_2	98.78	98.10	4.18	3.05	1.01	0.93
m_2v_3	98.08	98.23	3.95	2.89	0.99	0.90
m_2v_4	100.33	99.55	4.68	3.48	1.10	1.00
m_2v_5	95.90	97.43	2.97	2.65	0.78	0.92
m_3v_1	100.98	102.08	4.05	3.46	0.99	0.95
m_3v_2	100.03	104.98	4.26	3.45	1.18	0.92
m_3v_3	99.28	102.20	4.11	3.19	1.09	0.91
m_3v_4	101.78	104.43	4.95	3.53	1.25	1.00
m_3v_5	98.63	98.75	3.71	2.53	0.94	0.93
m_4v_1	101.58	101.83	4.60	3.56	0.99	0.93
m_4v_2	100.80	103.68	4.75	3.36	1.18	1.00
m_4v_3	100.25	103.70	4.48	3.10	1.09	1.05
m_4v_4	103.25	104.35	5.03	3.63	1.25	1.20
m_4v_5	98.25	100.88	4.01	2.51	0.94	0.89
SE m (+)	0.449	0.475	0.086	0.082	0.092	0.002
CD(0.05)	NS	1.35	0.783	NS	NS	NS

(COFC-8 irrigated at IW/CPE ratio of 0.8) recorded significantly higher number of branches (5.03) and it was on par with m_3v_4 (4.95), m_4v_2 (4.75), m_2v_4 (4.68), m_4v_1 (4.60), m_4v_3 (4.48), and m_3v_2 (4.26).

Under 25-35 % shade, soil moisture stress levels and interactions had no significant effect on the number of branches of fodder cowpea. However, varieties differed significantly and the variety COFC-8 (V_4) and UPC-618 (V_1) recorded significantly higher number of branches of 3.52 and 3.40.

4.1.3. Leaf: Stem Ratio

The results on the effect of soil moisture stress levels on leaf: stem ratio was not significant in open condition. The variety COFC-8 (V_4) recorded significantly higher leaf: stem ratio (1.18) which was on par with UPC-622 (V_2) (1.08). Least leaf: stem ratio was recorded by CO-5 (V_5) which was on par with UPC-618 (V_1).

The treatments had no significant effect on leaf: stem ratio of fodder cowpea under 25-35 per cent shade.

4.1.4. Root Volume

The results on the effect of soil moisture stress levels and varieties on root volume in open and shaded condition are presented in Table 6 & 7. The results revealed that the treatments had no significant effect on root volume of fodder cowpea. However, irrigation at IW/CPE ratio of 0.8 (M_4) recorded a higher root volume of 4.40 cm^3 in open and 2.55 cm^3 in shade, through not significantly different from the others. Among the varieties, COFC-8 (V_4) recorded higher root volume in both open and shade.

4.1.5. Root: Shoot Ratio

The results on the effect of soil moisture stress levels and varieties on root: shoot ratio in open and shaded conditions are presented in Table 6 & 7. Significantly higher root: shoot ratio (0.47) was recorded by life saving irrigation (M_1) followed by irrigation at IW/CPE ratio of 0.4 (M_2) (0.45) in open. Among

Table 6. Effect of soil moisture stress levels and varieties on root volume, root : shoot ratio and root dry weight of fodder cowpea

Treatments	Root volume (cm^3)		Root : shoot ratio		Root dry weight (g)	
	Open	Shade	Open	Shade	Open	Shade
Soil moisture stress levels (M)						
M_1- Life saving	3.20	1.70	0.47	0.11	0.59	0.29
M_2- IW/CPE = 0.4	3.50	1.75	0.45	0.10	0.58	0.24
M_3- IW/CPE = 0.6	4.20	2.35	0.32	0.12	0.66	0.39
M_4- IW/CPE = 0.8	4.40	2.55	0.27	0.12	0.72	0.43
SEm (±)	0.532	0.377	0.019	0.003	0.021	0.013
CD (0.05)	NS	NS	0.011	NS	0.031	0.022
Varieties (V)						
V_1 - UPC 618	4.00	2.06	0.38	0.12	0.66	0.32
V_2 - UPC 622	3.75	2.06	0.38	0.10	0.66	0.32
V_3- Bundel lobia-1	3.69	2.13	0.36	0.10	0.58	0.36
V_4 - COFC -8	4.19	2.19	0.41	0.12	0.80	0.41
V_5 - CO-5	3.56	2.00	0.35	0.11	0.49	0.29
SEm (±)	0.602	0.334	0.015	0.010	0.016	0.020
CD (0.05)	NS	NS	0.015	NS	0.022	0.030

Table 7. Interaction effect of soil moisture stress levels and varieties on root volume, root : shoot ratio and root dry weight of fodder cowpea

Treatments	Root volume (cm^3)		Root : shoot ratio		Root dry weight (g)	
	Open	Shade	Open	Shade	Open	Shade
M x V						
m_1v_1	3.00	1.75	0.49	0.11	0.65	0.25
m_1v_2	3.75	2.00	0.46	0.09	0.69	0.29
m_1v_3	3.50	1.25	0.47	0.08	0.49	0.24
m_1v_4	3.00	1.75	0.51	0.10	0.72	0.42
m_1v_5	2.75	1.75	0.40	0.10	0.46	0.23
m_2v_1	4.50	2.00	0.44	0.11	0.60	0.23
m_2v_2	3.25	1.50	0.43	0.10	0.68	0.25
m_2v_3	2.25	1.75	0.45	0.11	0.48	0.24
m_2v_4	3.75	1.50	0.50	0.10	0.71	0.23
m_2v_5	3.75	2.00	0.43	0.11	0.45	0.29
m_3v_1	4.50	2.50	0.31	0.13	0.75	0.34
m_3v_2	3.75	2.00	0.31	0.12	0.57	0.40
m_3v_3	4.75	3.00	0.33	0.12	0.49	0.40
m_3v_4	4.75	2.25	0.32	0.13	0.78	0.46
m_3v_5	3.25	2.00	0.32	0.08	0.72	0.34
m_4v_1	4.00	2.50	0.28	0.12	0.72	0.45
m_4v_2	4.25	2.75	0.24	0.11	0.74	0.33
m_4v_3	4.25	2.50	0.28	0.11	0.87	0.55
m_4v_4	5.25	2.75	0.30	0.16	0.99	0.51
m_4v_5	4.50	2.25	0.26	0.11	0.32	0.32
SE m (+)	0.602	0.334	0.015	0.010	0.016	0.020
CD (0.05)	NS	NS	0.029	NS	0.045	0.059

the fodder cowpea varieties COFC-8 (V_4) recorded significantly higher root: shoot ratio (0.41). Interaction effect was significant in open condition and COFC-8 given at life saving irrigation (m_1v_4) recorded higher root: shoot ratio (0.51) which was on par with m_1v_1 and m_2v_4. The treatments had no significant effect on root: shoot ratio of fodder cowpea in partial shade.

4.1.6. Root Dry Weight

The results on the effect of soil moisture stress levels and varieties on root dry weight of fodder cowpea in open and shade are presented in Table 6 & 7. Soil moisture stress levels and varieties had significant effect on root dry weight in open and shade. Significantly higher root dry weight (0.72 g) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4) in open. COFC-8 (V_4) recorded higher root dry weight of 0.80 g in open. M x V interaction was significant and COFC-8 irrigated at IW/CPE ratio of 0.8 (m_4v_4) recorded higher root dry weight of 0.99 g in open.

Significantly higher root dry weight (0.43 g) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4) in shade. COFC-8 (V_4) recorded higher root dry weight of 0.41g in shade. M x V interaction was significant and Bundel Lobia-1 irrigated at IW/CPE ratio of 0.8 (m_4v_3) recorded higher root dry weight (0.55 g) in partial shade.

4.2. YIELD PARAMETERS

4.2.1. Green Fodder Yield

The data on green fodder yield is presented in Table 8 & 9. Soil moisture stress levels, varieties and their interaction had significant effect on green fodder yield in open condition. Significantly higher green fodder yield was recorded by irrigation at IW/CPE ratio of 0.8 (M_4) (24.83 t ha^{-1}) followed by irrigating at IW/CPE ratio of 0.6 (M_3) (21.46 t ha^{-1}). The least green fodder yield was produced at life saving irrigation (M_1). Among the varieties, COFC-8 (V_4) recorded significantly higher green fodder yield of 24.21 t ha^{-1}, followed by UPC-

622 (V_2) (21.36 t ha^{-1}) and Bundel Lobia-1(V_3) (20.34 t ha^{-1}). The interaction effect between soil moisture stress levels and varieties was significant with m_4v_4 (COFC-8 irrigated at IW/CPE ratio of 0.8) recording significantly higher green fodder yield (29.24 t ha^{-1}), followed by m_4v_2 (UPC-622 irrigated at IW/CPE ratio of 0.8) (27.00 t ha^{-1}) which was on par with m_4v_3 (Bundel Lobia-1 irrigated at IW/CPE ratio of 0.8) (26.72 t ha^{-1}).

Soil moisture stress levels and varieties had significant influence on green fodder yield under 25-35 per cent shade. Irrigation at IW/CPE ratio of 0.8 (M_4) recorded highest green fodder yield (11.80 t ha^{-1}) which was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (11.44 t ha^{-1}). Life saving irrigation (M_1) produced least green fodder yield under shaded condition. Among the varieties tested, COFC-8 (V_4) produced significantly higher green fodder yield (11.5 t ha^{-1}), followed by UPC-618 (V_1) (10.80 t ha^{-1}). The least green fodder yield was recorded by the variety CO-5 (V_5). Perusal of the interaction effect showed that, m_4v_4 (COFC-8 irrigated at IW/CPE ratio of 0.8) produced the highest green fodder yield of 13.76 t ha^{-1} which was on par with m_3v_4 (COFC-8 irrigated at IW/CPE ratio of 0.6) (13.48 t ha^{-1}).

4.2.2. Dry Fodder Yield

Among the moisture stress levels, significantly higher dry fodder yield was recorded by irrigation at IW/CPE ratio of 0.8 (M_4) (4.72 t ha^{-1}) followed by irrigation at IW/CPE ratio of 0.6 (M_3) (4.01 t ha^{-1}). Life saving irrigation (M_1) produced least dry fodder yield. Among the varieties, COFC-8 (V_4) registered significantly higher dry fodder yield of 4.24 t ha^{-1}, followed by UPC-622 (V_2) (3.73 t ha^{-1}) and Bundel Lobia-1(V_3) (3.61 t ha^{-1}). The interaction effect was not significant.

Under 25-35 per cent shade, irrigation at IW/CPE ratio of 0.8 (M_4) recorded significantly higher dry fodder yield (2.20 t ha^{-1}) which was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (2.10 t ha^{-1}). Least dry fodder yield was produced by

Table 8. Effect of soil moisture stress levels and varieties on green fodder yield and dry fodder yield of fodder cowpea, t ha^{-1}

Treatments	Green fodder yield		Dry fodder yield	
	Open	Shade	Open	Shade
Soil moisture stress levels (M)				
M_1- Life saving	15.67	7.44	2.45	1.14
M_2- IW/CPE = 0.4	17.91	8.59	2.88	1.35
M_3- IW/CPE = 0.6	21.46	11.44	4.01	2.10
M_4- IW/CPE = 0.8	24.83	11.80	4.72	2.20
SEm (±)	0.236	0.331	0.148	0.066
CD (0.05)	0.378	0.531	0.237	0.106
Varieties (V)				
V_1 - UPC 618	18.93	11.00	3.34	1.87
V_2 - UPC 622	21.36	9.76	3.73	1.67
V_3- Bundel lobia-1	20.34	9.33	3.61	1.63
V_4 - COFC -8	24.21	11.50	4.24	1.99
V_5 - CO-5	15.01	7.70	2.65	1.34
SEm (±)	0.274	0.290	0.135	0.048
CD (0.05)	0.390	0.413	0.192	0.069

Table 9. Interaction effect of soil moisture stress levels and varieties on green fodder yield and dry fodder yield of fodder cowpea, t ha^{-1}

Treatments	Green fodder yield		Dry fodder yield	
	Open	Shade	Open	Shade
M x V				
m_1v_1	14.68	8.07	2.30	1.24
m_1v_2	16.76	7.28	2.59	1.10
m_1v_3	15.84	7.24	2.50	1.12
m_1v_4	19.88	8.56	3.10	1.31
m_1v_5	11.20	6.04	1.76	0.94
m_2v_1	16.88	9.56	2.72	1.51
m_2v_2	18.04	8.40	2.87	1.30
m_2v_3	17.32	8.00	2.81	1.27
m_2v_4	22.24	10.20	3.57	1.60
m_2v_5	15.08	6.80	2.44	1.07
m_3v_1	21.16	12.64	3.95	2.32
m_3v_2	23.63	11.48	4.38	2.09
m_3v_3	21.48	10.84	4.04	2.01
m_3v_4	25.48	13.48	4.75	2.48
m_3v_5	15.56	8.76	2.92	1.62
m_4v_1	23.00	12.92	4.37	2.41
m_4v_2	27.00	11.88	5.08	2.19
m_4v_3	26.72	11.24	5.12	2.11
m_4v_4	29.24	13.76	5.55	2.56
m_4v_5	18.20	9.20	3.47	1.73
SE m (+)	0.274	0.290	0.135	0.048
CD (0.05)	0.784	0.830	NS	NS

life saving irrigation (M_1). Among the varieties, COFC-8 (V_4) produced significantly higher dry fodder yield (1.99 t ha^{-1}) followed by UPC-618 (V_1) (1.87 t ha^{-1}). The variety CO-5 (V_5) recorded lowest dry fodder yield. The interaction effect was not significant.

4.3. PHYSIOLOGICAL OBSERVATIONS

The data on physiological observations like leaf area index, specific leaf area and leaf dry weight $plant^{-1}$ of fodder cowpea in open and shaded condition are given in the Table 10 & 11 and that of relative water content, leaf water potential and osmotic potential are given in Table 12 & 13.

4.3.1. Dry Matter Production

The data on dry matter production of fodder cowpea in open and shade is presented in Table 10 & 11. Soil moisture stress levels, varieties and their interaction had significant effect on dry matter production in open condition. Significantly higher dry matter production (8.14 t ha^{-1}) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4) in open condition. Among the varieties, COFC-8 (V_4) recorded significantly higher dry matter production of 7.98 t ha^{-1}, followed by UPC-622 (V_2) (7.02 t ha^{-1}). The interaction effect between soil moisture stress levels and varieties was significant with m_4v_4 (COFC-8 irrigated at IW/CPE ratio of 0.8) recording significantly higher dry matter production (9.66 t ha^{-1}) in open condition.

Soil moisture stress levels and varieties had significant effect on dry matter production under 25-35 per cent shade. Irrigation at IW/CPE ratio of 0.8 (M_4) recorded significantly higher dry matter production (3.87 t ha^{-1}) followed by irrigation at IW/CPE ratio of 0.6 (M_3) (3.08 t ha^{-1}). Among the varieties tested, COFC-8 (V_4) produced significantly higher dry matter production (3.53 t ha^{-1}), followed by UPC-618 (V_1) (3.39 t ha^{-1}). The interaction effect was not significant.

4.3.2. Leaf Area Index

The results on the effect of treatments on leaf area index presented in Table 10 & 11 showed significant variation with respect to soil moisture stress levels, varieties and their interaction in open condition. Significantly higher leaf area index (6.29) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4), followed by IW/CPE ratio of 0.6 (M_3) (5.37). Life saving irrigation (M_1) recorded the least leaf area index. Among the varieties, COFC-8 (V_4) recorded significantly higher leaf area index (6.00), followed by UPC-622 (V_2) (5.43). The interaction effect between soil moisture stress levels and varieties was significant and m_4v_4 (COFC-8 irrigated at IW/CPE ratio of 0.8) recorded significantly higher leaf area index (7.24), followed by m_4v_2 (UPC-622 irrigated at IW/CPE ratio of 0.8) (6.76).

The soil moisture stress levels and varieties had significant influence on leaf area index under 25-35 per cent shade. Irrigation at IW/CPE ratio of 0.8 (M_4) recorded higher leaf area index (3.01) which was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (2.86). Least leaf area index was recorded by life saving irrigation (M_1). Among the varieties, COFC-8(V_4) produced significantly higher leaf area index (3.03), followed by UPC-618 (V_1) (2.70). The interaction effect, m_4v_4 (COFC-8 irrigated at IW/CPE ratio of 0.8) recorded highest leaf area index (3.44) which was on par with m_3v_4 (3.34), m_2v_4 (3.34) and m_4v_1 (3.23).

4.3.3. Specific Leaf Area

The specific leaf area of fodder cowpea was not influenced by soil moisture stress level, varieties and their interaction.

4.3.4. Leaf dry weight

The results on the effect of soil moisture stress levels and varieties on leaf dry weight plant^{-1} are presented in Table 11 & 12. While the varietal variation was not significant, the variation due to the soil moisture stress levels and the interaction effect was significant in open condition. Significantly higher leaf dry weight plant^{-1} (3.73 g plant^{-1}) was recorded by irrigation at IW/CPE ratio of

Table 10. Effect of soil moisture stress levels and varieties on dry matter production, leaf area index, specific leaf area and leaf dry weight of fodder cowpea

Treatments	Dry matter production (t ha^{-1})		Leaf area index		Specific leaf area (cm^2 g^{-1})		Leaf dry weight (g $plant^{-1}$)	
	Open	Shade	Open	Shade	Open	Shade	Open	Shade
Soil moisture stress levels (M)								
M_1- Life saving	5.21	2.51	4.03	1.84	311.18	312.66	2.97	1.52
M_2- IW/CPE = 0.4	5.90	2.77	4.54	2.43	311.17	312.97	3.08	1.05
M_3- IW/CPE = 0.6	7.05	3.08	5.37	2.86	311.77	314.26	3.64	1.76
M_4- IW/CPE = 0.8	8.14	3.87	6.29	3.01	313.46	314.24	3.73	2.16
SEm (±)	0.334	0.074	0.052	0.106	1.438	0.872	0.144	0.197
CD (0.05)	0.119	0.193	0.084	0.171	NS	NS	0.231	0.316
Varieties (V)								
V_1 - UPC 618	6.26	3.39	4.73	2.70	311.37	312.24	3.31	1.69
V_2 - UPC 622	7.02	2.96	5.43	2.47	311.45	313.13	3.53	1.65
V_3- Bundel lobia-1	6.67	2.96	5.10	2.37	311.32	314.20	3.26	1.56
V_4 - COFC -8	7.98	3.53	6.00	3.03	316.04	316.71	3.56	1.77
V_5 - CO-5	4.94	2.46	4.04	2.13	309.28	311.39	3.13	1.45
SEm (±)	0.031	0.031	0.071	0.072	0.676	0.802	0.051	0.191
CD (0.05)	0.125	0.191	0.102	0.104	NS	NS	NS	NS

Table 11. Interaction effect of soil moisture stress levels and varieties on dry matter production, leaf area index, specific leaf area and leaf dry weight of fodder cowpea

Treatments	Dry matter production (t ha^{-1})		Leaf area index		Specific leaf area (cm^2 g^{-1})		Leaf dry weight (g plant^{-1})	
	Open	Shade	Open	Shade	Open	Shade	Open	Shade
M x V								
m_1v_1	4.9	2.87	3.65	2.02	310.13	311.13	2.81	1.38
m_1v_2	5.6	2.44	4.19	1.82	313.16	311.21	2.87	1.76
m_1v_3	5.21	2.52	4.03	1.83	310.92	314.05	2.72	1.34
m_1v_4	6.58	2.7	4.95	1.99	313.79	316.68	4.06	1.77
m_1v_5	3.74	2.03	3.36	1.57	307.89	310.68	2.39	1.37
m_2v_1	5.59	3.16	4.22	2.40	309.89	311.83	1.83	1.20
m_2v_2	5.99	2.53	4.80	2.11	314.17	312.03	3.57	1.07
m_2v_3	5.67	2.45	4.34	2.11	310.32	313.62	3.68	0.77
m_2v_4	7.32	3.37	5.46	3.34	313.55	315.82	3.25	1.07
m_2v_5	4.95	2.37	3.88	2.21	307.92	311.55	3.07	1.15
m_3v_1	7.01	3.32	5.29	3.17	312.23	312.96	4.34	2.03
m_3v_2	7.68	3.02	5.96	2.88	308.23	314.66	3.92	1.55
m_3v_3	6.98	3.16	5.36	2.71	311.89	314.82	3.31	1.69
m_3v_4	8.36	3.52	6.36	3.34	318.40	317.00	3.73	1.78
m_3v_5	5.22	2.39	3.89	2.21	308.10	311.86	2.90	1.75
m_4v_1	7.57	4.22	5.75	3.23	313.25	313.05	4.25	2.15
m_4v_2	8.8	3.88	6.76	3.06	310.25	314.60	3.75	2.24
m_4v_3	8.82	3.7	6.69	2.82	312.17	314.32	3.32	2.44
m_4v_4	9.66	4.52	7.24	3.44	318.42	317.32	3.18	2.46
m_4v_5	5.85	3.05	5.04	2.52	313.23	311.92	4.15	1.53
SEm (±)	0.031	0.031	0.071	0.072	0.676	0.802	0.051	0.191
CD (0.05)	0.252	NS	0.205	0.208	NS	NS	0.647	NS

0.8 (M_4) which was on par with that of irrigation at IW/CPE ratio of 0.6 (M_3) (3.64 g plant^{-1}). The results on the interaction effect showed that m_3v_1 (UPC-618 irrigated at IW/CPE ratio of 0.6), recorded higher leaf weight (4.34 g plant^{-1}) which was on par with m_3v_4 (3.73 g plant^{-1}), m_3v_2 (3.92 g plant^{-1}), m_4v_1 (4.25 g plant^{-1}), m_4v_5 (4.15 g plant^{-1}) and m_1v_4 (4.06 g plant^{-1}).

Under 25-35 % shade, the leaf dry weight plant^{-1} of fodder cowpea irrigated at IW/CPE ratio of 0.8 (M_4) was significantly higher (2.16 g plant^{-1}). The varieties and the interaction of moisture stress levels and varieties had no significant effect on the leaf weight of fodder cowpea in 25-35 per cent shade.

4.3.5. Relative Water Content

The data on relative water content is presented in Table 12 & 13. Significantly higher relative water content (83.43 per cent) was recorded by irrigating at IW/CPE ratio of 0.8 (M_4) in open condition. Among the varieties, COFC-8 (V_4) registered significantly higher relative water content (83.17 per cent) which was followed by UPC-622 (V_2) (81.90 per cent). The interaction effect was non-significant.

In partial shade, irrigation at IW/CPE ratio of 0.8 (M_4) registered significantly higher relative water content of 84.26 per cent. Among the varieties COFC-8 (V_4) registered significantly higher relative water content (84.38 per cent) followed by UPC-618 (V_1) (83.06 per cent). The interaction effect was not significant.

4.3.6. Leaf Water Potential

The results on the effect of soil moisture stress levels and varieties and their interaction on the leaf water potential of fodder cowpea in open and shaded conditions are presented in Table 12 & 13.

The perusal of the data showed that soil moisture stress levels, varieties and their interaction had significant effect on leaf water potential of fodder cowpea in open and shaded conditions. Irrigating at IW/CPE ratio of 0.8 (M_4) recorded

Table 12. Effect of soil moisture stress levels and varieties on relative water content, leaf water potential and osmotic potential of fodder cowpea

Treatments	Relative water content (%)		Leaf water potential (MPa)		Osmotic potential (m moles kg^{-1})	
	Open	Shade	Open	Shade	Open	Shade
Soil moisture stress levels (M)						
M_1- Life saving	78.10	79.50	-0.97	-1.33	456.00	396.40
M_2- IW/CPE = 0.4	80.50	81.30	-0.96	-1.30	466.60	400.20
M_3- IW/CPE = 0.6	81.83	83.56	-0.94	-1.19	471.40	413.00
M_4- IW/CPE = 0.8	83.43	84.26	-0.89	-1.15	477.00	421.60
SEm (±)	0.231	0.231	0.003	0.005	1.421	1.752
CD (0.05)	0.533	0.526	0.005	0.008	2.273	2.803
Varieties (V)						
V_1 - UPC 618	80.57	83.06	-0.92	-1.22	469.25	408.00
V_2 - UPC 622	81.90	81.94	-0.93	-1.23	467.75	412.00
V_3- Bundel lobia-1	80.84	81.87	-0.93	-1.23	469.75	412.50
V_4 - COFC -8	83.17	84.38	-0.93	-1.22	462.25	392.00
V_5 - CO-5	78.34	79.54	-0.99	-1.31	470.75	414.50
SEm (±)	0.258	0.258	0.004	0.006	1.889	1.866
CD (0.05)	0.520	0.519	0.006	0.008	2.685	2.654

Table 13. Interaction effect of soil moisture stress levels and varieties on relative water content, leaf water potential and osmotic potential of fodder cowpea

Treatments	Relative water content (%)		Leaf water potential (MPa)		Osmotic Potential (m moles kg^{-1})	
	Open	Shade	Open	Shade	Open	Shade
M x V						
m_1v_1	77.50	80.50	-0.96	-1.25	457.00	386.00
m_1v_2	78.50	78.50	-0.96	-1.30	453.00	399.00
m_1v_3	78.50	78.50	-0.98	-1.35	460.00	400.00
m_1v_4	80.50	82.50	-0.96	-1.30	450.00	364.00
m_1v_5	75.50	77.50	-0.99	-1.45	460.00	433.00
m_2v_1	80.50	82.25	-0.94	-1.26	467.00	390.00
m_2v_2	81.50	81.25	-0.99	-1.34	469.00	408.00
m_2v_3	80.50	81.25	-0.96	-1.25	469.00	410.00
m_2v_4	82.50	83.50	-0.94	-1.26	463.00	370.00
m_2v_5	77.50	78.25	-0.99	-1.42	472.00	423.00
m_3v_1	81.21	84.50	-0.93	-1.23	470.00	414.00
m_3v_2	83.25	83.75	-0.90	-1.17	470.00	417.00
m_3v_3	81.25	83.75	-0.93	-1.17	474.00	417.00
m_3v_4	84.21	85.50	-0.91	-1.16	469.00	397.00
m_3v_5	79.25	80.40	-1.01	-1.21	476.00	420.00
m_4v_1	83.07	85.01	-0.83	-1.16	482.00	421.00
m_4v_2	84.35	84.25	-0.87	-1.14	473.00	422.00
m_4v_3	83.12	84.00	-0.86	-1.15	487.00	422.00
m_4v_4	85.50	86.02	-0.91	-1.16	469.00	420.00
m_4v_5	81.10	82.04	-0.97	-1.16	487.00	425.00
SEm (±)	0.530	0.516	0.004	0.006	1.889	1.866
CD (0.05)	NS	NS	0.012	0.017	5.39	5.33

significantly higher leaf water potential of - 0.89 MPa under open. Among the varieties, UPC-618 (V1) recorded higher leaf water potential (-0.92 MPa) which was on par with all other varieties except CO-5. The interaction effect of m_4v_1 produced significantly higher leaf water potential of -0.83 MPa.

Under partial shade, irrigating at IW/CPE ratio of 0.8 resulted in significantly higher leaf water potential of -1.15 MPa. All varieties except CO-5 were on par and the interaction effect of m_3v_4 (1.16), m_4v_1 (1.16), m_4v_2 (1.14), m_4v_3 (1.15), m_4v_4 (1.16) and m_4v_5 (1.16) were also on par with respect to leaf water potential.

4.3.7. Osmotic Potential

The result on the effect of soil moisture stress levels and varieties on osmotic potential of fodder cowpea in open and shaded conditions are presented in Table 12 & 13.

The data showed that soil moisture stress levels, varieties and their interaction had significant effect on osmotic potential of fodder cowpea in open and shaded conditions. Irrigation at IW/CPE ratio of 0.8 (M_4) recorded significantly higher osmotic potential of 477 m moles kg^{-1} under open. Among the varieties, COFC-8 (V_4) registered a lower osmotic potential in all the soil moisture stress levels. Significantly lower osmotic potential was registered by m_1v_4 (COFC-8 at life saving irrigation) (450 m moles kg^{-1}) in open, it was on par with m_1v_2 (UPC-622 at life saving irrigation) (453 m moles kg^{-1}).

Under partial shade, irrigation at IW/CPE ratio of 0.8 resulted in higher osmotic potential in fodder cowpea (421.60 m moles kg^{-1}). Among the varieties, COFC-8 recorded the lowest osmotic potential of 392 m moles kg^{-1}. Significantly lower osmotic potential was registered by m_1v_4 (COFC-8 at life saving irrigation) (364 m moles kg^{-1}).

4.3.8. Stable Isotope Discrimination ($_{13}C$) Studies

The results of the effect of soil moisture stress levels and varieties on stable isotope discrimination of fodder cowpea in open and shaded condition are presented in Table 14 & 15. Both the treatments had significant impact on stable isotope discrimination of fodder cowpea in both conditions. In open condition, significantly lower carbon isotope discrimination ratio (CID) (18.99) was recorded by irrigating at IW/CPE ratio of 0.4 (M_2), followed by irrigation at IW/CPE ratio 0.6(M_3) (19.14) which was on par with IW/CPE ratio of 0.8(M_4) (19.18). Among the varieties COFC-8 (V_4) recorded significantly lower CID ratio (17.98) followed by UPC-622 (V_2) (19.34) which was on par with Bundel Lobia-1 (V_3) (19.53). The interaction effect was non-significant.

Under 25-35 per cent shaded condition both the treatments had significant influence on CID ratio of fodder cowpea. Significantly lower CID ratio (20.40) was recorded by irrigation at IW/CPE ratio of 0.6 (M_3) followed by irrigation at IW/CPE ratio of 0.8 (M_4) (21.91) which was on par with irrigation at IW/CPE ratio of 0.4 (M_2) (21.91). Among the varieties COFC-8(V_4) recorded significantly lower CID ratio (20.46) which was on par with UPC-618(V_1) (20.84). The interaction effect was non-significant.

4.3.9. Water Use Efficiency

The results on the effect of soil moisture stress levels and varieties on water use efficiency of fodder cowpea in open and shaded condition are presented in Table 14 & 15.

The effects of treatments are significant with respect to water use efficiency of fodder cowpea in open condition. Significantly higher water use efficiency (42.95 kg ha^{-1} mm^{-1}) was recorded by irrigation at IW/CPE ratio of 0.4 (M_2) which was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (41.31 kg $ha^{-1}mm^{-1}$). Among the varieties, COFC-8 (V_4) recorded significantly higher WUE (48.03 kg ha^{-1} mm^{-1}) followed by UPC-622 (V_2) (41.64 kg ha^{-1} mm^{-1}). The interaction effect was non-significant.

Table 14. Effect of soil moisture stress levels and varieties on stable isotope discrimination ($_{13}C$) and water use efficiency (WUE) of fodder cowpea

Treatments	Stable isotope discrimination		Water use efficiency (kg $ha^{-1}mm^{-1}$)	
	Open	Shade	Open	Shade
Soil moisture stress levels (M)				
M_1- Life saving	20.19	22.50	36.55	17.00
M_2- IW/CPE = 0.4	18.99	21.91	42.95	20.07
M_3- IW/CPE = 0.6	19.14	20.40	41.31	21.65
M_4- IW/CPE = 0.8	19.18	21.91	37.14	17.31
SEm (±)	0.546	0.293	1.249	0.671
CD (0.05)	0.874	0.469	1.999	1.073
Varieties (V)				
V_1 - UPC 618	19.98	20.84	37.53	20.95
V_2 - UPC 622	19.34	21.28	41.64	18.63
V_3- Bundel lobia-1	19.53	21.63	40.26	18.21
V_4 - COFC -8	17.98	20.46	48.03	22.24
V_5 - CO-5	20.81	22.85	29.99	15.01
SEm (±)	0.344	0.356	1.460	0.545
CD (0.05)	0.49	0.506	2.076	0.775

Table 15. Interaction effect of soil moisture stress levels and varieties on stable isotope discrimination ($_{13}C$) and water use efficiency (WUE) of fodder cowpea

Treatments	Stable isotope discrimination		Water use efficiency (kg ha^{-1}mm^{-1})	
	Open	Shade	Open	Shade
M x V				
m_1v_1	20.71	22.20	34.33	18.49
m_1v_2	20.11	22.80	38.66	16.39
m_1v_3	20.15	22.33	37.27	16.70
m_1v_4	18.16	21.49	46.25	19.55
m_1v_5	21.83	23.72	26.26	13.88
m_2v_1	19.65	20.35	40.63	22.42
m_2v_2	19.94	20.17	42.75	19.37
m_2v_3	18.94	21.20	41.78	18.84
m_2v_4	17.31	20.11	53.23	23.78
m_2v_5	20.10	22.30	36.30	15.94
m_3v_1	19.43	19.62	40.72	23.92
m_3v_2	18.58	20.43	45.12	21.55
m_3v_3	19.29	20.79	41.64	20.68
m_3v_4	17.82	19.33	48.99	25.47
m_3v_5	20.6	21.84	30.68	16.65
m_4v_1	20.11	21.19	34.43	18.96
m_4v_2	19.74	21.73	40.01	17.23
m_4v_3	19.72	22.22	40.28	16.63
m_4v_4	18.61	20.91	43.64	20.16
m_4v_5	20.70	23.52	27.34	30.58
SEm (±)	0.344	0.356	1.460	0.545
CD (0.05)	NS	NS	NS	NS

Under 25-35 per cent shade, significantly higher WUE (21.65 kg ha^{-1} mm^{-1}) was recorded by irrigation at IW/CPE ratio of 0.6 (M_3) followed by irrigation at IW/CPE ratio of 0.4 (M_2) (20.07 kg ha^{-1} mm^{-1}). Among the varieties, COFC-8 (V_4) recorded higher WUE of 22.24 kg $ha^{-1}mm^{-1}$ followed by UPC-618 (V_1) (20.95 kg ha^{-1} mm^{-1}). The interaction effect was non-significant.

4.4. BIOCHEMICAL STUDIES

Data on mean values of chlorophyll content and proline content of fodder cowpea are given in Table 16 & 17.

4.4.1. Chlorophyll Content

The results revealed that the treatments influenced on the chlorophyll content of fodder cowpea in open condition. Significantly higher chlorophyll content (2.16 mg g^{-1}) was registered by irrigation at IW/CPE ratio of 0.8 (M_4) followed by IW/CPE ratio of 0.6 (M_3) (1.99 mg g^{-1}). COFC-8 (V_4) recorded significantly higher chlorophyll content (1.98 mg g^{-1}) followed by Bundel Lobia-1 (V_3) (1.85 mg g^{-1}) which was on par with UPC-618 (V_1) (1.80 mg g^{-1}). The interaction effect was non-significant.

The soil moisture stress levels and varieties had significant influence on chlorophyll content of fodder cowpea under 25-35 per cent shade. Significantly higher chlorophyll content (2.59 mg g^{-1}) was registered by irrigation at IW/CPE ratio of 0.8 (M_4) followed by irrigation at IW/CPE ratio of 0.6 (M_3) (2.44 mg g^{-1}). Among the varieties, COFC-8 (V_4) recorded significantly higher chlorophyll content (2.5 mg g^{-1}) followed by Bundel Lobia-1 (V_3) (2.35 mg g^{-1}) which was on par with UPC-622 (V_2) (2.32 mg g^{-1}). The interaction effect was non-significant.

4.4.2. Proline Content

The results of the effect of soil moisture stress levels and varieties on proline content of fodder cowpea in open and shaded condition are presented in Table 16 & 17. In open condition, significantly higher proline content was

Table 16. Effect of soil moisture stress levels and varieties on chlorophyll content and proline content of fodder cowpea

Treatments	Chlorophyll content (mg g^{-1} FW)		Proline content (μ mole g^{-1})	
	Open	Shade	Open	Shade
Soil moisture stress levels (M)				
M_1- Life saving	1.46	2.11	1.20	1.19
M_2- IW/CPE = 0.4	1.66	2.24	1.18	1.18
M_3- IW/CPE = 0.6	1.99	2.44	1.06	1.07
M_4- IW/CPE = 0.8	2.16	2.59	1.03	1.03
SEm (±)	0.058	0.036	0.017	0.032
CD (0.05)	0.093	0.059	0.005	0.021
Varieties (V)				
V_1 - UPC 618	1.80	2.31	1.13	1.12
V_2 - UPC 622	1.77	2.32	1.12	1.12
V_3- Bundel lobia-1	1.85	2.35	1.12	1.11
V_4 - COFC -8	1.98	2.50	1.15	1.13
V_5 - CO-5	1.69	2.24	1.08	1.10
SEm (±)	0.073	0.048	0.027	0.047
CD (0.05)	0.104	0.068	0.005	NS

Table 17. Interaction effect of soil moisture stress levels and varieties on chlorophyll content and proline content of fodder cowpea

Treatments	Chlorophyll content (mg g^{-1} FW)		Proline content (μ mole g^{-1})	
	Open	Shade	Open	Shade
M x V				
m_1v_1	1.47	2.07	1.21	1.16
m_1v_2	1.40	2.09	1.20	1.20
m_1v_3	1.53	2.16	1.20	1.20
m_1v_4	1.57	2.18	1.23	1.22
m_1v_5	1.34	1.97	1.17	1.18
m_2v_1	1.66	2.26	1.19	1.18
m_2v_2	1.58	2.24	1.18	1.18
m_2v_3	1.63	2.23	1.18	1.18
m_2v_4	1.99	2.34	1.21	1.19
m_2v_5	1.46	2.14	1.16	1.18
m_3v_1	1.96	2.54	1.08	1.12
m_3v_2	1.98	2.60	1.06	1.07
m_3v_3	2.15	2.60	1.05	1.05
m_3v_4	2.02	2.64	1.11	1.08
m_3v_5	1.83	2.55	1.01	1.06
m_4v_1	2.12	2.37	1.04	1.02
m_4v_2	2.11	2.33	1.03	1.03
m_4v_3	2.11	2.41	1.03	1.03
m_4v_4	2.34	2.83	1.05	1.04
m_4v_5	2.13	2.28	0.99	1.01
SEm (±)	0.073	0.048	0.027	0.047
CD (0.05)	NS	NS	NS	NS

recorded by lifesaving irrigation (M_1) in open (1.20 μ mol g^{-1}). Among the varieties, COFC-8 (V_4) registered a higher proline content (1.15 μ mol g^{-1}) followed by UPC-618 (V_1) (1.13 μ mol g^{-1}) in open condition. The interaction effect was not significant.

In partial shade also, lifesaving irrigation recorded significantly higher proline content of 1.19 μ mol g^{-1} while the effect of varieties and interaction were non-significant.

4.5. QUALITY STUDIES

The results on the effect of soil moisture stress levels, varieties and their interaction with respect to quality aspects such as crude protein content, crude fibre content and crude protein yield are presented in Table 18 & 19.

4.5.1. Crude Protein Content

The results revealed that soil moisture stress didn't affect the crude protein content of fodder cowpea in open. COFC-8 (V_4) registered significantly higher crude protein content of 18.76 per cent, followed by Bundel Lobia-1 (V_3) (18.13 per cent). The interaction effect of soil moisture stress and varieties was not significant.

Under 25-35 per cent shade, soil moisture stress levels, varieties and their interaction had significant effect on crude protein content of fodder cowpea. Significantly higher crude protein content (19.13 per cent) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4) which was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (19.07 per cent). Among the varieties, COFC-8(V_4) recorded significantly higher crude protein content (20.81 per cent) followed by Bundel Lobia-1 (V_3) (18.95). Variety COFC-8 recorded significantly higher crude protein content of 20.84 per cent at soil moisture deficit level of IW/CPE ratio of 0.8 (m_4v_4) which was on par with m_1v_4 (20.78 %), m_2v_4 (20.81 %) and m_3v_4 (20.82 %).

4.5.2. Crude Fiber Content

The data on the effect of soil moisture stress levels and varieties on crude fiber content of fodder cowpea in open and shaded condition are presented in Table 18 & 19.

The results revealed that soil moisture stress didn't influence the crude fibre content while varieties had significant effect in open condition. Significantly lower crude fibre content was recorded by UPC-622 (V_2) (24.18 per cent).

Under 25-35 per cent shade, the treatments and their interaction failed to exert significant effect on the crude fibre content of fodder cowpea.

4.5.3. Crude Protein Yield

On perusal of the data presented in Table 18 & 19, it was observed that soil moisture stress levels and varieties had significant effect on crude protein yield of fodder cowpea. Irrigation at IW/CPE ratio of 0.8 (M_4) recorded significantly higher crude protein yield (0.85 t ha^{-1}), followed by irrigation at IW/CPE ratio 0.6 (M_3) (0.73 t ha^{-1}). Among the varieties, COFC-8 (V_4) recorded significantly higher crude protein yield (0.79 t ha^{-1}). The interaction was found to be non significant.

Crude protein yield recorded in shaded condition with respect to the soil moisture stress levels varied significantly with M_4 (irrigation at IW/CPE ratio of 0.8) recording the highest crude protein yield (0.42 t ha^{-1}) which was on par with that of M_3 (0.40 t ha^{-1}). Among the varieties, COFC-8 (V_4) recorded significantly higher crude protein yield of 0.41 t ha^{-1}. Among the treatment combinations, COFC-8 irrigated at IW/CPE of 0.8 recorded significantly higher crude protein yield of 0.54 t ha^{-1} which was on par with COFC-8 irrigated at IW/CPE ratio of 0.6 (0.52 t ha^{-1}).

Table 18. Effect of soil moisture stress levels and varieties on crude fibre content, crude protein content and crude protein yield of fodder cowpea

Treatments	Crude protein content (%)		Crude fibre content (%)		Crude protein yield (t ha^{-1})	
	Open	Shade	Open	Shade	Open	Shade
Soil moisture stress levels (M)						
M_1- Life saving	18.01	19.00	24.94	24.59	0.45	0.22
M_2- IW/CPE = 0.4	18.04	18.96	24.80	24.55	0.52	0.26
M_3- IW/CPE = 0.6	18.10	19.07	24.76	24.51	0.73	0.40
M_4- IW/CPE = 0.8	18.11	19.13	24.92	24.08	0.85	0.42
SEm (±)	0.072	0.039	0.091	0.450	0.027	0.013
CD (0.05)	NS	0.063	NS	NS	0.044	0.022
Varieties (V)						
V_1 - UPC 618	17.95	18.47	24.45	24.1	0.59	0.34
V_2 - UPC 622	17.81	18.61	24.18	23.93	0.66	0.31
V_3- Bundel lobia-1	18.13	18.95	25.63	25.20	0.66	0.31
V_4 - COFC -8	18.76	20.81	24.50	24.13	0.79	0.41
V_5 - CO-5	17.69	18.35	25.50	24.80	0.46	0.25
SEm (±)	0.074	0.057	0.134	0.541	0.025	0.010
CD (0.05)	0.106	0.081	0.191	NS	0.036	0.014

Table 19. **Interaction effect of soil moisture stress levels and varieties on crude fibre content, crude protein content and crude protein yield of fodder cowpea**

Treatments	Crude protein content (%)		Crude fibre content (%)		Crude protein yield (t ha^{-1})	
	Open	Shade	Open	Shade	Open	Shade
M x V						
m_1v_1	17.92	18.43	24.65	24.3	0.41	0.23
m_1v_2	17.97	18.43	24.30	24.00	0.46	0.20
m_1v_3	18.22	18.83	25.70	25.25	0.45	0.21
m_1v_4	18.72	20.78	24.65	24.2	0.58	0.27
m_1v_5	17.67	18.53	25.40	25.2	0.31	0.17
m_2v_1	17.97	18.51	24.45	24.12	0.48	0.28
m_2v_2	18.11	18.64	23.97	23.85	0.51	0.24
m_2v_3	18.78	19.01	25.47	25.15	0.50	0.24
m_2v_4	17.72	20.81	24.57	24.2	0.67	0.33
m_2v_5	17.70	18.34	25.52	25.42	0.43	0.20
m_3v_1	18.12	18.40	24.3	23.9	0.71	0.43
m_3v_2	17.68	18.65	24.02	23.8	0.77	0.39
m_3v_3	17.98	18.89	25.65	25.7	0.72	0.38
m_3v_4	18.73	20.82	24.35	24.22	0.89	0.52
m_3v_5	17.96	18.03	25.5	25.57	0.52	0.30
m_4v_1	17.79	18.53	24.42	24.07	0.77	0.44
m_4v_2	17.62	18.73	24.42	24.1	0.89	0.41
m_4v_3	18.18	19.09	25.72	25.32	0.93	0.40
m_4v_4	18.79	20.84	24.42	23.92	1.04	0.54
m_4v_5	17.65	18.51	25.72	23	0.61	0.31
SEm (±)	0.074	0.057	0.134	0.541	0.025	0.010
CD(0.05)	NS	0.164	NS	NS	NS	0.028

4.6. PLANT ANALYSIS

The data on the uptake of nutrients by fodder cowpea is presented in Table 20 & 21.

4.6.1. Nitrogen Uptake

The results summarized in Table 20 & 21 revealed a significant effect for the treatments (soil moisture stress levels and varieties) on the uptake of nitrogen in open condition. Irrigation at IW/CPE ratio of 0.8 (M_4) recorded significantly higher nitrogen uptake (136.04 kg ha^{-1}). Among the varieties, COFC-8 (V_4) recorded significantly higher nitrogen uptake (127.29 kg ha^{-1}). The interaction between the treatments did not record any significant variation.

The results presented in Table 20 & 21 indicated that the treatments had a significant effect on the uptake of nitrogen in shaded condition. Significantly higher nitrogen uptake (66.01 kg ha^{-1}) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4) and was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (64.42 kg ha^{-1}). Among the varieties tested, COFC-8 (V_4) recorded significantly higher uptake of nitrogen (66.12 kg ha^{-1}) followed by UPC-618 (V_1) (53.88 kg ha^{-1}). The interaction effect was not significant.

4.6.2. Phosphorus Uptake

The data on the effect of soil moisture stress levels, varieties and their interaction on phosphorus uptake are presented in Table 20 & 21. On perusal of the results, it was observed that the treatments had significant effect on phosphorus uptake of fodder cowpea whereas the interaction effect was not significant both in open and shaded condition.

In open condition, significantly higher uptake of phosphorus (5.89 kg ha^{-1}) was recorded by irrigation at IW/CPE ratio of 0.8 (M_4). Among the varieties, COFC-8 (V_4) recorded significantly higher phosphorus uptake of 5.55 kg ha^{-1}, followed by Bundel Lobia-1 (V_3) (4.61 kg ha^{-1}).

In 25-35 per cent shade, irrigation at IW/CPE ratio of 0.8 (M_4) recorded significantly higher phosphorus uptake (2.80 kg ha^{-1}) which was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (2.62 kg ha^{-1}). Among the varieties, COFC-8 (V_4) recorded significantly higher phosphorus uptake (2.58 kg ha^{-1}) and was on par with that of UPC-618 (V_1) (2.32 kg ha^{-1}).

4.6.3. Potassium Uptake

Data summarized in Table 20 & 21 showed that potassium uptake varied significantly with soil moisture stress level in open condition. Irrigation at IW/CPE ratio of 0.8 (M_4) recorded significantly higher potassium uptake (32.91 kg ha^{-1}). Among the varieties COFC-8 (V_4) recorded significantly higher uptake of potassium (29.86 kg ha^{-1}) followed by UPC-622 (V_2) (26.59 kg ha^{-1}). The interaction effect was non-significant.

The potassium uptake in shaded condition under the four soil moisture stress levels varied significantly with M_4 (irrigation at IW/CPE ratio of 0.8) recording significantly higher potassium uptake (15.73 kg ha^{-1}). Among the varieties, COFC-8 (V_4) recorded significantly higher potassium uptake of 14.59 kg ha^{-1} followed by UPC-618 (V_1) (13.23 kg ha^{-1}). The interaction effect was significant and m_4v_4 (COFC-8 irrigated at IW/CPE ratio of 0.8) registered significantly higher potassium uptake of 19.40 kg ha^{-1} followed by m_3v_4 (COFC-8 irrigated at IW/CPE ratio of 0.6) (17.50 kg ha^{-1}).

4.6.4. Calcium Uptake

The results on calcium uptake are presented in Table 20 & 21. The results showed that the soil moisture stress levels and varieties had significant effect on calcium uptake in open and shaded condition while the interaction effect was non-significant.

Calcium uptake recorded in open condition under the four soil moisture stress levels varied significantly, with M_4 (Irrigation at IW/CPE ratio of 0.8) recording significantly higher calcium uptake (45.52 kg ha^{-1}). Among the varieties

Table 20. Effect of soil moisture stress levels and varieties on nitrogen uptake, phosphorus uptake, potassium uptake, calcium uptake and magnesium uptake of fodder cowpea, kg ha^{-1}

Treatments	Nitrogen uptake		Phosphorus uptake		Potassium uptake		Calcium uptake		Magnesium uptake	
	Open	Shade	Open	Shade	Open	Shade	Open	Shade	Open	Shade
Soil moisture stress levels (M)										
M_1- Life saving	71.18	34.82	3.14	1.41	16.88	8.09	23.56	11.20	15.55	7.71
M_2- IW/CPE = 0.4	83.58	41.42	3.48	1.66	20.33	9.61	27.65	13.32	18.20	9.04
M_3- IW/CPE = 0.6	115.96	64.42	5.14	2.62	28.87	14.74	38.66	20.81	25.35	14.40
M_4- IW/CPE = 0.8	136.04	66.01	5.89	2.80	32.91	15.73	45.52	21.72	29.93	14.86
SEm (±)	4.589	3.027	0.439	0.226	1.231	0.479	1.701	0.659	0.957	0.489
CD (0.05)	7.341	4.843	0.703	0.362	1.969	0.969	2.722	1.055	1.531	0.783
Varieties (V)										
V_1 - UPC 618	95.86	53.88	4.20	2.32	23.26	13.23	31.80	18.45	21.16	12.71
V_2 - UPC 622	106.01	49.76	4.51	2.08	26.59	11.74	35.96	16.37	23.75	11.28
V_3- Bundel lobia-1	104.41	49.28	4.61	2.01	26.04	11.40	34.71	16.15	24.44	11.12
V_4 - COFC -8	127.29	66.12	5.55	2.58	29.86	14.59	41.77	19.72	27.29	13.41
V_5 - CO-5	74.86	39.26	3.19	1.62	17.98	9.26	25.00	13.14	16.63	9.00
SEm (±)	3.957	2.213	0.412	0.204	0.880	0.408	1.345	0.482	0.936	0.385
CD (0.05)	5.626	3.147	0.586	0.290	1.252	0.580	1.912	0.686	1.331	0.548

Table 21. Interaction effect of soil moisture stress levels and varieties on nitrogen uptake, phosphorus uptake, potassium uptake, calcium uptake and magnesium uptake of fodder cowpea, kg ha^{-1}

Treatments	Nitrogen uptake		Phosphorus uptake		Potassium uptake		Calcium uptake		Magnesium uptake	
	Open	Shade	Open	Shade	Open	Shade	Open	Shade	Open	Shade
M x V										
m_1v_1	66.00	36.60	2.95	1.43	15.33	8.57	21.59	12.77	14.28	8.44
m_1v_2	74.47	32.37	3.10	1.48	17.80	7.86	24.84	10.65	16.82	7.49
m_1v_3	72.80	33.30	3.14	1.20	17.80	7.89	23.98	11.02	15.74	7.41
m_1v_4	92.83	43.67	4.50	1.81	22.05	9.64	30.64	12.89	19.82	8.94
m_1v_5	49.77	27.65	1.98	1.12	11.43	6.61	16.74	9.23	11.06	6.24
m_2v_1	78.21	44.47	3.47	1.84	19.20	10.84	26.13	14.99	17.42	9.75
m_2v_2	82.35	38.87	3.23	1.62	20.27	8.82	27.21	12.74	18.62	8.43
m_2v_3	81.27	38.55	3.67	1.47	20.25	8.99	26.93	12.41	17.39	8.69
m_2v_4	107.1	53.02	3.92	2.08	25.57	11.87	35.11	16.08	22.46	11.00
m_2v_5	68.95	32.15	3.10	1.24	16.33	7.57	22.86	10.38	15.08	7.34
m_3v_1	114.65	68.72	4.68	2.84	27.70	16.64	37.92	22.95	24.08	16.00
m_3v_2	123.85	62.42	5.43	2.61	32.35	15.18	42.44	20.56	28.03	14.28
m_3v_3	116.20	60.97	5.22	2.44	29.67	14.07	38.80	20.24	25.42	13.79
m_3v_4	142.50	82.47	7.01	3.27	34.12	17.50	46.70	24.28	31.39	17.06
m_3v_5	82.57	47.47	3.36	1.89	20.10	10.31	27.42	16.00	17.80	10.84
m_4v_1	12.57	65.75	5.70	3.17	30.80	16.85	41.53	23.65	28.85	16.64
m_4v_2	143.37	65.40	6.26	2.57	35.92	15.12	49.34	21.51	31.52	14.89
m_4v_3	147.37	63.80	6.40	2.92	36.42	14.76	49.13	20.89	31.20	14.56
m_4v_4	166.75	85.32	6.77	3.14	37.70	19.40	54.64	25.59	35.48	16.63
m_4v_5	98.13	49.77	4.31	2.20	23.67	12.54	32.96	16.94	22.56	11.55
SEm (±)	3.957	2.213	0.412	0.204	0.880	0.408	1.345	0.482	0.936	0.385
CD (0.05)	NS	NS	NS	NS	NS	1.166	NS	NS	NS	NS

COFC-8 (V_4) was significantly superior in calcium uptake (41.77 kg ha^{-1}). The interaction effect was not significant.

Under 25-35 % shade, M_4 (irrigating at IW/CPE ratio of 0.8) and M_3 (irrigating at IW/CPE ratio of 0.6) were on par in terms of calcium uptake (21.72 and 20.81 kg ha^{-1}respectively) and significantly superior to M_2 (irrigation at IW/CPE ratio of 0.4) and M_1 (life saving irrigation). Among the varieties, COFC-8 (V_4) recorded significantly higher uptake of calcium (19.72 kg ha^{-1}) followed by UPC-618 (V_1) (18.45 kg ha^{-1}). The interaction effect was not significant.

4.6.5. Magnesium Uptake

The data presented in Table 20 & 21 showed that the treatments had significant effect on magnesium uptake while the interaction effect was non-significant in open and shaded conditions.

On perusal of the data, it was observed that M_4 (irrigation at IW/CPE ratio of 0.8) registered significantly higher magnesium uptake (29.93 kg ha^{-1}) in open condition. Among the varieties, COFC-8 (V_4) registered significantly higher uptake of magnesium (27.29 kg ha^{-1}) followed by Bundel Lobia-1 (V_3) (24.44 kg ha^{-1}).

Under 25-35 per cent shade, magnesium uptake under M_4 (irrigation at IW/CPE ratio of 0.8) was significantly higher (14.86 kg ha^{-1}) and was on par with M_3 (irrigation at IW/CPE ratio of 0.6) (14.40 kg ha^{-1}). The variety COFC-8(V_4) recorded significantly higher magnesium uptake (13.41 kg ha^{-1}) followed by UPC-618(V_1) (12.71 kg ha^{-1}).

4.7. SOIL ANALYSIS

The fertility status of the soil after the experiment was assessed in terms of organic carbon, available nitrogen, available phosphorus and available potassium.

Table 22. Effect of soil moisture stress levels and varieties on organic carbon, available nitrogen (N), available phosphorus (P) and available potassium (K) content of soil

Treatments	Organic carbon (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	Open	Shade	Open	Shade	Open	Shade	Open	Shade
Soil moisture stress levels (M)								
M_1- Life saving	0.56	0.58	204.97	206.04	53.51	54.21	100.15	98.62
M_2- IW/CPE = 0.4	0.56	0.59	204.90	206.07	52.92	52.93	98.07	98.06
M_3- IW/CPE = 0.6	0.55	0.57	205.11	206.11	53.78	54.11	99.61	97.21
M_4- IW/CPE = 0.8	0.54	0.59	205.03	205.89	52.87	53.72	99.50	97.33
SEm (±)	0.007	0.010	0.119	0.215	0.154	0.116	0.061	0.156
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Varieties (V)								
V_1 - UPC 618	0.54	0.57	204.91	205.90	99.42	98.32	52.40	53.36
V_2 - UPC 622	0.55	0.59	205.12	206.22	99.74	98.07	51.92	52.81
V_3- Bundel lobia-1	0.56	0.58	204.88	205.82	98.81	97.11	53.02	52.62
V_4 - COFC -8	0.55	0.57	205.04	206.09	98.92	97.26	52.66	51.96
V_5 - CO-5	0.54	0.58	204.92	206.11	100.04	99.02	51.87	52.22
SEm (±)	0.008	0.008	0.205	0.196	0.080	0.279	0.223	0.216
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 23. Interaction effect of soil moisture stress levels and varieties on organic carbon, available nitrogen (N), available phosphorus (P) and available potassium (K) content of soil

Treatments	Organic carbon (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	Open	Shade	Open	Shade	Open	Shade	Open	Shade
M x V								
m_1v_1	0.56	0.58	204.94	206.14	99.66	98.11	53.72	53.22
m_1v_2	0.57	0.59	205.00	206.19	98.82	97.32	51.99	54.12
m_1v_3	0.57	0.59	204.92	205.91	100.11	99..01	53.66	52.20
m_1v_4	0.55	0.57	205.04	205.97	100.21	97.26	53.92	53.71
m_1v_5	0.56	0.58	204.95	206.02	99.81	98.53	52.88	54.11
m_2v_1	0.54	0.59	204.91	205.99	98.77	99.12	53.66	52.92
m_2v_2	0.56	0.58	204.92	206.04	99.52	97.44	52.87	54.09
m_2v_3	0.53	0.57	205.11	205.97	98.66	98.02	53.11	53.82
m_2v_4	0.53	0.59	205.02	205.96	100.02	99.11	52.90	54.11
m_2v_5	0.55	0.58	204.86	206.01	99.51	100.02	51.97	52.98
m_3v_1	0.54	0.57	204.90	206.18	98.52	97.36	53.77	53.01
m_3v_2	0.55	0.59	206.01	206.05	100.01	98.17	52.66	54.03
m_3v_3	0.56	0.58	205.21	205.90	99.62	99.12	51.92	52.81
m_3v_4	0.54	0.58	204.86	204.99	98.82	98.36	52.86	53.24
m_3v_5	0.56	0.57	205.23	205.04	98.76	97.32	53.77	53.20
m_4v_1	0.57	0.59	204.99	204.97	99.57	97.47	53.62	52.13
m_4v_2	0.56	0.58	206.02	205.11	98.88	99.42	52.11	54.12
m_4v_3	0.55	0.57	204.92	204.98	99.36	98.62	51.87	52.62
m_4v_4	0.56	0.59	205.62	205.05	99.51	97.25	52.92	53.91
m_4v_5	0.57	0.59	204.81	205.04	100.01	97.52	53.12	53.99
SEm (±)	0.008	0.008	0.205	0.196	0.080	0.279	0.223	0.216
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

4.7.1. Organic Carbon

The results on the organic carbon status of the soil after the experiment (Table 22 & 23) showed that soil moisture stress levels, varieties and their interaction had no significant effect in open and shaded conditions.

4.7.2. Available Nitrogen

The result pertaining to the available nitrogen status of the soil after the experiment is presented in Table 22 & 23. None of the treatments nor their interaction could significantly affect the soil available nitrogen in open and shaded conditions.

4.7.3. Available Phosphorus

The results summarized in Table 22 & 23 showed that the available phosphorus status of the soil did not vary significantly between soil moisture stress levels, varieties and their interaction in open and shaded conditions.

4.7.4. Available Potassium

The results on the available potassium status of the soil after the experiment as affected by soil moisture stress levels, varieties and their interaction are presented in Table 22 & 23.

On perusal of the data, it was observed that neither the treatments nor their interaction affected the available potassium status of the soil in open and shaded conditions.

4.8. ECONOMIC ANALYSIS

The result of the effect of soil moisture stress levels and varieties on net income and BCR of fodder cowpea in open and shaded condition are presented in Table 24 & 25.

Irrigation at IW/CPE ratio of 0.8 (M_4) registered highest net income (Rs.39501) in open condition. Among the varieties, a higher net return of

Table 24. Effect of soil moisture stress levels and varieties on net income and benefit : cost ratio of fodder cowpea

Treatments	Net income (Rs ha^{-1})		Benefit : Cost ratio (BCR)	
	Open	Shade	Open	Shade
Soil moisture stress levels (M)				
M_1- Life saving	23767	4352	2.05	1.24
M_2- IW/CPE = 0.4	30723	7841	2.33	1.43
M_3- IW/CPE = 0.6	34388	11448	2.14	1.51
M_4- IW/CPE = 0.8	39501	10553	2.13	1.42
SEm (±)	547.512	526.603	0.019	0.026
Varieties (V)				
V_1 - UPC 618	29040	11873	2.05	1.55
V_2 - UPC 622	36011	8276	2.30	1.38
V_3- Bundel lobia-1	33266	6992	2.19	1.35
V_4- COFC -8	44880	13498	2.64	1.63
V_5 - CO-5	17274	2102	1.63	1.09
SEm (±)	612.137	588.760	0.021	0.029

Table 25. Interaction effect of soil moisture stress levels and varieties on net income and benefit : cost ratio of fodder cowpea

Treatments	Net income (Rs ha^{-1})		Benefit : Cost ratio (BCR)	
	Open	Shade	Open	Shade
M x V				
m_1v_1	21040	6405	1.91	1.35
m_1v_2	26028	3833	2.18	1.21
m_1v_3	24520	3728	2.06	1.20
m_1v_4	36640	7673	2.59	1.42
m_1v_5	10608	120	1.46	1.00
m_2v_1	27625	10988	2.20	1.60
m_2v_2	31105	7208	2.35	1.39
m_2v_3	28945	6000	2.25	1.33
m_2v_4	43713	12608	2.89	1.69
m_2v_5	22225	2400	1.96	1.13
m_3v_1	33488	15565	2.11	1.67
m_3v_2	40905	11425	2.36	1.49
m_3v_3	34433	9520	2.14	1.50
m_3v_4	46448	17440	2.54	1.75
m_3v_5	16665	3288	1.55	1.13
m_4v_1	34008	14533	1.97	1.57
m_4v_2	46008	10640	2.31	1.42
m_4v_3	45168	8720	2.29	1.34
m_4v_4	52720	16273	2.50	1.64
m_4v_5	19600	2600	1.56	1.10
SEm (±)	1224.275	1177.521	0.043	0.058

Rs.44880 was registered by the variety COFC-8 (V_4) in open. Among the interaction effect m_4v_4 (COFC-8 irrigated at IW/CPE ratio of 0.8) registered highest net returns (Rs.52720).

In partial shade, irrigation at IW/CPE ratio of 0.6 (M_3) registered highest net income (Rs.11448). Among the varieties, higher net returns of Rs.13498 was registered by the variety COFC-8 (V_4) in shade.

Both soil moisture stress levels and varieties had significant influence on BCR of fodder cowpea in both open and shade. Highest BCR (2.33) was registered by irrigation at IW/CPE ratio of 0.4 (M_2) in open condition. Among the varieties COFC-8 (V_4) recorded highest BCR of 2.64 in open. Among the interaction effect m_2v_4 (COFC-8 irrigated at IW/CPE ratio of 0.4) registered highest BCR (2.89) in open condition.

. In partial shade, irrigation at IW/CPE ratio of 0.6 (M_3) registered highest net returns (1.51). Among the varieties COFC-8 (V_4) recorded highest BCR of 1.63 in shade.

Based on the results of Investigation-I, two drought tolerant fodder cowpea varieties were selected each under open and shaded situation, for conducting Investigation-II. The fodder cowpea varieties COFC-8 (V_4) and UPC-622 (V_2) were selected for open condition and COFC-8 (V_4) and UPC-618 (V_1) were selected for shaded situation. The following aspects were considered in selecting the varieties for Investigation-II.

- Significantly higher green fodder yield
- Significantly higher crude protein yield
- Significantly higher proline content and water use efficiency.
- Significantly higher net returns and BCR.

4.9. SELECTION OF DROUGHT TOLERANT FODDER COWPEA VARIETIES FOR INVESTIGATION - II

Based on the yield, quality aspects, water use efficiency, proline content and net returns, obtained from the first investigation, two drought tolerant fodder cowpea varieties were selected under open and shaded situation for conducting Investigation II. For open condition, COFC-8 and UPC-622 and for 25-35 per cent shade, COFC-8 and UPC-618 were selected.

INVESTIGATION- II : EVALUATION OF GRASS-FODDER COWPEA MIXTURES UNDER OPEN AND SHADED SITUATIONS

4.10. BIOMETRIC OBSERVATIONS

4.10.1. Plant Height

The results on the effect of grasses, fodder cowpea varieties and row ratio on the plant height of grasses and fodder cowpea in open and shaded situations are presented in Table 26, 27 & 28. The results revealed that grasses and grass-legume row ratio had significant impact on plant height of grasses in open. Hybrid Napier (Suguna) (G_1) recorded highest plant height (185.58 cm and 184.25 cm) in open in the first and second year respectively. Among the row ratios, 1:3 (R_3) row ratio recorded significantly higher plant height (180.70 cm) in first and second year (179.55 cm) in open condition. Fodder cowpea varieties (V) had no significant influence on plant height of grasses. The interaction effects were non-significant.

In shaded condition, hybrid Napier (Suguna) (G_1) recorded highest plant height of 186.49cm and 185.34 cm in the first and second year respectively. The fodder cowpea varieties did not influence the plant height of grasses. The influence of row ratio on plant height of grasses was significant only in the second year of study and the row ratio of 1:3 (R3) recorded significantly higher plant height (180.55 cm) of grasses. None of the interactions were significant.

Table 26. **Plant height of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, cm**

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	185.58	184.25	186.49	185.34	125.01	124.59	125.96	125.48
G_2-Guinea grass	173.21	172.24	174.21	173.23	124.61	124.26	125.60	125.09
SEm (±)	0.098	0.096	0.518	0.384	0.515	0.337	0.157	0.182
CD (0.05)	0.206	0.199	1.076	0.798	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8 *	179.25	178.22	180.18	179.25	126.55	126.30	127.53	127.11
V_2 - UPC-622 **	179.55	178.26			123.08	122.55		
V_2- UPC-618 ***			180.52	179.32			124.03	123.47
SEm (±)	0.098	0.096	0.518	0.384	0.515	0.337	0.157	0.182
CD (0.05)	NS	NS	NS	NS	1.069	0.699	0.326	0.298
Grass-legume row ratio (R)								
R_1 - (1:1)	177.65	176.50	178.66	177.69	121.83	121.11	122.83	121.98
R_2 - (1:2)	179.86	178.58	180.73	179.62	127.14	126.68	128.07	127.62
R_3 - (1:3)	180.70	179.55	181.67	180.55	125.48	125.50	126.44	126.27
SEm (±)	0.121	0.117	0.635	0.471	0.631	0.413	0.192	0.223
CD	0.252	0.244	NS	0.977	1.309	1.024	0.398	0.462

Note: * V_1- COFC-8 (open and shade); ** V_2- UPC-622 (open);
*** V_2- UPC-618 (shade)

Table 27. Interaction effect (2 factor) of grass, cowpea varieties and grass – legume row ratios on plant height of grass and cowpea, cm

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	185.20	184.13	186.10	185.28	126.69	126.33	127.70	127.24
g_1v_2	185.97	184.37	186.88	185.40	123.33	122.85	124.22	123.73
g_2v_1	173.30	172.26	174.26	173.23	126.39	126.27	127.36	126.98
g_2v_2	173.13	172.20	174.17	173.23	122.82	122.82	123.83	123.21
SEm (±)	0.098	0.096	0.518	0.384	0.515	0.337	0.157	0.182
CD	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	183.95	182.95	184.91	183.97	122.13	121.20	123.12	121.99
g_1r_2	186.06	184.40	186.81	185.56	127.35	127.05	128.21	127.92
g_1r_3	186.75	185.40	187.75	186.50	125.56	125.53	126.55	126.54
g_2r_1	171.35	170.25	172.40	171.41	121.53	121.52	122.52	121.97
g_2r_2	173.65	172.75	174.65	173.68	126.92	126.31	127.94	127.31
g_2r_3	174.65	173.70	175.60	174.60	125.39	125.47	126.33	126.01
SEm (±)	0.121	0.117	0.635	0.471	0.631	0.413	0.192	0.223
CD	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	177.70	176.65	178.65	177.71	123.28	122.31	124.09	123.22
v_1r_2	179.65	178.55	180.55	179.66	129.09	128.79	130.16	129.77
v_1r_3	180.40	179.40	181.35	180.40	127.26	127.81	128.34	128.34
v_2r_1	177.60	176.56	178.67	177.67	120.38	119.91	121.55	120.74
v_2r_2	180.06	178.60	180.91	179.58	125.17	124.56	125.99	125.46
v_2r_3	181.00	179.70	182.00	180.70	123.69	123.19	124.54	124.20
SEm (±)	0.121	0.117	0.635	0.471	0.631	0.413	0.192	0.223
CD	NS	NS	NS	NS	NS	NS	NS	NS

Table 28. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on plant height of grass and cowpea, cm

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	183.90	182.90	184.80	183.92	123.72	122.73	124.65	123.64
$g_1v_1r_2$	185.50	184.30	186.30	185.62	129.05	128.76	130.10	129.72
$g_1v_1r_3$	186.20	185.20	187.21	186.31	127.32	127.51	128.35	128.36
$g_1v_2r_1$	184.01	183.01	185.03	184.02	120.54	119.67	121.58	120.34
$g_1v_2r_2$	186.62	184.50	187.33	185.50	125.64	125.34	126.33	126.13
$g_1v_2r_3$	187.30	185.60	188.30	186.70	123.82	123.55	124.76	124.71
$g_2v_1r_1$	171.50	170.40	172.50	171.50	122.84	121.88	123.54	122.80
$g_2v_1r_2$	173.80	172.80	174.80	173.70	129.13	128.83	130.22	129.82
$g_2v_1r_3$	174.60	173.60	175.50	174.50	127.21	128.11	128.34	128.32
$g_2v_2r_1$	171.20	170.11	172.31	171.33	120.21	120.16	121.52	121.15
$g_2v_2r_2$	173.50	172.70	174.50	173.67	124.71	123.79	125.66	124.80
$g_2v_2r_3$	174.70	173.80	175.70	174.70	123.57	122.82	124.32	123.70
SEm (±)	0.172	0.166	0.898	0.666	0.892	0.584	0.272	0.315
CD	NS	NS	NS	NS	NS	NS	NS	NS

Grasses had no significant effect on plant height of fodder cowpea. Among the fodder cowpea varieties, COFC-8 (V_1) registered significantly higher plant height (126.55 cm and 126.30 cm) in open respectively in the first and second year. Fodder cowpea recorded significantly higher plant height (127.14 cm and 126.68 cm) in first and second year when it was intercropped in-between grasses in a row ratio of 1:2 (R_2). The interaction effects were not significant.

The fodder cowpea varieties and grass legume row ratio influenced the plant height of fodder cowpea in shade. Significantly higher plant height of 127.53 cm and 127.11 cm was recorded by fodder cowpea variety COFC-8 (V1) in the first and second year respectively. Grass legume row ratio of 1:2 recorded significantly higher plant height of fodder cowpea (128.07 cm and 127.62 cm) in the first and second year respectively. The interaction effects were not significant

4.10.2. No. of tillers/branches

The results on the effect of grasses, fodder cowpea varieties and row ratio on the number of tillers/branches plant^{-1} of grasses and fodder cowpea in open and shaded situations are presented in Table 29, 30 & 31. The results revealed that grasses and grass-legume row ratio had significant impact on number of tillers plant^{-1} of fodder grasses. Hybrid napier (Suguna) (G_1) recorded significantly higher number of tillers plant^{-1} in open (32.00 and 31.11) in first year and second year respectively. Fodder cowpea varieties had no significant effect on number of tillers plant^{-1} of grasses. The row ratio of 1:3 (R_3) recorded significantly higher number of tillers plant^{-1} in open (27.23 and 26.20) in first and second year respectively. The interaction effects were not significant

In partial shade, number of tillers plant^{-1} was significant in first year only and hybrid napier recorded significantly higher number of tillers (22.65) in the first year. Fodder cowpea varieties had no significant effect on number of tillers plant^{-1} of grasses. The row ratio of 1:3 (R_3) recorded significantly higher number of tillers plant^{-1} in shade (23.75 and 23.04) in first and second year respectively. The interaction effects were not significant.

Table 29. Number of tillers / branches of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass- legume mixture

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	32.00	31.11	22.65	21.69	1.84	1.82	1.72	1.71
G_2-Guinea grass	19.90	18.72	21.83	21.33	1.87	1.85	1.75	1.74
SEm (±)	0.001	0.164	0.152	0.160	0.002	0.002	0.001	0.001
CD (0.05)	0.312	0.340	0.316	NS	0.006	0.006	0.003	0.002
Fodder cowpea varieties (V)								
V_1 - COFC-8	26.00	25.18	22.23	21.53	1.87	1.85	1.75	1.74
V_2 - UPC-622	25.90	24.65			1.84	1.82		
V_2- UPC-618			22.25	21.48			1.72	1.71
SEm (±)	0.001	0.164	0.152	0.160	0.002	0.002	0.001	0.001
CD (0.05)	NS	NS	NS	NS	0.006	0.006	0.003	0.002
Grass-legume row ratio (R)								
R_1 - (1:1)	24.20	23.19	19.94	19.18	1.72	1.70	1.60	1.59
R_2 - (1:2)	26.38	25.41	23.04	22.30	2.08	2.06	1.96	1.95
R_3 - (1:3)	27.23	26.20	23.75	23.04	1.77	1.75	1.65	1.64
SEm (±)	0.002	0.201	0.187	0.196	0.003	0.003	0.001	0.001
CD (0.05)	0.382	0.317	0.387	0.406	0.007	0.007	0.003	0.002

Table 30. Interaction effect (2 factor) of grass, cowpea varieties and grass-legume row ratios on number of tillers /branches of grass and cowpea

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	31.98	31.12	22.75	21.70	1.85	1.82	1.73	1.72
g_1v_2	32.02	31.10	22.55	21.67	1.82	1.80	1.70	1.69
g_2v_1	20.02	19.23	21.69	21.35	1.89	1.87	1.77	1.76
g_2v_2	19.77	18.19	21.96	21.30	1.86	1.84	1.74	1.73
SEm (±)	0.001	0.164	0.152	0.160	0.002	0.002	0.001	0.001
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	30.03	29.09	20.19	19.09	1.69	1.67	1.57	1.56
g_1r_2	32.36	31.64	23.56	22.61	2.06	2.04	1.94	1.93
g_1r_3	33.62	32.60	24.20	23.36	1.74	1.72	1.62	1.61
g_2r_1	18.38	17.29	19.68	19.27	1.74	1.72	1.62	1.61
g_2r_2	20.30	18.65	22.50	21.99	2.09	2.07	1.97	1.96
g_2r_3	21.02	20.19	23.30	22.71	1.79	1.77	1.67	1.66
SEm (±)	0.002	0.201	0.187	0.196	0.003	0.003	0.001	0.001
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	24.43	23.39	20.09	19.20	1.73	1.71	1.61	1.60
v_1r_2	26.43	25.34	22.93	22.32	2.09	2.07	1.97	1.96
v_1r_3	27.15	26.81	23.65	23.07	1.78	1.76	1.66	1.65
v_2r_1	23.49	23.00	19.78	19.16	1.70	1.68	1.58	1.57
v_2r_2	26.03	24.95	23.14	22.29	2.06	2.04	1.94	1.93
v_2r_3	27.53	25.99	23.85	23.01	1.75	1.73	1.63	1.62
SEm (±)	0.002	0.201	0.187	0.196	0.003	0.003	0.001	0.001
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 31. Interaction effect (3 factor) of grass, cowpea varieties and grass-legume row ratios on number of tillers /branches of grass and cowpea

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	30.52	29.08	20.41	19.11	1.71	1.68	1.59	1.58
$g_1v_1r_2$	32.99	31.50	23.61	22.63	2.08	2.06	1.96	1.95
$g_1v_1r_3$	33.57	32.79	24.25	23.38	1.76	1.74	1.64	1.63
$g_1v_2r_1$	29.38	29.11	19.98	19.07	1.68	1.66	1.56	1.55
$g_1v_2r_2$	32.80	31.78	23.52	22.60	2.05	2.03	1.93	1.92
$g_1v_2r_3$	33.42	32.42	24.15	23.35	1.73	1.71	1.61	1.60
$g_2v_1r_1$	18.67	17.70	19.78	19.29	1.76	1.74	1.64	1.63
$g_2v_1r_2$	20.50	19.18	22.25	22.01	2.11	2.09	1.99	1.98
$g_2v_1r_3$	21.72	20.83	23.05	22.76	1.81	1.79	1.69	1.68
$g_2v_2r_1$	17.60	16.89	19.58	19.25	1.73	1.71	1.61	1.60
$g_2v_2r_2$	20.21	18.13	22.76	21.98	2.08	2.06	1.96	1.95
$g_2v_2r_3$	20.65	19.56	23.56	22.67	1.78	1.76	1.66	1.65
SEm (±)	0.003	0.284	0.264	0.277	0.005	0.004	0.002	0.002
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

The number of branches $plant^{-1}$ in fodder cowpea was significantly higher (1.87 and 1.85) in open when intercropped in between guinea grass (G_2) in first and second year. Among the varieties, COFC-8 (V_1) registered higher number of branches $plant^{-1}$ in open (1.87 and 1.85) in both the years. Among the row ratio, 1:2 (R_2) recorded significantly higher number of branches $plant^{-1}$ (2.08 and 2.06) in open in the first and second year respectively. The interaction effects were not significant.

The treatments had significant effect on the number of branches $plant^{-1}$ in fodder cowpea in partial shade. Significantly higher number of branches $plant^{-1}$ of 1.75 and 1.74 was recorded when intercropped in between guinea grass (G_2) in first and second year. Among the varieties, COFC-8 (V_1) registered higher number of branches $plant^{-1}$ in shade (1.75 and 1.74) in both the years. Among the row ratio, 1:2 (R_2) recorded significantly higher number of branches $plant^{-1}$ (1.96 and 1.95) in open in the first and second year respectively. The interaction effects were not significant.

4.10.3. Leaf : Stem Ratio

The results summarized in Table 32, 33 & 34 revealed that grasses varied on leaf stem ratio. Significantly higher leaf : stem ratio of 1.84 and 1.83 was recorded by hybrid napier (G_1) in open in the first and second year. The fodder cowpea varieties, row ratio and the interaction effects had no significant influence on the leaf stem ratio of grasses.

In partial shade, grasses varied significantly on leaf stem ratio in both the years. Significantly higher leaf stem ratio of 1.43 and 1.42 was recorded by hybrid napier in first and second year respectively.

The results also revealed that the treatments had no significant impact on leaf: stem ratio of fodder cowpea in open and shaded conditions.

Table 32. Leaf : stem ratio of grass and cowpea as influenced by grass, varieties and row ratios of grass-legume mixture

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	1.84	1.83	1.43	1.42	0.61	0.59	0.55	0.55
G_2-Guinea grass	0.43	0.42	0.34	0.35	0.60	0.58	0.56	0.55
SEm (±)	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.003
CD (0.05)	0.002	0.002	0.002	0.003	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	1.13	1.13	0.90	0.89	0.60	0.58	0.55	0.55
V_2 - UPC-622	1.12	1.13	0.89	0.88	0.61	0.59		
V_2- UPC-618			1.29	1.30			0.56	0.54
SEm (±)	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	1.13	1.12	0.90	0.88	0.61	0.58	0.55	0.54
R_2 - (1:2)	1.13	1.13	0.89	0.89	0.60	0.59	0.56	0.55
R_3 - (1:3)	1.12	1.12	0.89	0.88	0.61	0.59	0.56	0.55
SEm (±)	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 33. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on leaf : stem ratio of grass and cowpea

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	1.84	1.83	1.42	1.41	0.60	0.59	0.55	0.54
g_1v_2	1.84	1.83	1.43	1.41	0.61	0.59	0.56	0.56
g_2v_1	0.41	0.42	0.36	0.34	0.61	0.58	0.56	0.55
g_2v_2	0.41	0.41	0.35	0.34	0.61	0.59	0.57	0.54
SEm (±)	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	1.84	1.83	1.45	1.44	0.61	0.58	0.56	0.55
g_1r_2	1.84	1.85	1.42	1.40	0.60	0.59	0.56	0.55
g_1r_3	1.84	1.83	1.41	1.40	0.61	0.59	0.55	0.56
g_2r_1	0.41	0.41	0.37	0.37	0.61	0.58	0.55	0.54
g_2r_2	0.42	0.42	0.34	0.33	0.60	0.59	0.56	0.55
g_2r_3	0.41	0.42	0.35	0.33	0.61	0.59	0.56	0.54
SEm (±)	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	1.13	1.12	0.91	0.90	0.61	0.58	0.59	0.53
v_1r_2	1.13	1.13	0.88	0.87	0.61	0.60	0.55	0.56
v_1r_3	1.14	1.12	0.88	0.86	0.60	0.59	0.55	0.54
v_2r_1	1.13	1.13	0.91	0.90	0.61	0.59	0.56	0.56
v_2r_2	1.13	1.13	0.88	0.86	0.60	0.59	0.57	0.54
v_2r_3	1.12	1.13	0.88	0.86	0.62	0.59	0.57	0.55
SEm (±)	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 34. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on leaf : stem ratio of grass and cowpea

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	1.85	1.83	1.45	1.44	0.60	0.58	0.56	0.54
$g_1v_1r_2$	1.84	1.84	1.42	1.41	0.61	0.59	0.55	0.55
$g_1v_1r_3$	1.85	1.83	1.41	1.40	0.60	0.60	0.55	0.54
$g_1v_2r_1$	1.84	1.84	1.45	1.44	0.62	0.59	0.55	0.56
$g_1v_2r_2$	1.85	1.85	1.42	1.40	0.60	0.60	0.57	0.55
$g_1v_2r_3$	1.84	1.84	1.42	1.40	0.62	0.58	0.56	0.57
$g_2v_1r_1$	0.41	0.42	0.38	0.37	0.61	0.57	0.58	0.53
$g_2v_1r_2$	0.43	0.43	0.35	0.34	0.61	0.60	0.56	0.57
$g_2v_1r_3$	0.41	0.41	0.35	0.33	0.61	0.58	0.55	0.54
$g_2v_2r_1$	0.42	0.41	0.37	0.37	0.61	0.59	0.55	0.56
$g_2v_2r_2$	0.41	0.41	0.34	0.33	0.62	0.58	0.57	0.53
$g_2v_2r_3$	0.41	0.43	0.35	0.33	0.62	0.60	0.58	0.54
SEm (±)	0.004	0.004	0.003	0.003	0.003	0.004	0.004	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 35. **Root volume of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass - legume mixture, cm^3**

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	678.66	675.33	319.50	318.00	3.88	3.73	2.30	2.18
G_2-Guinea grass	210.00	208.33	210.00	209.83	3.86	3.68	2.28	2.18
SEm (±)	0.379	0.388	0.164	0.150	0.002	0.003	0.002	0.003
CD (0.05)	0.786	0.805	0.340	0.312	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	444.16	442.16	265.00	263.83	3.88	3.73	2.28	2.18
V_2 - UPC-622	444.50	441.50			3.86	3.86		
V_2- UPC-618			264.5	264.00			2.26	2.23
SEm (±)	0.379	0.388	0.164	0.150	0.002	0.003	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	442.00	440.00	263.25	262.5	3.85	3.72	2.27	2.15
R_2 - (1:2)	445.25	442.50	265.5	264.5	3.90	3.72	2.30	2.20
R_3 - (1:3)	445.75	443.00	265.5	264.75	3.87	3.67	2.30	2.21
SEm (±)	0.464	0.475	0.200	0.184	0.003	0.004	0.003	0.004
CD (0.05)	0.963	0.985	0.416	0.382	NS	NS	NS	NS

Table 36. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on root volume of grass and cowpea, cm³

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	678.33	674.66	319.33	318.33	3.90	3.66	2.30	2.10
g_1v_2	679.00	676.00	319.66	317.66	3.86	3.70	2.30	2.26
g_2v_1	210.00	208.33	210.66	209.33	3.83	3.70	2.26	2.16
g_2v_2	210.00	208.30	209.33	210.33	3.90	3.76	2.30	2.21
SEm (±)	0.379	0.388	0.164	0.150	0.002	0.003	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	675.50	673.50	318.00	316.50	3.90	3.75	2.35	2.15
g_1r_2	680.00	676.00	320.50	318.50	3.90	3.65	2.25	2.20
g_1r_3	680.50	676.50	320.00	319.00	3.85	3.65	2.30	2.20
g_2r_1	208.50	206.50	208.50	208.50	3.80	370	2.20	2.15
g_2r_2	210.50	209.00	210.50	210.50	3.90	3.80	2.35	2.31
g_2r_3	211.00	209.50	211.00	210.50	3.90	3.70	2.30	2.20
SEm (±)	0.464	0.475	0.200	0.184	0.003	0.004	0.003	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	441.50	439.50	263.50	262.50	3.85	3.75	2.30	2.00
v_1r_2	445.50	442.00	265.50	264.50	3.90	3.65	2.30	2.25
v_1r_3	445.50	443.00	266.00	264.50	3.85	3.65	2.25	2.15
v_2r_1	442.50	440.50	263.00	262.50	3.85	3.70	2.25	2.30
v_2r_2	445.00	443.00	265.50	264.50	3.90	3.80	2.30	2.16
v_2r_3	446.00	443.00	265.00	265.00	3.90	3.70	2.35	2.25
SEm (±)	0.464	0.475	0.200	0.184	0.003	0.004	0.003	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 37. Interaction effect (3 factor) of grass, cowpea varieties and grass – legume row ratios on root volume of grass and cowpea, cm^3

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	675.00	673.00	318.00	317.00	4.00	3.70	2.40	2.00
$g_1v_1r_2$	680.00	675.00	320.00	319.00	3.80	3.60	2.30	2.20
$g_1v_1r_3$	680.00	676.00	320.00	319.00	3.90	3.70	2.20	2.10
$g_1v_2r_1$	676.00	674.00	318.00	316.00	3.80	3.80	2.30	2.30
$g_1v_2r_2$	680.00	677.00	321.00	318.00	4.00	3.70	2.20	2.20
$g_1v_2r_3$	681.00	677.00	320.00	319.00	3.80	3.60	2.40	2.30
$g_2v_1r_1$	208.00	209.00	209.00	208.00	3.70	3.80	2.20	2.00
$g_2v_1r_2$	211.00	210.00	211.00	210.00	4.00	3.70	2.30	2.30
$g_2v_1r_3$	211.00	207.00	212.00	210.00	3.80	3.70	2.30	2.20
$g_2v_2r_1$	209.00	209.00	208.00	209.00	3.90	3.60	2.20	2.30
$g_2v_2r_2$	210.00	209.00	210.00	211.00	3.80	3.90	2.40	2.13
$g_2v_2r_3$	211.00	209.00	210.00	211.00	4.00	3.80	2.30	2.20
SEm (±)	0.657	0.672	0.284	0.261	0.004	0.005	0.004	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

4.10.4. Root Volume

The results of the effect of grasses, fodder cowpea varieties and row ratio on root volume of grasses and fodder cowpea in open and shaded situations are presented in Table 35, 36 & 37. The results showed that grasses and row ratio had significant impact on root volume of grasses in open. Significantly higher root volume was recorded by hybrid napier (G_1) in open in both the years (678.66 cm^3 and 675.33 cm^3). Grass legume row ratio of 1:3 (R_3) recorded significantly higher root volume in open (445.75 cm^3 and 443.00 cm^3) which was on par with 1:2 (R_2) (445.25 cm^3 and 442.50 cm^3) in both the years. The interaction effects were not significant.

In partial shade, significantly higher root volume (319.50 cm^3 and 318.00 cm^3) was recorded by hybrid napier (G_1) in first and second year. Fodder cowpea varieties had no significant effect on root volume of grasses. Grass legume row ratio of 1:3 (R_3) recorded significantly higher root volume in open (265.5 cm^3 and 264.75.00 cm^3) which was on par with 1:2 (R_2) (265.50 cm^3 and 264.50 cm^3) in both the years. The interaction effects were not significant.

The results revealed that treatments and their interaction had no significant effect on root volume of fodder cowpea.

4.10.5. Root Dry Weight

The results of the effect of grasses, fodder cowpea varieties and row ratio on root dry weight of grasses and fodder cowpea in open and shaded situation are presented in Table 38, 39 & 40. The results revealed that grasses and row ratio had significant impact on root dry weight of fodder grasses. Significantly higher root dry weight (76.73g and 75.80g) was registered by hybrid napier in open in first and second year respectively. Grass legume row ratio of 1:3 (R_3) recorded significantly higher root dry weight which was on par with 1:2 (R_2) in open in both the years. The interaction effects were not significant.

Table 38. Root dry weight of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, g plant^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	76.73	75.80	55.45	54.45	0.32	0.31	0.25	0.24
G_2-Guinea grass	58.74	58.30	49.20	48.20	0.31	0.31	0.24	0.25
SEm (±)	0.206	0.384	0.163	0.225	0.002	0.003	0.005	0.003
CD (0.05)	0.427	0.797	0.339	0.466	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	67.77	67.05	52.33	51.32	0.33	0.32	0.25	0.25
V_2 - UPC-622	67.70	67.04			0.31	0.31		
V_2- UPC-618			52.32	51.33			0.24	0.24
SEm (±)	0.206	0.384	0.163	0.225	0.002	0.003	0.005	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	66.23	65.26	51.00	49.91	0.31	0.31	0.24	0.23
R_2 - (1:2)	68.33	67.92	52.94	52.02	0.32	0.32	0.25	0.24
R_3 - (1:3)	68.65	67.97	53.03	53.05	0.32	0.31	0.25	0.24
SEm (±)	0.252	0.470	0.200	0.275	0.002	0.004	0.006	0.004
CD (0.05)	0.523	0.976	0.415	0.571	NS	NS	NS	NS

Table 39. Interaction effect (2 factor) of grass, cowpea varieties and grass-legume row ratios on root dry weight of grass and cowpea, g plant^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	76.79	75.81	55.45	54.44	0.33	0.31	0.25	0.24
g_1v_2	76.67	75.79	55.45	54.46	0.30	0.30	0.24	0.24
g_2v_1	58.75	58.30	49.20	48.20	0.32	0.32	0.26	0.25
g_2v_2	58.73	58.30	49.19	48.21	0.31	0.31	0.24	0.24
SEm (±)	0.206	0.384	0.163	0.225	0.002	0.003	0.005	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	75.12	74.27	54.10	53.10	0.31	0.31	0.24	0.23
g_1r_2	77.40	76.51	56.03	55.12	0.32	0.31	0.25	0.24
g_1r_3	77.67	76.61	56.21	55.14	0.31	0.31	0.25	0.25
g_2r_1	57.33	56.23	47.90	46.71	0.32	0.30	0.24	0.23
g_2r_2	59.24	59.34	49.84	48.93	0.33	0.32	0.26	0.26
g_2r_3	59.64	59.33	49.85	48.97	0.32	0.31	0.26	0.24
SEm (±)	0.252	0.470	0.200	0.275	0.002	0.004	0.006	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	66.29	65.29	51.01	49.91	0.32	0.31	0.24	0.24
v_1r_2	68.37	67.91	52.93	52.01	0.33	0.32	0.26	0.26
v_1r_3	68.64	67.97	53.04	52.04	0.32	0.32	0.25	0.25
v_2r_1	66.15	65.22	50.99	49.91	0.31	0.30	0.23	0.23
v_2r_2	68.28	67.94	52.95	52.03	0.31	0.31	0.25	0.24
v_2r_3	68.67	67.98	53.02	52.07	0.30	0.30	0.26	0.24
SEm (±)	0.252	0.470	0.200	0.275	0.002	0.004	0.006	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 40. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on root dry weight of grass and cowpea, g plant^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	75.23	74.32	54.11	53.09	0.32	0.31	0.24	0.24
$g_1v_1r_2$	77.51	76.51	56.02	55.11	0.33	0.32	0.26	0.25
$g_1v_1r_3$	77.63	76.61	56.22	55.13	0.33	0.32	0.25	0.25
$g_1v_2r_1$	75.01	74.23	54.09	53.12	0.30	0.31	0.23	0.23
$g_1v_2r_2$	77.30	76.52	56.05	55.13	0.31	0.31	0.25	0.241
$g_1v_2r_3$	77.71	76.62	56.21	55.15	0.30	0.30	0.26	0.25
$g_2v_1r_1$	57.36	56.26	47.91	46.73	0.32	0.31	0.25	0.24
$g_2v_1r_2$	59.23	59.31	49.84	48.92	0.33	0.33	0.27	0.27
$g_2v_1r_3$	59.66	59.33	49.86	48.95	0.32	0.32	0.26	0.25
$g_2v_2r_1$	57.33	56.21	47.90	46.70	0.31	0.30	0.24	0.23
$g_2v_2r_2$	59.26	59.37	49.85	48.94	0.32	0.32	0.25	0.25
$g_2v_2r_3$	59.63	59.34	49.84	48.99	0.31	0.30	0.25	0.24
SEm (±)	0.357	0.666	0.283	0.389	0.003	0.005	0.009	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 41. Root - shoot ratio of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	0.91	0.90	0.89	0.89	0.09	0.09	0.08	0.07
G_2-Guinea grass	0.87	0.87	0.88	0.89	0.08	0.08	0.07	0.07
SEm (±)	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.003
CD (0.05)	0.006	0.002	NS	NS	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	0.89	0.89	0.90	0.89	0.09	0.09	0.07	0.07
V_2 - UPC-622	0.89	0.90			0.009	0.08		
V_2- UPC-618			0.89	0.90			0.07	0.08
SEm (±)	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	0.89	0.89	0.89	0.89	0.10	0.08	0.08	0.07
R_2 - (1:2)	0.90	0.89	0.90	0.90	0.09	0.09	0.07	0.08
R_3 - (1:3)	0.89	0.90	0.90	0.89	0.08	0.08	0.07	0.08
SEm (±)	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 42. Interaction effect (2 factor) of grass, cowpea varieties and grass-legume row ratios on root - shoot ratio of grass and cowpea

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	0.91	0.90	0.90	0.89	0.09	0.08	0.07	0.08
g_1v_2	0.92	0.92	0.89	0.89	0.08	0.09	0.08	0.06
g_2v_1	0.88	0.88	0.90	0.90	0.09	0.09	0.07	0.07
g_2v_2	0.87	0.87	0.89	0.90	0.09	0.08	0.08	0.08
SEm (±)	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	0.92	0.91	0.89	0.90	0.07	0.08	0.08	0.08
g_1r_2	0.91	0.91	0.89	0.90	0.09	0.10	0.08	0.07
g_1r_3	0.91	0.91	0.90	0.89	0.09	0.09	0.06	0.07
g_2r_1	0.87	0.88	0.89	0.89	0.08	0.09	0.09	0.07
g_2r_2	0.88	0.87	0.91	0.91	0.10	0.08	0.07	0.08
g_2r_3	0.87	0.87	0.90	0.89	0.09	0.08	0.08	0.09
SEm (±)	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	0.90	0.88	0.91	0.89	0.08	0.09	0.08	0.07
v_1r_2	0.90	0.90	0.89	0.90	0.11	0.09	0.08	0.08
v_1r_3	0.89	0.89	0.90	0.89	0.08	0.09	0.07	0.07
v_2r_1	0.89	0.90	0.88	0.90	0.07	0.08	0.09	0.08
v_2r_2	0.90	0.88	0.91	0.90	0.08	0.11	0.08	0.07
v_2r_3	0.89	0.90	0.89	0.89	0.10	0.08	0.07	0.08
SEm (±)	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 43. Interaction effect (3 factor) of grass, cowpea varieties and grass-legume row ratios on root - shoot ratio of grass and cowpea

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	0.91	0.90	0.90	0.88	0.08	0.07	0.07	0.09
$g_1v_1r_2$	0.90	0.91	0.89	0.89	0.11	0.09	0.08	0.08
$g_1v_1r_3$	0.92	0.90	0.91	0.90	0.09	0.10	0.06	0.08
$g_1v_2r_1$	0.93	0.92	0.88	0.91	0.07	0.09	0.09	0.07
$g_1v_2r_2$	0.92	0.91	0.90	0.90	0.08	0.11	0.08	0.06
$g_1v_2r_3$	0.91	0.93	0.89	0.88	0.10	0.08	0.06	0.07
$g_2v_1r_1$	0.88	0.87	0.91	0.89	0.09	0.11	0.08	0.06
$g_2v_1r_2$	0.89	0.89	0.90	0.91	0.11	0.09	0.07	0.09
$g_2v_1r_3$	0.87	0.88	0.89	0.87	0.07	0.08	0.08	0.07
$g_2v_2r_1$	0.86	0.89	0.88	0.89	0.08	0.07	0.09	0.08
$g_2v_2r_2$	0.87	0.86	0.91	0.90	0.09	0.10	0.07	0.08
$g_2v_2r_3$	0.88	0.87	0.90	0.91	0.10	0.08	0.08	0.09
SEm (±)	0.004	0.004	0.003	0.003	0.003	0.004	0.004	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

The results revealed that grasses and row ratio had significant impact on root dry weight of fodder grasses in partial shade. Significantly higher root dry weight (55.45g and 54.45g) was registered by hybrid napier in open in first and second year respectively. Grass legume row ratio of 1:3 (R_3) recorded significantly higher root dry weight which was on par with 1:2 (R_2) in open in both the years. The interaction effects were not significant

The results revealed that treatments and their interaction had no significant effect on root dry weight of fodder cowpea.

4.10.6. Root: Shoot Ratio

The results on the effect of grasses, fodder cowpea varieties and row ratio on root: shoot ratio are presented in Table 41, 42 & 43. The results revealed that grasses varied significantly with respect to root: shoot ratio in open condition. Hybrid napier (G_1) recorded significantly higher root: shoot ratio (0.91) in first year and second year (0.90). The other treatments and the interaction had no significant impact on root: shoot ratio of fodder grasses in open.

In shade, the treatments and interactions were non-significant with respect to root : shoot ratio of grasses.

The root : shoot ratio of fodder cowpea was also not influenced by fodder grasses, fodder cowpea varieties and row ratio in open and shade.

4.11. YIELD PARAMETERS

4.11.1. Green Fodder Yield

The results on the effect of grasses, fodder cowpea varieties and row ratio on green fodder yield of grasses, fodder cowpea and total green fodder yield in open and shade in first and second year are presented in Table 44, 45 & 46. The results revealed that grasses and grass legume row ratio had significant impact on green fodder yield of grasses in open in both the years. Significantly higher green fodder yield was recorded by hybrid napier (G_1) in open (282.54 t ha^{-1} $year^{-1}$ and

281.20 t ha-^{1} year^{-1}) in first and second year of experimentation. Fodder cowpea varieties had no significant effect on green fodder yield of grasses. Among the grass-legume row ratio, 1:3 (R_3) registered significantly higher green fodder yield of grasses in open (219.40 t ha^{-1} year^{-1}) in first and (218.15 t ha^{-1} year^{-1}) in second year. Among the interaction effect, grass-row ratio interaction was significant in open condition and g_1r_3 (hybrid napier + 1:3 row ratio) recorded higher green fodder yield (284.66 t ha^{-1} year^{-1}) in grasses in first year and 283.45 t ha^{-1}· year^{-1} in second year.

The results revealed that grasses and grass legume row ratio had significant impact on green fodder yield of grasses in shade in both the years. Significantly higher green fodder yield was recorded by hybrid napier (G_1) in open (203.26 t ha^{-1} year^{-1} and 202.98 t ha^{-1} year^{-1}) in first and second year of experimentation. Fodder cowpea varieties had no significant effect on green fodder yield of grasses. Among the grass-legume row ratio, 1:3 (R_3) registered significantly higher green fodder yield of grasses in open (162.45 t ha^{-1} year^{-1}) in first and (162.06 t ha^{-1} year^{-1}) in second year. The interactions effects were not significant.

The results on the green fodder yield of fodder cowpea revealed that grasses, fodder cowpea varieties and grass-legume row ratio had significant impact on green fodder yield of cowpea in open during first and second year. The green fodder yield of fodder cowpea was the highest in open (5.37 t ha^{-1} and 5.28 t ha^{-1}) in the first and second year when it was intercropped in between guinea grass (G_2). Among the fodder cowpea varieties, COFC-8 (V_1) recorded higher green fodder yield in open (5.14 t ha^{-1} and 5.08 t ha^{-1}) in the first and second year. Among the row ratios, 1:2 (R_2) recorded significantly higher green fodder yield in open (5.91 t ha^{-1} and 5.94 t ha^{-1}) in first and second year. Grass- row ratio interaction was significant in open condition. Significantly higher green fodder yield was registered by g_2r_2 (fodder cowpea intercropped in between guinea grass with a row ratio of 1:2) (6.01 t ha^{-1}) in first year and 6.08 t ha^{-1} in second year.

V x R interaction was also significant in open condition in both the years. Significantly higher green fodder yield of fodder cowpea was recorded when fodder cowpea cv. COFC-8 was intercropped in between grasses at a row ratio of 1:2 (v_1r_2) in open condition (6.18 t ha^{-1} and 6.15 t ha^{-1} in first and second years). G x V x R interaction effect was significant in open condition in both the years. Guinea grass intercropped with fodder cowpea cv. COFC-8 at a row ratio of 1:2 ($g_2v_1r_2$) recorded higher green fodder yield of 6.35 t ha^{-1} and 6.21 t ha^{-1} in first and second years respectively.

In partial shade, grasses and fodder cowpea varieties had significant influence on green fodder yield of fodder cowpea only in the first year. During first year, significantly higher green fodder yield (3.85 t ha^{-1}) was recorded when it was intercropped in between guinea grass (G_2). Among the fodder cowpea varieties, COFC-8 recorded higher green fodder yield of 3.70 t ha^{-1} in the first year. Among the row ratios, 1:2 (R_2) recorded significantly higher green fodder yield in open (4.45 t ha^{-1} and 4.47 t ha^{-1}) in first and second years.

The grasses and row ratio had significant effect on total green fodder yield in open in both the years. Hybrid napier recorded significantly higher total green fodder yield in open (287.21 t ha^{-1} $year^{-1}$ and 285.84 t ha^{-1} $year^{-1}$) in first and second year. Among the row ratios, total fodder yield was on par at 1:2 and 1:3 grass cowpea row ratio in open (224.13 t ha^{-1} $year^{-1}$ and 224.23 t ha^{-1} $year^{-1}$) in first year and 222.84 t ha^{-1} $year^{-1}$and 222.80 t ha^{-1} $year^{-1}$in second year respectively. Interaction effects were non-significant.

The grasses and row ratio had significant effect on total green fodder yield in shade in both the years. Hybrid napier recorded significantly higher total green fodder yield in open (206.65 t ha^{-1} $year^{-1}$ and 206.39 t ha^{-1} $year^{-1}$) in first and second year. Among the row ratios, total fodder yield was on par at 1:2 and 1:3 grass cowpea row ratio in open (165.74 t ha^{-1} $year^{-1}$ and 165.77 t ha^{-1} $year^{-1}$) in first year and 165.47 t ha^{-1} $year^{-1}$ and 165.44 t ha^{-1} $year^{-1}$ in second year respectively. Hybrid napier intercropped with fodder cowpea at 1:2 row ratio

Table 44. Green fodder yield of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, $t\ ha^{-1}\ year^{-1}$

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)												
G1-Hybrid napier	282.54	281.20	203.26	202.98	4.66	4.64	3.39	3.40	287.21	285.84	206.65	206.39
G2-Guinea grass	152.39	151.12	118.12	117.66	5.37	5.28	3.85	3.87	157.77	156.40	121.99	121.53
SEm (±)	0.031	0.036	0.053	0.020	0.012	0.001	0.010	0.221	0.034	0.037	0.056	0.022
CD (0.05)	0.074	0.065	0.111	0.041	0.026	0.004	0.021	NS	0.077	0.071	0.117	0.046
Fodder Cowpea Varieties (V)												
V1-COFC-8	217.49	216.18	160.69	160.33	5.14	5.08	3.70	3.70	222.63	222.26	164.40	164.03
V2-UPC-622	217.45	216.14	160.68		4.90	4.83			222.35	220.97	164.23	
V2-UPC-618				160.32			3.54	3.57				163.90
SEm (±)	0.031	0.036	0.053	0.020	0.012	0.001	0.010	0.221	0.034	0.037	0.056	0.022
CD (0.05)	NS	NS	NS	NS	0.026	0.004	0.021	NS	NS	NS	NS	NS
Grass-legume row ratio (R)												
R_1 - (1:1)	214.78	213.45	158.32	157.93	4.33	4.27	3.09	3.06	219.11	217.72	161.45	160.99
R_2 - (1:2)	218.22	216.90	161.29	160.99	5.91	5.94	4.45	4.47	224.13	222.84	165.74	165.47
R_3 - (1:3)	219.40	218.15	162.45	162.06	4.82	4.75	3.31	3.37	224.23	222.80	165.77	165.44
SEm (±)	0.038	0.044	0.065	0.024	0.015	0.002	0.012	0.271	0.042	0.045	0.069	0.027
CD (0.05)	0.091	0.080	0.136	0.051	0.032	0.004	0.026	0.563	0.095	0.088	0.144	0.057

Table 45. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on green fodder yield of grass and cowpea, t ha^{-1} year^{-1}

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V												
g_1v_1	282.56	281.21	203.24	202.97	4.80	4.79	3.49	3.43	287.36	286.01	206.74	206.40
g_1v_2	282.52	281.19	203.28	203.00	4.53	4.47	3.28	3.36	287.05	285.66	206.56	206.37
g_2v_1	152.41	151.15	118.15	117.69	5.48	5.36	3.91	3.96	157.89	156.51	122.06	121.66
g_2v_2	152.37	151.09	118.08	117.64	5.27	5.19	3.79	3.77	157.64	156.28	121.91	121.41
SEm (±)	0.031	0.036	0.053	0.020	0.012	0.001	0.010	0.221	0.034	0.037	0.056	0.022
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x R												
g_1r_1	279.61	278.2	200.97	200.62	3.92	3.88	2.81	2.81	283.53	282.08	203.78	203.44
g_1r_2	283.36	281.96	203.90	203.68	5.81	5.81	4.27	4.28	289.17	287.77	208.17	207.96
g_1r_3	284.66	283.45	204.91	204.66	4.26	4.21	3.08	3.11	288.92	287.66	208	207.77
g_2r_1	149.95	148.69	115.67	115.22	4.73	4.66	3.38	3.31	154.68	153.35	119.10	118.53
g_2r_2	153.08	151.82	118.68	118.31	6.01	6.08	4.63	4.66	159.09	157.90	123.32	122.97
g_2r_3	154.15	152.83	119.99	119.47	5.39	5.09	3.54	3.63	159.53	157.92	123.54	123.10
SEm (±)	0.038	0.044	0.065	0.024	0.015	0.002	0.012	0.271	0.042	0.045	0.069	0.027
CD (0.05)	0.130	0.113	NS	NS	0.046	0.006	NS	NS	NS	NS	NS	0.080

Table 45. continued

V x R												
v_1r_1	214.85	213.36	158.32	157.98	4.40	4.34	3.09	3.02	219.25	218.90	161.41	160.05
v_1r_2	218.16	216.89	161.32	160.98	6.18	6.15	4.62	4.66	224.35	223.05	165.94	164.64
v_1r_3	219.45	217.09	162.44	161.99	4.83	4.75	3.41	3.41	224.28	222.84	165.85	164.41
v_2r_1	214.71	213.33	158.32	157.82	4.25	4.20	3.10	3.08	218.96	217.53	161.48	160.92
v_2r_2	218.27	216.90	161.26	161.01	5.63	5.73	4.28	4.27	223.63	222.63	165.54	164.29
v_2r_3	219.35	218.19	162.46	162.13	4.82	4.55	3.22	3.33	223.75	222.75	165.68	164.46
SEm (±)	0.038	0.044	0.065	0.024	0.015	0.002	0.012	0.271	0.042	0.045	0.069	0.027
CD (0.05)	NS	NS	NS	NS	0.046	0.006	NS	NS	NS	NS	NS	0.080

Table 46. Interaction effect of (3 factor) grass, cowpea varieties and grass - legume row ratios on green fodder yield of grass and cowpea, t ha^{-1} year^{-1}

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R												
$g_1v_1r_1$	279.70	278.38	200.95	199.73	4.01	3.94	2.87	2.79	283.71	282.36	203.82	202.53
$g_1v_1r_2$	283.27	281.93	203.89	202.68	6.02	6.10	4.45	4.39	289.29	288.03	208.34	207.09
$g_1v_1r_3$	284.73	283.34	204.89	203.50	4.37	4.31	3.17	3.09	289.10	288.65	208.06	206.60
$g_1v_2r_1$	279.52	278.02	200.99	199.52	3.84	3.79	2.76	2.83	283.36	281.81	203.75	202.35
$g_1v_2r_2$	283.45	282.00	203.91	202.68	5.60	5.52	4.09	4.15	289.05	287.52	208.00	206.83
$g_1v_2r_3$	150.10	149.74	115.69	114.32	4.16	4.10	3.31	3.25	154.80	153.44	119.00	117.57
$g_2v_1r_1$	153.06	152.86	118.76	117.28	4.80	4.69	4.79	4.91	159.41	158.07	123.55	122.19
$g_2v_1r_2$	154.17	153.85	120.00	119.49	6.35	6.21	3.65	3.73	159.47	158.04	123.65	122.22
$g_2v_1r_3$	154.17	153.85	120.00	119.49	5.30	5.19	3.65	3.73	159.47	158.04	123.65	122.22
$g_2v_2r_1$	149.90	148.64	115.66	114.12	4.67	4.62	3.45	3.38	154.57	153.26	119.21	117.50
$g_2v_2r_2$	153.10	152.80	118.61	117.35	5.67	5.95	4.48	4.40	158.77	157.75	123.09	121.76
$g_2v_2r_3$	154.12	152.83	119.99	118.45	5.48	4.99	3.44	3.54	159.60	157.83	123.43	121.99
SEm (±)	0.054	0.062	0.092	0.001	0.022	0.003	0.018	0.384	0.060	0.065	0.098	0.039
CD (0.05)	NS	NS	NS	NS	0.065	0.009	NS	NS	NS	NS	NS	0.114

(g_1r_2) recorded significantly higher total green fodder yield of 207.96 t ha^{-1} $year^{-1}$ in partial shade during second year. V x R interaction was also significant and COFC-8 intercropped in between the grasses at 1:2 row ratio (v_1 r_2) recorded significantly higher total green fodder yield of 164 t ha^{-1} $year^{-1}$ in partial shade.

G x V x R interaction was significant in partial shade during second year and $g_1v_1r_2$ (hybrid napier intercropped with fodder cowpea cv. COFC-8 at 1:2 row ratio) recorded significantly higher total green fodder yield of in partial shade (207.09 t ha^{-1} $year^{-1}$).

4.11.2. Dry Fodder Yield

The results on the effect of grasses, fodder cowpea varieties and row ratio on dry fodder yield of grasses, fodder cowpea and total dry fodder yield in open and shade in both the years are presented in Table 47, 48 & 49. The results revealed that grass and grass-legume row ratio had significant impact on dry fodder yield of grasses in open. Hybrid napier (G_1) recorded significantly higher dry fodder yield in open (84.74 t ha-1 year-1 and 84.67 t ha-^{1} $year^{-1}$) in the first and second years respectively. Grass intercropped with fodder cowpea in the row ratio of 1:3 (R_3) recorded higher dry fodder yield in open (65.78 t ha^{-1} $year^{-1}$ and 65.74 t ha^{-1} $year^{-1}$) in the first and second years respectively. Interaction effects were non-significant.

The results revealed that grass and grass-legume row ratio had significant impact on dry fodder yield of grasses in partial shade. Hybrid napier (G_1) recorded significantly higher dry fodder yield in shade (61.91 t ha^{-1} $year^{-1}$ and 60.90 t ha^{-1} $year^{-1}$) in the first and second years respectively. Grass intercropped with fodder cowpea in the row ratio of 1:3 (R_3) recorded higher dry fodder yield in open (48.73 t ha^{-1} $year^{-1}$ and 48.61 t ha^{-1} $year^{-1}$) in the first and second years respectively. Interaction effects were non-significant.

The results on the dry fodder yield of fodder cowpea revealed that grasses, fodder cowpea varieties and row ratio had significant impact on dry fodder yield in both open and shade in both the years. Fodder cowpea intercropped between

Table 47. Dry fodder yield of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass - legume mixture, t ha^{-1} $year^{-1}$

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses(G)												
G1-Hybrid napier	84.74	84.67	61.91	60.90	0.89	0.80	0.64	0.64	85.62	85.43	61.65	61.56
G2-Guinea grass	45.73	45.65	35.47	35.32	1.02	0.91	0.73	0.73	46.75	46.54	36.20	36.05
SEm(±)	0.024	0.008	0.020	0.006	0.002	0.002	0.009	0.003	0.024	0.030	0.019	0.006
CD (0.05)	0.050	0.017	0.042	0.011	0.005	0.005	0.019	0.006	0.051	0.063	0.040	0.012
Fodder Cowpea Varieties (V)												
V1-COFC-8	65.23	65.17	48.23	48.12	0.98	0.88	0.70	0.70	66.21	66.03	48.94	48.83
V2-UPC-622	65.24	65.14			0.93	0.83			66.18	65.94		
V2-UPC-618			48.25	48.10			0.68	0.68			48.92	48.81
SEm(±)	0.024	0.008	0.020	0.006	0.002	0.002	0.009	0.003	0.024	0.030	0.019	0.006
CD (0.05)	NS	NS	NS	NS	0.005	0.005	NS	NS	NS	NS	NS	NS
Grass-legume row ratio(R)												
R_1 - (1:1)	64.43	64.32	47.50	47.37	0.82	0.75	0.59	0.58	65.28		48.08	47.95
R_2 - (1:2)	65.49	65.42	48.50	48.37	1.12	1.01	0.84	0.85	66.62	66.38	49.35	49.21
R_3 - (1:3)	65.78	65.74	48.73	48.61	0.92	0.80	0.64	0.64	66.70	66.53	49.36	49.25
SEm(±)	0.030	0.010	0.025	0.007	0.003	0.003	0.011	0.003	0.030	0.037	0.023	0.008
CD (0.05)	0.061	0.021	0.051	0.014	0.006	0.006	0.024	0.008	0.063	0.077	0.049	0.015

Table 48. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on dry fodder yield of grass and cowpea, t ha^{-1} $year^{-1}$

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V												
g_1v_1	84.72	84.68	61.00	60.91	0.91	0.81	0.66	0.65	85.64	85.50	61.66	61.57
g_1v_2	84.75	84.65	61.02	60.91	0.86	0.76	0.62	0.63	85.61	85.36	61.64	61.55
g_2v_1	45.74	45.66	35.47	35.34	1.04	0.91	0.74	0.75	46.78	46.57	36.21	36.09
g_2v_2	45.73	45.64	35.47	35.30	1.00	0.88	0.73	0.71	46.73	46.52	36.19	36.01
SEm (±)	0.024	0.008	0.020	0.006	0.002	0.002	0.009	0.003	0.024	0.030	0.019	0.006
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x R												
g_1r_1	83.88	83.75	60.28	60.18	0.74	0.66	0.53	0.53	84.63	84.41	60.81	60.71
g_1r_2	85.01	84.93	61.28	61.17	1.10	0.98	0.80	0.81	86.10	85.83	62.09	61.98
g_1r_3	85.33	85.33	61.47	61.39	0.80	0.71	0.58	0.59	86.14	86.04	62.05	61.98
g_2r_1	44.98	44.90	34.70	34.56	1.14	1.03	0.87	0.88	47.13	46.93	36.59	36.44
g_2r_2	46.99	45.90	35.72	35.56	1.14	1.03	0.87	0.88	47.13	46.93	36.59	36.44
g_2r_3	46.24	46.15	35.99	35.84	1.02	0.86	0.69	0.69	47.26	47.01	36.66	36.52
SEm (±)	0.030	0.010	0.025	0.007	0.003	0.003	0.011	0.003	0.030	0.037	0.023	0.008
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 48. continued

V x R												
$v_1 r_1$	64.45	64.36	47.48	47.40	0.83	0.73	0.58	0.57	65.29	65.10	48.07	47.97
$v_1 r_2$	65.48	65.43	48.49	48.39	1.17	1.04	0.87	0.88	66.65	66.48	49.37	49.27
$v_1 r_3$	65.77	65.72	48.73	48.59	0.91	0.80	0.64	0.65	66.69	66.53	49.38	49.24
$v_2 r_1$	64.41	64.29	47.50	47.34	0.81	0.71	0.58	0.58	65.22	65.00	48.09	47.92
$v_2 r_2$	65.51	65.39	48.51	48.35	1.07	0.97	0.81	0.80	66.58	66.28	49.32	49.15
$v_2 r_3$	65.80	65.75	48.73	48.63	0.91	0.77	0.63	0.63	66.71	66.53	49.34	49.26
SEm (±)	0.030	0.010	0.025	0.007	0.003	0.003	0.011	0.003	0.030	0.037	0.023	0.008
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 49. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on dry fodder yield of grass and cowpea, t ha^{-1} $year^{-1}$

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R												
$g_1v_1r_1$	83.91	83.80	60.28	60.21	0.76	0.67	0.54	0.53	84.67	84.48	60.82	60.74
$g_1v_1r_2$	84.97	84.96	61.26	61.19	1.14	1.03	0.84	0.84	86.12	86.00	62.10	62.03
$g_1v_1r_3$	85.30	85.29	61.46	61.34	0.83	0.73	0.60	0.58	86.13	86.03	62.06	61.93
$g_1v_2r_1$	83.85	8370	60.29	6015	0.73	0.64	0.52	0.54	84.59	84.34	60.81	6069
$g_1v_2r_2$	85.03	84.90	61.30	61.15	1.06	0.94	0.77	0.78	86.09	85.67	62.08	61.93
$g_1v_2r_3$	85.37	85.36	61.47	61.44	0.78	0.69	0.56	0.59	86.16	86.06	62.04	62.03
$g_2v_1r_1$	44.99	44.91	34.69	34.59	0.91	0.80	0.63	0.61	45.91	45.71	35.32	35.20
$g_2v_1r_2$	45.98	45.91	35.72	35.58	1.20	1.05	0.90	0.93	47.18	46.97	36.63	36.51
$g_2v_1r_3$	46.24	46.15	36.00	35.84	1.00	0.88	0.69	0.70	47.25	47.03	36.69	36.55
$g_2v_2r_1$	44.97	44.88	34.72	34.53	0.88	0.78	0.65	0.63	45.85	5.66	35.37	35.16
$g_2v_2r_2$	45.99	45.88	35.71	35.54	1.08	1.01	0.84	0.83	47.07	46.89	36.56	36.37
$g_2v_2r_3$	46.23	46.15	35.99	35.82	1.04	0.85	0.70	0.67	47.27	47.00	36.64	36.50
SEm (±)	0.042	0.015	0.035	0.010	0.004	0.004	0.016	0.005	0.043	0.053	0.034	0.011
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

guinea grass (G_2) recorded significantly higher dry fodder yield in open in both the years (1.02 t ha^{-1} year^{-1} and 0.91 t ha^{-1} year^{-1}). Fodder cowpea varieties varied significantly on dry fodder yield in open condition. COFC-8 (V_1) recorded higher dry fodder yield of 0.98 t ha^{-1} year^{-1} in first year and 0.88 t ha^{-1} year^{-1} in second year. Among the row ratios, fodder cowpea recorded significantly higher dry fodder yield in open when it was intercropped with grass at a row ratio of 1:2 (R_2) in both the years (1.12 t ha^{-1} year^{-1} in first and 1.01 t ha^{-1} year^{-1} in the second year). The interaction effects were not significant.

In partial shade, fodder cowpea intercropped between guinea grass (G_2) recorded significantly higher dry fodder yield in both the years (0.73 t ha^{-1} year^{-1} and 0.73 t ha^{-1} year^{-1}). Fodder cowpea varieties had no significant influence on dry fodder yield in partial shade. Among the row ratios, fodder cowpea recorded significantly higher dry fodder yield in open when it was intercropped with grass at a row ratio of 1:2 (R_2) in both the years (0.84 t ha^{-1} year^{-1} in first and 0.85 t ha^{-1} year^{-1} in the second year). The interaction effects were not significant.

The results on the dry fodder yield of fodder crops revealed that grasses and row ratio had significant effect on total dry fodder yield of fodder crops in open in both the years. Among the grasses, hybrid napier (G_1) recorded significantly higher total dry fodder yield in open in both the years (85.62 t ha^{-1} year^{-1} in the first year and 85.43 t ha^{-1} year^{-1} in the second year). Among the row ratios, total dry fodder yield was on par at 1:2 and 1:3 grass cowpea row ratio in open in both the years. The interaction effects were not significant.

The results on the dry fodder yield of fodder crops revealed that grasses and row ratio had significant effect on total dry fodder yield of fodder crops in shade in both the years. Among the grasses, hybrid napier (G_1) recorded significantly higher total dry fodder yield in shade in both the years (61.65 t ha^{-1} year^{-1} in the first year and 61.56 t ha^{-1} year^{-1} in the second year). Among the row ratios, total dry fodder yield was on par at 1:2 and 1:3 grass cowpea row ratio in partial shade in both the years. The interaction effects were not significant.

4.12. PHYSIOLOGICAL OBSERVATIONS

4.12.1. Dry Matter Production

The results on the effect of grasses, fodder cowpea varieties and row ratio on dry matter production of grass and cowpea in open and shade in both the years are presented in Table 50, 51 & 52. The results revealed that grasses and row ratio had significant impact on dry matter production of grasses in open. Significantly higher dry matter production was recorded by hybrid napier (G_1) in open in both the years (97.72 t ha^{-1} $year^{-1}$ in the first and 97.65 t ha^{-1} $year^{-1}$ in the second year). Among the row ratios, 1:3 (R_3) recorded significantly higher dry matter production in open in both the years (84.38 t ha^{-1} $year^{-1}$ in first year and 84.31 t ha^{-1} $year^{-1}$ in second year).

The results revealed that grasses and row ratio had significant impact on dry matter production of grasses in partial shade. Significantly higher dry matter production was recorded by hybrid napier (G_1) in shade in both the years (70.37 t ha^{-1} $year^{-1}$ in the first and 70.27 t ha^{-1} $year^{-1}$ in the second year). Among the row ratios, 1:3 (R_3) recorded significantly higher dry matter production in shade in both the years (63.12 t ha^{-1} $year^{-1}$ in first year and 63.00 t ha^{-1} $year^{-1}$ in second year).

The results on the dry matter production of fodder cowpea revealed that grasses, fodder cowpea varieties and row ratios had significant impact on dry matter production in open in both the years. Fodder cowpea intercropped between guinea grass (G_2) recorded significantly higher dry matter production in open in both the years (1.04 t ha^{-1} $year^{-1}$ in first year and 0.92 t ha^{-1} $year^{-1}$ in second year). Fodder cowpea varieties varied significantly on dry matter production in open condition. Fodder cowpea cv. COFC-8 (V_1) recorded significantly higher dry matter production (1.00 t ha^{-1} $year^{-1}$) in first year and second year (0.89 t ha^{-1} $year^{-1}$). Among the grass-legume row ratios, grasses intercropped with fodder cowpea in a row ratio of 1:2 (R_2) recorded significantly higher dry matter production in open in both the year (1.15 t ha^{-1} $year^{-1}$ in first year and

Table 50. Dry matter production of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, t ha^{-1} year^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	97.72	97.65	70.37	70.27	0.91	0.82	0.65	0.67
G_2-Guinea grass	69.00	68.89	54.11	53.96	1.04	0.92	0.74	0.75
SEm (±)	0.024	0.027	0.020	0.006	0.002	0.002	0.002	0.003
CD (0.05)	0.050	0.055	0.042	0.011	0.005	0.005	0.004	0.006
Fodder cowpea varieties (V)								
V_1 - COFC-8	83.36	83.27	62.24	62.13	1.00	0.89	0.72	0.72
V_2 - UPC-622	83.35	83.26			0.95	0.85		
V_2- UPC-618			62.25	62.10			0.68	0.70
SEm (±)	0.024	0.027	0.020	0.006	0.002	0.002	0.002	0.003
CD (0.05)	NS	NS	NS	NS	0.005	0.005	0.004	0.006
Grass-legume row ratio (R)								
R_1 - (1:1)	81.89	81.79	61.02	60.89	0.84	0.75	0.61	0.60
R_2 - (1:2)	83.79	83.72	62.59	62.46	1.15	1.04	0.86	0.86
R_3 - (1:3)	84.38	84.31	63.12	63.00	0.94	0.82	0.65	0.66
SEm (±)	0.030	0.033	0.025	0.007	0.003	0.003	0.002	0.003
CD (0.05)	0.061	0.067	0.051	0.014	0.007	0.006	0.005	0.008

Table 51. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on dry matter production of grass and cowpea, t ha^{-1} year^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	97.70	97.66	70.36	70.27	0.93	0.84	0.68	0.67
g_1v_2	97.73	97.63	70.38	70.27	0.88	0.78	0.64	0.65
g_2v_1	69.00	68.87	54.11	53.98	1.06	0.93	0.76	0.77
g_2v_2	68.99	68.90	54.12	53.94	1.02	0.90	0.73	0.73
SEm (±)	0.024	0.027	0.020	0.006	0.002	0.002	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	96.48	96.35	69.34	69.24	0.76	0.68	0.55	0.55
g_1r_2	98.08	98.01	70.70	70.59	1.13	1.02	0.82	0.83
g_1r_3	98.59	98.59	71.07	70.99	0.83	0.74	0.60	0.61
g_2r_1	67.31	67.23	52.69	52.55	0.92	0.81	0.66	0.64
g_2r_2	69.51	69.42	52.48	54.32	1.17	1.06	0.89	0.90
g_2r_3	70.18	70.02	55.17	55.01	1.05	0.89	0.69	0.71
SEm (±)	0.030	0.033	0.025	0.007	0.003	0.003	0.002	0.003
CD	NS	NS	NS	NS	0.010	0.009	0.007	NS
V x R								
v_1r_1	81.91	81.82	61.01	60.92	0.86	0.75	0.60	0.58
v_1r_2	83.78	83.73	62.58	62.48	1.20	1.07	0.89	0.90
v_1r_3	84.37	84.25	63.12	62.98	0.94	0.82	0.66	0.66
v_2r_1	81.87	81.75	61.03	60.86	0.83	0.73	0.60	0.60
v_2r_2	83.81	83.69	62.60	62.44	1.10	1.00	0.83	0.82
v_2r_3	84.40	84.35	63.12	63.02	0.93	0.79	0.62	0.65
SEm (±)	0.030	0.033	0.025	0.007	0.003	0.003	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 52. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on dry matter production of grass and cowpea, t ha^{-1} year^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	96.51	96.40	69.34	69.27	0.78	0.69	0.55	0.54
$g_1v_1r_2$	98.05	98.04	70.68	70.61	1.74	1.06	0.86	0.86
$g_1v_1r_3$	98.56	98.55	71.06	70.94	0.85	0.75	0.61	0.59
$g_1v_2r_1$	96.45	96.30	69.35	69.21	0.75	0.66	0.53	0.55
$g_1v_2r_2$	98.11	97.98	70.72	70.57	1.09	0.96	0.79	0.80
$g_1v_2r_3$	98.63	98.62	71.07	71.04	0.80	0.71	0.57	0.61
$g_2v_1r_1$	67.32	67.24	52.68	52.58	0.93	0.82	0.65	0.63
$g_2v_1r_2$	69.50	69.43	54.48	54.34	1.23	1.08	0.92	0.95
$g_2v_1r_3$	70.18	69.95	55.18	55.02	1.03	0.90	0.71	0.72
$g_2v_2r_1$	67.30	67.21	52.71	52.52	0.90	0.80	0.67	0.65
$g_2v_2r_2$	69.51	69.40	54.47	54.30	1.11	1.04	0.86	0.85
$g_2v_2r_3$	70.17	70.09	55.17	55.00	0.17	0.87	0.67	0.69
SEm (±)	0.042	0.046	0.035	0.010	0.005	0.004	0.003	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

1.04 t ha^{-1} $year^{-1}$ in second year). Grass-row ratio interaction was significant and $g_2 r_2$ (guinea grass intercropped with fodder cowpea at 1:2 row ratio) recorded significantly higher dry matter production of 1.17 t ha^{-1} $year^{-1}$ in the first year and 1.06 t ha^{-1} $year^{-1}$ in the second year. The other interactions were non-significant.

In partial shade, fodder cowpea intercropped between guinea grass (G_2) recorded significantly higher dry matter production in open in both the years (0.74 t ha^{-1} $year^{-1}$ in first year and 0.75 t ha^{-1} $year^{-1}$ in second year). Fodder cowpea varieties did not vary significantly on dry matter production in partial shade. Among the grass-legume row ratios, grasses intercropped with fodder cowpea in a row ratio of 1:2 (R_2) recorded significantly higher dry matter production in open in both the years (0.86 t ha^{-1} $year^{-1}$ in first year and second year). Grass-row ratio interaction was significant only in the first year and $g_2 r_2$ (guinea grass intercropped with fodder cowpea at 1:2 row ratio) recorded significantly higher dry matter production of 0.89 t ha^{-1} $year^{-1}$. The other interactions were non-significant.

4.12.2. Leaf Area Index

The results on the effect of grasses, fodder cowpea varieties and row ratio on leaf area index of grasses and fodder cowpea in open and shade in both the years are presented in Table 53, 54 & 55. The results revealed that grasses and row ratio had significant impact on leaf area index of grasses in open. Significantly higher leaf area index was recorded by hybrid napier (G_1) in open condition in both the years (6.81 in the first year and 6.79 in the second year). Among the grass-legume row ratio, 1:3 (R_3) row ratio recorded significantly higher leaf area index in open in both the years (6.04 in the first and 6.01 in the second year). Grass-row ratio interaction was significant and $g_1 r_3$ recorded significantly higher leaf area index of 7.02 in the first year and 7.03 in the second year. Other interactions were not significant.

In partial shade, significantly higher leaf area index was recorded by hybrid napier (G_1) in both the year (6.79 in the first year and 6.77 in the second year).

Table 53. Leaf area index of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	6.81	6.79	6.79	6.77	2.01	2.01	1.99	1.98
G_2-Guinea grass	4.72	4.70	4.70	4.73	2.02	2.00	2.01	1.95
SEm (±)	0.004	0.005	0.001	0.004	0.005	0.004	0.005	0.004
CD (0.05)	0.008	0.011	0.003	0.008	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	5.77	5.75	5.77	5.76	2.20	2.01	2.01	1.94
V_2 - UPC-622	5.76	5.75			2.01	2.00		
V_2- UPC-618			5.77	5.75			2.00	1.99
SEm (±)	0.004	0.005	0.001	0.004	0.005	0.004	0.005	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	5.32	5.30	5.32	5.31	2.01	1.99	1.99	1.99
R_2 - (1:2)	5.94	5.93	5.95	5.93	2.01	2.00	2.02	2.01
R_3 - (1:3)	6.04	6.01	6.03	6.01	2.03	2.01	2.00	1.99
SEm (±)	0.005	0.006	0.002	0.005	0.006	0.005	0.007	0.005
CD (0.05)	0.009	0.013	0.004	0.010	NS	NS	NS	NS

Table 54. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on leaf area index of grass and cowpea

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	6.81	6.79	6.79	6.77	2.01	2.01	2.01	1.98
g_1v_2	6.81	6.80	6.79	6.78	2.00	1.99	1.99	1.98
g_2v_1	4.73	4.71	4.75	4.73	2.03	2.10	2.02	1.89
g_2v_2	4.72	4.70	4.74	4.73	2.02	2.01	2.01	2.00
SEm (±)	0.004	0.005	0.001	0.004	0.005	0.004	0.005	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	6.39	6.38	6.38	6.37	1.99	1.98	1.99	1.97
g_1r_2	6.99	6.97	6.98	6.95	2.03	2.02	2.02	2.00
g_1r_3	7.06	7.03	7.02	7.01	2.01	2.00	2.00	1.98
g_2r_1	4.24	4.23	4.27	4.25	2.02	2.00	2.01	1.79
g_2r_2	4.90	4.88	4.92	4.91	2.03	2.02	2.03	2.02
g_2r_3	6.39	6.38	6.38	6.37	1.99	1.98	1.99	1.97
SEm (±)	0.005	0.006	0.002	0.005	0.006	0.005	0.007	0.005
CD	0.014	0.018	0.005	0.014	NS	NS	NS	NS
V x R								
v_1r_1	5.34	5.32	5.34	5.32	2.02	2.00	2.01	1.82
v_1r_2	5.94	5.92	5.94	5.92	2.04	2.03	2.03	2.01
v_1r_3	6.03	6.01	6.04	6.01	2.01	2.00	2.00	1.98
v_2r_1	5.29	5.29	5.31	5.30	2.00	1.98	1.99	1.98
v_2r_2	5.95	5.94	5.96	5.94	2.03	2.01	2.02	2.01
v_2r_3	6.05	6.02	6.04	6.02	2.02	2.00	2.01	1.99
SEm (±)	0.005	0.006	0.002	0.005	0.006	0.005	0.007	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 55. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on leaf area index of grass and cowpea

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	6.42	6.40	6.40	6.38	2.01	2.00	2.01	1.98
$g_1v_1r_2$	6.98	6.95	6.96	6.93	2.03	2.03	2.02	2.01
$g_1v_1r_3$	7.05	7.02	7.02	7.00	2.00	2.00	1.99	1.97
$g_1v_2r_1$	6.36	6.36	6.36	6.36	1.98	1.97	1.97	1.97
$g_1v_2r_2$	7.01	7.00	7.00	6.97	2.02	2.01	2.01	2.00
$g_1v_2r_3$	7.07	7.04	7.03	7.02	2.01	2.00	2.00	1.99
$g_2v_1r_1$	4.26	4.24	4.28	4.26	2.02	2.01	2.01	1.66
$g_2v_1r_2$	4.90	4.89	4.92	4.91	2.04	2.03	2.03	2.02
$g_2v_1r_3$	5.02	5.00	5.05	5.02	2.02	2.01	2.01	2.00
$g_2v_2r_1$	4.22	4.22	4.26	4.25	2.01	2.00	2.00	2.00
$g_2v_2r_2$	4.90	4.88	4.92	4.91	2.03	2.02	2.03	2.02
$g_2v_2r_3$	5.04	5.01	5.06	5.03	2.02	2.01	2.01	2.00
SEm (±)	0.007	0.009	0.003	0.007	0.009	0.006	0.009	0.006
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Among the grass-legume row ratio, 1:3 (R_3) row ratio recorded significantly higher leaf area index in shade in both the years (6.03 in the first and 6.01 in the second year). Grass-row ratio interaction was significant and g_1r_3 recorded significantly higher leaf area index of 7.02 in the first year and 7.01 in the second year. Other interactions were not significant.

The effect of treatments on leaf area index of fodder cowpea was not significant.

4.13. BIOCHEMICAL STUDIES

4.13.1. Chlorophyll Content

The results presented in Table 56, 57 & 58 indicated that the treatments and their interaction had no significant effect on chlorophyll content of grasses in open and shade in both years. The chlorophyll content of fodder cowpea in open and shade in both years varied among the fodder cowpea varieties. Significantly higher chlorophyll content was recorded by COFC-8 (V_1) (2.21 mg g^{-1} in the first year and 2.20 mg g^{-1} in the second year). The interaction effects were not significant.

In partial shade, significant variation was recorded by the fodder cowpea varieties and the variety COFC-8 (V1) recorded significantly higher chlorophyll content of 2.32 mg g^{-1} in the first year and 2.23 mg g^{-1} in the second year. The other treatment effects and interaction effects were non-significant.

4.13.2. Proline Content

The results on the effect of grasses, fodder cowpea varieties and row ratio on proline content of grasses and fodder cowpea in open and shaded situations are presented in Table 59, 60, & 61. The results revealed that the treatments and their interaction had no significant impact on proline content of grasses and fodder cowpea.

Table 56. Chlorophyll content of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, mg g^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	2.10	2.10	2.12	2.12	2.16	2.17	2.18	2.19
G_2-Guinea grass	2.09	2.10	2.11	2.12	2.16	2.16	2.18	2.18
SEm (±)	0.007	0.006	0.010	0.004	0.015	0.004	0.006	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	2.10	2.10	2.12	2.12	2.21	2.21	2.32	2.23
V_2 - UPC-622	2.01	2.09			2.12	2.12		
V_2- UPC-618			2.11	2.12			2.13	2.13
SEm (±)	0.007	0.006	0.010	0.004	0.015	0.004	0.006	0.004
CD (0.05)	NS	NS	NS	NS	0.031	0.022	0.012	0.012
Grass-legume row ratio (R)								
R_1 - (1:1)	2.10	2.11	2.12	2.13	2.17	2.16	2.19	2.18
R_2 - (1:2)	2.09	2.10	2.12	2.12	2.16	2.17	2.18	2.19
R_3 - (1:3)	2.10	2.10	2.11	2.12	2.17	2.16	2.18	2.19
SEm (±)	0.008	0.008	0.013	0.005	0.018	0.005	0.007	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 57. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on chlorophyll content of grass and cowpea, mg g^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	2.10	2.11	2.12	2.12	2.21	2.22	2.23	2.24
g_1v_2	2.09	2.10	2.12	2.12	2.11	2.12	2.13	2.13
g_2v_1	2.09	2.10	2.11	2.12	2.21	2.21	2.23	2.23
g_2v_2	2.09	2.09	2.11	2.11	2.12	2.11	2.13	2.12
SEm (±)	0.007	0.006	0.010	0.004	0.015	0.004	0.006	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	2.09	2.10	2.10	2.12	2.17	2.18	2.19	2.18
g_1r_2	2.11	2.11	2.12	2.13	2.15	2.16	2.17	2.18
g_1r_3	2.11	2.11	2.13	2.12	2.18	2.17	2.19	2.19
g_2r_1	2.11	2.10	2.13	2.12	2.17	2.15	2.18	2.17
g_2r_2	2.08	2.08	2.11	2.10	2.18	2.17	2.19	2.19
g_2r_3	2.09	2.11	2.10	2.13	2.15	2.15	2.17	2.17
SEm (±)	0.008	0.008	0.013	0.005	0.018	0.005	0.007	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	2.10	2.12	2.12	2.13	2.22	2.22	2.24	2.23
v_1r_2	2.09	2.10	2.11	2.12	2.21	2.23	2.23	2.24
v_1r_3	2.10	2.10	2.12	2.12	2.22	2.21	2.23	2.23
v_2r_1	2.09	2.09	2.12	2.11	2.12	2.11	2.14	2.12
v_2r_2	2.10	2.09	2.12	2.11	2.12	2.11	2.13	2.12
v_2r_3	2.09	2.12	2.11	2.13	2.11	2.11	2.13	2.13
SEm (±)	0.008	0.008	0.013	0.005	0.018	0.005	0.007	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 58. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on chlorophyll content of grass and cowpea, mg g^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	2.09	2.12	2.10	2.13	2.22	2.23	2.25	2.24
$g_1v_1r_2$	2.10	2.11	2.12	2.13	2.19	2.22	2.12	2.24
$g_1v_1r_3$	2.11	2.09	2.13	2.11	2.23	2.22	2.24	2.25
$g_1v_2r_1$	2.08	2.08	2.10	2.10	2.11	2.13	2.13	2.13
$g_1v_2r_2$	2.11	2.10	2.12	2.12	2.10	2.11	2.12	2.12
$g_1v_2r_3$	2.10	2.12	2.13	2.13	2.13	2.12	2.14	2.14
$g_2v_1r_1$	2.11	2.11	2.13	2.12	2.21	2.21	2.23	2.23
$g_2v_1r_2$	2.08	2.09	2.10	2.11	2.22	2.23	2.24	2.25
$g_2v_1r_3$	2.09	2.10	2.10	2.13	2.20	2.20	2.22	2.22
$g_2v_2r_1$	2.10	2.09	2.13	2.11	2.12	2.10	2.14	2.12
$g_2v_2r_2$	2.09	2.08	2.12	2.10	2.13	2.12	2.14	2.13
$g_2v_2r_3$	2.08	2.11	2.10	2.13	2.10	2.11	2.12	2.13
SEm (±)	0.011	0.011	0.018	0.008	0.026	0.006	0.010	0.006
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 59. Proline content of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass - legume mixture, μ mol g^{-1} FW

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	0.58	0.58	0.55	0.56	0.68	0.68	0.67	0.68
G_2-Guinea grass	0.57	0.57	0.55	0.55	0.67	0.69	0.67	0.68
SEm (±)	0.006	0.006	0.004	0.004	0.004	0.003	0.006	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	0.58	0.57	0.56	0.56	0.67	0.69	0.69	0.67
V_2 - UPC-622	0.57	0.57			0.68	0.68		
V_2- UPC-618			0.55	0.55			0.66	0.67
SEm (±)	0.006	0.006	0.004	0.004	0.004	0.003	0.006	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	0.57	0.58	0.56	0.56	0.68	0.68	0.68	0.68
R_2 - (1:2)	0.58	0.57	0.55	0.56	0.68	0.69	0.67	0.67
R_3 - (1:3)	0.58	0.58	0.55	0.55	0.67	0.69	0.68	0.67
SEm (±)	0.007	0.007	0.005	0.005	0.005	0.004	0.008	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 60. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on proline content of grass and cowpea, µ mol g^{-1} FW

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	0.58	0.57	0.55	0.55	0.67	0.69	0.69	0.68
g_1v_2	0.57	0.57	0.56	0.55	0.68	0.67	0.66	0.68
g_2v_1	0.58	0.57	0.56	0.56	0.67	0.69	0.69	0.68
g_2v_2	0.58	0.58	0.54	0.55	0.68	0.68	0.67	0.67
SEm (±)	0.006	0.006	0.004	0.004	0.004	0.003	0.006	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	0.56	0.58	0.56	0.56	0.68	0.68	0.69	0.68
g_1r_2	0.58	0.57	0.55	0.56	0.66	0.69	0.66	0.67
g_1r_3	0.58	0.58	0.55	0.55	0.68	0.68	0.68	0.68
g_2r_1	0.57	0.58	0.56	0.56	0.67	0.67	0.67	0.69
g_2r_2	0.58	0.57	0.55	0.55	0.69	0.68	0.68	0.68
g_2r_3	0.59	0.58	0.54	0.56	0.67	0.69	0.69	0.67
SEm (±)	0.007	0.007	0.005	0.005	0.005	0.004	0.008	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	0.57	0.57	0.56	0.55	0.68	0.69	0.70	0.68
v_1r_2	0.58	0.57	0.55	0.56	0.67	0.69	0.68	0.67
v_1r_3	0.59	0.58	0.55	0.56	0.67	0.70	0.69	0.68
v_2r_1	0.56	0.58	0.56	0.56	0.68	0.67	0.66	0.69
v_2r_2	0.58	0.67	0.54	0.55	0.68	0.68	0.66	0.68
v_2r_3	0.58	0.57	0.54	0.54	0.67	0.68	0.67	0.69
SEm (±)	0.007	0.007	0.005	0.005	0.005	0.004	0.008	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 61. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on proline content of grass and cowpea, μ mol g^{-1} FW

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	0.57	0.56	0.56	0.54	0.69	0.70	0.71	0.68
$g_1v_1r_2$	0.59	0.58	0.55	0.58	0.66	0.71	0.66	0.66
$g_1v_1r_3$	0.58	0.59	0.54	0.55	0.68	0.69	0.70	0.69
$g_1v_2r_1$	0.56	0.56	0.56	0.57	0.68	0.67	0.66	0.68
$g_1v_2r_2$	0.57	0.56	0.55	0.55	0.67	0.68	0.67	0.69
$g_1v_2r_3$	0.58	0.58	0.56	0.54	0.68	0.67	0.65	0.67
$g_2v_1r_1$	0.58	0.56	0.57	0.56	0.67	0.68	0.68	0.69
$g_2v_1r_2$	0.57	0.57	0.56	0.55	0.68	0.69	0.71	0.68
$g_2v_1r_3$	0.59	0.57	0.56	0.57	0.67	0.70	0.68	0.67
$g_2v_2r_1$	0.57	0.59	0.55	0.55	0.68	0.67	0.66	0.69
$g_2v_2r_2$	0.59	0.58	0.54	0.58	0.70	0.68	0.65	0.68
$g_2v_2r_3$	0.58	0.59	0.53	0.54	0.67	0.68	0.69	0.66
SEm (±)	0.010	0.011	0.007	0.007	0.007	0.005	0.011	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

4.14. QUALITY STUDIES

4.14.1. Crude Protein Content

The result of the effect of grasses, fodder cowpea varieties and row ratio on crude protein content of grasses and fodder cowpea in open and shaded situations are presented in Table 62, 63 & 64. The results showed that grasses and row ratio had significant impact on crude protein content of grasses in open in both the years. Significantly higher crude protein content was recorded by hybrid napier (G_1) in open (9.21 % in first year and 9.20 % in second year). Grass-legume row ratio of 1:3 (R_3) recorded significantly higher crude protein content in open (8.65 %) in both the years. Grass-row ratio interaction was significant in open condition with g_1r_3 (hybrid napier + fodder cowpea planted at 1:3 row ratio) recording significantly higher crude protein content of 9.24 % in both the years.

The results also showed that grasses and row ratio had significant impact on crude protein content of grasses in shade in both the years. Significantly higher crude protein content was recorded by hybrid napier (G_1) in open (9.22 % in first year and 9.21 % in second year). Grass-legume row ratio of 1:3 (R_3) recorded significantly higher crude protein content in open (8.66 %) in both the years. The interaction effects were not significant.

The results also revealed that the treatments and their interactions had no significant impact on crude protein content of fodder cowpea.

4.14.2. Crude Fibre Content

The results on the effect of grasses, fodder cowpea varieties and row ratio on crude fibre content of grasses and fodder cowpea in open and shaded situations are presented in Table 65, 66 & 67. The results revealed that the grasses varied significantly with respect to crude fibre content in open. Significantly lower crude fibre content (25.86 % and 24.97 %) was recorded by hybrid napier (G_1) in open in first and second years respectively. Fodder cowpea varieties, row ratio

Table 62. Crude protein content of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, %

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	9.21	9.20	9.22	9.21	16.00	16.01	16.02	16.02
G_2-Guinea grass	8.03	8.05	8.04	8.05	16.01	16.00	16.01	16.02
SEm (±)	0.002	0.003	0.002	0.003	0.005	0.004	0.006	0.004
CD (0.05)	0.003	0.003	0.003	0.003	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	8.63	8.62	8.64	8.63	16.02	16.01	16.01	16.03
V_2 - UPC-622	8.62	8.63			16.00	16.00		
V_2- UPC-618			8.63	8.64			16.03	16.02
SEm (±)	0.002	0.003	0.002	0.003	0.005	0.004	0.006	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	8.60	8.61	8.61	8.62	16.01	15.99	16.01	16.02
R_2 - (1:2)	8.62	8.62	8.63	8.64	16.02	16.01	16.02	16.03
R_3 - (1:3)	8.65	8.65	8.66	8.66	15.99	16.02	16.03	16.03
SEm (±)	0.003	0.004	0.003	0.004	0.006	0.005	0.007	0.005
CD (0.05)	0.004	0.004	0.004	0.004	NS	NS	NS	NS

Table 63. Interaction effect (2 factor) of grass, cowpea varieties and grass – legume row ratios on crude protein content of grass and cowpea,%

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	9.22	9.20	9.23	9.21	16.01	16.02	16.03	16.03
g_1v_2	9.21	9.21	9.22	9.22	15.99	16.01	16.01	16.01
g_2v_1	8.04	8.04	8.05	8.05	16.02	16.01	16.03	16.03
g_2v_2	8.03	8.05	8.04	8.05	16.00	16.00	16.01	16.02
SEm (±)	0.002	0.003	0.002	0.003	0.005	0.004	0.006	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	9.19	29.18	9.20	9.19	15.9	16.00	16.01	16.01
g_1r_2	9.20	9.20	9.21	9.22	16.01	16.02	16.02	16.02
g_1r_3	9.24	9.24	9.25	9.25	16.01	16.02	16.03	16.03
g_2r_1	8.01	8.032	8.03	8.04	16.02	15.98	16.01	16.01
g_2r_2	8.04	8.04	8.04	8.05	16.02	16.01	16.03	16.03
g_2r_3	8.05	8.06	8.06	8.06	16.02	16.02	16.04	16.04
SEm (±)	0.003	0.004	0.003	0.004	0.006	0.005	0.007	0.005
CD (0.05)	0.006	0.005	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	8.60	8.61	8.61	8.61	16.01	15.99	16.02	16.02
v_1r_2	8.62	8.61	8.63	8.63	16.02	16.02	16.04	16.04
v_1r_3	8.65	8.65	8.66	8.65	16.03	16.03	16.05	16.04
v_2r_1	8.60	8.61	8.62	8.61	15.99	15.99	16.00	16.01
v_2r_2	8.63	8.62	8.62	8.64	16.01	16.02	16.03	16.02
v_2r_3	8.64	8.65	8.65	8.66	16.01	16.02	16.02	16.03
SEm (±)	0.003	0.004	0.003	0.004	0.006	0.005	0.007	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 64. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on crude protein content of grass and cowpea,%

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	9.19	9.18	9.20	9.19	16.00	16.01	16.02	16.02
$g_1v_1r_2$	9.21	9.19	9.22	9.21	16.02	16.03	16.04	16.03
$g_1v_1r_3$	9.25	9.24	9.26	9.25	16.03	16.03	16.04	16.04
$g_1v_2r_1$	9.20	9.18	9.21	9.19	15.98	16.00	16.00	16.01
$g_1v_2r_2$	9.20	9.21	9.21	9.22	16.00	16.01	16.01	16.02
$g_1v_2r_3$	9.24	9.24	9.25	9.25	16.00	16.01	16.02	16.02
$g_2v_1r_1$	8.02	8.03	8.03	8.04	16.01	15.98	16.01	16.04
$g_2v_1r_2$	8.04	8.04	8.05	8.05	16.03	16.03	16.04	16.04
$g_2v_1r_3$	8.06	8.06	8.07	8.06	16.03	16.03	16.05	16.04
$g_2v_2r_1$	8.01	8.03	8.03	8.04	16.00	15.98	16.00	16.01
$g_2v_2r_2$	8.04	8.05	8.04	8.06	16.01	16.00	16.02	16.03
$g_2v_2r_3$	8.05	8.06	8.06	8.07	16.01	16.02	16.02	16.03
SEm (±)	0.004	0.005	0.004	0.005	0.008	0.006	0.010	0.006
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 65. Crude fibre content of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, %

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	25.86	24.97	25.94	25.69	24.26	24.49	23.59	24.14
G_2-Guinea grass	26.98	26.97	26.96	26.10	24.28	24.29	24.14	24.12
SEm (±)	0.055	0.024	0.001	0.007	0.006	0.005	0.559	0.005
CD (0.05)	0.115	0.049	0.003	0.015	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	26.98	26.44	26.96	26.95	24.28	24.27	23.58	24.14
V_2 - UPC-622	26.86	26.52			24.63	24.50		
V_2- UPC-618			26.94	26.86			24.14	24.13
SEm (±)	0.055	0.024	0.001	0.007	0.006	0.005	0.559	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	26.78	26.51	26.96	26.88	24.28	24.38	24.14	24.09
R_2 - (1:2)	26.95	26.42	26.94	27.07	24.29	24.39	24.13	24.15
R_3 - (1:3)	27.03	26.50	26.96	27.17	24.26	24.38	23.32	24.16
SEm (±)	0.068	0.029	0.002	0.009	0.007	0.006	0.684	0.006
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 66. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on crude fibre content of grass and cowpea, %

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	25.76	24.96	25.93	25.69	24.27	24.30	23.03	24.16
g_1v_2	25.96	24.99	25.95	25.17	24.24	24.68	24.14	24.13
g_2v_1	27.96	27.92	27.94	28.01	24.28	24.24	24.14	24.12
g_2v_2	28.00	28.04	2798	28.02	24.28	24.32	24.14	24.13
SEm (±)	0.055	0.024	0.001	0.007	0.006	0.005	0.559	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	25.63	25.06	25.91	25.67	24.27	24.36	24.14	24.12
g_1r_2	25.96	24.88	25.94	25.84	24.26	24.61	24.15	24.15
g_1r_3	25.99	24.98	25.97	25.58	24.25	24.50	22.47	24.16
g_2r_1	27.92	27.96	28.01	28.09	24.29	24.40	24.40	24.07
g_2r_2	27.96	27.96	27.94	28.30	24.32	24.16	24.12	24.15
g_2r_3	28.08	28.02	27.95	27.96	24.24	24.27	24.18	24.16
SEm (±)	0.068	0.029	0.002	0.009	0.007	0.006	0.684	0.006
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	26.38	26.42	26.96	27.11	24.30	24.35	24.10	24.06
v_1r_2	26.95	26.43	26.87	27.16	24.27	24.21	24.17	24.17
v_1r_3	27.05	26.48	26.96	26.58	24.27	24.25	22.49	24.18
v_2r_1	26.97	26.61	26.95	26.65	24.26	24.41	24.18	24.13
v_2r_2	26.95	26.42	27.00	26.98	24.31	24.56	24.09	24.12
v_2r_3	97.02	26.52	26.96	26.95	24.22	24.52	24.17	24.14
SEm (±)	0.068	0.029	0.002	0.009	0.007	0.006	0.684	0.006
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 67. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on crude fibre content of grass and cowpea, %

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	25.35	25.02	26.00	25.92	24.32	24.41	24.11	24.12
$g_1v_1r_2$	25.89	24.82	25.86	25.81	24.21	24.22	24.19	24.20
$g_1v_1r_3$	26.05	25.05	25.92	25.36	24.30	24.28	24.79	24.16
$g_1v_2r_1$	25.92	25.11	25.83	25.42	24.22	24.32	24.18	24.13
$g_1v_2r_2$	26.02	24.95	26.01	25.88	24.31	25.31	24.10	24.10
$g_1v_2r_3$	25.94	24.91	26.03	25.80	24.20	24.72	24.16	24.17
$g_2v_1r_1$	27.82	27.82	27.92	28.31	24.28	24.30	24.09	24.00
$g_2v_1r_2$	28.02	28.04	27.89	28.52	24.33	24.20	24.15	24.15
$g_2v_1r_3$	28.06	27.91	28.01	27.81	24.24	24.22	24.18	24.21
$g_2v_2r_1$	28.03	28.11	28.09	27.88	24.30	24.50	24.18	24.14
$g_2v_2r_2$	27.89	27.89	27.99	28.09	24.31	24.12	24.09	24.15
$g_2v_2r_3$	28.10	28.13	27.88	28.11	24.24	24.33	24.17	24.11
SEm (±)	0.096	0.041	0.003	0.013	0.010	0.008	0.969	0.008
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

and the interactions had no significant effect on crude fibre content of grasses in open.

The results also revealed that the grasses varied significantly with respect to crude fibre content in partial shade. Significantly lower crude fibre content (26.96 % and 26.10 %) was recorded by hybrid napier (G_1) in shade in first and second years respectively. Fodder cowpea varieties, row ratio and the interactions had no significant effect on crude fibre content of grasses in shade.

The results also revealed that the treatments and their interactions had no significant impact on crude fibre content of fodder cowpea.

4.14.3. Crude Protein Yield

The results of the effect of grasses, fodder cowpea varieties and row ratio on crude protein yield of grasses and fodder cowpea in open and shaded situations in both the year are presented in Table 68, 69 & 70. The results showed that grasses and row ratio had significant impact on crude protein yield of grasses. Significantly higher crude protein yield was registered by hybrid napier (G_1) in open in both the year (7.28 t ha^{-1} and 7.27 t ha^{-1} respectively in first and second year). Grass-legume row ratio of 1:3 (R_3) recorded significantly higher crude protein yield in open (5.42 t ha^{-1} in first year and 5.41 t ha^{-1} in the second year). Grass- row ratio interaction alone was significant in open condition and g_1r_3 (hybrid napier intercropped with fodder cowpea at 1:3 row ratio) recorded significantly higher crude protein yield (7.33 t ha^{-1}) in open in both the year.

In partial shade, significantly higher crude protein yield was registered by hybrid napier (G_1) in open in both the years (5.24 t ha^{-1}). Grass-legume row ratio of 1:3 (R_3) recorded significantly higher crude protein yield in open (4.01 t ha^{-1} in first year and 4.00 t ha^{-1} in the second year). The interaction effects were non-significant.

The results revealed that grasses fodder cowpea varieties and row ratio had significant effect on crude protein yield of fodder cowpea. Significantly higher crude protein yield was recorded by fodder cowpea when intercropped in between guinea grass (G_2) in open condition (0.16 t ha^{-1}) in first year and second year (0.14 t ha^{-1}). Fodder cowpea varieties showed significant difference on crude protein yield of fodder cowpea in open condition during the first year. The crude protein yield was the highest (0.16 t ha^{-1}) in fodder cowpea cv. COFC-8 in open condition. Among the grass legume row ratios, significantly higher crude protein yield was recorded by fodder cowpea when it was intercropped with grasses at a row ratio of 1:2 (R_2) in both the years (0.17 t ha^{-1} in the first and 0.16 t ha^{-1} in the second year). Grass row ratio interaction was significant only in open condition and g_2r_2 (fodder cowpea intercropped with guinea grass at 1:2 row ratio) recorded significantly higher crude protein yield in open condition in first (0.18 t ha^{-1}) and second year (0.16 t ha^{-1}). .

Significantly higher crude protein yield was recorded by fodder cowpea when intercropped in between guinea grass (G_2) in shaded condition in the second year (0.12 t ha^{-1}). Fodder cowpea varieties did not vary significantly on crude protein yield in shade. Among the grass legume row ratios, significantly higher crude protein yield was recorded by fodder cowpea when it was intercropped with a row ratio of 1:2 (R_2) in both the years (0.13 t ha^{-1} in the first and 0.14 t ha^{-1} in the second year). The interaction effects were non-significant.

The results also revealed that grasses and grass-legume row ratio had significant impact on total crude protein yield in open in both the years. Among the grasses, hybrid napier registered a higher total crude protein yield in open in two years (7.42 t ha^{-1} in the first year and 7.41 t ha^{-1} in the second year). Fodder cowpea intercropped with grasses at a row ratio of 1:2 (R_2) recorded significantly higher total crude protein yield in open in both the years (5.58 t ha^{-1} in the first year and 5.55 t ha^{-1} in the second year). Grass-row ratio interaction was significant in open condition and g_1r_2 (hybrid napier intercropped with 1:2 row ratio) registered significantly higher total crude protein yield in open condition in two years (7.48 t ha^{-1} in the first year and 7.42 t ha^{-1} in the second year).

Table 68. Crude protein yield of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, t ha^{-1}

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses(G)												
G1-Hybrid napier	7.28	7.27	5.24	5.24	0.14	0.12	0.10	0.10	7.42	7.41	5.35	5.34
G2-Guinea grass	3.47	3.46	2.70	2.69	0.16	0.14	0.11	0.12	3.63	3.61	2.82	2.81
SEm (±)	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002
CD (0.05)	0.004	0.001	0.003	0.001	0.001	0.001	NS	0.001	0.004	0.004	0.003	0.001
Fodder Cowpea Varieties (V)												
V1-COFC-8	5.37	5.37	3.98	3.96	0.16	0.13	0.11	0.11	5.53	5.51	4.09	4.08
V2-UPC-622	5.38	5.36			0.14	0.13			5.52	5.52		
V2-UPC-618			3.97	3.96			0.11	0.10			4.08	4.07
SEm (±)	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002
CD (0.05)	NS	NS	NS	NS	0.001	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio(R)												
R_1 - (1:1)	5.30	5.29	3.91	3.89	0.13	0.11	0.09	0.09	5.44	5.41	4.00	3.99
R_2 - (1:2)	5.40	5.39	4.00	3.99	0.17	0.16	0.13	0.14	5.58	5.55	4.13	4.12
R_3 - (1:3)	5.42	5.41	4.01	4.00	0.14	0.12	0.10	0.10	5.57	5.53	4.11	4.11
SEm (±)	0.003	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.003
CD (0.05)	0.005	0.001	0.004	0.001	0.001	0.001	0.001	0.001	0.005	0.005	0.003	0.001

Table 69. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on crude protein yield of grass and cowpea, t ha^{-1}

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V												
g_1v_1	7.27	7.27	5.24	5.24	0.14	0.13	0.10	0.10	7.42	7.40	5.35	5.34
g_1v_2	7.28	7.27	5.24	5.24	0.13	0.12	0.09	0.10	7.41	7.38	5.34	5.34
g_2v_1	3.47	3.46	2.70	2.69	0.16	0.14	0.11	0.11	3.63	3.61	2.82	2.81
g_2v_2	3.47	3.46	2.70	2.68	0.16	0.14	0.11	0.11	3.63	3.60	2.82	2.80
SEm (±)	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x R												
g_1r_1	7.19	7.18	5.17	5.17	0.11	0.10	0.08	0.08	7.31	7.29	5.26	5.25
g_1r_2	7.30	7.29	5.27	5.26	0.17	0.15	0.12	0.12	7.48	7.42	5.4	5.39
g_1r_3	7.33	7.33	5.29	5.28	0.12	0.11	0.09	0.09	7.46	7.40	5.38	5.37
g_2r_1	3.41	3.40	2.63	2.62	0.14	0.12	0.10	0.10	3.55	3.52	2.74	2.72
g_2r_2	3.49	3.48	2.72	2.71	0.18	0.16	0.14	0.14	3.67	3.64	2.86	2.85
g_2r_3	3.51	3.50	2.74	2.73	0.16	0.14	0.10	0.11	3.67	3.64	2.85	2.84
SEm (±)	0.003	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.003
CD (0.05)	0.007	0.002	NS	NS	0.004	0.001	NS	NS	0.007	0.007	NS	NS

Table 69. continued

V x R												
v_1r_1	5.30	5.29	3.90	3.90	0.13	0.11	0.09	0.09	4.00	1.01	4.00	3.99
v_1r_2	5.39	5.39	3.99	3.98	0.18	0.16	0.13	0.14	4.13	4.12	4.13	4.13
v_1r_3	5.42	5.41	4.01	4.00	0.14	0.12	0.10	0.11	4.12	4.11	4.12	4.10
v_2r_1	5.30	5.29	3.91	3.81	0.12	0.11	0.09	0.09	4.00	3.99	4.00	3.99
v_2r_2	5.39	5.38	3.99	3.98	0.17	0.15	0.12	0.13	4.12	4.11	4.12	4.11
v_2r_3	5.42	5.42	4.01	4.00	0.14	0.12	0.09	0.10	4.11	4.10	4.11	4.11
SEm (±)	0.003	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 70. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on crude protein yield of grass and cowpea, t ha^{-1}

Treatments	Grass				Cowpea				Total			
	Open		Shade		Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R												
$g_1v_1r_1$	7.20	7.19	5.17	5.16	0.12	0.10	0.08	0.09	5.26	5.27	5.26	5.25
$g_1v_1r_2$	7.30	7.30	5.27	5.26	0.18	0.16	0.13	0.14	5.40	5.41	5.40	5.40
$g_1v_1r_3$	7.33	7.32	5.29	5.28	0.13	0.11	0.09	0.09	5.38	5.37	5.38	5.37
$g_1v_2r_1$	7.19	7.18	5.18	5.16	0.11	0.10	0.08	0.08	5.26	5.27	5.26	5.25
$g_1v_2r_2$	7.30	7.29	5.27	5.26	0.16	0.15	0.12	0.12	5.39	5.40	5.39	5.38
$g_1v_2r_3$	7.33	7.33	5.29	5.28	0.12	0.11	0.09	0.09	5.38	5.39	5.38	5.38
$g_2v_1r_1$	3.41	3.40	2.63	2.63	0.14	0.12	0.01	0.09	2.73	2.72	2.73	2.72
$g_2v_1r_2$	3.49	3.48	2.72	2.71	0.19	0.16	0.14	0.15	2.86	2.85	2.86	2.86
$g_2v_1r_3$	3.51	3.50	2.74	2.73	0.16	0.14	0.11	0.12	2.85	2.84	2.85	2.84
$g_2v_2r_1$	3.40	3.40	2.64	2.62	0.14	0.12	0.10	0.11	2.74	2.73	2.74	2.72
$g_2v_2r_2$	3.49	3.48	2.72	0.70	0.17	0.16	0.13	0.14	2.85	2.84	2.85	2.84
$g_2v_2r_3$	3.51	3.50	2.74	2.73	0.16	0.13	0.10	0.11	2.84	2.83	2.84	2.83
SEm (±)	0.004	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.004
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

In shade, hybrid napier registered a higher total crude protein yield in two years (5.35 t ha^{-1} in the first year and 5.34 t ha^{-1} in the second year). Fodder cowpea intercropped with grasses at a row ratio of 1:2 (R_2) recorded significantly higher total crude protein yield in open in both the years (4.13 t ha^{-1} in the first year and 4.12 t ha^{-1} in the second year).

4.15.1. N Uptake

The results summarized in Table 71, 72 & 73 revealed that grasses and row ratio had significant impact on N uptake of fodder grasses in open both the years. Significantly higher uptake N was recorded by hybrid napier in open (124.57 kg ha^{-1}) in the first year and second year (124.46 kg ha^{-1}). Grass-legume row ratio of 1:3 (R_3) recorded significantly higher N uptake in open in first (92.08 kg ha^{-1}) and second year (92.02 kg ha^{-1}). Grass-row ratio interaction was significant in open condition in the second year and g_1r_3 (hybrid napier intercropped with fodder cowpea at a row ratio of 1:3) recorded higher N uptake (125.43 kg ha^{-1}).

In partial shade, significantly higher uptake of N was recorded by hybrid napier in open (89.68 kg ha^{-1}) in the first year and second year (89.54 kg ha^{-1}). Grass-legume row ratio of 1:3 (R_3) recorded significantly higher N uptake in open in first (68.03 kg ha^{-1}) and second year (67.87 kg ha^{-1}).

The results revealed that grasses, fodder cowpea varieties and row ratio had significant impact on N uptake of fodder cowpea in open. The N uptake of fodder cowpea was significantly higher when it was intercropped with guinea grass in open in both the years (2.61 kg ha^{-1} in the first year and 2.26 kg ha^{-1} in the second year). Among the varieties, COFC-8 (V_1) recorded significantly higher N uptake in open (2.50 kg ha^{-1} in first year and 2.18 kg ha^{-1} in second year). Row ratio of 1:2 (R_2) recorded higher N uptake in open in first year (2.87 kg ha^{-1}) and second year (2.55 kg ha^{-1}). Grass-row ratio interaction was significant in open condition in the first year. Significantly higher N uptake (2.92 kg ha^{-1}) was recorded by g_2r_2 (fodder cowpea intercropped with guinea grass with 1:2 row ratio).

Table 71. N uptake of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	124.57	124.46	89.68	89.54	2.26	2.01	1.65	1.65
G_2-Guinea grass	58.08	57.97	45.05	44.85	2.61	2.26	1.86	1.87
SEm (±)	0.036	0.012	0.028	0.008	0.007	0.026	0.006	0.007
CD (0.05)	0.073	0.024	0.059	0.016	0.014	0.053	0.011	0.015
Fodder cowpea varieties (V)								
V_1 - COFC-8	91.33	91.24	67.36	67.21	2.50	2.18	1.79	1.79
V_2 - UPC-622	91.32	91.20			2.38	2.09		
V_2- UPC-618			67.38	67.18			1.71	1.72
SEm (±)	0.036	0.012	0.028	0.008	0.007	0.026	0.006	0.007
CD (0.05)	NS	NS	NS	NS	0.014	0.053	0.011	0.015
Grass-legume row ratio (R)								
R_1 - (1:1)	90.21	90.07	66.34	66.18	2.11	1.85	1.50	1.48
R_2 - (1:2)	91.68	91.57	67.72	67.54	2.87	2.55	2.15	2.16
R_3 - (1:3)	92.08	92.02	68.03	67.87	2.34	2.02	1.60	1.64
SEm (±)	0.043	0.014	0.035	0.010	0.009	0.032	0.007	0.009
CD (0.05)	0.090	0.029	0.072	0.019	0.017	0.065	0.014	0.019

Table 72. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on N uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	124.55	124.49	89.67	89.55	2.33	2.08	1.69	1.66
g_1v_2	124.59	124.44	89.70	89.54	2.20	1.94	1.59	1.63
g_2v_1	58.09	57.98	45.05	44.88	2.66	2.28	1.89	1.92
g_2v_2	58.08	57.96	45.05	44.83	2.56	2.25	1.83	1.82
SEm (±)	0.036	0.012	0.028	0.008	0.007	0.026	0.006	0.007
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	123.30	123.11	88.61	88.46	1.91	1.69	1.36	1.36
g_1r_2	124.95	124.84	90.08	88.92	2.82	2.53	2.07	2.07
g_1r_3	125.44	125.43	90.36	90.24	2.06	1.83	1.49	1.51
g_2r_1	57.12	57.02	44.07	43.89	2.30	2.02	1.63	1.60
g_2r_2	58.40	58.29	45.36	45.16	2.92	2.57	2.24	2.25
g_2r_3	58.72	58.61	45.71	45.51	2.61	2.21	1.71	1.76
SEm (±)	0.043	0.014	0.035	0.010	0.009	0.032	0.007	0.009
CD (0.05)	NS	0.042	NS	NS	0.024	NS	NS	NS
V x R								
v_1r_1	90.24	90.11	66.33	66.22	2.14	1.89	1.50	1.46
v_1r_2	91.65	91.60	67.71	67.57	3.00	2.60	2.24	2.26
v_1r_3	92.06	91.99	68.03	67.85	2.35	2.06	1.65	1.65
v_2r_1	90.19	90.02	66.36	66.13	2.07	1.82	1.50	1.50
v_2r_2	91.70	95.53	67.74	67.51	2.73	2.49	2.07	2.06
v_2r_3	92.11	92.04	68.04	67.90	2.33	1.97	1.55	1.62
SEm (±)	0.043	0.014	0.035	0.010	0.009	0.032	0.007	0.009
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 73. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on N uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	123.34	123.19	88.61	88.51	1.95	1.73	1.39	1.34
$g_1v_1r_2$	124.91	124.89	90.05	89.95	2.92	2.65	2.16	2.14
$g_1v_1r_3$	125.39	125.08	90.35	90.17	2.12	1.87	1.54	1.50
$g_1v_2r_1$	123.26	123.03	88.62	88.42	1.87	1.65	1.34	1.38
$g_1v_2r_2$	124.99	124.80	90.12	89.89	2.71	2.40	1.98	2.00
$g_1v_2r_3$	125.50	125.48	90.37	90.31	2.01	1.78	1.45	1.52
$g_2v_1r_1$	57.14	57.04	44.06	43.92	2.33	2.04	1.61	1.58
$g_2v_1r_2$	58.39	58.31	45.37	45.19	3.08	2.55	2.32	2.38
$g_2v_1r_3$	58.73	58.61	45.72	45.52	2.57	2.24	1.76	1.80
$g_2v_2r_1$	57.11	57.00	44.09	43.85	2.27	1.99	1.66	1.62
$g_2v_2r_2$	58.41	58.27	45.36	45.14	2.76	2.58	2.17	2.12
$g_2v_2r_3$	58.71	58.61	45.71	45.49	2.66	2.17	1.66	1.72
SEm (±)	0.062	0.020	0.049	0.013	0.012	0.044	0.010	0.013
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

The N uptake was significantly highest when it was intercropped with guinea grass in shade in both the years (1.86 kg ha^{-1}in first year and 1.87 kg ha^{-1} in second year). Among the varieties, COFC-8 (V_1) recorded significantly higher N uptake in shade (1.79kg ha^{-1}) in both the years. Row ratio of 1:2 (R_2) recorded higher N uptake in shade in first year (2.15 kg ha^{-1}) and second year (2.16 kg ha^{-1}). The interaction effects were non-significant.

4.15.2. P Uptake

The results of the effect of grasses, fodder cowpea varieties and row ratio on uptake of P are presented in Table 74, 75 & 76. The results revealed that grass and row ratio had significant impact on uptake of P in open in both the years. Hybrid napier (G_1) recorded significantly higher P uptake in open in two years (15.25 kg ha^{-1} and 15.24 kg ha^{-1} in first and second year respectively). Significantly higher uptake of P was recorded by 1:3 row ratio (R_3) in open in first (11.84 kg ha^{-1}) and second year (11.83 kg ha^{-1}). The interaction effects were non-significant.

Hybrid napier (G_1) recorded significantly higher P uptake in partial shade in two years (10.98 kg ha^{-1} and 10.96 kg ha^{-1} in first and second year respectively). Significantly higher uptake of P was recorded by 1:3 row ratio (R_3) in shade in first (8.77 kg ha^{-1}) and second year (8.75 kg ha^{-1}). The interaction effects were non-significant.

The uptake of P by cowpea was significantly higher when intercropped with guinea grass cv. Harithasree (G_2) (0.11 and 0.10 kg ha^{-1}) in open in first and second year respectively. Grass-legume row ratio of 1:2 (R_2) recorded significantly higher P uptake by fodder cowpea (0.12 kg ha^{-1} and 0.11 kg ha^{-1}) in first and second year respectively in open condition. The interaction effects were not significant.

In partial shade, the uptake of P by cowpea was significantly higher when intercropped with guinea grass cv. Harithasree (G_2) (0.08 kg ha^{-1}and 0.10 kg ha^{-1}) in first and second year, respectively. Grass - legume row ratio of 1:2 (R_2)

Table 74. P uptake of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	15.25	15.24	10.98	10.96	0.09	0.08	0.07	0.06
G_2-Guinea grass	8.23	8.21	6.38	6.35	0.11	0.10	0.08	0.10
SEm (±)	0.004	0.001	0.003	0.001	0.001	0.001	0.001	0.045
CD (0.05)	0.009	0.003	0.007	0.002	0.001	0.002	0.002	0.002
Fodder cowpea varieties (V)								
V_1 - COFC-8	11.74	11.73	8.68	8.66	0.10	0.09	0.07	0.07
V_2 - UPC-622	11.73	11.72			0.10	0.08		
V_2- UPC-618			8.67	8.65			0.07	0.08
SEm (±)	0.004	0.001	0.003	0.001	0.001	0.001	0.001	0.045
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	11.59	11.57	8.54	8.52	0.08	0.07	0.06	0.06
R_2 - (1:2)	11.78	11.77	8.73	8.70	0.12	0.11	0.09	0.08
R_3 - (1:3)	11.84	11.83	8.77	8.75	0.10	0.08	0.07	0.07
SEm (±)	0.005	0.002	0.004	0.002	0.002	0.001	0.002	0.055
CD (0.05)	0.011	0.003	0.009	0.002	0.001	0.003	0.002	0.002

Table 75. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on P uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	15.25	15.24	10.98	10.96	0.09	0.08	0.07	0.07
g_1v_2	15.25	15.23	10.98	10.96	0.09	0.08	0.06	0.06
g_2v_1	8.23	8.21	6.38	6.36	0.11	0.10	0.08	0.08
g_2v_2	8.23	8.21	6.38	6.35	0.11	0.09	0.07	0.07
SEm (±)	0.004	0.001	0.003	0.001	0.001	0.001	0.001	0.045
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	15.09	15.07	10.85	10.83	0.07	0.07	0.06	0.05
g_1r_2	15.30	15.28	11.03	11.01	0.12	0.10	0.08	0.08
g_1r_3	15.30	15.35	11.06	11.05	0.09	0.07	0.06	0.06
g_2r_1	8.09	8.08	6.42	6.22	0.10	0.08	0.06	0.06
g_2r_2	8.27	8.26	6.24	6.40	0.12	0.11	0.09	0.10
g_2r_3	8.32	8.30	6.47	6.45	0.11	0.09	0.07	0.07
SEm (±)	0.005	0.002	0.004	0.002	0.002	0.001	0.002	0.055
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	11.60	11.58	8.54	8.52	0.08	0.08	0.06	0.07
v_1r_2	11.78	11.77	8.72	8.70	0.13	0.12	0.09	0.11
v_1r_3	11.83	11.80	8.77	8.74	0.10	0.09	0.07	0.08
v_2r_1	11.59	11.57	8.55	8.52	0.09	0.07	0.06	0.07
v_2r_2	11.79	11.77	8.73	8.70	0.12	0.10	0.08	0.10
v_2r_3	11.84	11.83	8.77	8.75	0.10	0.08	0.06	0.08
SEm (±)	0.005	0.002	0.004	0.002	0.002	0.001	0.002	0.055
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 76. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on P uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	15.10	15.08	10.85	10.83	0.07	0.07	0.06	0.05
$g_1v_1r_2$	15.29	15.29	11.02	11.02	1.13	0.11	0.09	0.09
$g_1v_1r_3$	15.35	15.35	11.06	11.04	0.09	0.08	0.07	0.06
$g_1v_2r_1$	15.09	15.6	10.85	10.82	0.08	0.07	0.06	0.05
$g_1v_2r_2$	15.30	15.28	11.03	11.00	0.12	0.10	0.08	0.08
$g_1v_2r_3$	15.36	5.36	11.06	11.05	0.09	0.07	0.06	0.06
$g_2v_1r_1$	8.09	8.08	6.24	6.22	0.10	0.09	0.06	0.07
$g_2v_1r_2$	8.27	8.26	6.43	6.40	0.13	0.12	0.09	0.10
$g_2v_1r_3$	8.32	8.30	6.48	6.45	0.11	0.10	0.07	0.07
$g_2v_2r_1$	8.09	8.07	6.24	6.21	0.10	0.08	0.07	0.06
$g_2v_2r_2$	8.27	8.25	6.42	6.39	0.12	0.10	0.09	0.36
$g_2v_2r_3$	8.32	8.30	6.47	6.44	0.11	0.09	0.07	0.07
SEm (±)	0.008	0.003	0.006	0.003	0.003	0.002	0.003	0.077
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

recorded significantly higher P uptake by fodder cowpea (0.09 kg ha^{-1} and 0.08 kg ha^{-1}) in first and second year, respectively in shaded condition. The interaction effects were not significant.

4.15.3. K Uptake

The results of the effect of grasses, fodder cowpea varieties and row ratio on uptake of K are presented in Table 77, 78 & 79. The results revealed that grasses and row ratio had significant impact on uptake of K by grasses in open. Significantly higher uptake of potassium was recorded by hybrid napier cv. Suguna (G_1) in open in both the years (59.31 kg ha^{-1} in first year and 59.26 kg ha^{-1} in second year). Among the row ratios, 1:3 (R_3) recorded significantly higher K uptake in open in both the years (46.05 kg ha^{-1} in first year and 46.02 kg ha^{-1} in second year). Grass row ratio interaction was significant in open condition in second year and hybrid napier grass planted at 1:3 row ratio (g_1r_3) registered significantly higher K uptake of 59.73 kg ha^{-1} in open.

The results revealed that the grasses, fodder cowpea varieties and row ratio had significant effect on K uptake of fodder cowpea in open and shade. Fodder cowpea recorded significantly higher K uptake in open in both the years (0.67 kg ha^{-1} in first year and 0.59 kg ha^{-1} in second year) when intercropped with guinea grass cv. Harithasree (G_2). Among the fodder cowpea varieties, COFC-8 (V_1) recorded significantly higher uptake of 0.64 kg ha^{-1} in the first year and 0.57 kg ha^{-1} in the second year in open condition. Grass legume row ratio of 1:2 (R_2) recorded higher K uptake by fodder cowpea in open in both years (0.74 kg ha^{-1} in first year and 0.66 kg ha^{-1} in second year). Grass row ratio interaction was significant in open condition and g_2r_2 (fodder cowpea planted with guinea grass at 1:2 row ratio) recorded significantly higher uptake of 0.75 kg ha^{-1} in first year and 0.68 kg ha^{-1} in second year.

Fodder cowpea recorded significantly higher K uptake in partial shade in both the years (0.48 kg ha^{-1}) when intercropped with guinea grass cv. Harithasree (G_2). Fodder cowpea varieties did not vary significantly with respect to potassium

Table 77. K uptake of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	59.31	59.26	42.70	42.64	0.58	0.52	0.42	0.43
G_2-Guinea grass	32.01	31.95	24.83	24.72	0.67	0.59	0.48	0.48
SEm (±)	0.017	0.006	0.014	0.004	0.001	0.002	0.001	0.001
CD (0.05)	0.035	0.012	0.012	0.008	0.004	0.004	0.003	0.003
Fodder cowpea varieties (V)								
V_1- COFC-8	45.66	45.62	33.76	33.69	0.64	0.57	0.46	0.46
V_2 - UPC-622	45.67	45.60			0.61	0.54		
V_2- UPC-618			33.77	33.67			0.44	0.45
SEm (±)	0.017	0.006	0.014	0.004	0.001	0.002	0.001	0.001
CD (0.05)	NS	NS	NS	NS	0.004	0.004	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	45.10	45.03	33.24	33.16	0.54	0.48	0.39	0.38
R_2 - (1:2)	45.84	45.79	33.95	33.85	0.74	0.66	0.55	0.56
R_3 - (1:3)	46.05	46.02	34.11	34.02	0.60	0.52	0.42	0.42
SEm (±)	0.021	0.007	0.017	0.005	0.002	0.003	0.002	0.002
CD (0.05)	0.043	0.014	0.036	0.009	0.004	0.005	0.004	0.004

Table 78. Interaction effect (2 factor) of grass, cowpea varieties and grass – legume row ratios on K uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	59.31	59.28	42.70	42.64	0.60	0.53	0.43	0.43
g_1v_2	59.32	59.25	42.71	42.64	0.56	0.50	0.40	0.42
g_2v_1	32.01	31.96	24.83	24.73	0.68	0.60	0.49	0.49
g_2v_2	32.01	31.94	24.83	24.71	0.66	0.58	0.47	0.47
SEm (±)	0.017	0.006	0.014	0.004	0.001	0.002	0.001	0.001
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	58.71	58.62	42.19	42.12	0.49	0.43	0.35	0.35
g_1r_2	59.50	59.45	42.89	42.82	0.72	0.65	0.53	0.53
g_1r_3	59.73	59.73	43.02	42.97	0.53	0.47	0.38	0.39
g_2r_1	31.48	31.43	24.29	24.19	0.59	0.52	0.42	0.41
g_2r_2	32.19	32.13	25.00	24.89	0.75	0.68	0.57	0.58
g_2r_3	32.36	32.30	25.19	25.08	0.67	0.57	0.44	0.45
SEm (±)	0.021	0.007	0.017	0.005	0.002	0.003	0.002	0.002
CD (0.05)	NS	0.066	NS	NS	0.006	0.007	NS	NS
V x R								
v_1r_1	45.11	45.05	33.24	33.18	0.55	0.48	0.38	0.37
v_1r_2	45.83	45.80	33.94	33.87	0.77	0.69	0.57	0.58
v_1r_3	46.04	46.00	34.11	34.01	0.61	0.53	0.42	0.42
v_2r_1	45.08	45.00	33.25	33.13	0.53	0.47	0.38	0.38
v_2r_2	45.86	45.77	33.95	33.84	0.70	0.64	0.53	0.53
v_2r_3	46.06	46.02	34.11	34.04	0.60	0.51	0.40	0.41
SEm (±)	0.021	0.007	0.017	0.005	0.002	0.003	0.002	0.002
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 79. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on K uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	58.73	58.66	42.19	42.15	0.50	0.44	0.36	0.35
$g_1v_1r_2$	59.48	59.47	42.88	42.83	0.75	0.68	0.55	0.55
$g_1v_1r_3$	59.71	59.70	43.02	42.94	0.54	0.48	0.40	0.38
$g_1v_2r_1$	58.69	58.59	42.20	42.10	0.48	0.42	0.34	0.35
$g_1v_2r_2$	59.52	59.43	42.91	42.80	0.70	0.62	0.50	0.51
$g_1v_2r_3$	51.76	59.75	43.03	43.00	0.51	0.46	0.37	0.39
$g_2v_1r_1$	31.49	31.44	24.28	24.21	0.60	0.52	0.42	0.40
$g_2v_1r_2$	32.18	32.14	25.00	24.91	0.79	0.69	0.59	0.61
$g_2v_1r_3$	32.37	32.30	25.20	25.09	0.66	0.58	0.45	0.46
$g_2v_2r_1$	31.47	31.42	24.30	24.17	0.58	0.51	0.43	0.42
$g_2v_2r_2$	32.19	32.11	25.00	24.88	0.71	0.66	0.55	0.54
$g_2v_2r_3$	32.36	32.30	25.19	25.07	0.68	0.56	0.43	0.44
SEm (±)	0.030	0.010	0.025	0.007	0.003	0.004	0.003	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

uptake in partial shade. Grass legume row ratio of 1:2 (R_2) recorded higher K uptake by fodder cowpea in open in both years (0.55 kg ha^{-1} in first year and 0.56 kg ha^{-1} in second year).

4.15.4. Ca Uptake

The results on the effect of grasses, fodder cowpea varieties and row ratio on uptake of Ca are presented in Table 80, 81 & 82. The results revealed that grasses and row ratio had significant impact on uptake of calcium of fodder grasses both in open and shade. Significantly, higher uptake of calcium was registered by hybrid napier cv. Suguna (G_1) in open in both the years (25.42 kg ha^{-1} in the first year and 25.40 kg ha^{-1} in the second year). Row ratio of 1:3 (R_3) recorded significantly higher uptake of calcium in open in first (19.73 kg ha^{-1}) and second year (19.72 kg ha^{-1}). The interaction effects were not significant.

Significantly, higher uptake of calcium was registered by hybrid napier cv. Suguna (G_1) in partial shade in both the years (18.30 kg ha^{-1} in the first year and 18.27 kg ha^{-1} in the second year). Row ratio of 1:3 (R_3) recorded significantly higher uptake of calcium in shade in first (14.62 kg ha^{-1}) and second year (14.58 kg ha^{-1}). The interaction effects were not significant.

The results revealed that grasses, fodder cowpea varieties and row ratio had significant effect on Ca uptake of fodder cowpea in open and shade. Fodder cowpea registered significantly higher Ca uptake in open when intercropped in between guinea grass cv. Haritha (G_2) in both the years (0.81 kg ha^{-1} in first year and 0.71 kg ha^{-1} in second year). Among the fodder cowpea varieties, COFC-8 (V_1) recorded significantly higher calcium uptake of 0.78 kg ha^{-1} in first year and 0.69 kg ha^{-1} shade in the second year. Grass legume row ratio of 1:2 (R_2) recorded significantly higher Ca uptake in open in both the years (0.89 kg ha^{-1} in first year and 0.80 kg ha^{-1} in second year). Grass row ratio interaction was significant and g_2r_2 (fodder cowpea intercropped with guinea grass cv.

Table 80. Ca uptake of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	25.42	25.40	18.30	18.27	0.71	0.63	0.51	0.52
G_2-Guinea grass	13.72	13.69	10.64	10.59	0.81	0.71	0.58	0.60
SEm (±)	0.007	0.002	0.006	0.002	0.002	0.002	0.001	0.009
CD (0.05)	0.015	0.005	0.012	0.003	0.005	0.004	0.003	0.019
Fodder cowpea varieties (V)								
V_1 - COFC-8	19.57	19.55	14.47	14.43	0.78	0.69	0.56	0.56
V_2 - UPC-622	19.57	19.54			0.74	0.66		
V_2- UPC-618			14.48	14.43			0.53	0.56
SEm (±)	0.007	0.002	0.006	0.002	0.002	0.002	0.001	0.009
CD (0.05)	NS	NS	NS	NS	0.005	0.004	0.003	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	19.33	19.29	14.24	14.21	0.66	0.58	0.47	0.49
R_2 - (1:2)	19.64	19.62	14.55	14.51	0.89	0.80	0.67	0.67
R_3 - (1:3)	19.73	19.72	14.62	14.58	0.73	0.63	0.50	0.51
SEm (±)	0.009	0.003	0.007	0.002	0.003	0.003	0.002	0.011
CD (0.05)	0.018	0.006	0.015	0.004	0.006	0.005	0.004	0.023

Table 81. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on Ca uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	25.41	25.40	18.30	18.27	0.73	0.65	0.53	0.52
g_1v_2	25.42	25.39	18.30	18.27	0.68	0.60	0.49	0.51
g_2v_1	13.72	13.69	10.64	10.60	0.83	0.73	0.59	0.60
g_2v_2	13.72	13.69	10.64	10.59	0.80	0.70	0.57	0.60
SEm (±)	0.007	0.002	0.006	0.002	0.002	0.002	0.001	0.009
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	25.16	25.12	18.08	18.05	0.59	0.52	0.42	0.42
g_1r_2	25.50	25.47	18.38	18.35	0.88	0.78	0.64	0.64
g_1r_3	25.60	25.59	18.44	18.41	0.64	0.57	0.47	0.47
g_2r_1	13.49	13.47	10.41	10.36	0.71	0.63	0.51	0.55
g_2r_2	13.79	13.77	10.71	10.67	0.91	0.82	0.70	0.70
g_2r_3	13.87	13.84	10.79	10.75	0.81	0.69	0.53	0.55
SEm (±)	0.009	0.003	0.007	0.002	0.003	0.003	0.002	0.011
CD (0.05)	NS	NS	NS	NS	0.008	0.007	0.006	NS
V x R								
v_1r_1	19.33	19.30	14.24	14.22	0.67	0.59	0.46	0.46
v_1r_2	19.64	19.63	14.54	14.51	0.93	0.83	0.70	0.71
v_1r_3	19.73	19.71	14.62	14.57	0.73	0.64	0.51	0.52
v_2r_1	19.32	19.28	14.25	14.20	0.64	0.57	0.47	0.52
v_2r_2	19.65	19.61	14.55	14.50	0.85	0.78	0.64	0.64
v_2r_3	19.74	19.72	14.62	14.59	0.72	0.61	0.48	0.51
SEm (±)	0.009	0.003	0.007	0.002	0.003	0.003	0.002	0.011
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 82. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on Ca uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	25.17	25.14	18.08	18.06	0.61	0.54	0.43	0.42
$g_1v_1r_2$	25.49	25.48	18.37	18.35	0.91	0.82	0.67	0.67
$g_1v_1r_3$	25.59	25.58	18.43	18.40	0.66	0.58	0.48	0.46
$g_1v_2r_1$	25.15	25.11	18.08	18.04	0.58	0.51	0.42	0.43
$g_1v_2r_2$	25.51	25.47	18.39	18.34	0.85	0.75	0.61	0.62
$g_1v_2r_3$	25.61	25.60	18.44	18.43	0.62	0.55	0.45	0.47
$g_2v_1r_1$	13.49	13.47	10.40	10.37	0.73	0.64	0.50	0.49
$g_2v_1r_2$	13.79	13.77	10.77	10.67	0.96	0.84	0.72	0.74
$g_2v_1r_3$	13.87	13.84	10.80	10.75	0.80	0.70	0.55	0.56
$g_2v_2r_1$	13.49	13.46	10.41	10.35	0.70	0.62	0.52	0.61
$g_2v_2r_2$	13.79	13.76	10.71	10.66	0.86	0.81	0.67	0.66
$g_2v_2r_3$	13.87	13.84	10.79	10.74	0.83	0.68	0.52	0.54
SEm (±)	0.013	0.004	0.011	0.003	0.004	0.004	0.003	0.016
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Harithasree at 1:2 row ratio) registered significantly higher Ca uptake of 0.91 kg ha^{-1} in first year and 0.82 kg ha^{-1} in the second year.

Fodder cowpea registered significantly higher Ca uptake in shade when intercropped in between guinea grass cv. Haritha (G_2) in both the years (0.58 kg ha^{-1} in first year and 0.60 kg ha^{-1} in second year). Among the fodder cowpea varieties, COFC-8 (V_1) recorded significantly higher calcium uptake of 0.56 kg ha^{-1} in first year. Grass legume row ratio of 1:2 (R_2) recorded significantly higher Ca uptake in shade in both the years (0.67 kg ha^{-1}). Grass row ratio interaction was significant in first year only and g_2r_2 (fodder cowpea intercropped with guinea grass cv. Harithasree at 1:2 row ratio) registered significantly higher Ca uptake of 0.70 kg ha^{-1} in first year.

4.15.5. Magnesium Uptake

The results on the effect of grasses, fodder cowpea mixture and row ratio on the Mg uptake are presented in Table 83, 84 & 85. The results revealed that grasses and row ratio had significant impact on uptake of magnesium of fodder grasses in open in both years. Significantly, higher uptake of magnesium was registered by hybrid napier cv. Suguna (G_1) in open (16.94 kg ha^{-1} in the first year and 16.93 kg ha^{-1} in second year). Grass legume row ratio of 1:3 (R_3) recorded significantly higher uptake of magnesium in open in both the years (13.15 kg ha^{-1} in first year and 13.14 kg ha^{-1} in second year). Grass row ratio interaction was significant in open condition during the second year and g_1r_3 (hybrid napier intercropped with fodder cowpea at 1:3 row ratio) recorded significantly higher magnesium uptake of 17.06 kg ha^{-1}.

In partial shade, significantly higher uptake of magnesium was registered by hybrid napier cv. Suguna (G_1) (12.20 kg ha^{-1} in the first year and 12.18 kg ha^{-1} in second year). Grass legume row ratio of 1:3 (R_3) recorded significantly higher uptake of magnesium in shade in both the years (9.74 kg ha^{-1} in first year and 9.72 kg ha^{-1} in second year). The interaction effects were non-significant.

The results showed that the treatments had significant impact on Mg uptake

Table 83. Mg uptake of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	16.94	16.93	12.20	12.18	0.54	0.48	0.39	0.44
G_2-Guinea grass	9.14	9.13	7.09	7.06	0.62	0.54	0.44	0.40
SEm (±)	0.005	0.002	0.004	0.001	0.002	0.001	0.001	0.001
CD (0.05)	0.010	0.003	0.008	0.002	0.005	0.003	0.003	0.006
Fodder cowpea varieties (V)								
V_1 - COFC-8	13.04	13.03	9.64	9.63	0.59	0.52	0.42	0.42
V_2 - UPC-622	13.04	13.02			0.57	0.50		
V_2- UPC-618			9.65	9.62			0.40	0.41
SEm (±)	0.005	0.002	0.004	0.001	0.002	0.001	0.001	0.001
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	12.88	12.86	9.49	9.47	0.51	0.44	0.36	0.35
R_2 - (1:2)	13.10	13.08	9.70	9.67	0.68	0.61	0.51	0.51
R_3 - (1:3)	13.15	13.14	9.74	9.72	0.55	0.48	0.38	0.39
SEm (±)	0.006	0.002	0.005	0.001	0.003	0.002	0.002	0.003
CD (0.05)	0.012	0.04	0.010	0.002	0.006	0.004	0.004	0.007

Table 84. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on Mg uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	16.94	16.93	12.20	12.18	0.56	0.49	0.40	0.39
g_1v_2	16.95	16.93	12.20	12.18	0.52	0.46	0.38	0.40
g_2v_1	9.14	9.13	7.09	7.06	0.63	0.55	0.45	0.45
g_2v_2	9.15	9.12	7.09	7.06	0.61	0.53	0.43	0.43
SEm (±)	0.005	0.002	0.004	0.001	0.002	0.001	0.001	0.001
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	16.77	16.75	12.05	12.03	0.46	0.40	0.32	0.32
g_1r_2	17.00	16.98	12.25	12.23	0.67	0.60	0.49	0.50
g_1r_3	17.06	17.06	12.29	12.27	0.49	0.43	0.35	0.37
g_2r_1	8.99	8.98	6.94	6.91	0.54	0.48	0.38	0.38
g_2r_2	9.19	9.18	7.14	7.11	0.69	0.63	0.53	0.53
g_2r_3	9.24	9.23	7.19	7.16	0.62	0.52	0.41	0.42
SEm (±)	0.006	0.002	0.005	0.001	0.003	0.002	0.002	0.003
CD (0.05)	NS	0.006	NS	NS	0.009	0.006	NS	NS
V x R								
v_1r_1	12.89	12.87	9.49	9.48	0.51	0.44	0.35	0.35
v_1r_2	13.09	13.08	9.69	9.67	0.71	0.63	0.53	0.54
v_1r_3	13.15	13.14	9.74	9.71	0.56	0.49	0.39	0.39
v_2r_1	12.88	12.85	9.50	9.46	0.49	0.43	0.35	0.35
v_2r_2	13.10	13.07	9.70	9.67	0.65	0.59	0.49	0.49
v_2r_3	13.16	13.15	9.74	9.72	0.55	0.47	0.37	0.40
SEm (±)	0.006	0.002	0.005	0.001	0.003	0.002	0.002	0.003
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 85. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on Mg uptake of grass and cowpea, kg ha^{-1}

Treatments	Grass				Cowpea			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	16.78	16.76	12.05	12.04	0.47	0.41	0.33	0.32
$g_1v_1r_2$	16.99	16.99	12.25	12.23	0.70	0.63	0.51	0.51
$g_1v_1r_3$	17.06	17.05	12.29	12.26	0.50	0.45	0.37	0.35
$g_1v_2r_1$	16.77	16.74	12.05	12.03	0.45	0.39	0.32	0.33
$g_1v_2r_2$	17.00	16.98	12.26	12.23	0.64	0.57	0.47	0.48
$g_1v_2r_3$	17.07	17.07	12.29	12.28	0.47	0.42	0.34	0.39
$g_2v_1r_1$	8.99	8.98	6.93	6.91	0.56	0.48	0.38	0.37
$g_2v_1r_2$	9.19	9.18	7.14	7.11	0.73	0.64	0.55	0.56
$g_2v_1r_3$	9.24	9.23	7.20	7.16	0.61	0.53	0.42	0.43
$g_2v_2r_1$	8.99	8.97	6.94	6.90	0.53	0.47	0.39	0.38
$g_2v_2r_2$	9.19	9.17	7.14	7.10	0.65	0.61	0.51	0.50
$g_2v_2r_3$	9.24	9.23	7.19	7.16	0.63	0.51	0.40	0.41
SEm (±)	0.008	0.003	0.007	0.002	0.005	0.003	0.003	0.005
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

of fodder cowpea in open condition. Fodder cowpea intercropped with guinea grass cv. Harithasree (G_2) recorded significantly higher Mg uptake in open in both the years (0.62 kg ha^{-1} and 0.54 kg ha^{-1} in second year). Grass legume row ratio of 1:2 (R_2) recorded significantly higher Mg uptake in open in first (0.68 kg ha^{-1}) and second year (0.61 kg ha^{-1}). G x R interaction was significant in open condition and g_2r_2 (guinea grass cv. Harithasree intercropped with fodder cowpea at 1:2 row ratio) registered significantly higher Mg uptake of 0.69 kg ha^{-1} in first year and 0.63 kg ha^{-1} in second year in open condition.

Fodder cowpea intercropped with guinea grass cv. Harithasree (G_2) recorded significantly higher Mg uptake in partial shade in both the years (0.44 kg ha^{-1}). Grass legume row ratio of 1:2 (R_2) recorded significantly higher Mg uptake in open in first and second year (0.51 kg ha^{-1}). The interaction effects were non-significant.

4.16. SOIL ANALYSIS

The fertility status of soil after the experiment was assessed in terms of organic carbon, available nitrogen, available phosphorus and available potassium.

4.16.1. Organic Carbon

The results on the organic carbon status of the soil after the experiment (Table 86, 87 & 88) showed that grasses, varieties and row ratio had no significant impact on organic carbon content of soil in open and shaded condition.

4.16.2. Available Nitrogen

The result pertaining to the available nitrogen status of the soil after the experiment is presented in Table 86, 87 & 88. From the result, it was observed that grasses and varieties had no significant effect on available N status of soil. However, grass-legume row ratio had significant impact on available N content of soil in open condition. Row ratio of 1:3 (R_3) recorded significantly higher N

Table 86. Organic C and N content of soil as influenced by grass, cowpea varieties and row ratios of grass-legume mixture

Treatments	Soil organic C (%)				Soil N (kg ha^{-1})			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	0.61	0.63	0.60	0.62	210.00	211.31	211.04	212.24
G_2-Guinea grass	0.60	0.62	0.59	0.61	209.71	211.17	211.26	212.43
SEm (±)	0.001	0.002	0.002	0.002	0.255	0.195	0.267	0.166
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	0.61	0.63	0.60	0.62	209.95	211.25	211.18	212.31
V_2 - UPC-622	0.60	0.62			209.74	211.23		
V_2- UPC-618			0.60	0.61			211.13	212.36
SEm (±)	0.001	0.002	0.002	0.002	0.255	0.195	0.267	0.166
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	0.61	0.62	0.60	0.62	209.00	210.20	210.14	211.62
R_2 - (1:2)	0.60	0.63	0.59	0.61	210.27	211.67	211.64	212.44
R_3 - (1:3)	0.61	0.63	0.60	0.62	210.28	211.85	212.14	212.95
SEm (±)	0.002	0.003	0.003	0.003	0.312	0.239	0.327	0.203
CD (0.05)	NS	NS	NS	NS	0.551	0.419	0.412	0.416

Table 87. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on organic C and N content of soil

Treatments	Soil organic C (%)				Soil N (kg ha^{-1})			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	0.61	0.63	0.61	0.62	209.88	211.13	211.00	212.17
g_1v_2	0.61	0.62	0.59	0.62	209.52	211.22	211.09	212.30
g_2v_1	0.59	0.63	0.59	0.62	210.03	211.34	211.36	212.44
g_2v_2	0.60	0.63	0.60	0.61	209.97	211.28	211.17	212.42
SEm (±)	0.001	0.002	0.002	0.002	0.255	0.195	0.267	0.166
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	0.62	0.62	0.60	0.61	208.92	210.29	210.01	211.75
g_1r_2	0.59	0.63	0.61	0.62	210.15	211.50	211.62	212.29
g_1r_3	0.61	0.63	0.60	0.63	211.03	211.73	212.51	212.67
g_2r_1	0.59	0.63	0.60	0.62	209.07	210.11	210.28	211.49
g_2r_2	0.60	0.62	0.61	0.61	210.42	211.85	211.73	212.58
g_2r_3	0.61	0.63	0.59	0.62	210.51	211.97	211.78	213.23
SEm (±)	0.002	0.003	0.003	0.003	0.312	0.239	0.327	0.203
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	0.61	0.63	0.61	0.63	209.12	210.18	210.23	211.58
v_1r_2	0.59	0.63	0.59	0.62	210.42	211.72	211.74	212.36
v_1r_3	0.61	0.63	0.60	0.62	210.33	211.80	211.57	212.99
v_2r_1	0.61	0.62	0.59	0.61	208.88	210.22	210.06	211.66
v_2r_2	0.60	0.62	0.62	0.61	210.15	211.63	211.61	212.51
v_2r_3	0.62	0.63	0.59	0.62	210.21	211.89	211.72	212.91
SEm (±)	0.002	0.003	0.003	0.003	0.312	0.239	0.327	0.203
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 88. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on organic C and N content of soil

Treatments	Soil organic C (%)				Soil N (kg ha^{-1})			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	0.62	0.63	0.61	0.62	209.13	210.26	210.11	211.69
$g_1v_1r_2$	0.60	0.64	0.59	0.63	210.31	211.44	211.58	212.22
$g_1v_1r_3$	0.61	0.62	0.62	0.62	211.20	211.69	211.32	212.62
$g_1v_2r_1$	0.63	0.62	0.59	0.61	208.72	210.33	209.92	211.82
$g_1v_2r_2$	0.59	0.62	0.62	0.62	209.99	211.56	211.66	212.37
$g_1v_2r_3$	0.62	0.64	0.58	0.63	209.86	211.77	211.70	212.72
$g_2v_1r_1$	0.60	0.63	0.61	0.61	209.11	210.11	210.36	211.47
$g_2v_1r_2$	0.58	0.62	0.59	0.62	210.52	212.01	211.90	212.51
$g_2v_1r_3$	0.61	0.64	0.58	0.61	210.47	211.92	211.82	213.36
$g_2v_2r_1$	0.59	0.63	0.60	0.62	209.04	210.12	210.20	211.51
$g_2v_2r_2$	0.62	0.64	0.61	0.61	210.32	211.70	211.56	212.66
$g_2v_2r_3$	0.61	0.62	0.60	0.61	210.56	212.02	211.75	213.11
SEm (±)	0.003	0.004	0.004	0.004	0.442	0.339	0.462	0.287
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 89. P content and K content of soil as influenced by grass, cowpea varieties and row ratios of grass-legume mixture, kg ha^{-1}

Treatments	Soil P				Soil K			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses (G)								
G_1-Hybrid napier	50.90	50.87	50.10	50.02	100.11	101.00	99.23	100.19
G_2-Guinea grass	50.88	50.79	49.92	49.93	99.91	100.98	99.19	100.18
SEm (±)	0.191	0.033	0.021	0.071	0.016	0.010	0.004	0.008
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fodder cowpea varieties (V)								
V_1 - COFC-8	51.00	50.88	50.09	49.90	100.14	101.01	99.30	100.24
V_2 - UPC-622	50.80	50.78			99.99	100.88		
V_2- UPC-618			49.88	50.05			99.21	100.14
SEm (±)	0.191	0.033	0.021	0.071	0.016	0.010	0.004	0.008
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Grass-legume row ratio (R)								
R_1 - (1:1)	50.70	50.71	49.98	49.84	100.23	101.10	99.32	100.50
R_2 - (1:2)	50.91	50.93	49.96	50.42	100.12	100.90	99.12	100.22
R_3 - (1:3)	51.07	50.86	49.93	50.07	99.92	100.88	99.19	99.98
SEm (±)	0.234	0.041	0.026	0.087	0.020	0.012	0.005	0.009
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 90. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on P content and K content of soil, kg ha^{-1}

Treatments	Soil P				Soil K			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	51.15	50.83	50.14	49.99	100.25	100.96	99.27	100.28
g_1v_2	50.65	50.92	49.84	49.87	99.55	101.04	99.18	100.09
g_2v_1	50.83	50.74	50.04	49.81	100.02	101.24	99.33	100.20
g_2v_2	50.94	50.84	49.81	50.24	100.41	100.72	99.19	100.17
SEm (±)	0.191	0.033	0.021	0.071	0.016	0.010	0.004	0.008
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
G x R								
g_1r_1	50.78	50.61	49.94	49.34	99.87	101.23	99.20	100.67
g_1r_2	50.72	50.18	50.27	50.46	99.61	101.00	99.47	99.77
g_1r_3	51.21	50.84	49.77	49.98	100.22	100.77	99.05	100.10
g_2r_1	50.62	50.82	49.93	49.54	100.59	101.22	99.43	100.33
g_2r_2	51.09	50.68	49.65	50.37	100.03	100.69	98.79	100.46
g_2r_3	50.94	50.88	50.19	50.16	100.01	101.04	99.03	99.77
SEm (±)	0.234	0.041	0.026	0.087	0.020	0.012	0.005	0.009
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
V x R								
v_1r_1	50.91	50.59	50.20	49.51	100.13	101.29	99.46	100.49
v_1r_2	51.09	50.95	49.83	50.24	99.86	100.92	98.78	100.05
v_1r_3	50.98	50.81	50.25	49.93	100.41	101.09	99.68	100.17
v_2r_1	50.49	50.83	49.66	49.36	100.33	101.17	99.18	100.51
v_2r_2	50.72	50.91	50.09	50.59	99.78	100.77	99.46	100.18
v_2r_3	51.16	50.90	49.72	50.20	99.82	100.71	98.69	99.88
SEm (±)	0.234	0.041	0.026	0.087	0.020	0.012	0.005	0.009
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 91. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on P content and K content of soil, kg ha^{-1}

Treatments	Soil P				Soil K			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	51.20	50.68	50.17	49.57	100.19	101.27	99.60	100.64
$g_1v_1r_2$	51.07	51.26	50.04	50.24	99.47	100.90	98.92	99.68
$g_1v_1r_3$	51.19	50.55	50.22	50.16	101.12	100.70	99.31	100.51
$g_1v_2r_1$	50.36	50.53	49.70	49.12	99.60	101.20	98.80	100.71
$g_1v_2r_2$	50.37	51.11	50.50	50.69	99.73	101.10	100.01	99.96
$g_1v_2r_3$	51.21	51.13	49.33	49.79	99.31	100.83	98.73	99.69
$g_2v_1r_1$	50.61	50.51	50.23	49.46	100.12	101.31	99.31	100.34
$g_2v_1r_2$	51.12	50.64	49.63	50.25	100.24	100.94	98.63	100.42
$g_2v_1r_3$	50.77	51.08	50.28	49.71	99.69	101.48	100.05	99.84
$g_2v_2r_1$	50.63	51.12	49.63	49.61	101.07	101.14	99.55	100.31
$g_2v_2r_2$	51.07	50.72	49.67	50.50	99.83	100.44	98.91	100.51
$g_2v_2r_3$	51.11	50.68	50.11	50.62	100.32	100.60	98.64	99.71
SEm (±)	0.331	0.057	0.037	0.123	0.028	0.017	0.007	0.013
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

content of soil in open in both the years (210.28 kg ha^{-1} in the first year and 211.85 kg ha^{-1} in the second year). None of the interactions were significant.

In partial shade, it was observed that grasses and varieties had no significant effect on available N status of soil. However, grass-legume row ratio had significant impact on available N content of soil in shade. Row ratio of 1:3 (R_3) recorded significantly higher N content of soil in shade in both the years (212.14 kg ha^{-1} in the first year and 212.95 kg ha^{-1} in the second year). None of the interactions were significant

4.16.3. Available Phosphorus

The result summarized in Table 89, 90 & 91 showed that the available phosphorus status of the soil did not vary significantly between grasses, fodder cowpea mixtures and row ratio both in open and shaded experiments in two years.

4.16.4. Available Potassium

The results on the available potassium status of the soil after the experiment as affected by grasses, cowpea mixtures and row ratio are presented in Table 89, 90 & 91. On perusal of data, it was observed that neither the treatments nor their interaction could affect the available potassium status of the soil in open and shaded experiments in both the years.

4.17. ECONOMIC ANALYSIS

4.17.1. Net Income and BCR

The results summarized in Table 92, 93 & 94 revealed that grasses, fodder cowpea varieties and row ratio had significant impact on net income of fodder crops both in open and shaded conditions in two years. Hybrid napier cv. Suguna (G_1) recorded significantly higher net income in open in both the year (Rs. 204853 in the first year and Rs. 204594 in the second year). Among the grass legume row ratio, 1:2 (R_2) recorded significantly higher net income in open in both the year (Rs.152593 in the first year and Rs.152647 in the second year).

Table 92. Net income and BCR of grass and cowpea as influenced by grass, cowpea varieties and row ratios of grass-legume mixture

Treatments	Net income (Rs ha^{-1})				BCR			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Grasses(G)								
G1-Hybrid napier	204853	204594	134987	134560	3.24	3.23	2.72	2.72
G2-Guinea grass	93617	93048	61310	60910	2.25	2.24	1.97	1.89
SEm (±)	265.24	50.06	61.94	209.49	0.003	0.002	0.001	0.99
Fodder Cowpea Varieties (V)								
V1-COFC-8	149744	149216	98419	97853	2.75	2.74	2.34	2.30
V2-UPC-622	148726	148427			2.74	2.73		
V2-UPC-618			97878	97618			2.33	2.30
SEm (±)	265.24	50.06	61.94	209.49	0.003	0.002	0.001	0.99
Grass-legume row ratio(R)								
R_1 - (1:1)	146268	145419	96900	94823	2.73	2.72	2.33	2.30
R_2 - (1:2)	152593	152647	100890	100698	2.79	2.79	2.36	2.34
R_3 - (1:3)	148843	148397	97900	97685	2.71	2.70	2.30	2.27
SEm (±)	324.85	61.31	75.86	256.58	0.004	0.003	0.002	1.21

Table 93. Interaction effect (2 factor) of grass, cowpea varieties and grass - legume row ratios on net income and BCR of grass and cowpea

Treatments	Net income (Rs ha^{-1})				BCR			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V								
g_1v_1	205093	205085	135306	134486	3.24	3.24	2.72	2.72
g_1v_2	204612	204103	134667	134633	3.23	3.26	2.71	2.71
g_2v_1	94394	93345	61532	61218	2.25	2.24	2.00	1.89
g_2v_2	92839	92750	61089	60602	2.24	2.23	1.94	1.88
SEm (±)	265.24	50.06	61.94	209.49	0.003	0.002	0.001	0.99
G x R								
g_1r_1	201250	200703	132905	131890	3.23	3.22	2.73	2.73
g_1r_2	208860	209010	138850	138760	3.28	3.28	2.78	2.78
g_1r_3	204448	204070	133205	133030	3.19	3.18	2.64	2.64
g_2r_1	91287	90135	58405	57755	2.24	2.25	2.10	1.85
g_2r_2	96325	96284	62930	62635	2.28	2.28	1.87	1.89
g_2r_3	93238	92723	62596	62340	2.22	2.21	1.92	1.91
SEm (±)	224.85	61.31	75.86	256.58	0.004	0.003	0.002	1.21

Table 93. continued

V x R								
$v_1 r_1$	146897	145728	95630	94590	2.74	2.72	2.50	2.29
$v_1 r_2$	153090	153275	101475	101250	2.79	2.79	2.29	2.34
$v_1 r_3$	149245	148643	98152	97718	2.71	2.70	2.30	2.28
$v_2 r_1$	145640	145110	95680	95055	2.73	2.72	2.33	2.29
$v_2 r_2$	152095	152020	100305	100145	2.77	2.78	2.35	2.33
$v_2 r_3$	148442	148150	97648	97653	2.71	2.69	2.26	2.27
SEm (±)	324.85	61.31	75.86	256.58	0.004	0.003	0.002	1.21

Table 94. Interaction effect (3 factor) of grass, cowpea varieties and grass - legume row ratios on net income and BCR of grass and cowpea

Treatments	Net income (Rs ha^{-1})				BCR			
	Open		Shade		Open		Shade	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
G x V x R								
$g_1v_1r_1$	201595	201152	133050	131520	3.24	3.23	2.74	2.73
$g_1v_1r_2$	208855	209845	139480	139150	3.28	3.29	2.79	2.79
$g_1v_1r_3$	204830	204260	133390	132790	3.20	3.16	2.64	2.64
$g_1v_2r_1$	200905	200255	132760	132260	3.23	3.22	2.73	2.73
$g_1v_2r_2$	208865	208175	138220	138370	3.28	3.28	2.77	2.78
$g_1v_2r_3$	204067	203880	133020	133270	3.19	3.18	2.64	2.64
$g_2v_1r_1$	92198	90305	58210	57660	2.25	2.22	2.27	1.85
$g_2v_1r_2$	97325	96705	63470	63350	2.30	2.29	1.80	1.90
$g_2v_1r_3$	93660	93027	62915	62645	2.22	2.22	1.95	1.92
$g_2v_2r_1$	90375	89965	58600	57850	2.23	2.22	1.94	1.86
$g_2v_2r_2$	95325	95865	62390	61920	2.27	2.28	1.94	1.89
$g_2v_2r_3$	92817	92420	62276	62035	2.23	2.20	1.89	1.91
SEm (±)	459.41	86.71	107.28	362.86	0.005	0.004	0.002	1.71

Grass row ratio interaction was significant in open condition in the second year of experimentation. Fodder cowpea intercropped with guinea grass cv. Harithasree at 1:2 row ratio (g_1r_2) recorded significantly higher net income (Rs.209010) in open in the second year.

Hybrid napier cv. Suguna (G_1) recorded significantly higher net income in shade in both the year (Rs. 134987 in the first year and Rs. 134560 in the second year). Among the fodder cowpea varieties, COFC-8 (V_1) recorded significantly higher net income (Rs.98419) under partial shade in the first year. Among the grass legume row ratio, 1:2 (R_2) recorded significantly higher net income in shade in both the year (Rs.100890 in the first year and Rs.100698 in the second year). Grass row ratio interaction was significant in partial shade in the second year of experimentation. Fodder cowpea intercropped with guinea grass cv. Harithasree at 1:2 row ratio (g_1r_2) recorded significantly higher net income (Rs.138850) in shade in the first year.

The results also revealed that grasses, fodder cowpea varieties and row ratio had significant impact on BCR of fodder crops in open and shade. Hybrid napier cv. Suguna (G_1) recorded significantly higher BCR in open in both the year (3.24 in first year and 3.23 in second year). Grass-legume row ratio of 1:2 (R_2) recorded significantly higher BCR in open in both the year (2.79). Grass row ratio interaction was significant in the first year under open. Fodder cowpea intercropped with guinea grass cv. Harithasree at 1:2 row ratio (g_1r_2) recorded higher BCR (3.28) in open in the second year.

In partial shade, hybrid napier cv. Suguna (G_1) recorded significantly higher BCR in both the year (2.72). Grass-legume row ratio of 1:2 (R_2) recorded significantly higher BCR in shade in both the year (2.36 in first year and 2.34 in second year). Grass row ratio interaction was significant in both the year. Fodder cowpea intercropped with guinea grass cv. Harithasree at 1:2 row ratio (g_1r_2) recorded higher BCR (2.78) in the first year and second year.

G x V x R interaction were not significant

Discussion

5. DISCUSSION

The experiment entitled "Fodder production technology under light and moisture stress situations" was conducted to identify drought tolerant varieties of fodder cowpea and their performance evaluation in varying proportions of grass legume mixtures under open and shaded conditions. The results of the experiment, presented in the previous chapter are discussed here under.

INVESTIGATION – I : DROUGHT TOLERANCE STUDIES IN FODDER COWPEA UNDER OPEN AND SHADED SITUATIONS.

5.1. BIOMETRIC OBSERVATIONS

The results of the study revealed that the plant height decreased as the soil moisture stress levels increased. Maximum plant height was recorded at IW/CPE ratio of 0.8 in both open and shade (Fig 7). Minimum plant height was recorded at lifesaving irrigation. This might be due to the fact that plants grown under water stress conditions caused a reduction in plant height by reduction of photosynthesis and consequent reduction of internode length. A similar result was also reported by Hajibabaee *et al.* (2012) in forage corn hybrids and by Purbajanti *et al.* (2012) in guinea and napier grasses.

There was significant difference in plant height between the varieties both in open and shade. COFC-8 recorded more plant height in both experiments. Considerable varietal variations in plant height was also reported by Shekara *et al.* (2012) in fodder cowpea genotypes viz., MFC 08-14, IL-117, UPC-5286, Bundel lobia-1 and UPC-9202. Similar results were also reported by AICRP (2012) in an advanced varietal trial conducted with forage cowpea varieties.

M x V interaction was significant only in shaded condition. COFC-8 irrigated at IW/CPE ratio of 0.6 and Bundel Lobia-1 and UPC-622 irrigated at IW/CPE ratio of 0.8 recorded higher plant height in shade. Similar result was also reported by Hayatu and Mukhtar (2010) in some cowpea genotypes.

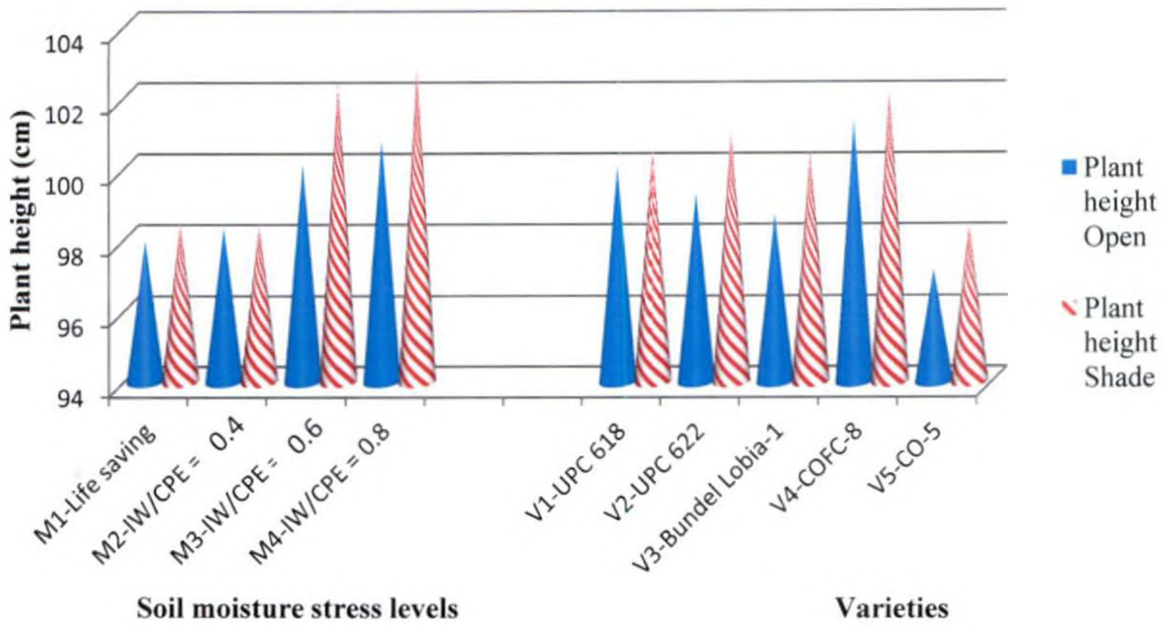


Figure 7. Effect of soil moisture stress levels and varieties on plant height, (cm)

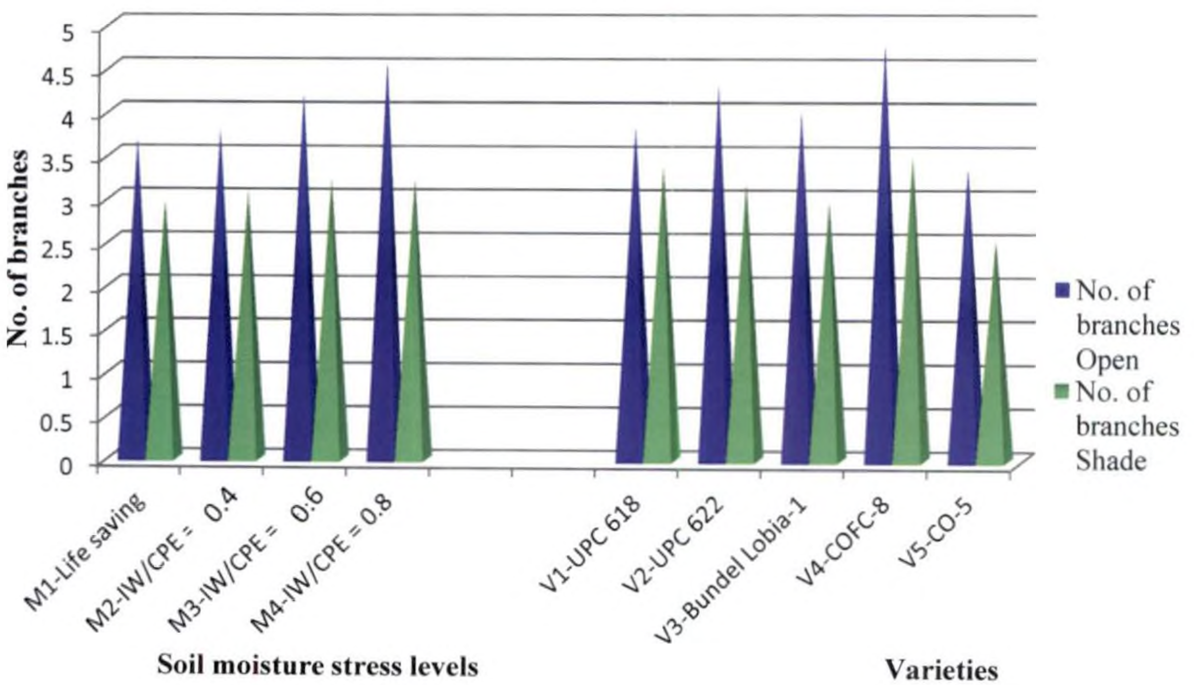


Figure 8. Effect of soil moisture stress levels and varieties on number of branches

The study revealed that soil moisture stress caused reduction in number of branches in both open and shade. The number of branches increased with irrigation at IW/CPE ratio of 0.8 (Fig. 8). Minimum number of branches was recorded at lifesaving irrigation. Lima *et al.* (2011) reported that reduction in plant branching under water deficit mainly occurs due to low immediate availability of nutrients for the growth conditions because the nutrients are absorbed by the system through the soil solution. The cell expansion is another process that depends on the cell water conditions, also decreasing with the water deficit. The water availability is essential for the vegetative growth, mainly for branch emerging in forage plants

There was significant variation in number of branches between varieties both in open and shade. COFC-8 recorded more number of branches in open and in shade. Considerable variations in number of branches were also reported in some fodder cowpea genotypes by Shekara *et al.* (2012). Similar results were also reported by Rajasree and Pillai (2001) in some forage legumes like stylosanthes and fodder cowpea.

M x V interaction was significant only in open condition. COFC-8 when irrigated at IW/CPE ratio of 0.8 resulted in an increase in the number of branches. Similar result was also reported by Hayatu and Mukhtar (2010) in seven cowpea genotypes.

Results on leaf : stem ratio showed that soil moisture stress levels had no significant influence in open and shade. However, varieties had significant effect in open condition. The fodder cowpea variety COFC-8 recorded significantly higher leaf: stem ratio in open. Considerable variations in leaf: stem ratio was reported in different cowpea genotypes by Shekara *et al.* (2012).

Results on root volume showed that soil moisture stress levels, varieties and interaction had no significant influence on root volume of fodder cowpea.

The study revealed that soil moisture stress levels had significant effect on root: shoot ratio only in open condition. Life-saving irrigation recorded significantly higher root: shoot ratio in open. Water stress results in significant reduction in stem dry weight and increased root length. Increase in root biomass in water stressed fodder cowpea may be due to the ability of the plant to divert assimilates to enhance the growth of the roots so as to exploit deeper soil layers for water. This accords with reported observations by Stasovski and Peterson (1991) and indicates that root growth is usually much less depressed than shoot growth, leading to a typical increase in root : shoot ratio. Similar results were reported by Hayatu and Mukhtar (2010) in cowpea genotypes.

There was significant variation in root : shoot ratio between varieties in open condition. Among the varieties, COFC-8 recorded higher root : shoot ratio in open. Increases in root biomass and root : shoot ratio were recorded in all the fodder cowpea genotypes when grown under water stressed conditions (Hayatu and Mukhtar, 2010).

Interaction effect was significant in open condition and COFC-8 at lifesaving irrigation and IW/CPE ratio of 0.4 recorded higher root : shoot ratio which was on par with UPC-618 receiving lifesaving irrigation. Similar results were also reported by Hayatu and Mukhtar (2010) in fodder cowpea genotypes, showing variation in root : shoot ratio at different soil moisture stress levels.

The study revealed that soil moisture stress levels and varieties had significant effect on root dry weight of fodder cowpea in both open and shade. Root dry weight was significantly higher at higher levels of irrigation. Heenan and Thompson (1984) observed reduced root proliferation under water stressed condition compared to well irrigated plants. Moreover, stress could lead to several physiological and biochemical changes which are directly and indirectly related to root generation. For instance, the stress induced changes in the level of endogenous growth hormones and carbohydrate which could result in a differential rooting pattern. At IW/CPE ratio of 0.8, the roots were deeper and had more weight and volume. Availability of sufficient water favoured better root growth. This supports the findings by Hayatu and Mukhtar (2010) in fodder cowpea genotypes.

There was significant variation in root dry weight between varieties in open and shade. Among the varieties, COFC-8 recorded higher root dry weight in open and shade. This could be attributed to the better ability of this variety to produce better root characters.

M x V interaction was significant in open and partial shade. COFC-8 irrigated at IW/CPE ratio of 0.8 recorded significantly higher root dry weight in open. Under partial shade, Bundel Lobia-1 irrigated at IW/CPE ratio of 0.8 recorded significantly higher root dry weight. . Similar results on reduction of root dry weight due to moisture stress was reported by Hayatu and Mukhtar (2010) in fodder cowpea genotype

5.2. YIELD PARAMETERS

Results on green fodder yield showed that soil moisture stress levels, varieties and interaction had significant effect both in open and shade. Irrigation at IW/CPE ratio of 0.8 recorded significantly higher green fodder yield in open (Fig. 9). While irrigating at IW/CPE ratio of 0.8 and 0.6 were on par under shade. Water stress treatment cause decreased water supply and decreased stomatal opening leading to decreased leaf CO_2 absorption followed by decrease in photosynthesis. Finally plant growth is decreased. Moisture stress caused premature aging of leaves, reduction in number of leaves, leaf area, number of branches and thus reduce the yield (Ravarizadesh and Ehsanpour, 2005). In this experiment, increased plant height, number of branches and root dry weight of fodder cowpea at higher irrigation levels contributed to the higher green fodder yield.

Green fodder yield was also significantly influenced by the varieties in open and shade. Among the varieties, significantly higher green fodder yield was recorded by COFC-8 followed by UPC-622 in open condition. This resulted due to the higher plant height, number of branches, leaf stem ratio, root shoot ratio and

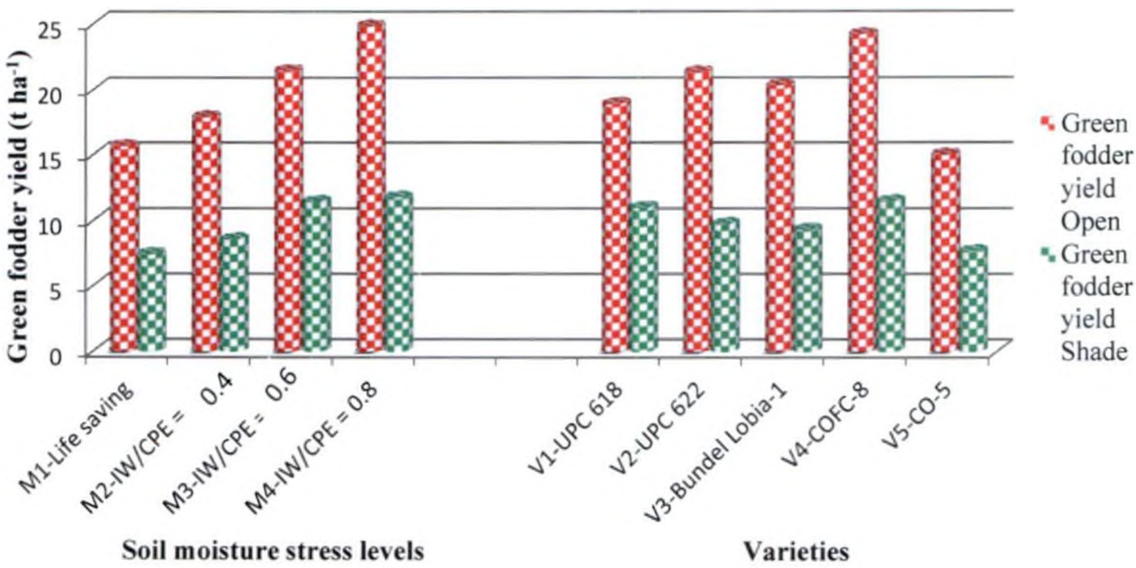


Figure 9. Effect of soil moisture stress levels and varieties on green fodder yield ($t\ ha^{-1}$)

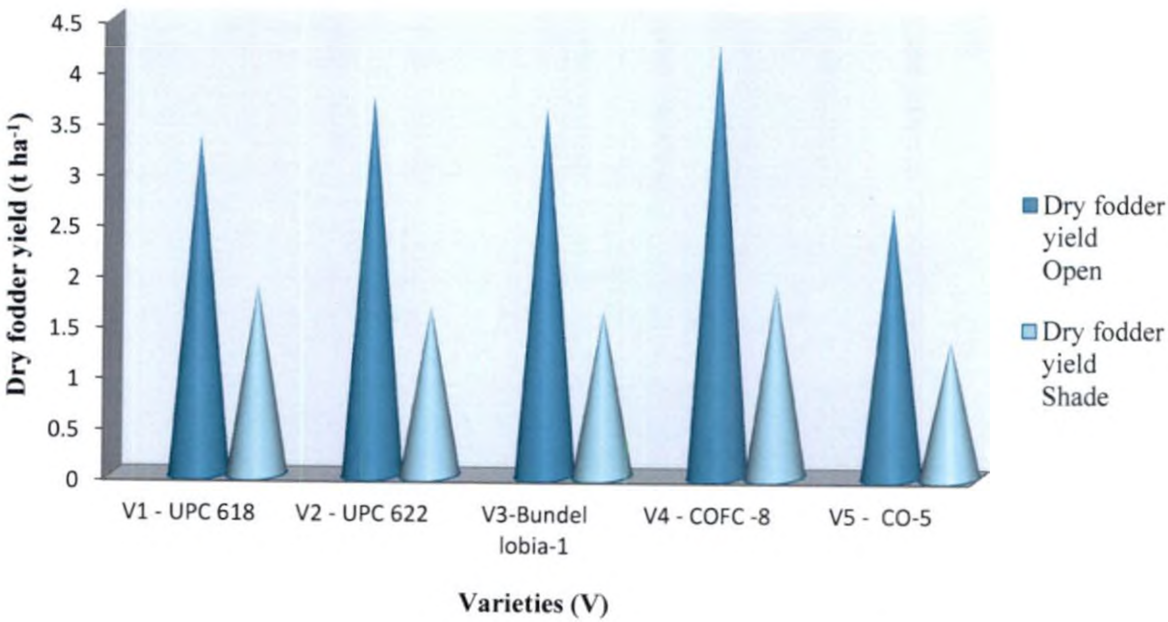


Figure 10. Effect of varieties on dry fodder yield ($t\ ha^{-1}$)

root dry weight recorded by these varieties. In partial shade, COFC-8 recorded maximum green fodder yield followed by UPC-618. This might be due to the higher number of branches produced by these varieties and better uptake of nutrients. Considerable variations in green fodder yield among different cowpea genotypes was reported by Shekara *et al.* (2012).

M x V interaction effect was significant in open and shade. COFC-8 irrigated at IW/CPE ratio of 0.8 recorded significantly higher green fodder yield in open and shade and it was on par with irrigation at IW/CPE ratio of 0.6 in partial shade. Least green fodder yield was recorded by all the varieties given life saving irrigation. Water stress in plants causes reduced yield and reduction in total biomass through reduction in photosynthesis and plant growth due to leaf senescence. In the case of COFC-8 irrigated at IW/CPE ratio of 0.8, higher plant height in shade, number of branches plant^{-1} and root dry weight in open contributed to high green fodder yield. Similar findings were reported by Hayatu and Mukhtar (2010) in some fodder cowpea genotypes.

The soil moisture stress levels and varieties significantly influenced the dry fodder yield in open and shade. Irrigation at IW/CPE ratio of 0.8 recorded significantly higher dry fodder yield (Fig. 10). Least dry fodder yield was recorded in life saving irrigation. This variation could be due to the low uptake, transport and food construction during water shortages which reduce plant dry matter accumulation. Dry weight loss and reduced photosynthetic materials due to water limitation have also been reported by other researchers such as Kisman (2003) and Osborne *et al.* (2002) in forage corns. This is in conformity with the findings of Slama *et al.* (2011) in alfalfa cultivars and Haffani *et al.* (2013) in *Vicia sp.*

The dry fodder yield was significantly influenced by varieties also in open and shade. Among the varieties, COFC-8 recorded significantly higher dry fodder yield followed by UPC-622 in open condition. Under partial shade, significantly higher dry fodder yield was recorded by COFC-8 followed by UPC-618. This might be due to the higher green forage production recorded by these varieties under different stress levels. Considerable variations for dry fodder yield under different soil moisture stress treatments were recorded by Haffani *et al*. (2013) in three *Vicia sp.* by Shekara *et al*. (2012) in different cowpea genotypes and by Radhika (2003) in 50 accessions of fodder cowpea.

5.3. PHYSIOLOGICAL OBSERVATIONS

A significant influence of soil moisture stress levels on dry matter production was noticed in open and partial shade. The dry matter production was found to be maximum at irrigation at IW/CPE ratio of 0.8 in open and shade (Fig. 11). The reduction in dry matter production from water stress was more due to the reduction in number of branches plant^{-1} and decrease in plant height. Drought stress also had great influence on partitioning of carbohydrates and nitrogen. Severe stress conditions often decrease root growth (Prasad and Staggenborg, 2008). Similar results were also reported by Bade *et al.* (1985) in *Cynodon dactylon* and *Panicum coloratum* and by Hajibabaee *et al*. (2012) in forage corn hybrids.

Dry matter production was also significantly influenced by varieties in open and shade. Significantly higher dry matter production was registered by COFC-8 in open and shade (Fig. 12). Least dry matter production was recorded by the variety CO-5 in open and shade. Significant differences for dry matter production of 18 cultivars of cowpea grown for forage were reported by Pal (1988).

M x V interaction was significant only in open condition. The variety COFC-8 irrigated at IW/CPE ratio of 0.8 recorded significantly higher dry matter production in open due to higher number of branches plant^{-1}, root dry weight and leaf dry weight resulting in higher uptake of water and nutrients. Similar results were reported by Hajibabaee *et al*. (2012) in various forage corn hybrids.

A significant influence of soil moisture stress levels on leaf area index was noticed both in open and shade. Irrigation at IW/CPE ratio of 0.8 recorded significantly higher leaf area index both in open and shade (Fig. 13). The

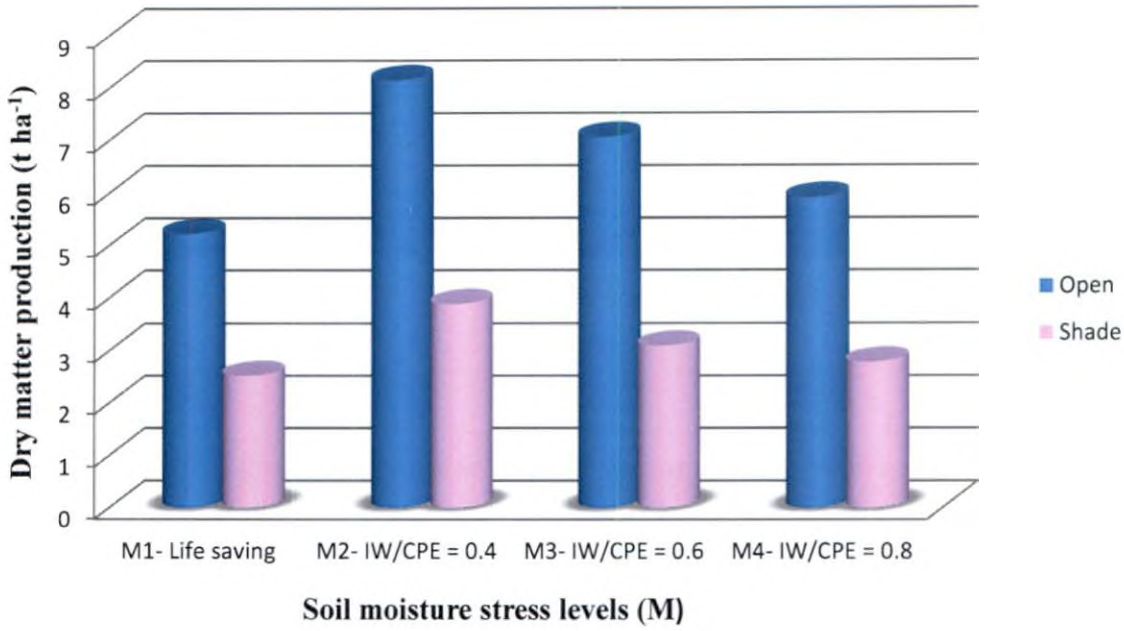


Figure 11. Effect of soil moisture stress levels on dry matter production (t ha^{-1})

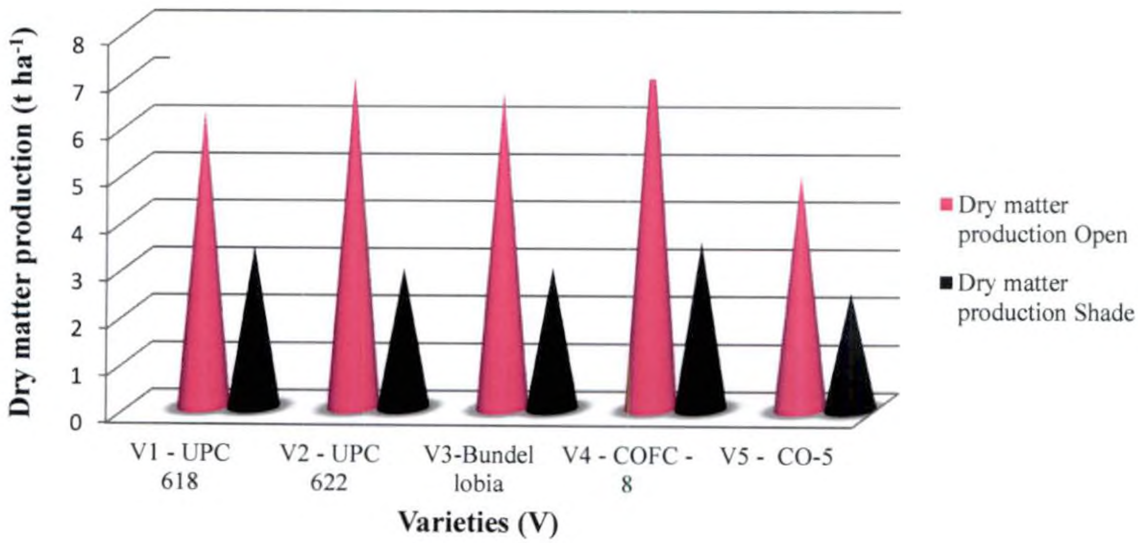


Figure 12. Effect of varieties on dry matter production (t ha^{-1})

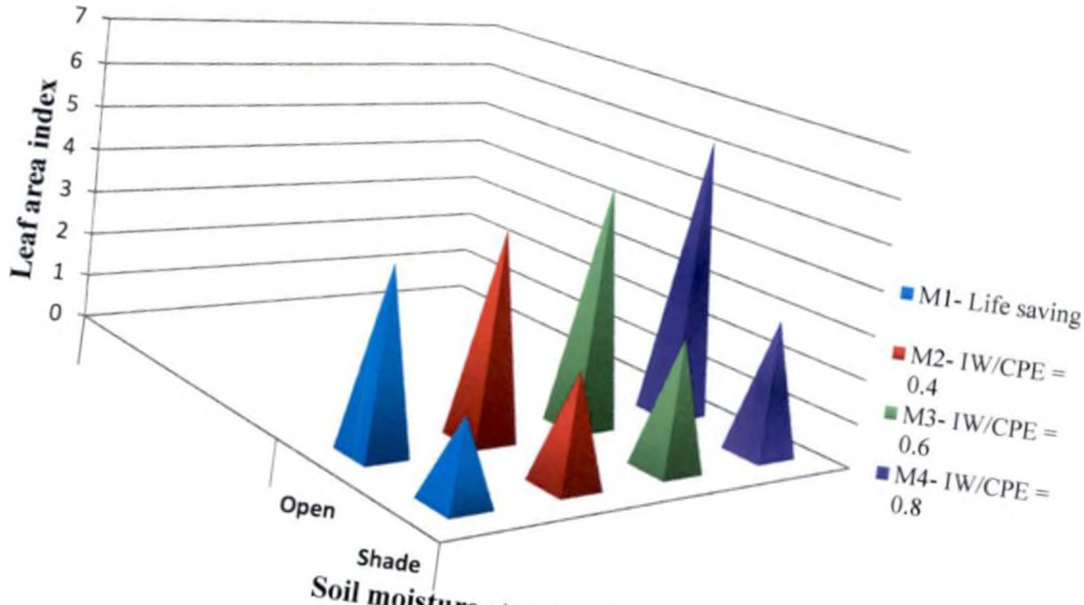


Figure 13. Effect of soil moisture stress levels on leaf area index

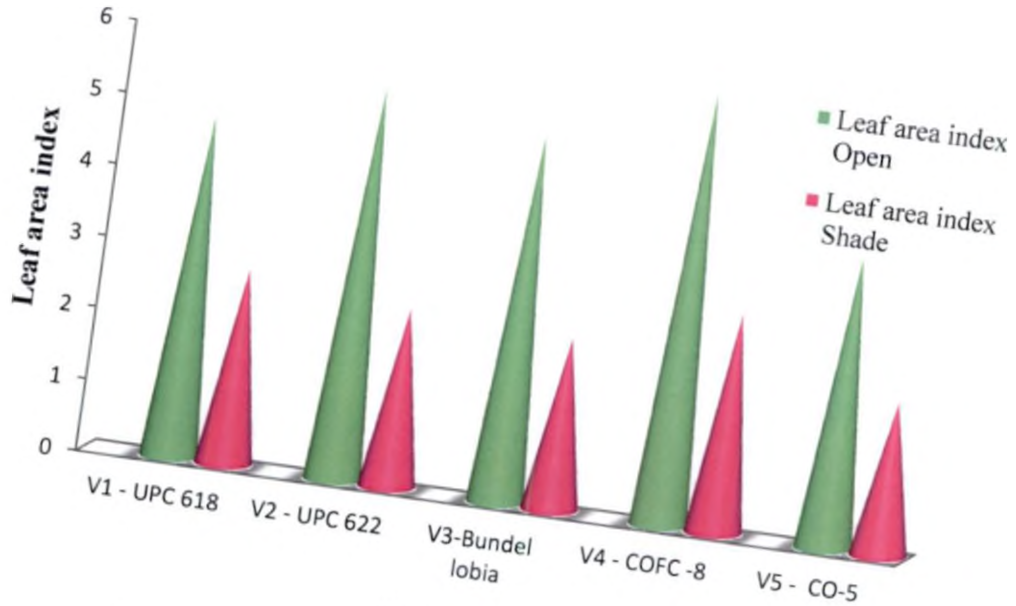


Figure 14. Effect of varieties on leaf area index

increased leaf area index in well irrigated plants might be due to the result of increased plant height, number of branches plant^{-1} and increased leaf area (Bade *et al.*, 1985). Similar findings of decreased leaf area index due to drought stress were reported by Hajibabaee *et al.* (2012) in forage corn hybrids. Ritchie (1987) reported increase of LAI of forage corn plants irrigated normally than plants under drought stress condition.

Leaf area index was also significantly influenced by varieties. COFC-8 recorded significantly higher leaf area index in open and shade which is due to higher number of branches plant^{-1} recorded by this variety which may have contributed to more number of leaves (Fig. 14). Similar result was also reported in forage corn hybrids by Hajibabaee *et al.* (2012) and in fodder cowpea varieties by Rajasree and Pillai (2001).

M x V interaction was significant in open and shade. COFC-8 irrigated at IW/CPE ratio of 0.8 recorded significantly higher leaf area index in open and shade. Ritchie (1987) reported increase of LAI of forage corn plants irrigated normally than plants under drought stress condition.

The results revealed that soil moisture stress levels and varieties had no significant influence on specific leaf area both in open and shade.

The results revealed that soil moisture stress levels significantly influenced the leaf dry weight both in open and shade. Irrigation at IW/CPE ratio of 0.8 recorded significantly higher leaf dry weight both in open and partial shade. Lifesaving irrigation recorded a lower leaf weight in both the conditions. This reduction in leaf dry weight might be due to leaf area reduction caused by water stress. The leaf area reduction results due to photosynthetic and chloroplast reduction, consequently resulting in rapid leaf necrosis, which implies that leaves are considered to play an important role in drought tolerance (Flagella *et al.*, 2002; Goksoy *et al.*, 2004). Similar result was reported by Hajibabaee *et al.* (2012) in forage corn hybrids. Varieties had no significant influence on leaf dry weight both in open and shade.

M x V interaction was significant in open condition and UPC-618 irrigated at IW/CPE ratio of 0.6 recorded significantly higher leaf dry weight in open. Considerable variations in leaf dry weight was reported in 14 corn forage hybrids under water stressed condition by Hajibabaee *et al.* (2012).

Soil moisture stress levels and varieties significantly influenced the relative leaf water content of the plant in both open and shade. Irrigation at IW/CPE ratio of 0.8 recorded higher relative leaf water content in both the conditions (Fig. 15). Lifesaving irrigation recorded the least relative leaf water content. Lesser availability of soil moisture and poor development of root system and reduced water uptake resulted in lower RWC. Moreover, the available soil water was not sufficient to maintain better water relations in plant. Several studies have reported the decrease of RWC under severe water deficit stress conditions (Mohsenzadeh *et al.*, 2006; Slama *et al.*, 2008; Nunes *et al.*, 2008; Yousfi *et al.*, 2010; Gorai *et al.*, 2010; Slama *et al.*, 2011).

Varieties also had significant influence on relative leaf water content of plant. COFC-8 recorded significantly higher RWC followed by UPC-622 in open condition. In partial shade, significantly higher RWC was recorded by COFC-8 followed by UPC-618 (Fig. 16). In addition to the severity of stress, plant response to water deficit stress was variety dependent. The results show considerable variations for drought tolerance among the cultivars, COFC-8, UPC-622 and UPC-618 preserved the highest RWC values when compared to other cultivars, suggesting the ability of these cultivars to avoid relatively tissue dehydration as consequence of osmotic adjustment (Slama *et al.*, 2011). Considerable variations in RWC among alfalfa cultivars were reported by Slama *et al.* (2011).

The study revealed that soil moisture stress levels and varieties had significant influence on leaf water potential of the plant both in open and shade. Significantly higher leaf water potential was recorded by irrigation at IW/CPE ratio of 0.8 in both the conditions. Leaf water potential decreased in all cultivars

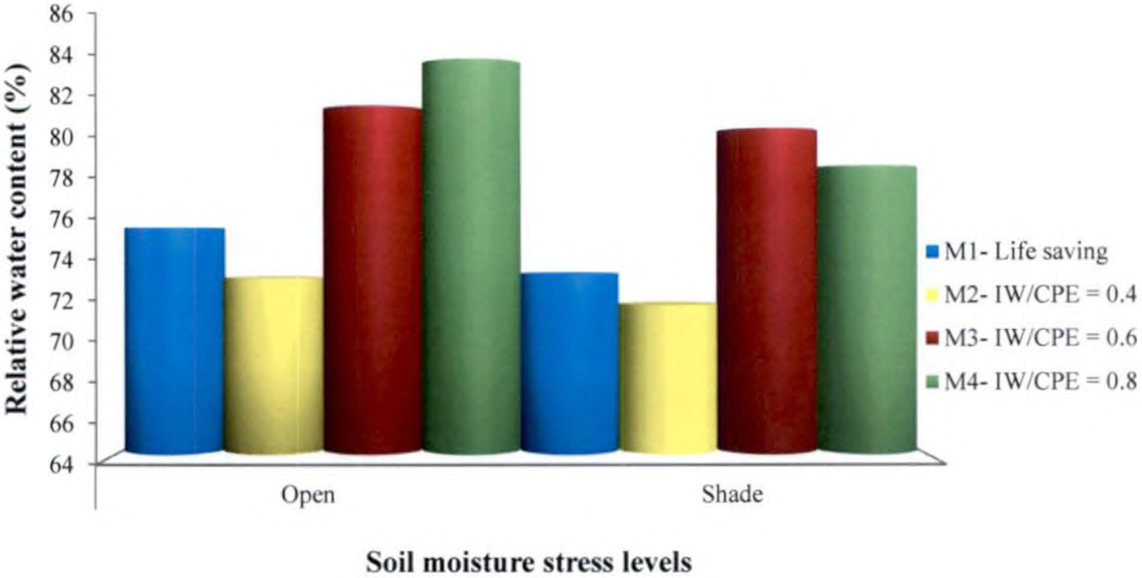


Figure 15. Effect of soil moisture stress levels on relative water content (%)

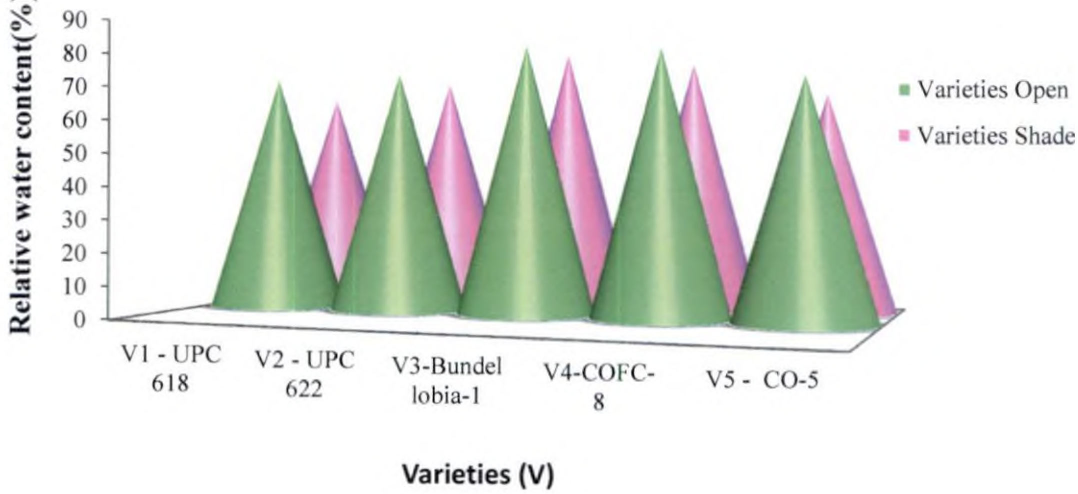


Figure 16. Effect of varieties on relative water content (%)

subjected to water deficit stress. As soil dries under drought stress, hydraulic conductivity of soil decreases, and the rate of water movement towards root and absorption are slow to completely replace the water lost from the plant by transpiration. Thus, drought results in lower plant water potential. The changes in the plant water potential can be attributed to change in osmotic pressure or osmotic component of the water potential. When leaf water potential is low, it causes the stomata to close, which causes decreased transpiration which in turn leads to increased water potentials. However, if drought persists, the water potential will continue to decrease and reach a zero turgor (Prasad and Staggenborg, 2008).

Leaf water potential was also significantly influenced by the varieties in open and shade. Among the varieties, all varieties except CO-5 were on par in open and shade. Leaf water potential decreased in all varieties subjected to water deficit stress. Jaafari (1993) showed that the osmotic adjustment is a criterion of selection to characterize the tolerant varieties of plants to water deficit stress. Considerable variations in leaf water potential were reported in alfalfa cultivars by Slama *et al.* (2011).

M x V interaction was significant in open and shade. Among the varieties, UPC-618 (V1) recorded higher leaf water potential (-0.92 MPa) which was on par with all other varieties except CO-5. Considerable variation for drought tolerance among the cultivars were noticed, suggesting the ability of these cultivars to avoid relatively tissue dehydration as consequence of osmotic adjustment (Slama *et al.*, 2011).

The results of the study revealed that soil moisture stress levels and varieties had significant influence on osmotic potential of plant in open and also in shade. Irrigation at IW/CPE ratio of 0.8 registered significantly higher osmotic potential both in open and shade. Osmotic potential of leaf decreases when subjected to water deficit stress. This adaptive mechanism includes traits which promote the maintenance of high tissue water content, as well as those for promoting tolerance to low water availability (Moinuddin *et al.*, 2005; Chaves *et al.,* 2010). This osmotic adjustment is defined as the lowering of osmotic potential in plant tissues due to net accumulation of organic solutes (Yang *et al.*, 2011). This accumulation of the compatible solutes in cells leads to decrease in the osmotic potential and finally resulted in higher water uptake capacity by roots and water saving in cells. Similar results were reported in alfalfa cultivars by Slama *et al.* (2011) and in *Medicago sativa* and *Agropyron cristatum* by Jefferson and Cutforth (2005).

Osmotic potential was also influenced by varieties in open and shade. COFC-8 registered lower osmotic potential both in open and partial shade. In addition to the severity of stress, plant response to water deficit stress was variety-dependent. Considerable variation for drought tolerance among the cultivars was observed, suggesting the ability of these cultivars to avoid relatively tissue dehydration as consequence of osmotic adjustment. Jaafari (1993) showed that the osmotic adjustment is a criterion of selection to characterize the tolerant varieties to water deficit stress. This is in conformity with the findings of Slama *et al.* (2011) in *Medicago sativa* cultivars.

M x V interaction effect was significant in both open and shade. COFC-8 at lifesaving irrigation recorded significantly lower osmotic potential in open and shade. This might be attributed to the accumulation of compatible solutes in high concentrations at water deficit stress conditions, in order to keep the osmotic balance.

The results of the study revealed that soil moisture stress and varieties had significant influence on stable isotope discrimination ratio of plant both in open and shade. Significantly lower carbon isotope discrimination ratio was recorded by irrigation at IW/CPE ratio of 0.4 in open and 0.6 in partial shade (Fig. 17). Carbon isotope discrimination tends to decrease in a linear manner from the highest to lowest water level (Johnson *et al.*, 2003). The isotopic ratio of $_{13}C$ to $_{12}C$ in plant tissue is less than the isotopic ratio of $_{13}C$ to $_{12}C$ in the atmosphere, indicating that plants discriminate against $_{13}C$ during photosynthesis. The isotopic

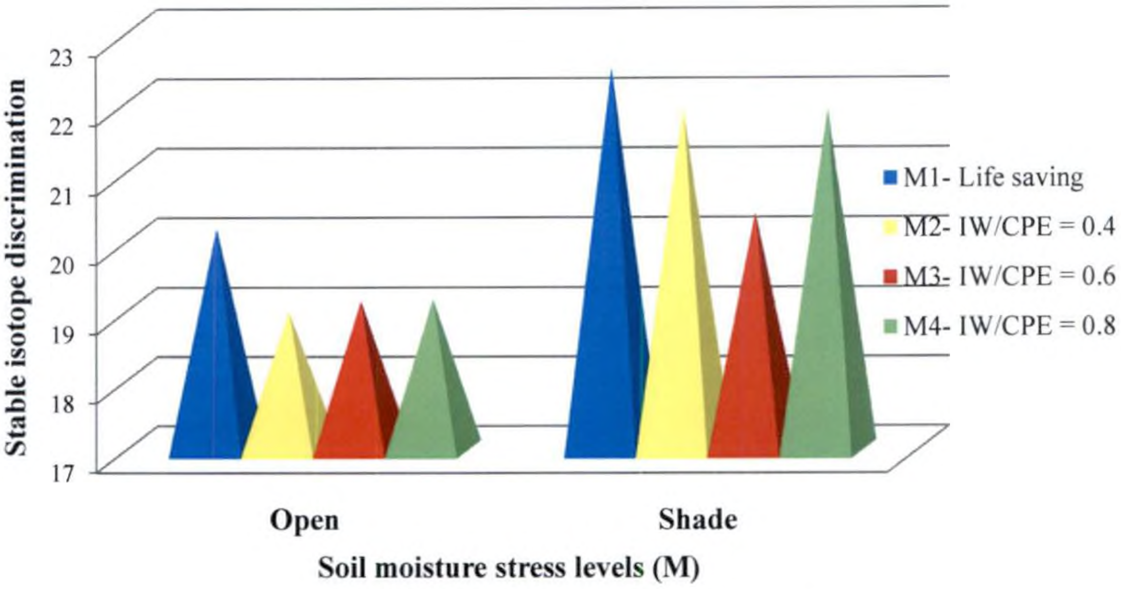


Figure 17. Effect of soil moisture stress levels on stable isotope discrimination

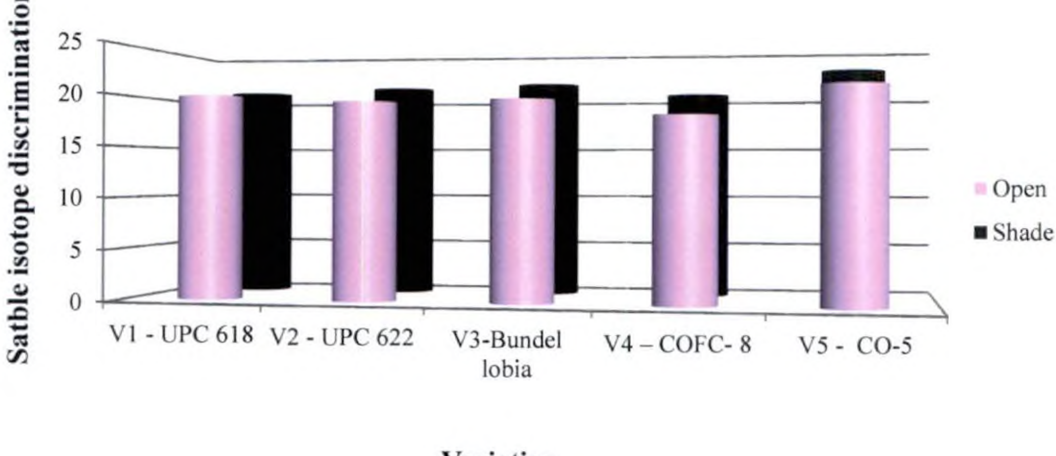


Figure 18. Effect of varieties on stable isotope discrimination

ratio of $_{13}C$ to $_{12}C$ in C_3 plants varies mainly due to discrimination during diffusion and enzymatic process (Farquhar *et al.*, 1989). Decreasing soil moisture during dry periods decreased leaf conductance and intercellular CO_2 levels, which in turn lowered carbon isotope discrimination (Farquhar and Richards, 1984; Johnson *et al.*, 1990). Considerable variations in carbon isotope discrimination were reported in forage grasses and legumes under different soil moisture stress levels by Sima *et al.* (2010).

Varieties also showed significant influence on stable isotope discrimination both in open and shade. Among the varieties, COFC-8 recorded lower carbon isotope discrimination in both the conditions (Fig. 18). The rate of diffusion of $_{13}C$ across the stomatal pore in this variety is more compared to other varieties, which leads to higher water use efficiency. Similar results were also reported by Sima *et al.* (2010) in *Festuca pratensis* and *Lolium corniculatus*.

The results of the study revealed that both soil moisture stress levels and varieties had significant influence on water use efficiency of the plant in open and shade. Higher WUE was recorded by irrigation at IW/CPE ratio of 0.4 in open and 0.6 in partial shade (Fig. 19). This might be attributed to the strong sensitivity of cowpea stomata to water stress with reduction in photosynthetic capacity. Supporting results were recorded by Ahmed and Suliman (2010) in fodder cowpea genotypes. They attributed the effect of drought on WUE to stomatal closure, decreased transpiration and decreased leaf turgidity, which have consequences on photosynthesis. Similar results were reported by Volesky and Berger (2012) in warm season annual grasses and Hayatu and Mukhtar (2010) in fodder cowpea genotypes.

Significant variations among varieties were also recorded in open and partial shade. Among the varieties, COFC-8 recorded a higher WUE both in open and in partial shade (Fig. 20). Isotope discrimination is inversely related to water use efficiency and COFC-8 had higher WUE and lower $_{13}$**C**. Hamidou *et al.* (2007) showed that stomatal closure is the common strategy used by cowpea

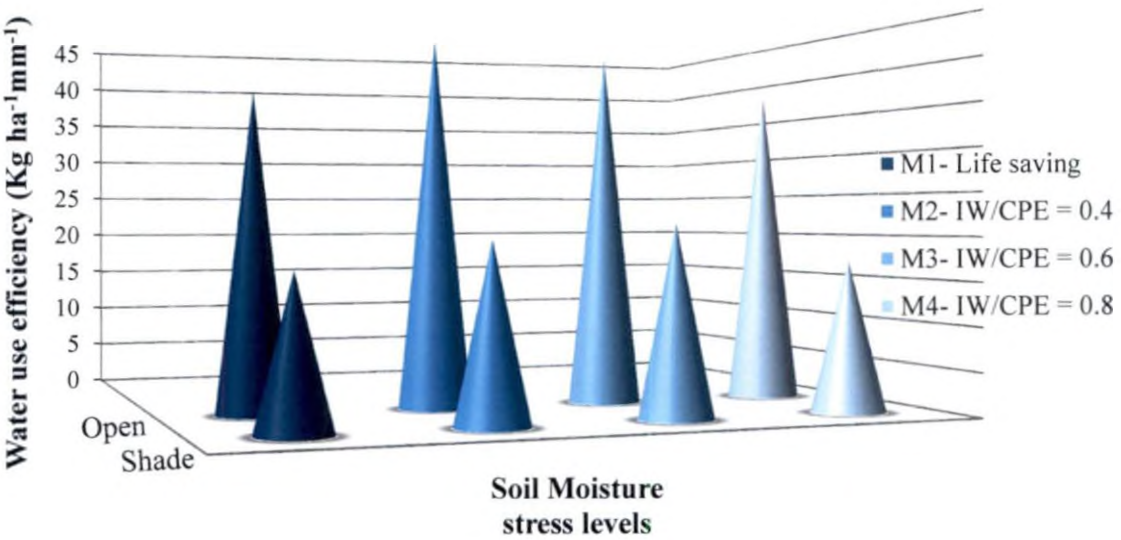


Figure 19. Effect of soil moisture stress levels on water use efficiency (kg ha^{-1}mm^{-1})

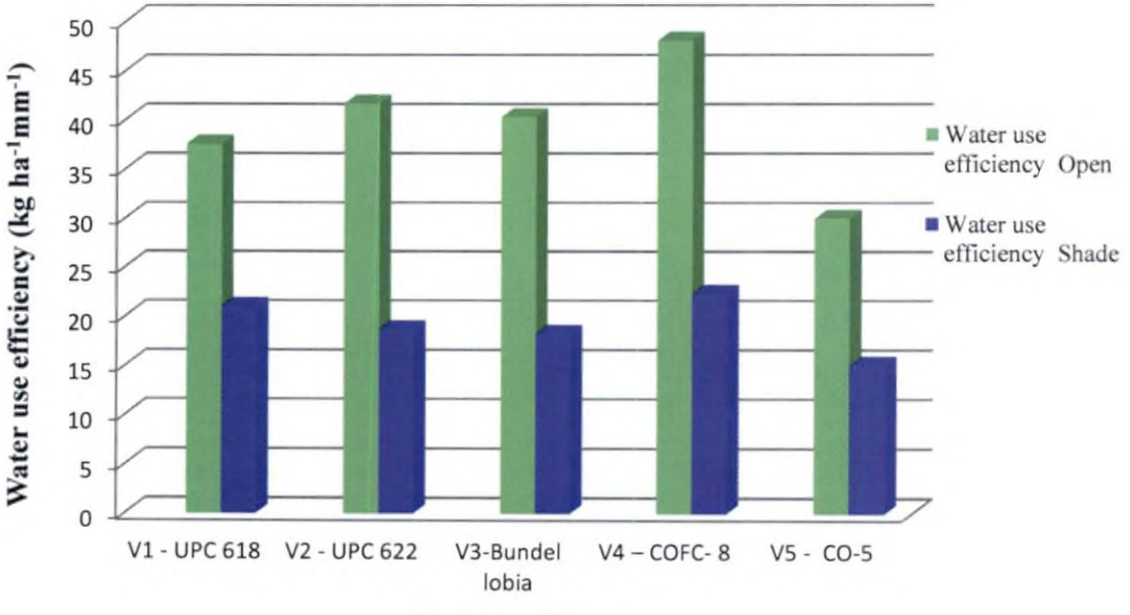


Figure 20. Effect of varieties on water use efficiency (kg ha^{-1}mm^{-1})

genotypes to avoid dehydration. Considerable variations in WUE in fodder cowpea genotypes were reported by Hayatu and Mukhtar (2010).

5.4. BIOCHEMICAL STUDIES

The results of the study revealed that soil moisture stress levels and varieties had significant effect on chlorophyll content both in open and shade (Fig. 21). Chlorophyll is one of the major chloroplast component for photosynthesis (Rahdari *et al*., 2012). The decrease in chlorophyll content under drought stress has been considered a typical symptom of pigment photo oxidation and chlorophyll degradation (Anjum *et al*., 2011). Water deficiency causes pigment and plastid damage. Drought stress decrease chlorophyll and carotenoids (Duysen and Freman, 1975). Similar results were reported in chickpea cultivars by Mafakheri *et al*. (2012) and Hajibabaee *et al*. (2012).

Chlorophyll content was also significantly influenced by varieties in open and shade. COFC-8 recorded higher chlorophyll content followed by Bundel Lobia-1 in both open and partial shade (Fig. 22). Since these varieties exhibited higher chlorophyll content under water stressed conditions, these are concluded to be adaptive to water stress. The results are in conformity with the findings of Hayatu and Mukhtar (2010) in cowpea genotypes and Haffani *et al*. (2013) in *Vicia* sp.

Results on proline content showed that soil moisture stress levels and varieties had significant influence both in open and shade. Maximum proline content was observed in life saving irrigation followed by irrigation at IW/CPE ratio of 0.4 both in open and shade. The accumulation of the proline is one of the adaptive responses frequently observed in the plants to limit the effects of drought. Proline accumulation under stress protects the cell by balancing the osmotic strength of cytosol with that of vacuole and external environment. In addition to its role as cytosolic osmotica, it may interact with cellular macromolecules such as enzymes and stabilize the structure and function of such macro molecules. Thus, this compound is often proposed as a relevant tool for

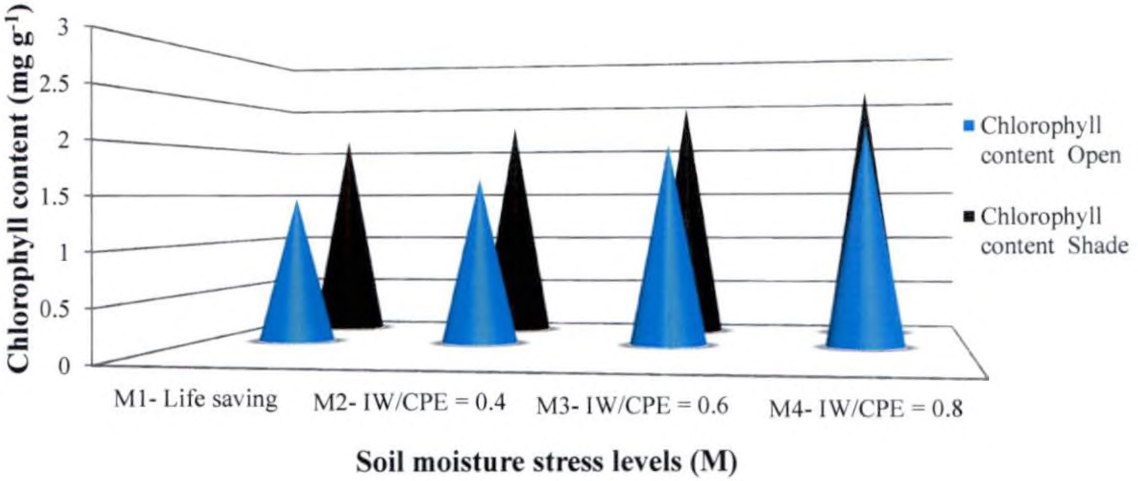


Figure 21. Effect of soil moisture stress levels on chlorophyll content (mg g^{-1})

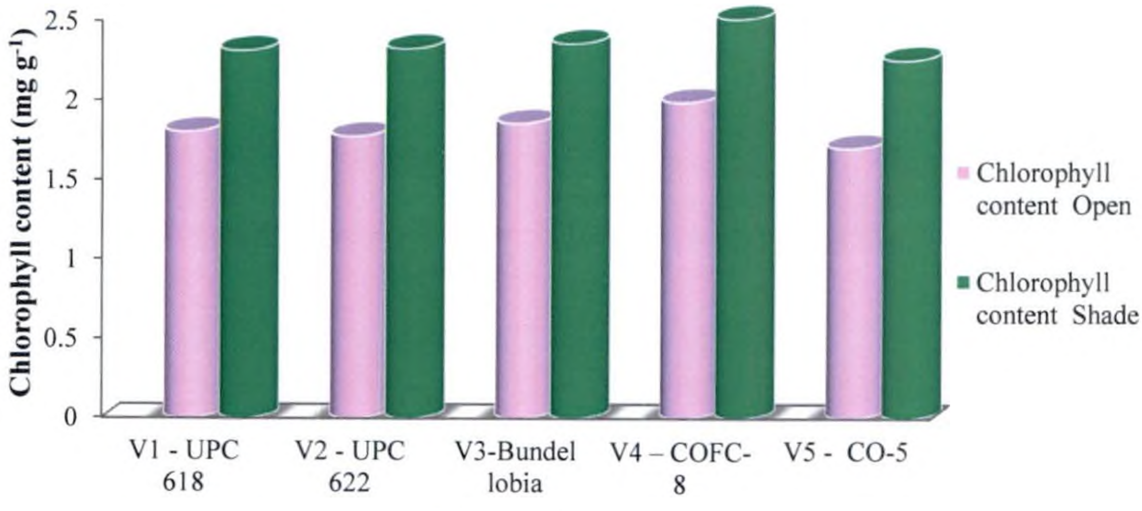


Figure 22. Effect of varieties on chlorophyll content (mg g^{-1})

selection of plant species and varieties tolerant to the osmotic constraints (Ashraf and Foolad, 2007). Proline can be accumulated in high concentrations in order to keep osmotic balance, without perturbing the normal physiological functions (Safarnejad *et al*., 1996). This is in conformity with the findings of Slama *et al.* (2011) in *Medicago sativa* and Rouchad *et al*. (2013) in *Medicago truncatula* and *Sulla carnosa.*

Proline content was also significantly influenced by varieties in open conditions only. COFC-8 recorded higher proline accumulation followed by UPC-618. Least accumulation of proline was observed in CO-5. Proline accumulation differs between cultivars adapted to certain growth conditions or regions, as well as within species more or less tolerant to drought (Heuer, 1994). It was observed that COFC-8, the most tolerant cultivar, on the basis of growth and water relations, showed the highest concentrations in proline. In the same context, it has been observed that there is higher proline content in drought-tolerant fodder sorghum than in sensitive ones (Turken *et al*., 2005). Similar results were also reported by Slama *et al*. (2011) in *Medicago sativa* cultivars.

5.5. QUALITY STUDIES

The study revealed that soil moisture stress levels didn't affect the crude protein content of plant in open condition. However, under 25-35 per cent shade, irrigation at IW/CPE ratio of 0.8 recorded higher crude protein content which was on par with irrigation at IW/CPE ratio of 0.6. Nutritive value is an important component of forage quality, which may be affected by water stress. Barnet and Naylor (1996) reported that amino acids were continuously synthesized during the water stress treatments, but protein synthesis was inhibited and protein content reduced in Bermuda grass. A specific crude protein concentration is the result of N uptake and the development of biomass production which is greatly determined by water availability (Kuchenmeister, 2013).

Varieties also had significant effect on crude protein content both in open and shade. COFC-8 recorded high CP content in both the conditions. This is in

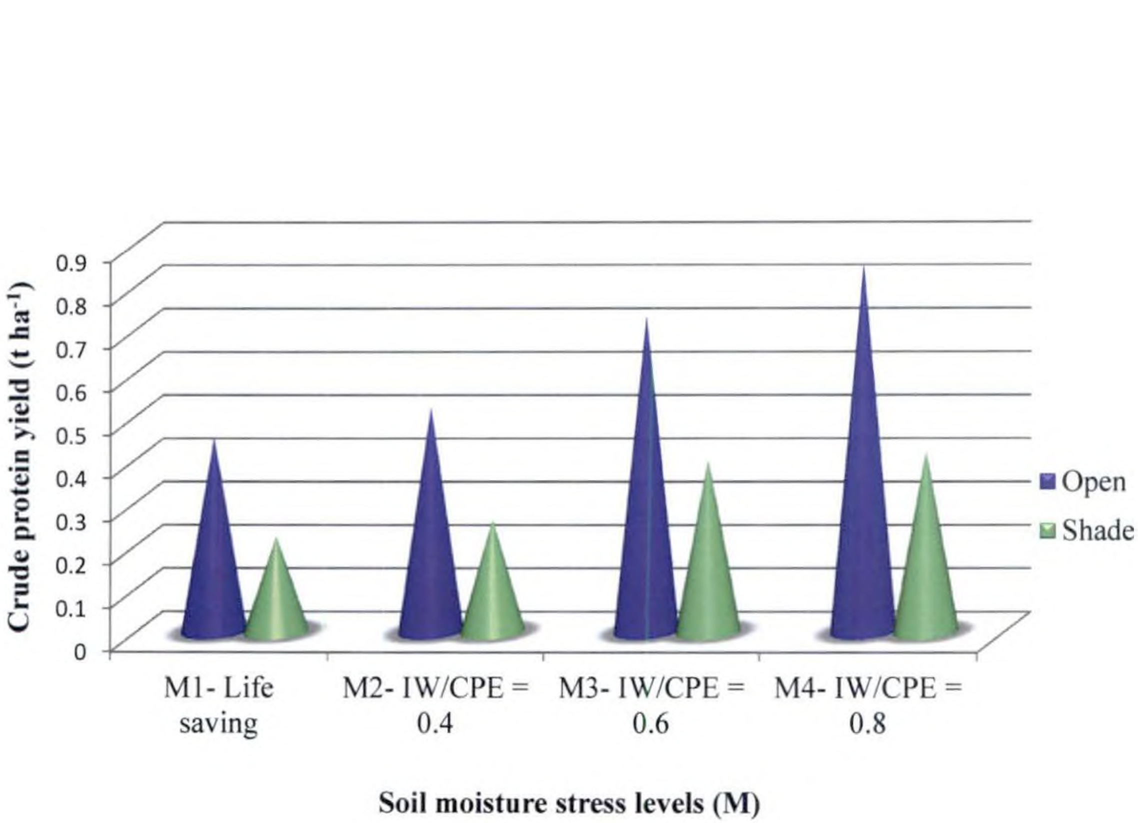


Figure 23. Effect of soil moisture stress levels on crude protein yield (t ha^{-1})

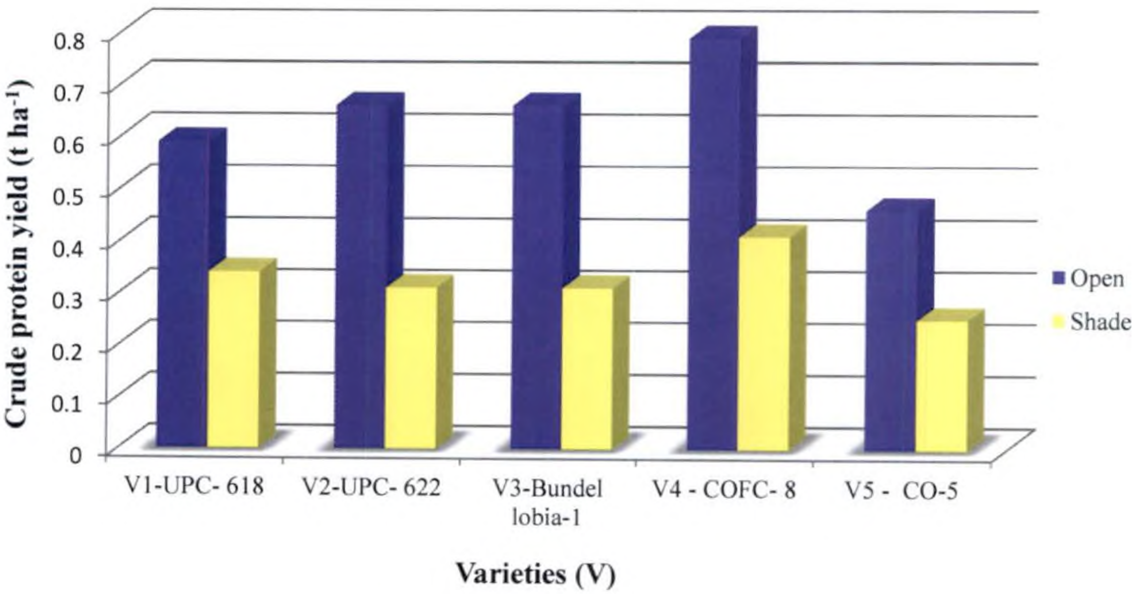


Figure 24. Effect of varieties on crude protein yield (t ha^{-1})

conformity with the findings of Shekara *et al*. (2012) in fodder cowpea genotypes.

Interaction effect was significant only in partial shade. COFC-8 irrigated at IW/CPE ratio of 0.8 recorded higher crude protein content which was on par with 0.6, 0.4 and lifesaving irrigation under partial shade. This might be due to the higher green fodder yield produced by the varieties at higher levels of irrigation.

The results of the study revealed that soil moisture stress levels had no influence on crude fibre content of the plant both in open and shade. Varieties had significant effect on crude fibre content only in open condition. UPC-622 recorded lowest crude fibre content among the varieties. This might be attributed to the reduced lignification of the fibre under water stress condition by this variety. Similar variation for crude fibre content was reported by Radhika (2003) in 50 accessions of fodder cowpea.

Crude protein yield was significantly influenced by soil moisture stress levels and varieties. Crude protein yield was found to be significantly higher at irrigation at IW/CPE ratio of 0.8 in open and shade (Fig. 23). This was due to the effect of dry fodder yield which was highest at higher levels of irrigation and lowest in life saving irrigation. Similar result was also reported by Kuchenmeister (2013) in birds foot trefoil and yellow alfalfa.

Among the varieties, COFC-8 recorded significantly higher crude protein yield both in open and shade which is also due to the higher dry matter production by this variety (Fig. 24). Considerable variations in crude protein yield were reported by Shekara *et al*. (2012) in fodder cowpea genotypes.

M x V interaction was significant only in partial shade. COFC-8 irrigated at IW/CPE ratio of 0.8 and 0.6 recorded higher crude protein yield which might be due to the higher dry fodder yield produced by this variety under these irrigation levels.

5.6. PLANT ANALYSIS

Soil moisture stress levels and varieties had significant effect on N, P, K, Ca

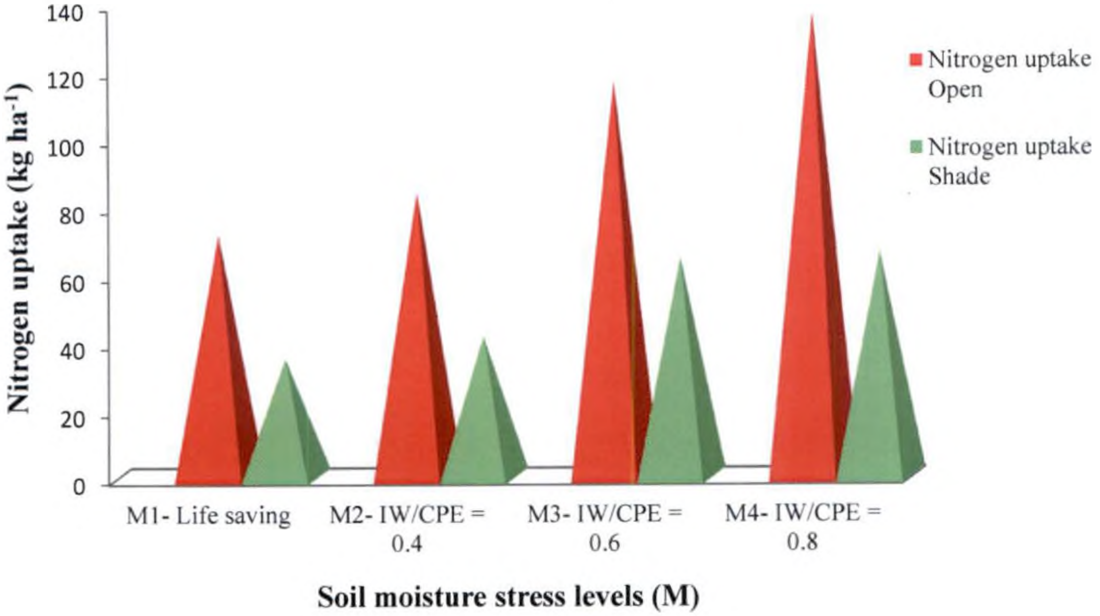


Figure 25. Effect of soil moisture stress levels on nitrogen uptake (kg ha^{-1})

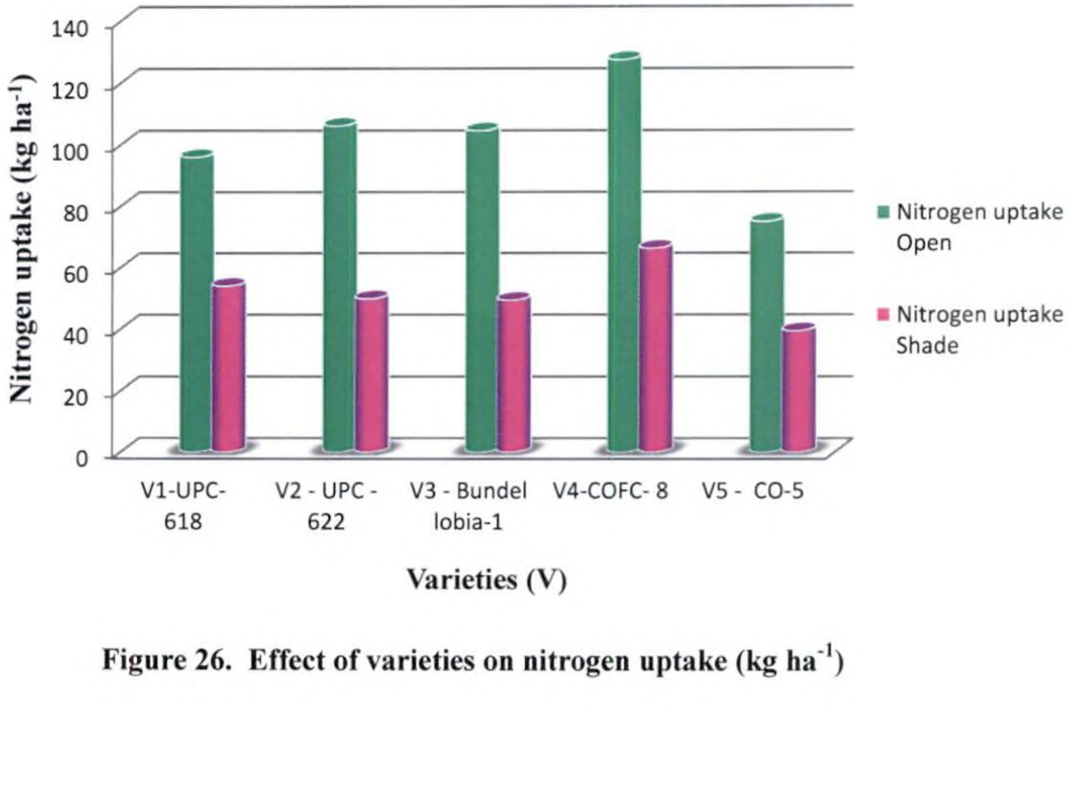


Figure 26. Effect of varieties on nitrogen uptake (kg ha^{-1})

and Mg uptake both in open and shade. Significantly higher uptake of all nutrients was recorded by irrigation at IW/CPE ratio of 0.8 in both conditions (Fig. 25). This might be due to the increased dry matter at high irrigation levels. Most studies have reported that mineral uptakes are decreased when the intensity of water stress is decreased. Nutrient uptake by forages is generally decreased under water-stress conditions owing to a substantial decrease in transpiration rates and impaired active transport and membrane permeability resulting in a reduced root-absorbing power of crop plants. A decline in soil moisture content is associated with a decrease in the diffusion rate of nutrients from the soil matrix to the absorbing root surface. Similar reductions in N uptake was reported by Barnet and Naylor (1996); P uptake by Seyed *et al.* (2012); K uptake by Fening *et al.* (2009) and Ca and Mg uptake by Nuttall (1976) and Seyed *et al*. (2012).

Varieties also varied significantly in nutrient uptake in both the conditions. COFC-8 recorded significantly higher uptake of all nutrients in both the experiments (Fig. 26). This might be due to the higher dry matter yield registered by this variety. Considerable variation for nutrient uptake was reported by Thaware *et al*. (1992) in 30 varieties of fodder cowpea.

Interaction effect was significant only in K uptake in shade condition. COFC-8 irrigated at IW/CPE ratio of 0.8 recorded high K uptake in shade. The higher dry matter yield produced by this variety at this irrigation level resulted in high uptake of K.

5.7. SOIL ANALYSIS

Soil moisture stress levels, varieties and shade levels had no significant influence on organic carbon, available nitrogen, phosphorus and potassium of the soil after the experiment.

5.8. ECONOMIC ANALYSIS

Highest net returns and benefit : cost ratio was obtained for irrigation at IW/CPE ratio of 0.8 in open condition, whereas in shade, highest net returns was

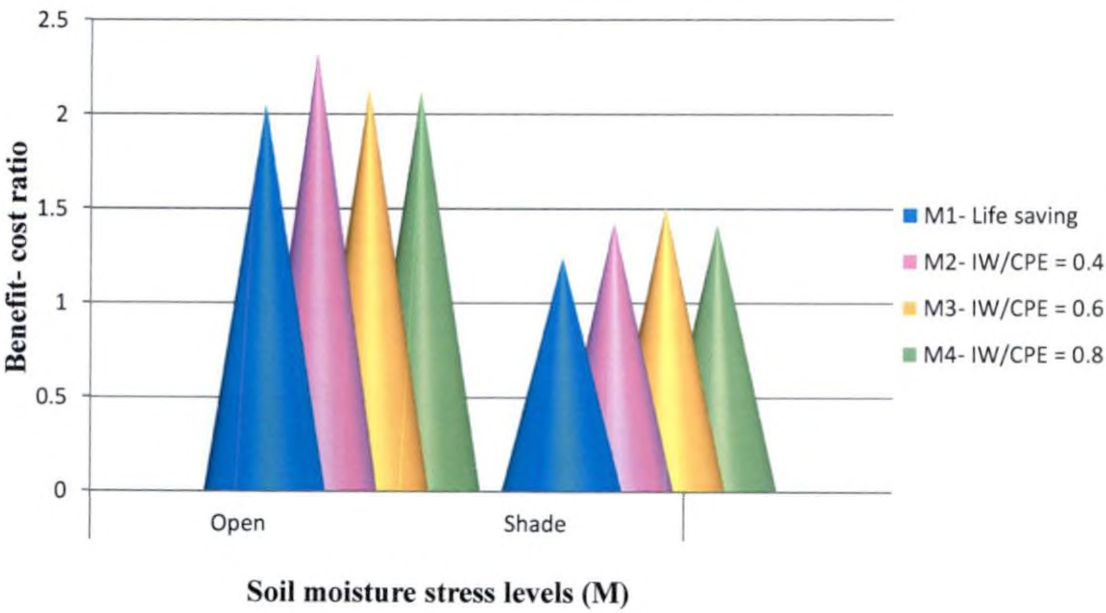


Figure 27. Effect of soil moisture stress levels on BCR

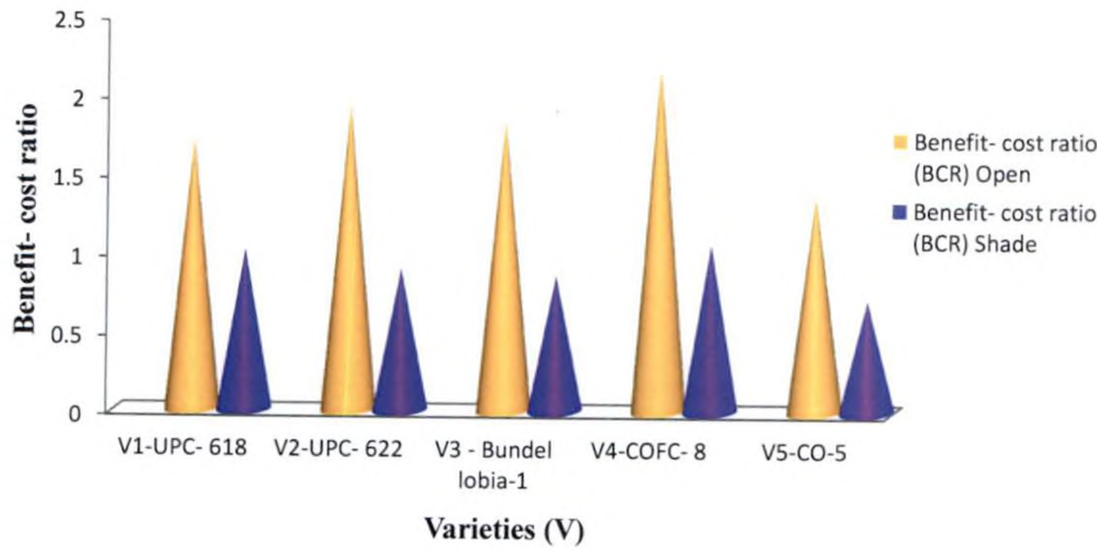


Figure 28. Effect of varieties on BCR

fetched by irrigation at IW/CPE ratio of 0.6 (Fig. 27). This is mainly due to the higher green fodder and dry fodder yields realized from the said treatments. Among the varieties, COFC-8 registered higher net returns and benefit : cost ratio in both the conditions compared to other varieties, which is also attributed to the high fodder yield of the variety (Fig. 28). COFC-8 was followed by UPC-622 (BCR of 2.30) in open and UPC-618 (BCR of 1.55) in shade with respect to net income and BCR. This is mainly due to the higher green fodder yield produced by these varieties.

INVESTIGATION- II : EVALUATION OF GRASS - FODDER COWPEA MIXTURES UNDER OPEN AND SHADED SITUATIONS

5.9. BIOMETRIC OBSERVATIONS OF GRASS AND COWPEA AS INFLUENCED BY GRASS, VARIETIES AND ROW RATIOS OF GRASS-LEGUME MIXTURE

The results showed that grasses and grass-legume row ratio had significant effect on plant height and number of tillers of fodder grasses. Hybrid napier recorded significantly higher plant height and number of tillers in open and shade in both the year. BN hybrid is a clump grass, with erect nature and superior in growth compared to guinea grass which is short statured, which explains the difference in plant height and tiller number between two grasses. Grass-legume row ratio of 1:3 recorded higher plant height and tiller number of grasses. This result might be due to the residual effect of decayed leaves and nodules of legume. Legumes are known to fix nitrogen directly which aid the growth of companion grasses. More N could have been fixed by 3 rows of leguminous crop. This observation agrees with the result of Tripathi and Psychas (1992) and Alalade *et al*. (2013) in guinea grass-stylosanthes mixture.

The results of the study revealed that among the treatments, grasses alone had significant effect on leaf: stem ratio of fodder grasses in open and shade. Morphological characteristics such as broad leaves also contributed to higher leaf: stem ratio in hybrid napier. This is in conformity with the findings of Njarui *et al*. (2007) when hybrid napier and guinea grass were intercropped with seca and siratro. Higher leaf: stem ratio was registered by hybrid napier cv. Suguna in open and shade in both the year compared to guinea grass. This might be due to higher proportion of leaf in the hybrid napier grass which accounted for the leaf dry matter yield. This is in confirmation with the findings of Gayathri (2010) in hybrid napier grass. The study also showed that the treatments had no significant effect on leaf: stem ratio of fodder cowpea.

Fodder cowpea varieties had no significant influence on growth characters of grasses. The results of the study also revealed that grasses had no significant effect on plant height of fodder cowpea. However, significantly higher number of branches was recorded in cowpea when it was intercropped in between guinea grass cv. Harithasree in open and shade in both the year. Spread for fodder cowpea was superior when grown with guinea grass than when grown with napier grass and consequently resulted in higher plot cover than with napier grass, an indication that guinea grass is less competitive than hybrid napier grass (Njarui *et al.*, 2007). Among the fodder cowpea varieties, COFC-8 recorded higher plant height and number of branches compared to UPC-622 in open and UPC-618 in shade. This difference in plant height of cowpea varieties may be due to their varietal difference.

Among the grass legume row ratio, cowpea intercropped with grasses at 1:2 ratio recorded higher plant height and number of branches in open and shade in both the year. When legumes are planted in double rows, they tended to spread in most areas than when planted in single rows. The reverse trend noticed in 1:3 row ratio which may be due to higher population of legumes resulting in higher competition for resources such as light, soil etc than the grass (Baba *et al.*, 2011). Similar results were reported by Njarui *et al.* (2007) in seca-guniea grass and seca-hybrid napier intercropping system. This is also in confirmation with the findings of Bakhashwain (2010) in rhodes grass - alfalfa mixtures.

It was observed from the results that root volume and root dry weight of grasses were significantly influenced by grasses and grass-legume row ratio. Significantly higher root volume and root dry weight were recorded by hybrid napier cv. Suguna in open and shade in both the years (Fig 29). The root biomass of hybrid napier was significantly higher than that of guinea grass as shown in plate no. 8 & 9. Among the row ratios, grasses intercropped with fodder cowpea at a row ratio of 1:3 and 1:2 recorded higher root volume and root dry weight in open and shade in both the years (Fig. 30). This is likely to be the main cause of the greater success of grasses, compared with legumes, in terms of growth and

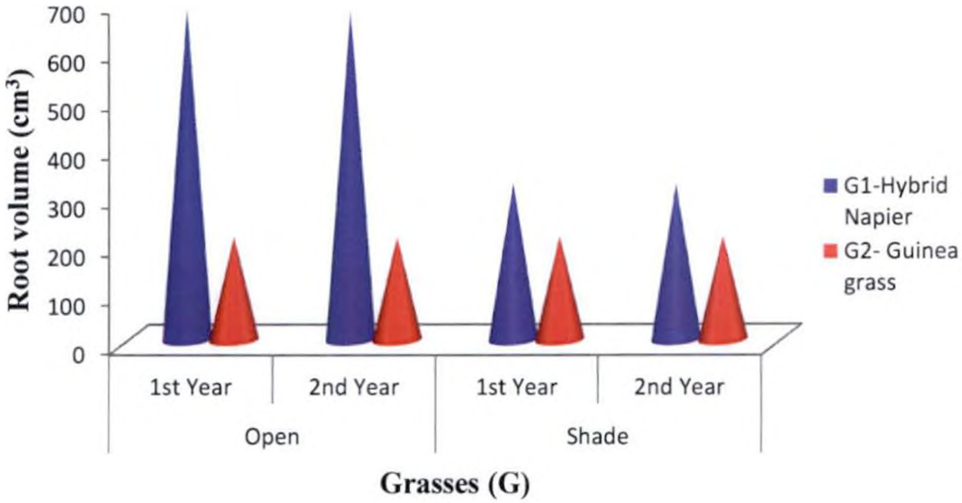


Figure 29. Effect of grasses on root volume of grass (cm^3)

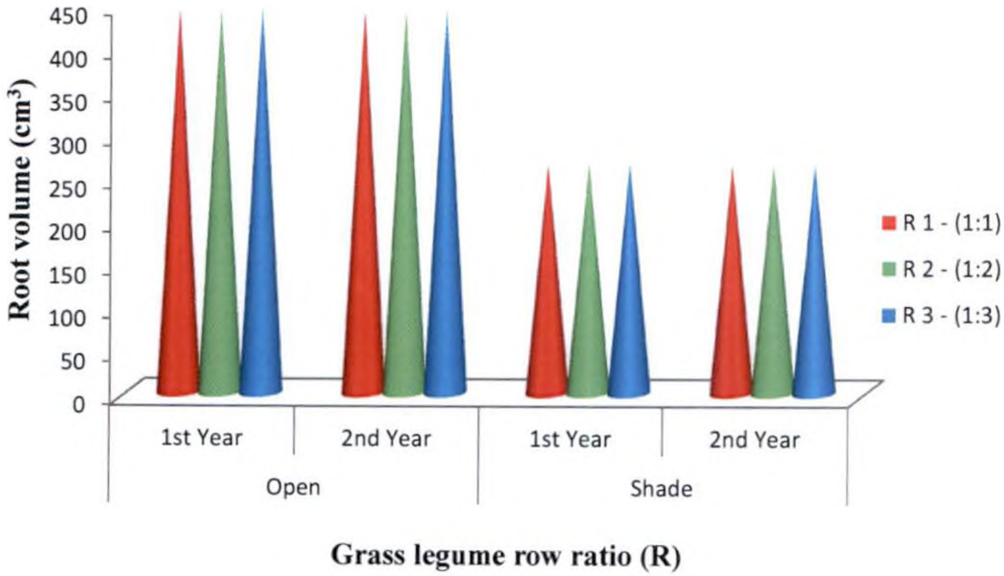


Figure 30. Effect of row ratio on root volume of grass (cm^3)

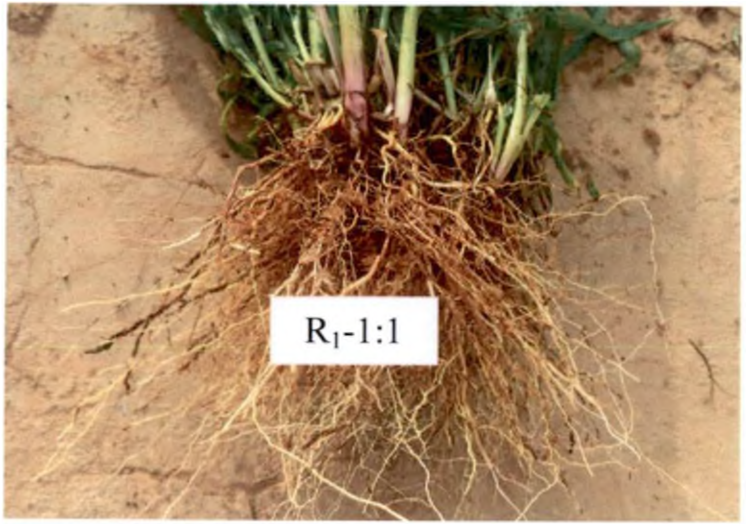


Plate 8. Roots of Hybrid napier cv.Suguna

Plate 9. Roots of Guinea grass cv. Harithasree

competitive ability (Schmid and Kazda, 2001). The study also revealed that grasses varied significantly on root: shoot ratio in open condition in both the years. Significantly higher root: shoot ratio was recorded by hybrid napier cv. Suguna in open condition only. Grasses had high tillering ability, and an extensive rooting system that enabled it to take up nutrients and water from the subsoil of legumes and thereby overcome periods of low nutrient and water available in the topsoil (Neukirchen *et al.*, 1999). So the root biomass increased faster than above ground biomass which leads to higher root: shoot ratio in grass. Similar findings were reported by Xu *et al.* (2008) in switch grass and sainfoin intercropping system.

5.10. YIELD PARAMETERS OF GRASS AND COWPEA AS INFLUENCED BY GRASS, VARIETIES AND ROW RATIOS OF GRASS-LEGUME MIXTURE

The results of the present study indicated that green fodder yield and dry fodder yield were significantly influenced by the treatments in open and shade in both the year. Among the grasses, hybrid napier produced significantly higher green fodder and dry fodder yields in open and shade in first and second year (Fig. 31) which could be attributed to the significant improvement in plant height, number of tillers and L: S ratio of the grass. Hybrid napier was superior in growth than guinea grass and this could attributed to difference in vigour during regrowth after cutting. Moreover, the stem of hybrid napier is thicker and is likely to store more carbohydrate reserves for growth than that of guinea grass and consequently survive better under reduced moisture than guinea grass. Similar results were reported by Njoka-Njiru (2006) in a grass-legume intercropping system. Fodder cowpea varieties had no significant effect on green fodder yield of grasses. Grasses intercropped with fodder cowpea at a row ratio of 1:3 recorded higher green fodder yield in open and shade in both the years (Fig. 32). This might be attributed to the growth behavior and plant density of the legumes with respect to the grass (plate 11). The increase in biomass yield was due to increase in leaf production, increased number of tillers and increased rate of leaf extension which

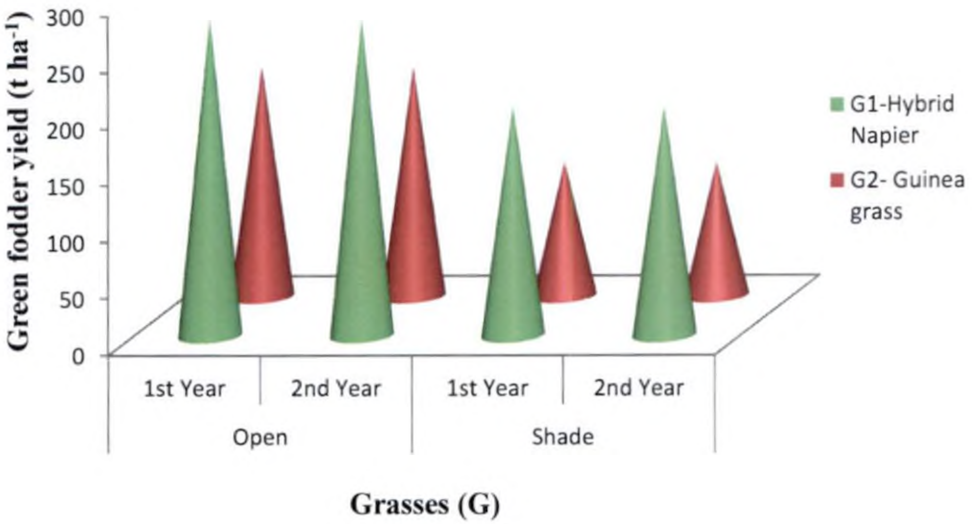


Figure 31. Effect of grasses on green fodder yield of grass (t ha^{-1})

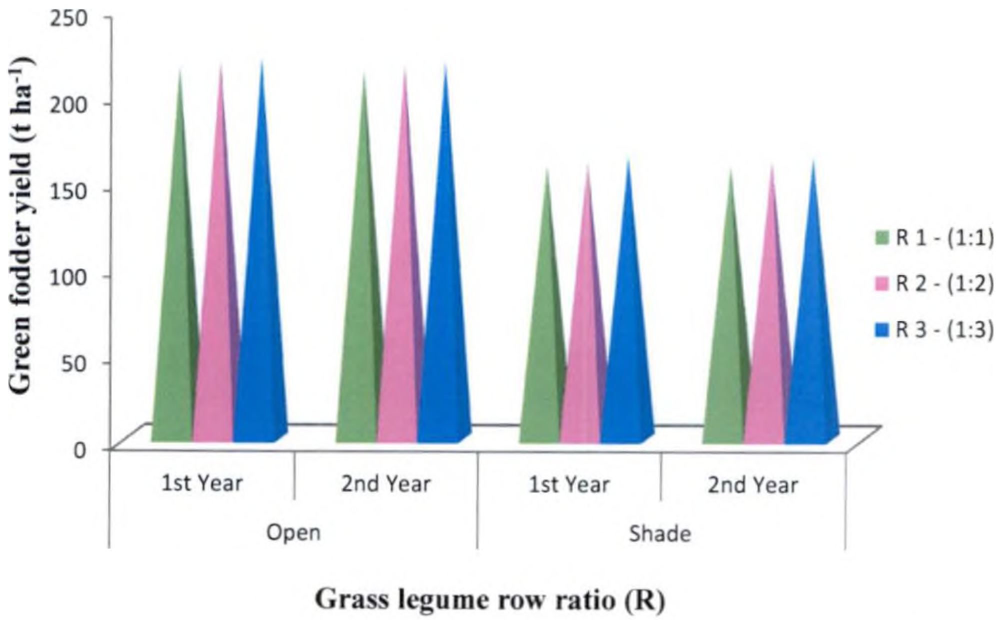


Figure 32. Effect of row ratio on green fodder yield of grass (t ha^{-1})

stimulated the greater light capture and hence photosynthesis and thus increased yield. This was in harmony with the report of Reynolds (1995) that inter planting of grass with legume at a more proportion transferred more nitrogen in legume grass mixture than the low proportion. Alalade *et al*. (2013) also observed similar results in *Panicum Stylosanthes* intercropping system. Grass row ratio interaction effect was significant only in open condition in both years. Hybrid napier intercropped with fodder cowpea at a row ratio of 1:3 recorded higher green fodder yield in open condition. The improved growth in hybrid napier resulted to the development of a larger canopy at a row ratio of 1:3. Similar results were reported by Njarui *et al.* (2007) in grass legume mixture.

Green fodder yield and dry fodder yield of cowpea were also significantly influenced by treatments. Fodder cowpea intercropped in between guinea grass recorded higher green fodder yield in open and shade in the first year and in shade in the second year (Fig. 33). Fodder cowpea yield was 13.6 % to 15.24 % higher when intercropped with guinea grass. The growth of fodder cowpea was more superior when grown with guinea grass than when grown with napier grass and consequently resulted in higher plot cover, an indication that guinea grass is less competitive than hybrid napier grass. Similar results were reported by Njarui *et al*. (2007) in grass legume intercropping system. Among the fodder cowpea varieties, COFC-8 recorded higher green fodder yield and dry fodder yield in open and shade in the first year and in open condition in the second year. Higher green fodder yield produced by this variety could be primarily due to the difference in growth behavior such as more plant height, more number of branches etc, which is genetically controlled. Considerable variations in yield characters were reported by Njarui and Wandera (2004) in seca and siratro. Among the grass legume row ratios, cowpea intercropped inbetween grasses at 1:2 row ratio recorded higher green fodder yield (Plate. 10) in open and shade in two years (Fig. 34). Legumes planted in double rows between grasses maintained higher plant numbers than in single rows indicating that double rows may give superior legume persistence in fodder grasses. This could be attributed to more

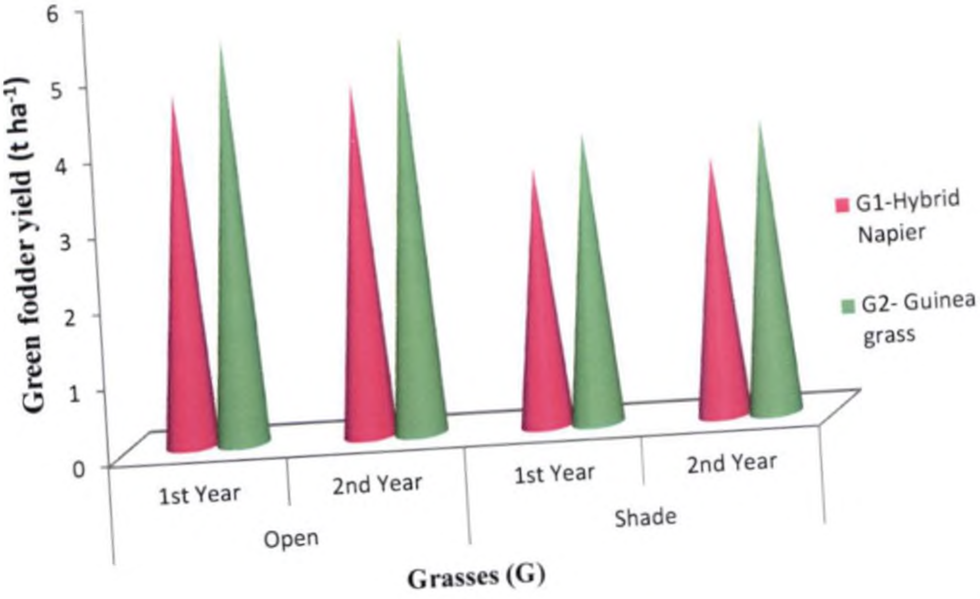


Figure 33. Effect of grasses on green fodder yield of fodder cowpea (t ha^{-1})

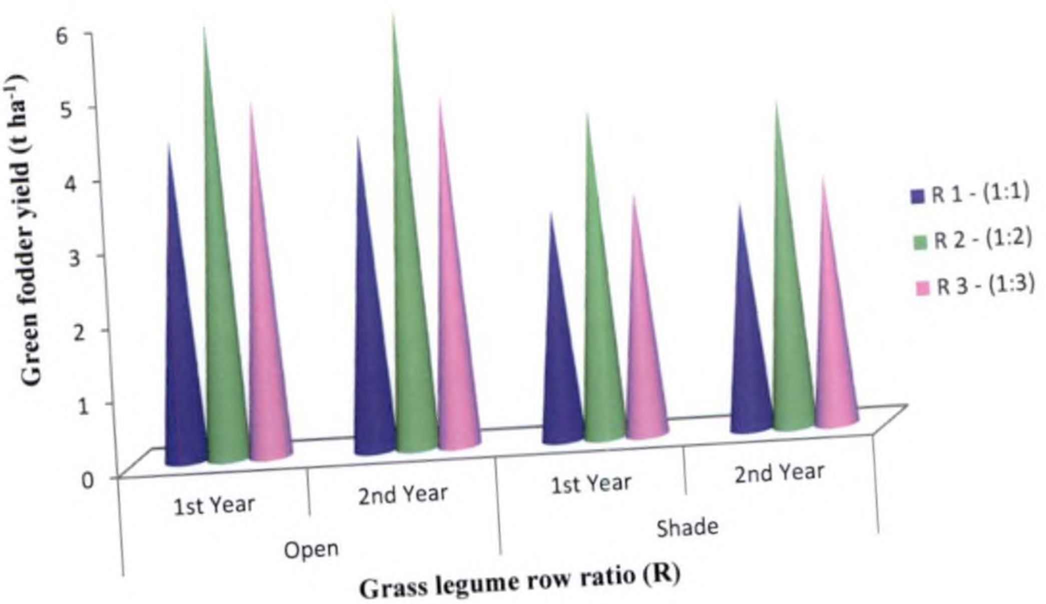


Figure 34. Effect of row ratio on green fodder yield of fodder cowpea (t ha^{-1})

Plate 10. Treatment combination which shows higher green fodder yield of fodder cowpea

Plate 11. Treatment combination which shows higher green fodder yield of grasses

space available for growth and less competition for nutrients (Njarui *et al*., 2007). The reverse trend seen in 1:3 grass legume row ratio might be due to higher population of legumes resulting in higher competition for light and soil resources than the grass (Baba *et al.,* 2011). Grass row ratio interaction effect was significant only in open condition in both the years. Fodder cowpea planted inbetween guinea grass at 1:2 row ratio recorded higher green fodder yield of cowpea in open condition. This is in conformity with the findings of Njarui *et al*. (2007).

Fodder cowpea variety-row ratio interaction was also significant in open condition in both the years. Significantly higher green fodder yield was recorded when fodder cowpea cv. COFC-8 was intercropped in between grasses at a row ratio of 1:2 in open condition. G x V x R interaction was significant in open condition in both the years. Fodder cowpea cv. COFC-8 intercropped in between guinea grass at a row ratio of 1:2 recorded higher green fodder yield in both the years.

The total green fodder yield and dry fodder yield were also significantly influenced by grasses and grass-legume row ratio in open and shade in both the years. Hybrid napier fodder cowpea mixture recorded higher total green fodder yield in open and shade, which can be attributed to the higher plant height, tiller production and L: S ratio of the grass. The total green fodder yield and dry fodder yield of the fodder crops were significantly higher when cowpea was intercropped in between grasses at 1:2 and 1:3 row ratio. Eventhough the green fodder yield of grasses was higher at 1:3 row ratio, due to higher green fodder yield of fodder cowpea at 1:2 row ratio, the combined total yield (grass + legume) differences between the planting patterns were small and were on par. The contribution of legumes to total green fodder yield was low due to relatively high yield of grasses. Similar results were reported by Njarui *et al*. (2007) when hybrid napier/guinea grass intercropped with seca/siratro in different row proportions.

G x R and V x R interactions were significant in partial shade only in second year. Hybrid napier intercropped with fodder cowpea at 1:2 row ratio recorded significantly higher total green fodder yield. Fodder cowpea cv. COFC-8 intercropped in between grasses at a row ratio of 1:2 recorded significantly higher total green fodder yield in partial shade. G x V x R interaction was significant in partial shade and hybrid napier intercropped with fodder cowpea cv. COFC-8 at 1:2 row ratio recorded significantly higher total green fodder yield.

5.11. PHYSIOLOGICAL PARAMETERS OF GRASS AND COWPEA AS INFLUENCED BY GRASS, VARIETIES AND ROW RATIOS OF GRASS-LEGUME MIXTURE

Dry matter production and leaf area index were also significantly influenced by the treatments. Among the grasses, significantly higher dry matter production and leaf area index were recorded by hybrid napier in open and shade in both the years. The higher dry matter production of hybrid napie rgrass could be due to vigourous nature of grass growth than guinea grass. The rapid establishment of the hybrid napier might have had a profound effect on the root system that enabled it to extract growth resources from the soil (Kechero, 2008). The broad leaves of hybrid napier grass and higher tiller production resulted in a higher leaf area index compared to guinea grass. This is in conformity with the findings of Gayathri (2010) in hybrid napier. Fodder cowpea varieties had no significant effect on physiological parameters of grasses. Among the row ratios, grasses intercropped with fodder cowpea at 1:3 ratio recorded significantly higher dry matter production and leaf area index in open and shade in both the years. This might be attributed to the transfer of more nitrogen to grasses from higher proportion of legumes which contributed to higher yields of grasses. All the vegetative characters like plant height, number of tillers, leaf: stem ratio were higher for hybrid napier. This is in conformity with the findings of Alalade *et al.* (2013) in *Panicum – Stylosanthes* intercropping system.

It was also observed that the dry matter production of fodder cowpea was influenced by the treatments. Significantly higher dry matter production of fodder cowpea was recorded when it was intercropped in between guinea grass in open condition and dry matter production was lower when cowpea was intercropped inbetween hybrid napier, but when intercropped with guinea grass it had the highest dry matter production. Among the fodder cowpea varieties, COFC-8 recorded significantly higher dry matter production in open condition. Grass - legume row ratio of 1:2 recorded higher dry matter production of fodder cowpea. This might be attributed to the higher forage yield recorded by fodder cowpea when planted in double rows between grasses than in single or triple rows (Njarui *et al.*, 2007). Grass row ratio interaction was significant in fodder cowpea and higher dry matter production was obtained when it was intercropped in between guinea grass at a row ratio of 1:2. The treatments had no significant effect on leaf area index of fodder cowpea.

5.12. BIOCHEMICAL ASPECTS OF GRASS AND COWPEA AS INFLUENCED BY GRASS, VARIETIES AND ROW RATIOS OF GRASS-LEGUME MIXTURE

The results of the study revealed that the treatments had no significant effect on chlorophyll content of grasses. However, varietal effect was seen in chlorophyll content of fodder cowpea. Among the fodder cowpea varieties, COFC-8 registered higher chlorophyll content in open and shade in both the years. Considerable variation in chlorophyll content was reported by Haffani *et al.* (2013) in *Vicia* sp. It was observed that the treatments had no significant effect on proline content of grasses and fodder cowpea.

5.13. QUALITY ASPECTS OF GRASS AND COWPEA AS INFLUENCED BY GRASS, VARIETIES AND ROW RATIOS OF GRASS-LEGUME MIXTURE

The crude protein content of grasses alone was significantly influenced by the treatments. Among the grasses, hybrid napier cv. Suguna recorded significantly higher crude protein content in open and shade in both the years. This may be attributed to the higher nitrogen content in this grass. The genetic superiority of this grass in this character has been an added advantage in this respect. However, fodder cowpea varieties had no significant effect on protein content of grasses. Among the grass-legume row ratio, grasses intercropped with fodder cowpea at 1:3 row ratio resulted in a higher crude protein content of grasses. The triple rows of cowpea were superior to double or single row (Sleugh *et al*., 2000; Berdahl *et al*., 2001; Albayrak and Ekiz, 2005; Sima *et al*., 2010) owing to utilization of symbiotically fixed nitrogen (Whitehead, 1995), more enhanced interception of light (Hay and Walker, 1989) and allelopathic (Pudnam and Duke, 1978) and other effects. These factors created a micro-environment that favoured higher protein content than those obtained from sole legume or grass stands (Sengul, 2003). Generally, mixing of legumes in grass fodder is a better way to increase the quality of grass fodder. That is because fodder quality of grassy hay is lower than that required to meet production goals for many livestock classes (Karadau, 2003). Ta and Faris (1987) reported that the nitrogen released from legumes was used by the grasses in mixtures. Thus, the mixtures had higher CP contents than the monoculture grasses (Sanderson, 2010; Kim and Albrecht, 2011). This is in conformity with the findings of Alalade *et al*. (2013) in Stylosanthes - guinea grass intercropping system. Grass-row ratio interaction was significant and hybrid napier intercropped with fodder cowpea at 1:3 row ratio recorded higher crude protein content in open condition in both the years.

The results of the study revealed that grasses had significant effect on crude fibre content of grasses in open and shade in both the years. Hybrid napier recorded lower crude fibre content compared to guinea grass. The genetic superiority of this variety in this character has been an added advantage in this respect. The crude fibre content decreased with increase in level of crude protein content in the grass. This is in line with the findings of Adepoju (2005) who observed a decrease in crude fibre percentage as the crude protein percentage increased. This might be due to the fact that the more the crude protein content of forage the lesser the fibre fraction.

Crude protein yield of grass and fodder cowpea were significantly influenced by the treatments. Among the grasses, hybrid napier recorded significantly higher crude protein yield in open and shade in both the years (Fig. 35). This could be attributed to significantly higher dry fodder yield produced by this grass. Fodder cowpea varieties had no significant effect on crude protein yield of grasses. Grass-legume row ratio was significant in open and shade and grasses intercropped with fodder cowpea at 1:3 row ratio recorded significantly higher crude protein yield (Fig. 36). This might be attributed to the higher dry fodder yield produced by the grass at a higher proportion of legume. Similar results were reported by Alalade *et al.* (2013) in stylosanthes and guinea grass mixture. Grass-row ratio interaction was significant in open condition only and hybrid napier intercropped at 1:3 row ratio recorded higher crude protein yield in open.

It was also observed that crude protein yield of fodder cowpea was significantly influenced by the treatments. Grasses had significant effect in crude protein yield of fodder cowpea in open condition in the first year and in open and shade in the second year. Fodder cowpea intercropped in between guinea grass recorded significantly higher crude protein yield in open and shade. This is attributed to the higher dry fodder yield produced by the fodder cowpea, when intercropped with guinea grass. This is in line with the findings of Alalade *et al.* (2013) in stylosanthes-guinea grass mixture. Grass legume row ratio was significant and fodder cowpea intercropped with grass at 1:2 row ratio recorded higher crude protein yield in open and shade in both the years. At 1:2 row ratio, fodder cowpea produced higher dry fodder yield which might have contributed to the higher crude protein also. This is in conformity with the report of Ojo *et al.* (2013) when *P. maximum* was intercropped with *L. purpureus*. Grass row ratio interaction was significant in open condition and fodder cowpea intercropped in between guinea grass cv. Harithasree at 1:2 row recorded significantly higher crude protein yield in open.

Total crude protein yield was also influenced by the treatments. Total crude protein yield was significantly higher for hybrid napier + fodder cowpea mixture. Significantly higher dry fodder yield of hybrid napier contributed to the higher

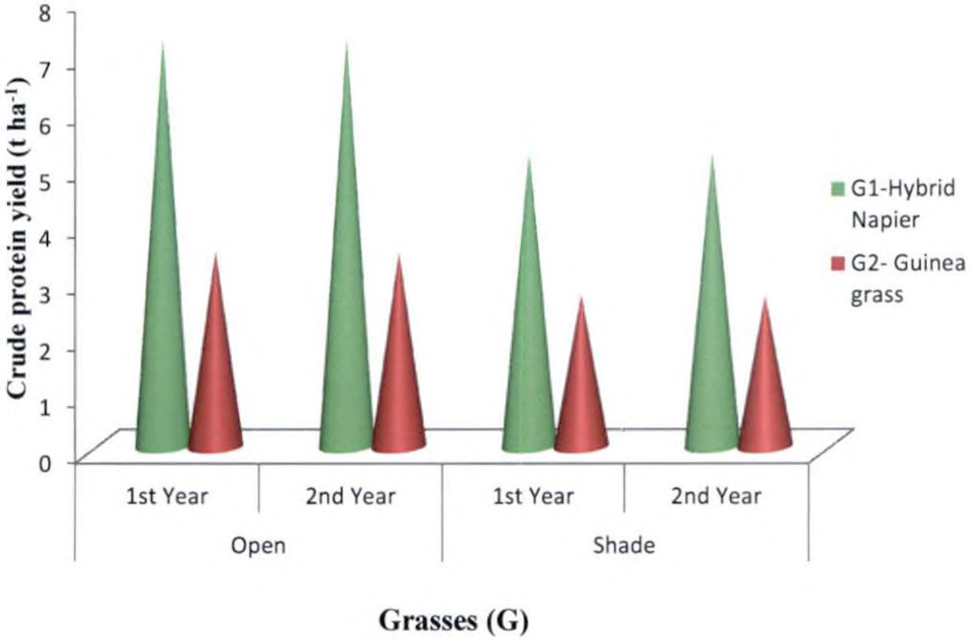


Figure 35. Effect of grasses on crude protein yield of grass (t ha^{-1})

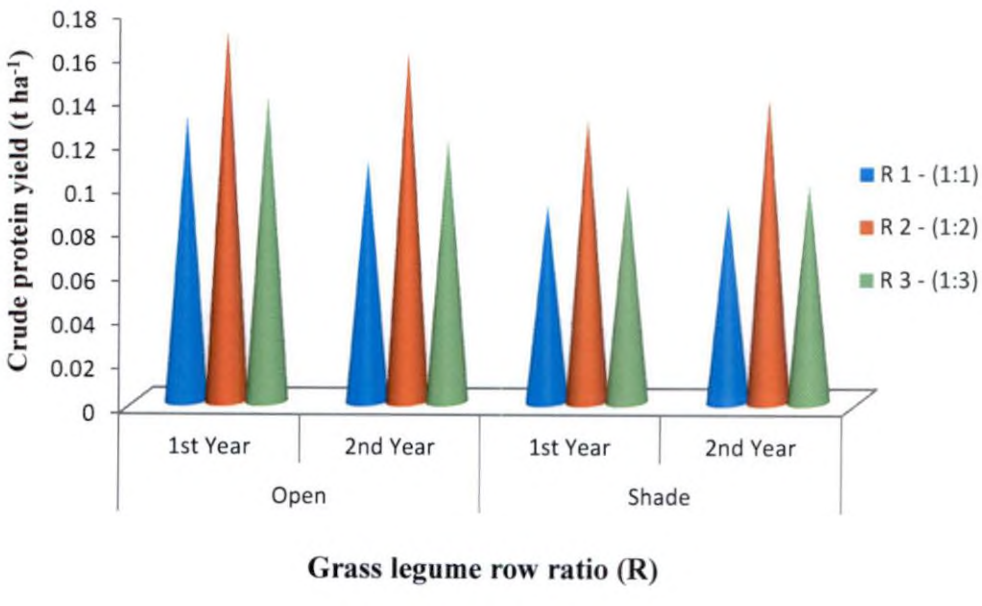


Figure 36. Effect of row ratio on crude protein yield of grass (t ha^{-1})

total crude protein yield in the mixture. Hybrid napier intercropped with fodder cowpea at 1:2 row ratio recorded significantly higher crude protein yield in open and shade in both the years. This might be attributed to the higher dry fodder yield produced at 1:2 row ratio by the mixture. This was in harmony with the report of Alalade *et al*. (2013) when stylosanthes was intercropped with guinea grass at different proportions.

5.14. NUTRIENT UPTAKE OF GRASS AND COWPEA AS INFLUENCED BY GRASS, VARIETIES AND ROW RATIOS OF GRASS-LEGUME MIXTURE

Nutrient uptake was also influenced by the treatments in open and shade in both the years. Among the grasses, hybrid napier recorded significantly higher uptake of N, P, K, Ca and Mg in open and shade in both the years. This was due to the higher dry matter yield registered by this grass. Similar result was also reported by Gayathri (2010) in hybrid napier. The uptake of nutrients was the highest when grasses were intercropped with fodder cowpea at 1:3 row ratio which may be attributed to the increase in dry matter yield at this row proportion. This is in line with the findings of Alalade *et al*. (2013) in guinea grass when it was intercropped with stylosanthes in different proportions. Grass row ratio interaction was significant only in open condition in the second year. Hybrid napier grass intercropped with fodder cowpea at 1:3 row ratio recorded higher uptake of N, K and Mg in open condition.

It was also observed that nutrient uptake of fodder cowpea was influenced by the treatments. Fodder cowpea intercropped in between guinea grass recorded significantly higher uptake of N, P, K, Ca and Mg in open and partial shade in both the years. This may be attributed to the higher dry fodder yield produced by the fodder cowpea when intercropped in between guinea grass. This is in conformity with the findings of Njarui *et al*. (2007) in seca/siratro when intercropped with guinea grass/hybrid napier. Among the fodder cowpea varieties, COFC-8 recorded higher N and Ca uptake in open and shade and K uptake in open condition. Higher dry fodder yield produced by this variety resulted in high N and Ca uptake. Significantly higher N, P, K, Ca and Mg uptake was recorded by fodder cowpea when it was intercropped with grasses at 1:2 row ratio in open and partial shade in both the years. This may be due to the higher dry fodder yields produced by the fodder cowpea at 1:2 row ratio. Legumes planted in double rows between grasses maintained higher plant numbers and consequently higher yields than in simple or triple rows. This might have contributed to higher uptake of nutrients at 1:2 row ratio (Meena and Mann, 2011). Interaction effects were significant in N, K, Ca and Mg uptake in open condition. Nitrogen, Potassium, Calcium and Magnesium uptake were significantly higher in fodder cowpea when it was planted in between guinea grass at a row ratio of 1:2. This might be due to the higher dry fodder yield produced by fodder cowpea when intercropped in between guinea grass at 1:2 row ratio.

5.15. SOIL ANALYSIS AS INFLUENCED BY GRASS, VARIETIES AND ROW RATIOS OF GRASS-LEGUME MIXTURE

The results on the chemical analysis of the soil after the experiment revealed that organic carbon content, available phosphorus and available potassium was not significantly influenced by the treatments. This might be due to the fact that the treatments received the same nutrient regime. Similar result was reported by Mouat and Nes (1985) in rye grass. However available nitrogen content was significantly influenced by the grass-legume row ratio in open and shade in both the years. Legumes benefit the grass by contributing nitrogen to the soil through atmospheric N_2 fixation, decay of dead root nodules and mineralization of shed leaves (Seresinhe *et al.*, 1994). Inclusion of legumes in a pasture increases the levels of nitrate residue in the soil and this enhances the grass growth (Vliegher and Carlier, 2008).

5.16. NET INCOME AND BCR OF GRASS AND COWPEA AS INFLUENCED BY GRASS, VARIETIES AND ROW RATIOS OF GRASS-LEGUME MIXTURE

Among the grasses hybrid napier recorded highest net returns and

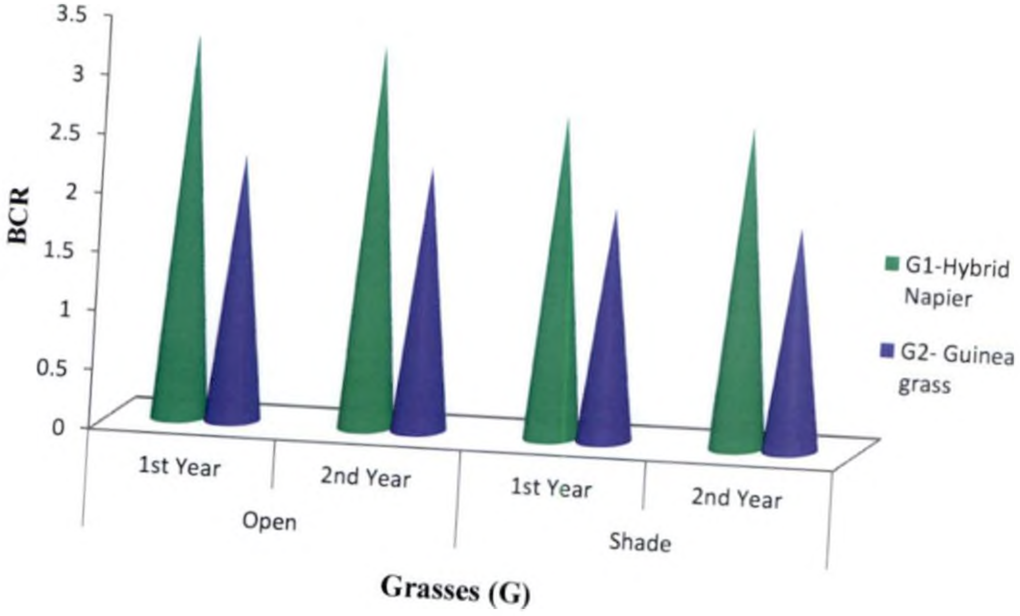


Figure 37. Effect of grasses on BCR

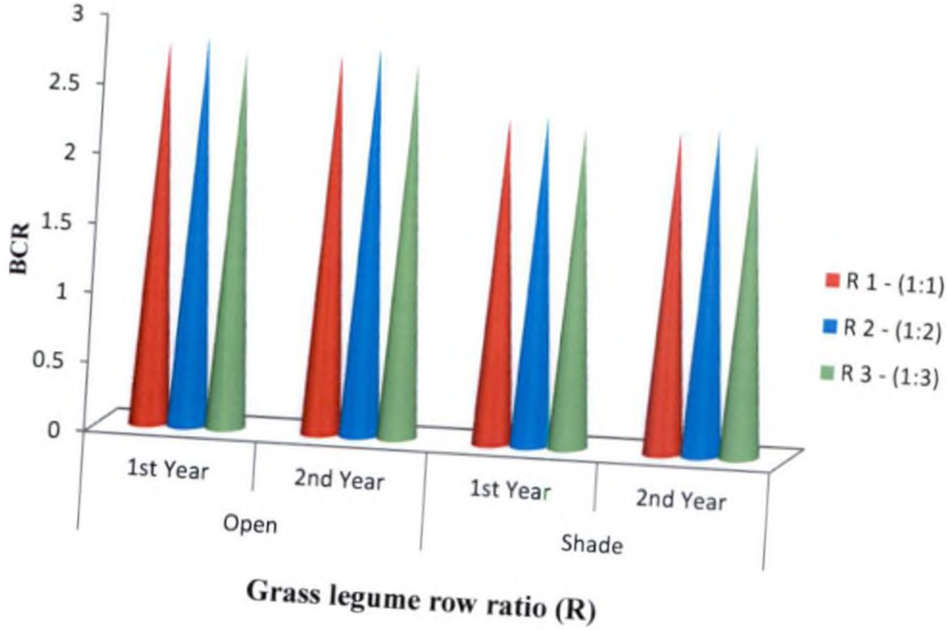


Figure 38. Effect of row ratio on BCR

benefit : cost ratio in open and shade in both the years (Fig. 37). This is mainly due to the higher green fodder and dry fodder yields realized from this grass. Among the fodder cowpea varieties, COFC-8 recorded higher net returns and was significant only in partial shade in the first year. Grass-legume row ratio of 1:2 registered higher net returns and benefit : cost ratio in open and shade in both the years which is also due to the high green fodder yield produced at this row ratio (Fig. 38). Grass row ratio interaction was significant in open condition in the first year and in shade in the second year. Hybrid napier grass intercropped with fodder cowpea at 1:2 row ratio registered higher net income compared to other treatment combinations. BCR was also significant in shaded condition in first year and in open and shade in the second year. Hybrid napier grass intercropped with fodder cowpea at 1:2 row ratio recorded higher BCR due to the higher fodder yield produced at this row proportion.

Summary

6. SUMMARY

The experiment entitled "Fodder production technology under light and moisture stress situations" was undertaken at the Instructional Farm, College of Agriculture, Vellayani, during January 2012 to March 2014. The main objectives of the study were to identify drought tolerant varieties of fodder cowpea suitable for the dry summer months and their evaluation in mixtures with the popular fodder grasses of Kerala for improving the quantity, quality and economics of fodder production under open and shaded situations.

The study comprised of two investigations. The first investigation, entitled "Drought tolerance studies in fodder cowpea under open and shaded situations" was conducted during the summer season (January to March) of 2012 as two experiments, one in open and another in shade with the same treatments. The second investigation on "Evaluation of grass fodder cowpea mixtures under open and shaded situations" was conducted during the summer season (March to May) of 2012-2013 and 2013-2014. Two best drought tolerant fodder cowpea varieties for open and shaded conditions were selected based on the results of the first investigation. These fodder cowpea varieties were evaluated in combination with the grasses in two separate experiments under open and shaded conditions.

Five fodder cowpea varieties (V_1-UPC-618, V_2-UPC-622, V_3-Bundel Lobia -1, V_4 - COFC-8 and V_5- CO-5) were evaluated for their drought tolerance under four soil moisture stress levels (M_1 – pre sowing irrigation + life saving irrigation, M_2 – pre sowing irrigation + irrigation at IW/CPE ratio of 0.4, M_3 – pre sowing irrigation + irrigation at IW/CPE ratio of 0.6 and M_4 – pre sowing irrigation + irrigation at IW/CPE ratio of 0.8), as Investigation-I. The investigation was conducted as two separate experiments, one in open and other in shade. The experiments were laid out in split plot design with four replications. Major findings of Investigation-I are as follows.

Significantly higher green fodder yield was recorded by irrigating at IW/CPE ratio of 0.8 (m_4) in open (24.83 t ha^{-1}). In partial shade m_4 recorded the highest green fodder yield (11.80 t ha^{-1}) which was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (11.44 t ha^{-1}). Among the varieties, COFC-8 (V_4) recorded significantly higher green fodder yield of 24.21 t ha^{-1} in open and 11.5 t ha^{-1} in shade. The interaction effect was significant with m_2v_4 (COFC-8 irrigated at IW/CPE ratio of 0.8) recording significantly higher green fodder yield (29.24 t ha^{-1}) in open condition. In shade m_4v_4 (13.76 t ha^{-1}) was on par with m_3v_4 (COFC- 8 irrigated at IW/CPE ratio of 0.6 (13.48 t ha^{-1}).

Leaf area index and dry matter production decreased significantly with increasing moisture stress levels in open and shade. COFC-8 recorded significantly higher leaf area index and dry matter production in both the situations. The treatment combination m_4v_4 recorded significantly higher leaf area index in open and shade and higher drymatter production in open condition.

Soil moisture stress levels, varieties and interaction had no significant influence on specific leaf area in open and shade. The leaf dry weight was significantly higher at IW/CPE ratio of 0.8.

The treatments had significant effect on relative water content, leaf water potential and osmotic potential in open and shade. These physiological characters were significantly higher at IW/CPE ratio of 0.8. The variety COFC- 8 recorded higher relative water content, LWP and osmotic potential both in open and shade.

Stable isotope discrimination values were significantly lower at IW/CPE ratio of 0.8 in open and 0.6 in shade. Water use efficiency was negatively correlated to stable isotope discrimination values. COFC- 8 recorded significantly lower discrimination values and higher water use efficiency in both open and shade.

Irrigation improved the quality of fodder in partial shade. Crude protein content of the plant enhanced with increase in irrigation levels. Among the varieties protein content was significantly higher in COFC-8 in open and shade. COFC-8 at all levels of irrigation (m_4v_4, m_3v_4, m_2v_4 and m_1v_4) recorded significantly higher crude protein content.

N uptake, P_2O_5 uptake, K_2O uptake, Ca uptake and Mg uptake increased significantly with increase in irrigation levels. Among the varieties, COFC- 8 recorded significantly higher nutrient uptake in open and shade.

The net returns and benefit cost ratio was positive for all the treatments. Highest BCR was registered by irrigation at IW/CPE ratio of 0.4 in open condition. In partial shade, irrigation at IW/CPE ratio of 0.6 registered higher net returns. Among the varieties, COFC- 8 recorded higher BCR in open and shade.

Two drought tolerant fodder cowpea varieties were selected based on yield, quality and net returns under open and shaded situation, for conducting investigation-II. The fodder cowpea varieties COFC-8 (V_4) and UPC-622 (V_2) were selected for open condition and COFC-8 (V_4) and UPC-618 (V_1) were selected for shaded situation. The following aspects were considered in selecting the varieties for Investigation-II.

- Significantly higher green fodder yield
- Significantly higher crude protein yield
- Significantly higher proline content and water use efficiency.
- Significantly higher net returns.

Major findings of Investigation-II are as follows:

Growth parameters such as plant height and number of tillers/ branches of fodder crops were significantly influenced by grasses and grass-legume row ratio. Hybrid napier recorded significantly higher plant height and number of tillers in open and shade. The number of branches of fodder cowpea was significantly higher when it was intercropped in between guinea grass. Grasses had significantly higher number of tillers and plant height when it was intercropped with fodder cowpea at 1:3 row ratio, whereas fodder cowpea recorded significantly higher growth parameters when it was intercropped in between grasses at 1:2 row ratio.

Root volume and root dry weight were significantly higher in hybrid napier cv. Suguna in open and shade. Root volume and root dry weight were on par at 1:2 and 1:3 grass fodder cowpea row ratio.

Hybrid napier recorded significantly higher green fodder and dry fodder yield compared to guinea grass in open and shade. Fodder cowpea yield was 13.6 % to 15.24 % higher when intercropped with guinea grass. Fodder cowpea yield was significantly higher when intercropped in between hybrid napier and guinea grass at 1:2 ratio in open and shade. Total fodder yield was on par at 1:2 and 1:3 grass-cowpea row ratio.

Hybrid napier grass recorded significantly higher dry matter production and leaf area index in open and shade compared to guinea grass. Fodder cowpea intercropped in between guinea grass recorded higher dry matter production. Among the varieties, COFC-8 recorded significantly higher dry matter production in open and shade. Hybrid napier recorded higher dry matter production and leaf area index when it was intercropped with fodder cowpea at 1:3 row ratio. Dry matter production of fodder cowpea was significantly higher when it was intercropped in between grasses at 1:2 row ratio in open and shade.

The treatments and their interactions had no significant effect on chlorophyll content of grasses. Significantly higher chlorophyll content was recorded by COFC-8 in open and shade. The proline content of fodder crops were not affected by the treatments.

Crude protein content and crude protein yield were significantly higher for hybrid napier in open and shade. Crude protein yield was significantly higher for hybrid napier + cowpea at 1:2 row ratio.

Among the grasses, hybrid napier recorded significantly higher uptake of N, P, K, Ca and Mg in open and shade. Grasses recorded significantly higher uptake of nutrients when intercropped with cowpea at 1:3 row ratio, whereas fodder cowpea recorded significantly higher uptake of nutrients like N, P, K, Ca and Mg when it was intercropped at a row ratio of 1:2.

Hybrid napier cv. Suguna recorded significantly higher net income and BCR. Net returns and BCR was significantly higher for hybrid napier + fodder cowpea at 1:2 row ratio.

The result indicated the superiority of the grass-legume mixture of hybrid napier cv. Suguna with both the fodder cowpea varieties (COFC-8 and UPC-622) in the grass legume row ratio of 1:2 with respect to green fodder yield, crude protein yield and net returns in open. In shade, the grass-legume mixture of hybrid napier cv. Suguna with both the fodder cowpea varieties (COFC-8 and UPC-618) in the grass legume row ratio of 1:2 recorded significantly higher green fodder yield, crude protein yield and net returns.

Based on the results, it can be concluded that hybrid napier cv. Suguna intercropped with fodder cowpea varieties COFC-8 and UPC-622 in open condition and with COFC-8 and UPC -618 in partial shade (30 per cent) in the row ratio of 1:2 resulted in obtaining significantly higher fodder yield, quality of fodder and net returns.

Future line of work

Similar studies may be conducted to identify suitable grass legume mixtures of commonly cultivated fodder grasses and legumes under different light intensities.

References

7. REFERENCES

Achten, W.M.J., Maes, W.H., Reubens, B. Mathijs, E., Singh, V.P., Verchot, L. and Muys, B. 2010. Biomass production and allocation in *Jatropha curcas* L. seedlings under different levels of drought stress. *Biomass and Bioenergy*. 34(5): 667-676.

Addison, H.J. 2003. Legumes to improve nutrient cycling in agroforestry systems. Ph.D thesis, James Cook University, Townsville, 300p.

Adepoju, A.O. 2005. Performance and digestibility of West African dwarf Sheep feed on Andropogon subjected to varying levels of fertilizer nitrogen during a water stress period. B.Tech. Project Report, Ladoke Akintola University Technology, Ogbomoso, Oyo State, Nigeria. pp.18- 19.

Aderinola, O.A., Alamu, L.O., Asaolu, V.O., Okunlola, D.O. and Oyogho, E. 2012. Effect of canopy shade on the agronomic and in-vitro performance of *Chlorisgayana* (Kunth). *J. Biol. Agric. and Healthc.* 2(10): 165-170.

Ahmed, F.E and Suliman, A.S.H. 2010. Effect of water stress applied at different stages of growth on seed yield and water-use efficiency of cowpea. *Agric. and Biol. J. N. Am.* 1(4): 534-540.

AICRP [All India Co-ordinated Research Project]. 2009. *Annual Report 2008-2009*. ICAR, New Delhi, 315p.

AICRP [All India Co-ordinated Research Project]. 2012. *Annual Report 2011-2012*. ICAR, New Delhi, 341p.

Akhter, N., Rehman, M.M., HasanuZzaman, M., and Nahar, K. 2009. Plant characters and seed yield of garden pea under different light intensity. *Am. Eurasian J. Agron.* 2 (3): 152-155.

Akinci, S. and Losel, D.M. 2010. The effects of water stress and recovery periods on soluble sugars and starch content in cucumber cultivars. *Fresen. Environ. Bull.* 19(2): 164-171.

Akmal, M., Kausar, N., Habib, G., Ahmad, S., Asim, M. and Shah, N.H. 2011. Yield comparison of forage legumes under partial stress and normal irrigation. *Sarhad J. Agric.* 26(4): 507-513.

Alalade, J.A., Akinlade, J.A, Aderinola, O.A., Ameo, S.R. and Adaramola, K.A. 2013. Effect of number of *Stylosanthes hamata* rows on herbage yield, nutritive quality and performance of wad sheep fed native *Panicum maximum*. *J. Biol. Agric. and Healthc.* 3(10): 73-79.

Albayrak, S. and Ekiz, H. 2005. An investigation on the establishment of artificial pasture under Ankara's ecological conditions. *Turkish J. Agric. For.* 29: 69-74.

Albayrak, S., Turk, M., Yuksel, O. and Yilmaz, M. 2011. Forage yield and the quality of perennial legume-grass mixtures under rain fed conditions. *Notulae Botanicae Hortic. Agrobotanici* Cluj- Napoca 39(1): 114-118.

Albayrak, S. and Turk, M. 2013. Changes in the forage yield and quality of legume-grass mixtures throughout a vegetation period. *Turkish J. Agric. and For.* 37: 139-147.

Allard, G., Nelson, C.J. and Pallardy, S.G. 1991. Shade effects on growth of tall fescue: Leaf anatomy and dry matter partitioning. *Crop Sci.* 31: 163-167.

Angadi, S.S. and Gumaste, S.K. 1989. Influence of legume species on yield in South Africanmaize-legume mixed cropping system. *Environ. and Ecol.* 7: 302-305.

Angima, S.D., Green, S. and Reeb, J. 2010. Forage production and animal stocking rates in thinned Douglas-Fir forests. *J. NACAA.* 3 (1): 68-72.

Anita, M.R. 2002. Shade response of guinea grass (*Panicum maximum* J.) under varying levels of potash. M.Sc. (Ag) thesis, KAU, Thrissur, 140p.

Anjum, S., Xie, X., Wang, L. Saleem, M., Man, C. and Lei, W. 2011. Effect of drought stress on proline, soluble sugars, chlorophyll and RWC level in *Melissa oggicinalis. Iranian J. Med. Plants Res.* 23(4): 504-513.

A.O.A.C. 1975. *Official and Tentative Methods of Analysis.* Association of official Agricultural Chemists, Washington, D.C., 350p.

Aravindhan, S. and Das, L.D.V. 1995. Correlation and path analysis for fodder attributes in cowpea. *Madras Agric. J.* 82: 420-422.

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts – olyphenol oxidase in *Beta vulgaris. Plant Physiol.* 12: 1-15.

Ashraf, M. and Foolad, M.R. 2007. Roles of glycine betaine and proline in improving plant abiotic stress resistance. *Environ. Exp. Bot.* 59: 206- 216

Attridge, T.H. 1990. *Light and Plant Reponses*. Hodder and Stoughton Ltd., London, 148p.

Azam, S., Akmal, M., Amjad, M. and Wasiullah. 2008. Extension in green forage availability through cereal-legume mixtures of different seeding rates. *Sarhad J. Agric.* 24(3): 415-422.

Baba, M., Halim, R.A., Alimon, A.R. and Abubakar, I. 2011. Grass-legume mixtures for enhanced forage production : Analysis of dry matter yield and competition indices. *Afr. J. Agric. Res.* 6(23): 5242-5250.

.Backiyarani, S. and Natarajan, N. 1996. Variability studies in cowpea. *Legume Res.* 19: 59-61.

Bade, D.H., Conrad, B.E. and Holt, E.C. 1985. Temperature and water stress effects on growth of Tropical grasses. *J. Range Manag.* 38(4): 321-324.

Bai, M., Lakshmi, S. andPillai, R.G. 1993. P and K nutrition of guinea and congosignal grasses grown in coconut gardens. *J. Trop. Agric.* 31: 181-183.

Baisakh, B. 1992. Inter relationship between yield and yield attributes in rice bean. *Indian J. Agric. Sci.* 62: 620-622.

Bakhashwain, A.A. 2010. Fodder yield and quality of Rhodes grass-alfalfa mixtures as affected by sowing rates in Makkah Region. *JKAU. Meteorol. Environ. and Aridland Agric. Sci.* 21(1): 19-33.

Barker, D.J., Chu, A.C.P. and Korte, C.J. 1985. Some effects of spring defoliation and drought on perennial rye grass swards. *N. Z. J. Agric. Res.* 26: 159-168.

Barnett, N.M. and Naylor, A.W. 1996. Aminoacid and protein metabolism in bermuda grass during water stress. *Plant Physiol.* 41: 1222-1230.

Barro, R.S., Varella, A.C., Lamaire, G., Medeiros, R.B., Saibro, J.C., Nabinger, C., Bangel, F.V. and Carassi, I.J. 2012. Forage yield and nitrogen dynamics of warm-season native forage genotypes under two shading levels and in full sunlight. *R. Bras. Zootec.* 41(7): 1589-1597.

Baruch, Z. and Guenni, O. 2007. Irradiance and defoliation effects in three species of the forage grass *Brachiaria. Trop. Grassl.* 41: 269-276.

Bates, L.S., Waldren, R.P. and Teak, T.D. 1973. Rapid determination of free proline for water stress studies. *Plant Soil* 39: 205-207.

Bazil John, A.E. 2011. Evaluation of tropical legumes under *Pinus caribaea* var. *hondurensis* in Turrialba Costa Rica. *Agrofor. Syst.* 61: 97-108.

Belsky, A.J. 1992. Effects of trees on nutritional quality of understory graminous forage in tropical savannas. *Trop. Grassl.* 26: 12-20.

Berdahl, J.D., Karn, J.F. and Hendrickson, J.R. 2001. Dry matter yields of cool-season grass monocultures and grass-alfalfa binary mixtures. *Agron. J.* 93: 463-467.

Bingcheng, X., Lun, S., Fengmin, L. and Jum, J. 2007. Seasonal and spatial root biomass and water use efficiency of four forage legumes in semiarid northwest China. *Afr. J. Biotechnol.* 6(23): 2708-2714.

Blair, R.M., Aleaniz, R. and Harrell, A. 1983. Shade intensity influences the nutrient quality and digestibility of southern deer browse leaves. USDA *J. Range Manag.* 36(2): 257-264.

Blanche, S. A. 1999. The influence of light reduction upon the production, persistence and chemical composition of some forages. *J. Wildl. Manag.* 63: 96-102.

Blum, A. 2005. Drought resistance, water use efficiency and yield potential - are they compatible, dissonant, or mutually exclusive? *Aust. J. Agric. Res.* 56: 1159-1168.

Bokhari, U.G. and Trent, J.D. 1985. Proline concentrations in water stressed grasses. *J. Range Manag.* 38: 37-38.

Boloko, M.S. 2004. The influence of forage legumes on annual fodder grasses in different intercropping systems in the Limpopo province. M.Sc. (Ag) thesis, School of Agriculture and Environmental Sciences, University of the North Central Alberta, Canada, 180p.

Borah, H.K. and Fazlullahkhan, A.K. 2000. Genetic analysis in fodder cowpea. *Madras Agric. J.* 87: 65.

Boutraa, T. 2010. Effects of water stress on root growth, water use efficiency, leaf area and chlorophyll content in the desert shrub *Calotropis procera*. *J. Int. Environ. and Appl. Plant Sci.* 5(1): 124-132.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agron. J.* *5* 4: 404-405.

Brown, P.W., Tanner, C.B. 1983. Alfalfa stem and leaf growth during water stress. *Agro. J.* 75(5): 799-804.

Burner, D.M. and Brauer, D.K. 2003. Herbage response to spacing of loblolly pine trees in a minimal management silvipasture in south eastern USA. *Agrofor. Syst.* 57: 69-77.

Burt, S., Leung, P. and Love, G. 1986. *Intensive Grazing Management-Forage, Animals, Man Profits*. The Graizers Hui, Kamucla, Hawaii, 282p.

Buxton, D.R. 1996. Quality related characteristics of forage as influenced by plant environment and agronomic factors. *Anim. feed Sci. and Technol.* 59: 37-49.

Buxton, D.R. 2001. Growing forages under variable Environmental conditions. *Res. Bull.* No.21. U.S. Dairy Forage Research Centre, IOWA State University, Ames, 204p.

Buxton, D.R. and Fales, S.L. 1994. Plant environment and quality. Forage Quality, Evaluation and Utilizaion. In: Fahney, G.C. and Barnes, D.K. (eds.), *Proceedings of the Symposium on Forage Quality, Evaluation and Utilization,* March 3-9, 1992. American Society of Agronomy, Madison, USA, pp.155-199.

Buxton, D.R. and Mertins, D.R. 1995. Quality related characteristics of forages. In: Barnes, R.F., Miller, D.A. and Nelson, C.J. (eds.), *The Science of Grassland Agriculture* (5^{th} Ed.). Iowa University Press, Ames, pp.83-96.

Canan, T. and Orak, A. 2002. Yield and yield components of some important common vetch (*Vicia sativa* L.) genotypes. *Bulgarian J. Agric. Sci.* 15: 215-218.

Cattivelli, L., Rizza, F., Badeck, F.W., Mazzucotelli, E., Mastrangelo, A.M., Francia, E., Mare, C., Tondelli, A. and Stanca, A.M. 2008. Drought tolerance improvement in crop plants : An integrated view from breeding to genomics. *Field Crop Res.* 105: 1-14.

Chaves, M.M., Zarrouk, O., Fransisco, R., Costa, J.M., Santos, T., Regalado, A.P., Rodrigues, M.L. and Lopes, C.M. 2010. Grapevine under deficit irrigation-hints from physiological and molecular data. *Ann. Bot.* 105: 661-676.

Chebouti, A. and Abdelguerfi, A. 2004. Effect of water stress on growth and forage yield of three species of medics [on-line]. Available: http://www.om.ciheam.org/om/pdf/c62/04600179.pdf [11.09.2013].

Chelliah, N. and Ernest, J. 1994. Fodder production of cereal legume mixture. *Livest. Adviser* 19: 15-18.

Chen, C.P., Ahmed, T.Z., Mohammed, W.W.E., Ibrahim, C.E., Tajuddin, I. and Mod, S.R. 1991. Research and Development on Integrated Systems in Livestock, Forage and Tree Crops Production in Malaysia. In: *Proceedings of the International Livestock-Tree Cropping Workshop*, 5-9 December 1988. FAO/MARDI, Serdang, Malaysia, pp.55-72.

Choubey, S., Prasad, N.K. and Bhagat, R.K. 1997. Suitable grass-legume combination for higher forage production. *J. Res.* Birsa Agricultural University, 9(1): 81-83.

Cruz, P. 1996. Growth and nitrogen nutrition of a *Dichanthium aristatum* pasture under shading. *Trop. Grassl.* 30: 407-413.

Cruz, P. 1997. Effect of shade on the growth and mineral nutrition of a C_4 perennial grass under field conditions. *Plant and Soil.* 188: 227-237.

Cruz, P., Jolain, M.N.M., Tournebize, R. and Seioquet, H. 1993. Growth and mineral nutrition in a *Dichanthium aristatum* sward shaded by trees. In: *Proceedings of the XVII International Grassland Congress, 8-21 February 1993,* New Zealand. New Zealand Grassland Association, Palmerston North, New Zealand, pp.2056-2057.

Cruz, P., Slirra, J., Wilson, J.R., Dulormne, M. and Tournebize, R. 1999. Effects of shade on the growth and mineral nutrition of tropical grasses in silvipastoral systems. *Ann. Arid zone.* 38: 335-361.

Dehabadi, M.H., Kemp, P.D., Barker D.J. and Hodgson, J. 1994. Physiological and morphological responses of Lucerne to soil moisture stress. In : Li Bo (ed). *Proceedings of the International symposium on Grassland Resources.* 15-20 August 1993, Hohhot, China, pp.661-672.

Deinum, B., Sulastri, R.D., Zeinab, M.H.J. and Maasen, A. 1996. Effects of light intensity on growth, anatomy and forage quality of two tropical grasses (*Brachiaria brizantha* and *Panicum maximum* var. trichoglum). *Neth. J. Agric. Sci.* 44: 111-124.

Dias-Filho, M.B. 2000. Growth and biomass allocation of the C_4 *Agropecuaria* grasses *Brachiaria brizantha* and *B. humidicola* under shade. *Pesquisa Brasileira* 35: 2335-2341.

Durr, P.A. and Rangel, J. 2000. The response of *Panicum maximum* to a stimulated sub canopy environment - Soil x Shade interaction. *Trop. Grassl.* 34: 110-117.

Duyseen, M.E. and Freman, T.P. 1975. Partial restoration of the high rate of plastid pigment development and the ultra-culture of plants in detached water stressed wheat leaves. *Plant Physiol.* 55: 768-773.

East, R.M. and Felker, P. 1993. Forage production and quality of 4 perennial grasses grown under and outside canopies of mature *Prosopis glandulosa* Torr. var. *glandulosa* (mesquite). *Agrofor. Syst.* 22: 91-110.

Ebdon, J.S. and kopp, K.L. 2004. Relationships between water use efficiency, carbon isotope discrimination, and turb performance in genotypes of kentucky blue grass during drought. *Crop Sci.* 44: 1754-1762.

Ebringerova, A., Hoomadkova, Z., Heinze, T. 2005. Hemicellulose. *Adv. Polym. Sci.* 186: 1-67.

Eriksen, F.I. and Whitney, A.S. 1981. Interaction of light intensity and nitrogen fertilizers on six forage grasses. *Agron. J.* 73: 427-433.

Evans, J.R. and Seemann, J.R. 1996. Carbondioxide diffusion inside leaves. *Plant Physiol.* 110: 339-346.

Ezenwa, I. and Akenova, M.E. 1998. Performance of mixtures of selected grasses and adapted herbaceous legumes in South-West Nigeria. *Trop. Grassl.* 32: 131-138.

Fanindi, A., Prawiradiputra, B.R. and Abdullah, L. 2010. Effect of light intensity on forages and seed production of Kalopo (*Calopogonium muconoicles*). *Indonesian J. Anim. and Vet. Sci.* 153(3): 37-39.

Farquhar, G.D. and Richards, R.A. 1984. Isotopic composition of plant carbon correlates with water-use efficiency of wheat genotypes. *Aust. J. Plant Physiol.* 11: 539-552.

Farquhar, G.D., Ehleringer, J.R. and Hubick, K.T. 1989. Carbon isotope discrimination and photosynthesis. *Ann. Rev. Plant Physiol.* 40: 503-537.

Fatokun, C., Boukar, O., Muranaka, S. and Chikoye, D. 2009. Enhancing drought tolerance in cowpea. *Afr. Crop Sci. J.* 9: 531-536.

Fening, J.O., Quansah, C. and Kantanka, A.S. 2009. Response of three forage legumes to soil moisture stress. *J. Sci. and Tech.* 29(3): 24-30.

Fernandez, F. 2012. Water stress and nutrient deficiency. AG Professional magazine, Vance Publishing [on-line]. Available: http://www.agprofessional.com/resourcecenters/crop [11.09.2013].

Fischer, G. and Barker, C. 1996. The chemical composition of forb species in grassland. In: Parente, Giframe, J. and Orses (eds.). *Grassland and Land Use Systems*. Proceedings of 16th General meeting of European Grassland Federation, Grado, Italy, September 1996, pp.429-437.

Flagella, Z., Rotunno, T., Tarantino, E., Caterina, R.D. and Caro, A.D. 2002. Changes in seed yield and oil fatty acid composition of high oleic sunflower (*Helianthus annus* L.) hybrids in relation to the sowing date and the water regime. *Eur. J. Agron.* 17: 221-230.

Francisco, J.S., Manzaranes, M., Andres, D.E.F., Tenorio, J.L. and Ayerbe, L. 1998. Turgor maintenance, osmotic adjustment and soluble sugar and proline accumulation in 49 pea cultivars in response to water stress. *Field Crop Res.* 59: 225-235.

Frank, A.B. 1994. Physiological comparisons of crested wheat grass and western wheat grass to water. *J. Range Manag.* 47: 40-46.

Fu, J. and Huang, B. 2001. Involvement of antioxidants and lipid peroxidation in the adaptation of two cool season grasses to localized drought stress. *Environ. and Exp . Bot.* 45: 105-114.

Fujital, K., Ofosu-Budu, K.G. and Ogota, S. 1992. Biological nitrogen fixation in mixed cereal cropping systems. *J. Plant and Soil.* 141(2): 155-175.

Gallegos, J.A., Shibata, J.K. 1989. Effect of water stress on growth and yield of indeterminate dry bean (*P. vulgaris*) cultivars. *Field Crop Res.* 20: 81-93.

Gangwar, K.S. and Sharma, S.K. 1994. Performance of maize (*Zea mays*)-fodder legume intercropping systems. *Indian J. Agron.* 39(1): 1-3.

Gauthir, H., Grancher, C.V. and Hazard, L. 1999. Tillering Responses to the Light Environment and to Defoliation in Populations of Perennial Ryegrass (*Lolium perenne* L.) selected for Contrasting Leaf Length. *Ann. Bot.* 83: 423-429.

Gayathri, P. 2010. Alley cropping in cassava (*Manihotesculenta* Crantz.) for food-fodder security. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 130p.

George, S. 1996. Agronomic evaluation of biofarming technique for forage production in coconut gardens. Ph.D. thesis, Kerala Agricultural University, Thrissur, 224p.

Gil, J.L. and Fick, W.H. 2001. Soil nitrogen mineralization in mixtures of eastern gamba grass with alfalfa and red clover. *Agron. J.* 93: 902-910.

Gill, A.S. and Gangwar, K.S. 1990. Evaluation of intensive forage production under guava (*Psidium guavajava* L.) plantation. *Indian J. Agron.* 35(4): 437- 438.

Goksoy, A.T., Demir, A.O., Turan, Z.M. and Daustu, N. 2004. Responses of sunflower to full and limited irrigation at different growth stages. *Field Crops Res.* 87: 167-178.

Gomez, K.A. 1972. *Techniques for Field Experiments with Rice.* International Rice Research Institute, Los Banos, Phillipines, 33p.

Gomez, S., Guenni, O. and Guenni, B.D.L. 2013. Growth, leaf photosynthesis and canopy light use efficiency under differing irradiance and soil N supplies in the forage grass *Brachiaria decumbens* Stapf. *Grass and Forage Sci.* 68(3): 395-407.

Gopalan, A., Raja, D. and Sudhagar, R. 2003. Associative cropping pattern that enhance the animal yield. *Asp. Appl. Plant Biol.* 70: 137-141.

Gorai, M., Maraghni, M., and Neffati, M. 2011. Relationship between phenological triats and water potential patterns of the wild jujube *Ziziphus lotus* (L.) Lam. in Southern Tunisia. *Plant Ecol. and Diversity* 3: 273-280.

Gosse, G., Chartier, M., Lemaire, G. and Guy, P. 1982. Influence des facteurs climatiques sur la production de luzerne. *Fourrages*. 90: 113-133.

Gregory, D.A., Ludlow, M.M. and Ovalle, C. 1987. Light relations in pasture plants. *Trop. Grassl.* 21: 38-41.

Grimes, D.W., Wiley, P.L., and Sheesley, W.R. 1992. Alfalfa yield and plant water relations with variable irrigation. *Crop Sci.* 32: 1381 – 1387.

Guenni, O., Seiter, S. and Figueroa, R. 2008. Growth responses of three *Brachiaria* species to light intensity and nitrogen supply. *Trop. Grassl.* 42: 75-87.

Gupta, R.P. and Dakshinamoorthy, C. 1980. *Procedures for Plant Physical Analysis of Soil and Collection of Agro Meteorological Data*, IARI. New Delhi, 280p.

Haffani, S., Mezni, M. and Chaibi, W. 2013. Effect of drought on growth and chlorophyll content in three *Vetch* species. *IOSR J. Agric. and Vet. Sci.* 2: 50-56.

Hajibabaee, M., Azizi, F. and Zargari, K. 2012. Effect of drought stress on some Morphological, Physiological and Agronomic traits in various forage corn hybrids. *Am. Eur. J. Agric. and Environ. Sci.* 12(7): 890-896.

Hakimi, A.M.A. 2006. Counteraction of drought stress on soybean plants by seed soaking salicylic acid. *Int. J. Bot.* 2: 421-426.

Hall, M.H. 1993. Alfalfa growth flowering release from drought stress. *Agro. J.* 85(5): 991-994.

Hamidou, F., Zombre, G., Diouf, O., Diop, N., Guinko, S. and Braconnier, S. 2007. Physiological, biochemical and agro morphological responses of five cowpea genotypes (*Vigna unquiculata* (L) walp.) to water deficit under glass house conditions. *Biotechnol. Agron. Soc. Environ.* 11(3): 225-234.

Hay, R.K.M. and Walker, A.J. 1989. *An Introduction to the Physiology of Crop Yield.* Harlow: Longman Scientific and Technical (1989), England, 292p.

Hayatu, M. and Mukhtar, F.B. 2010. Physiological responses of drought resistant cowpea genotypes (*Vigna unguiculata* L. Walp) to water stress. *Bayero J. Pure and Appl. Plant Sci.* 3(2): 69-75.

Hazra, P., Som, M.G. and Das, P.K. 1996. Selection of parent for vegetable cowpea breeding by multi variate analysis. *Veg. Sci.* 23: 57-63.

Heenan, D.P. and Thomson, J.A. 1984. Growth, grain yield and water use of rice grown under restricted water supply in New South Wales. *Aust. J. Exp. Agri.* 24 (124): 104 – 109.

Herrara, J., Jaguinet, P. and Corona, L. 1985. Effect of irrigation rates on the yield and water use in three tropical pasture species. *Ciencia J. Technica en la Agricultura Partos J. Forrajes* 8(2): 25-47.

Heuer, D.M. 1994. Contribution of carbohydrates and solutes to osmotic adjustment in wheat leaves under water stress. *J. Plant Physiol.* 145: 363-366.

Hong, K.S., Lee, H.J. and Rhyu, J.H.. 1987. Response of maize and soybean canopy structure, dry matter and yield to intercropping. *Korean J. Crop Sci.* 32: 357-358.

Humphreys, L.R. 1991. *Tropical Pasture Utilisation.* Cambridge University Press, Cambridge (UK), 202p.

Ibrahim, M., Rafiq, M., Sultan, A., Akram, M. and Goneer, M.A. 2006. Green fodder yield and quality evaluation of maize and cowpea sown alone and in combination. *J. Agric. Res.* 44(1): 15-21.

Jaafari, E.S. 1993. Contribution a letude des mecanismes biophysiques et biochimiques de resistance a la secheresse chez le ble (*Triticum aestivum* L.) Doctorat de la Faculte des Sciences Agronomiques de Gembloux, Belgique, 214p.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd. New Delhi, 498p.

Jacob, R. 1999. Intensive fodder production under irrigated conditions in partial shade. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 128p.

Jalalpoori, M.A. 2013. Changes in total chlorophyll in response to drought stress in alfalfa (vs. Nick Urban) in Climatic Conditions of the South West Iran. *Environ. Sci.* 1(2): 65-68.

Jaleel, C.A., Gopi, R., Sankar, B., Manivannan, P., Kishore Kumar, A., Sridharan, R. and Panneerselvam, R. 2007. Studies on germination, seedling vigour, lipid peroxidation and proline metabolism in *Cartharanthus roseus* seedlings under salt stress. *S. Afr. J. Bot.* 73: 190-195.

Jayakumar, G. 1997. Intensive fodder production through legume intercropping in hybrid napier. M.Sc. (Ag) thesis Kerala Agricultural University, Thrissur, 130p.

Jefferson, P.G. and Cutforth, H.W. 2005. Comparative forage yield, water use and water use efficiency of alfalfa, crested wheatgrass and spring wheat in a semiarid climate in southern Saskatchewan. *Can. J. Plant Sci.* 85: 877-888.

Jiang, Y., Yao, Y. and Wang, Y. 2012. Physiological response, cell wall components and gene expression of switchgrass under short term drought stress and recovery. *Crop Sci.* 52: 2718-2727.

Jindal, S.K. 1989. Path coefficient analysis in fodder cowpea grown under rain fed conditions. *Madras Agric. J.* 76: 121-124.

Johnson, D.A., Asay, K.H., Tieszen, L.L., Ehleringer, J.R. and Jefferson, P.G. 1990. Carbon isotope discrimination potential in screening cool-season grasses in water-limited environments. *Crop Sci.* 30: 338-343.

Johnson, D.A., Assay, K.H. and Jensen, K.K. 2003. Trends in carbon isotope discrimination and forage yield of 14 cool-season perennial grasses across an irrigation gradient. *J. Range Manag.* 56: 654-659.

Jones, M.B., Leafe, E.L. and Stiles, W. 1980. Water stress in field-grown perennial rye grass : Its effect on leaf water status, stomatal resistance and leaf morphology. *Ann. Appl. Plant Biol.* 96: 103-110.

Kaligis, D.A. and Sumolong, C. 1991. Forage species for coconut plantations in North Sulawesi. In: Shelton, H.M. and Stur, W.W. (eds.), *Proceedings of Workshop on Forages for Plantation Crops,* ACIAR Proc. No.32, June 27-29, 1990. ACIAR, Melbourne, pp.16-20.

Katoch, R.S. and Marwah, C.L. 2006. Intercropping of forage crops with grasses- an innovative fodder production system for mid-Himalayan hills. *Range Manag. and Agrofor.* 27(1): 13-17.

Karadau, Y. 2003. Effects of seed rates on forage production, seed yield and hay quality of annual legume-barley mixtures. *Turkish J. Agric. For.* 27: 196-174.

Kechero, V. 2008. Effects of seed proportions of Rhodes grass (*Chlorisgayana*) and white sweet clover (*Melilotus alba*) at sowing on agronomic characteristics and nutritional quality. *Livest. Res. for Rural Dev.* 20(28): 2-15.

Kennet, G.A., Laccy, J.R., Butt, C.A., Rutz, O.K.M. and Haferkamp, M.R. 1992. Effects of defoliation, shading and competition on spotted knapweed and blue bunch wheat grass. *J. Range Manag.* 45: 363-369.

Kephart, K.D., Buxton, D.R. and Taylor, S.E. 1992. The utilization of carbohydrate reserves in pasture plants after defoliation. *Crop Sci.* 32: 1033-1038.

Kephart, K.D. and Buxton, D.R. 1993. Cell wall digestibility affects forage value of woody twigs. *Crop Sci.* 33: 831-837.

Kephart, K.D. and Buxton, D.R. 1996. Non-structural carbohydrates in cool and warm season perennial grasses adapted to shaded conditions. *Research Summaries*. U.S. Dairy Forage Research Centre, IOWA State Univ., Ames, USA, 210p.

Kher, G.C., Patel, B.S., Patel, J.C. and Malavia, D.D. 1994. Response of summer cowpea (*Vigna unguiculata*) to irrigation, nitrogen and phosphorus. *Indian J. Agron.* 39 (1): 175-177.

Khistaria, M. K., Shelke, V.B. and Karle, A.S. 1991. Effect of nitrogen and Jalshakti on yield of winter sorghum (*Sorghum bicolor*) under rainfed and irrigated conditions. *Indian J. Agron.* 36: 83-85.

Khogali, M.E., Eltayeb, E., Ahmed, A. and Huweris, S.O.E. 2011. Effect of nitrogen, intercropping with lablab bean (*Lablab purpureus*) and water stress on yield and quality of fodder maize. *J. Sci. and Tech.* 12(3): 55-66.

Kidambi, S.P., Matches, A.G. and Bolger, T.P. 1990. Mineral concentrations in alfalfa and sainfoin as influenced by soil moisture level. *Agron. J.* 82: 229.

Kim, B.W. and Albrecht, K.A. 2011. Forage quality management of kura clover in binary mixtures with Kentucky blue grass, orchard grass or smooth brome grass. *Asian-Aust. J. Anim. Sci.* 24: 344-350.

Kinyanario, J.I., Trlica, M.J. and Njoka, T.J. 1995. Influence of tree shade on plant water status, gas exchange and water use efficiency of *Panicum maximum* J. and *Themeda triandra* Forsk in a Kenya savanna. *Afr. J. Ecol.* 33: 114-123.

Kisman, A. 2003. Effects of drought stress on growth and yield of soyabean. *Sci. Philos. Term Paper,* Graduate School, Borgor Agric. Univ. (Institute Pertanian Borgor), Indonesia, December 2003, 702p.

Kuchenmeister, K. 2013. Performance of underutilized forage legumes as an alternative to *Trifolium repens* under drought stress: yield, water utilization and nutritive value. Ph.D. thesis, University of Gottingen, Germany, 181p.

Kumar, A. and Mishra, S.N. 1981. Note on genetic variability for forage yield components in cowpea. *Indian J. Agric. Sci.* 51: 807-809.

Kumari, R.V., Nanjundappa, G. and Hattappa, S. 2008. Drumsticks in horti-pasture system under protective irrigation. *Environ. Ecol.* 26(1A): 465-466.

Kunelius, H.T., Durr, G.H., McRae, K.B. and Fillmore, S.A.E. 2006. Performance of Timothy-based Grass/Legume mixtures in cold winter Region. *J. Agron. and Crop Sci.* 192(3): 159-167.

Kyriazopoulos, A.P., Abraham, E.M., Parissi, Z.M., Koukoura, Z. and Nastis, A.S. 2012. Forage production and nutritive value of *Dactylis glomerata* and *Trifolium subterraneum* mixtures under different shading treatments. *Grass and Forage Sci.* 68(1): 72-82.

Ladyman, K.P., Kerley, M.S., Kallenbach, R.L., Garrett, H.E., Sambeek, J.W.V. and Tindall, N.E.N. 2003. Quantity and Quality Evaluations of shade grown Forages. In: *Proceedings of the 8th AFTA Conference, 22-25 June 2003,* Univ. of Mo., Columbia, pp.175-181..

Lakshmi, S., Devi, L.G., Nair, M.A. and Vidya, C. 2002. Yield and economics of Fodder legume-hybrid napier intercropping systems. *Forage Res.* 28(1): 13-15.

Lakshmi, S., Sumabai, D.I., and Salini, G.S. 2007. Effects of phosphorus on yield and quality of fodder cowpea (*Vigna unguiculata*) cultivars. *In: Abstracts, National Symposium on A New Vista to Forage Crop Research*; 10-11 September 2007, Bidhan Chandra Krishi Viswa Vidyalaya, Kalyani, West Bengal, p.67.

Lazaridou, M., Karatassiou, M. and Kostopoulou, P. 2012. Competition in an alfalfa-tall fescue mixture under Mediterranean conditions. *Options Mediteraneennes.* 102: 87-91.

Lewis, C.E., Burton, G.W., Monson, W.G. and Cormick, M.W.C. 1983. Integration of pines, pastures and cattle in South Georgia. USA. *Agrofor. Syst.* 1: 277-297.

Lima, D.B., Santos, P.M., Mendonca, F.C. and Araujo, D. 2011. Critical periods of sorghum and palisade grass intercropped cultivation for climatic risk zoning. *R. Bras. Zootec.* 40(7): 18-20.

Lin, C.H., McGraw, M.F. and Garnett, H.E. 1999. Shade effects on forage crops with potential in temperate agroforestry practices. *Agrofor. Syst.* 44: 109-119.

Liu, Z.Q., Liu, Z.Y., Mad, P. and Zong, S.F. 1984. A study of relationship between chlorophyll content and photosynthetic rate in rice. *Acta Agronomicasinica* 10: 57-62.

Mafakheri, A., Siosemardeh, A., Bahramnejad, B., Struik, P.C. and Sohrabi, E. 2010. Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. *Aust. J. Crop Sci.* 4(8): 580-585.

Manonmani, S., Khan, A.K.F. and Ravikesavan, R. 2000. Genetic studies in forage cowpea. *Madras Agric.* J. 86: 500-501.

Mansfield, C.W., Mislery, P. and Hammond, L.C. 1990. Yield and nutritive values of forages grown under irrigated and non-irrigated conditions. *Trop. Grassl.* 24(1): 55-60.

Mapairwe, D.R., Sabiiti, E.N., Ummuna, N.N., Tegegne, A. and Osuji, P. 2002. Effect of intercropping cereal crops with forage legumes and source of nutrients on cereal grain yield and fodder dry matter yields. *Afr. Crop Sci. J.* 10: 81-97.

Marchiol, L., Miceli, F., Pinosa, M. and Zerbi, G. 1992. Intercropping of soybean and maize for silage in Northern Italy. *Eur. J. Agron.* 1(3): 207-211

Martinielli, P., Silva, D.T.A. 2011. Physiological and bio agronomical aspects involved in growth and yield components of cultivated forage species in Mediterranean environments: a review. *Eur J. Plant Sci. and Biotechnol.* 5(2): 64-98.

Masinde, P.W., Stutzed, H., Agong, S.G. and Fricke, A. 2006. Plant growth, water relations and transpiration of two species of African nightshade (*Solanum villosum* Mill. ssp. *Miniatum* (Bernh. ex Willd.) Edmonds and *S. sarrochoides* Sendtn.) under water limited conditions. *Sci. Hortic.* 110: 7-15.

Meena, L.R. and Mann, J.S. 2011. Productivity, Quality and Residual soil fertility as influenced by intercropping row ratios and sources of nitrogen management in semi-arid region of Rajasthan. *Indian J. Dryland Agric. Res. and Dev.* 26(2): 91-96.

Menezes, R.S.C., Salcedo, I.H. and Elliot, E.T. 2002. Microclimate and nutrient dynamics in a silvopastoral system of semiarid north eastern Brazil. *Agrofor. Syst.* 56: 27-38.

Mimenza, H.E., Ibrahim, M., Harvey, C.A., Benjamin, T. and Sinclair, F.L. 2013. Standing herbage biomass under different tree species dispersed in pastures of cattle farms. *Trop. and Sub Trop. Agro Ecosyst.* 16: 271-288.

Mishra, A.K., Tiwari, H.S. and Bhatt, R.K. 2010. Growth, biomass production and photosynthesis of *Cenchrusciliaris* L. under *Acacia tortilis* (Forssk.) Hayne based silvopastoral systems in semi-arid tropics. *J. Environ. Biol.* 31(6): 987-993.

Mohammed, W.W.E. 1986. Integration of small ruminants with rubber and oil palm cultivation in Malaysia. In: *Proceedings of the Workshop on Small Ruminant Production System for South and South East Asia*; Bogor, Indonesia, 6-10 October, 1986. Organised by International Development Research Centre (IDRC), Canada. (In: Press).

Mohsenzadeh, S., Malboodi, M.A., Razavi, K. and Aschtiani, F.S. 2006. Physiological and molecular responses of *Aeluropus lagopoides* (Poaceae) to water deficit. *Environ. Exp. Bot.* 56: 314-322.

Moinuddin, A., Fischer, R.A., Sayre, K.D. and Reynolds, M.P. 2005. Osmotic adjustment in wheat in relation to grain yield under water deficit environments. *J. Agron.* 97: 1062-1071.

Mouat, M.C.H. and Nes, P. 1985. Soil water content affects the availability of phosphate. *Proceedings of the New Zealand Grassland Association*, Grasslands Division, DSIR, Palmerston North, New Zealand, 46:.185-189.

Muldoon, D.K. 1986. Production of tropical and sub-tropical grasses and legumes, with and without irrigation, in central western new South Wales. *Trop. Grassl.* 20(1): 18-25.

Mullakoya, P. 1982. Shade tolerance of guinea grass cv. Mackuenii under different levels of potassium. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 109p.

Mullen, B.F. and Shelton, H.M. 1996. *Stenotaphrum secundatum*: A valuable forage species for shaded environments. *Trop. Grassl.* 30: 289-297.

Muinga, R.W., Mureithi, J.G., Juma, H., and Saha, H.M. 1992. The effect of supplementing napier grass or maize stover based diet with either glyricidia, clitoria or Mucuna on manure quality and quantity in Jersy cows. *Trop. and Sub Trop. Agro Ecosyst.* 7 (3): 157-163.

Mureithi, J.G., Tayler, R.S. and Thorpe, W. 1995. Productivity of alley farming with leucaena (*Leucaenalenco-cephala* Lam de wit) and Napier grass (*Pennisetum purpureum* K. Schum.) in coastal lowland Kenya. *Agrofor. Syst.* 31: 59-78.

Mwangi, D.M. 1999. Integration of herbaceous legumes into napier grass fodder systems in central Kenya: Constraints and potential. Ph.D. thesis, Wye College, University of London, London, U.K., 205p.

Mwangi, D.M., Romney, D., Staal, S, Baltenweck,I and Mwendia, S. W. 2005. Strategies for feeding small holder dairy cattle in intensive maize production systems and implications for Integrated Pest Management. In: Wanyangu, S.W., Kariuki, D.P. and Mbogo, S.K. (eds.), *Proceedings of the 17th KARI Biennial Scientific Conference, 13-17 November 2004,* KARI HQs, Nairobi, Kenya, pp.23-27.

Nadeem, M., Ansar, M., Anwar, A., Hussain, A. and Khan, S. 2010. Performance of winter cereal-legumes fodder mixtures and their pure stand at different growth stages under rain fed conditions of Pothowar. *J. Agric. Res.* 48(2): 181-192.

Nair, B.G.K. 1989. Seed production in *Stylosanthes gracilis* under varying levels of population density, nutrition, moisture regimes and cuttings. Ph.D. thesis, Kerala Agricultural University, Thrissur, 169 p.

Neukirchen, D., Hinken, M., Lammel, J., Czypionka-Krause, O. and Olfs, H.W. 1999. Spatial and temporal distribution of the root system and root nutrient content of an established *Miscanthus* crop. *Eur. J. Agron.* 11: 301-309.

Niang, A., Styger, E., Gahamanyi, A., Hoekstra, D. and Coe, R. 1998. Fodder quality improvement through contour planting of legume-shrub/grass mixtures, in croplands of Rwanda highlands. *Agrofor. Syst.* 39: 263-274.

Njarui, D.M.G. and Wandera, F.P. 2000. Effect of intercropping pasture legumes with fodder grasses and maize on forage and grain yield in the semi-arid Kenya. In: Mureithi, J.G., Mwendia, C.W., Muyekho, F.N., Onyango, M.A. and Maobe, S.N. (eds.). *Participatory Technology Development for Soil Management by Small Holders in Kenya.* Special publication of soil management and legume research network projects. Kenya Agricultural Research Institute, Nairobi, Kenya, pp.155-168.

Njarui, D.M.G., Keating, B.A., Jones, R.K. and Beattie, W.M. 2004. Evaluation of forage legumes in the semi-arid region of Eastern Kenya. Persistence and dry matter production of selected forage legume. *Trop. and Sub Trop. Agro Ecosyst.* 4: 57-68

Njarui, D.M.G., Njoka, E.N., Abdulrazak, S.A. and Mureithi, J.G. 2007. Effect of planting pattern of two herbaceous forage legumes in fodder grasses on productivity of grass/legume mixture in semi-arid tropical Kenya. *Trop. and Sub Trop. Agro Ecosyst.* 7: 73-85.

Njoka-Njiru, E.N., Njarui, M.G., Abdulrazak, S.A. and Mureithi, J.G. 2006. Effect of intercropping herbaceous legumes with napier grass on dry matter yield and nutritive value of the feedstuffs in semi-arid region of Eastern Kenya. *Agricultura Tropicaet Subtropica*, 39(4): 260-272.

Noitsakis, B., Radoglon, K.M. and Jarvis, P.G. 1991. Water relation and growth in two years old seedlings of *Medicago arborea* under short-time water stress. *Phyton* 31(1): 111-120.

Nunes, C., Araujo, S.S., Silva, D.J.M., Fevereiro, M.P.S.F. and Silva, D.A.B. 2008. Physiological responses of the legume model *Medicago truncatula* cv. Jemalong to water deficit. *Environ. Exp. Bot.* 63: 289-296.

Nuttall, W.F. 1976. Effect of soil moisture tension and amendment on yields and on herbage N, P and S concentrations of alfalfa. *Agron. J.* 68: 791.

Ojo, V.O.A., Dele, P.A., Amole, T.A., Anele, U.Y., Adeoye, S.A., Hassan, O.A., Olanite, J.A. and Idowu, O.J. 2013. Effect of intercropping *Panicum maximum*var. Ntchisi and *Lablabpurpureus* on the growth, herbage yield and chemical composition of *Panicum maximum*var. Ntchisi at different harvesting times. *Pakist. J. Biol. Sci.* 16(22): 1605-1608.

Olanite, J.A., Tarawali, S.A. and Akenova, M.E. 2004. Biomass yield, quality and acceptability of selected grass-legume mixtures in the moist savanna of West Africa. *Trop. Grassl.* 38: 117-128.

Oliveira, D., Ramos, F.L., Veronica, A.M., Soares, R.M., David, T.S.L., Faria, N.J. and Castro, G.L. 2013. Comportamento de Andropogongayanus cv. planaltinae *Panicum maximum* cv. 'tanzania' sob sombreamento. *Ciencia Rural* 43(2): 348-354.

Orak, A., Tuna, C. and Nizam, I. 1999. Growing barley as a nurse crop in seed production of Hungarian Vetch. In: *Proceedings of the 3rd Field Crops Congress,* 15-18 November 1999, Adana, Turkey, pp.63-68.

Oren-shanir, M., Gussakovsky, E.E., Sphiegel, E., Nissin-Levi, A., Ratner, K., Ovadia, R., Raffo, A., La Malfa, G., Fogliano, V., Maiani, G., Quaglia, G. 2006. Seasonal variations in antioxidant components of cherry tomatoes (*Lycopersicum esculentum* cv. Naomi F1). *J. Food Compos. Anal.* 19: 11-19.

Osborne, S.L., Schepers, D.D., Francis, J.S. and Schlemmer, M.R. 2002. Use of spectral radiance to estimate in–season biomass and grain yield in nitrogen and water stress on corn. *Crop Sci.* 42: 165-171.

Oussalem, Z. 1998. Effect du stress hydrique appliqué a differentes phases phenologiques sur la croissance, le developpent et les composantes du rendement du haricot nain (*P. vulgaris* L.) Thes. Magist. INA, El-Harrach. 83 pp.

Paciullo, D.S.C., Fernandes, P.B., Gomide, C.A.D.M.G., Castro, C.R.T.D., Sobrinho, F.D.S. and Carvalho, C.A.B.D. 2011. The growth dynamics in *Brachiaria* species according to nitrogen dose and shade. *R. Bras. Zootec.* 40(2): 15-17.

Paez, A., Maria, E., Gonzalez, O. and Villasmil, Y.J.J. 1997. Acclimation of *Panicum maximum* to different light regimes and effect of subsequent defoliation. *Rev. Fac. Agron.* 14: 625-639.

Pal, R. 1988. Performance of fodder cowpea varieties in South Andaman. *J. Andaman Sci. Assoc.* 4: 83-84.

Pandey, C.,Verma, S., Dagar, J. and Srivastava, R. 2011. Forage production and nitrogen nutrition in three grasses under coconut tree shades in the humid tropics. *Agrofor. Syst.* 83(1): 1.

Panse, V.G. and Sukhatme, P.V. 1967. *Statistical Method for Agricultural Workers.* Third edition. Indian council of Agricultural Research, New Delhi, 381p.

Peterson, P.R., Sheaffer, C.C. and Hall, M.H. 1992. Drought effects on perennial forage legumes yields and quality. *Agron. J.* 84: 774-779.

Pillai, R.G. 1986. Production potential of two fodder grasses under different management practices. Ph.D. thesis, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala., 169p.

Pitman, W.D., Victor, D.M. and Holt, E.C. 1981. Digestibility of Wein grass forage growth under moisture stress. *Crop Sci.* 21: 951-953.

Poez, A., Gonzolez, M.E. and Pereira, Y.N. 1994. Comportamiento de *Panicum maximum* en condiciones de sombreado y de luz solar total. Efecto de la intensided de corte. *Rev. Fac. Agron.* (LUZ). 11: 25-42.

Popastylianou, I.. 1999. Response of pure stand and mixtures of cereals and legumes to nitrogen fertilizer and residual effect on subsequent barley. *J. Agric. Sci.* 115: 15-22.

Posler, G.L., Lensen, A.W. and Fine, G.L. 1993. Forage yield, quality, compatibility and persistence of warm-season grass-legume mixtures. *Agron. J.* 85: 554-560.

Prasad, P.V.V. and Staggenborg, S.A. 2008. Impacts of drought and heat stress on physiological, developmental, growth and yield processes of crop plants. *Adv. in Agric. Syst. Modelling Ser.* 1: 301-355.

Pudnam, A.R. and Duke, W.B. 1978. Allelopathy in agro-ecosystems. *Annu. Rev. Phytopathol.* 16: 431-451.

Purbajanti, E.D., Wydiati, S.A. and Kusmiyati, F. 2012. Drought stress effect on morphology characters, water use efficiency, growth and yield of guinea and napier grasses. *Int. Res. J. Plant Sci.* 3(4): 47-53.

Radhika, V.S. 2003. Genetic analysis of yield and quality attributes in fodder cowpea (*Vigna unguiculata* (L.) Walp). Ph.D. thesis, Kerala Agricultural University, Thrissur, 132p.

Rahdari, P., Hoseini, S.M. and Tavakoli, S. 2012. The effect of drought stress on germination, proline, sugar, lipid, protein and chlorophyll content in Purslane (*Portulaca oleraceae* L.) leaves. *J. Med. Plants Res.* 6(9): 1539-1547.

Rajasree, G. 1994. Herbage production of leguminous crops in summer rice fallows. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 121p.

Rajasree, G. and Pillai, R. 2001. Performance of fodder legumes under lime and phosphorus nutrition in summer rice fallows. *J. Trop. Agric.* 39: 67-70.

Ramus, D.A.H. 1995. Forage Growth and its relationship to grazing management. *Res. Bull.* No.21. University of South Western Louisiana, Lafayett, 96p.

Ravarizadesh, R. and Ehsanspour, A.A. 2005. Effect of UV-C on drought tolerance of alfalfa (*Medicago sativa*) callus. *Am. J. Biochem. and Biotechnol.* 1(2): 107-110.

Ray, I. and Townsend, M. 2013. Variation for yield, water-use efficiency and canopy morphology among nine alfalfa germplasms. *Crop Sci.* 35(5): 1386-1390.

Raymundo, M. 1997. Effects of shade on temperate pasture species. M.Sc. thesis, Lincoln University, New Zealand, 128p.

Reddy, V.C and Naik, G. 1999. Effect of intercrops of annual forage legumes and nitrogen levels on the performance of hybrid napier. *Legume Res.* 22(4): 275-276.

Reddy, V.C., Praveen, B., Murthy, K.N.K. and Shekara, B.G. 2004. Grass and legume intercropping for sustainable fodder production. *Environ. Ecol.* 22(4): 874-876.

Reynolds, S.G. 1988. Pastures and Cattle under Coconuts. FAO plant production and protection paper No.91. FAO of United Nations, Rome, 321p.

Reynolds, S.G. 1995. *Pasture-Cattle-Coconut Systems.* Seventh edition. FAO, RAPA Publication, Rome, 668p.

Ritchie, J.T. 1987. Influence of soil water status and meteorological conditions on evaporation from a corn canopy. *Agron. J.* 65: 893-897.

Roquib, M.A. and Patnaik, R.K. 1990. Genetic variability in forage yield and its components in cowpea (*Vigna unguiculata* (L). Walp.). *Environ. Ecol.* 8: 236-238.

Rouched, A., Slama, I., Zoorig, W., Cuckier, C., Rabhi, M., Talbi, O., Limani, A.M. and Abdelly, C. 2013. Differential performance of two forage species, *Medicago truncatula* and *Sulla Carnosa* under water deficit stress and recovery. *Crop and Pasture Sci.* 64(3): 254-264.

Safarnejad, A., Collin, H.A., Bruce, K.D. and Mcveilly, T. 1996. Characterization of alfalfa (*Medicago sativa* L.) following invitro selection for salt tolerance. *Euphytica* 92: 55-61.

Sambo, E.Y. 1981. Osmotic adjustment as a mechanism of drought resistance in crop and forage species. *J. Sci. Technol.* 2: 21-37.

Sambo, E.Y. and Aston, M.J. 1985. Evidence for osmotic adjustment in *Phalaris tuberosa* L. cv. Australian and Sirosa. *Aust. J. Plant Physiol.* 12: 481-486.

Samarakoon, S.P., Wilson, J.R. and Shelton, H.M. 1990. Growth, morphology and nutritive quality of shaded *Stenotaphrum secundatum, Axonopus compressus* and *Pennisetum clandestinum. J. Agric. Sci.* Cambridge, 114: 161-169.

Samson, H. and Helmut, H. 2007. Drought effect on yield, leaf parameters and evapotranspiration efficiency of cowpea [abstract]. In: *Abstracts, International Agricultural Research for Development Conference, Tropentag 2007*, 9-11, October 2007, Witzenhausen, Germany. University of Kassel, Witzenhausen and University of Gottingen, 432p.

Samuil, C., Vintu, V., Sirbu, C. and Surmei, G.M. 2012. Behaviour of fodder mixtures with alfalfa in north – eastern Romania. *Romanian Agric. Res.* 29: 227-235.

Sanderson, M. 2010. Nutritive value and herbage accumulation rates of pastures sown to grass, legume and chicory mixtures. *Agron. J.* 102: 728-733.

Sanehez, R.A., Hall, A.J., Trapani, N. and Hunau de, C.R. 1983. Effects of water stress on the chlorophyll content, nitrogen level and photosynthesis of leaves of two maize genotypes. *Photosynth. Res.* 4: 35-47.

Saren, B.K. and Jana, P.K. 1999. Effect of irrigation and intercropping system on yield, water use, concentration and uptake of nitrogen, phosphorus and potassium in maize (*Zea mays* L.) and groundnuts (*Arachis hypogea*) grown sole and intercrop. *Indian J. Agric. Sci.* 69: 317-332.

Sasani, S., Jahansooz, M.R. and Ahmadi, A. 2002. The effects of deficit irrigation on water-use efficiency, yield and quality of forage pearl millet. In: Fischer, R.A. (ed.), *New Directions for a Diverse Planet.* Proceedings of the Fourth International Crop Science Congress, 26th September – 1st October 2004, Brisbane, Australia, pp.27-36.

Schaff, B.E. and Skogley, E.D. 1982. Diffusion of potassium, calcium and magnesium in Bozeman silt loam as influenced by temperature and moisture. *Soil Sci. Am. J.* 46: 521-524.

Schmid, I. and Kazda, M. 2001. Vertical distribution and radial growth of coarse roots in pure and mixed stands of *Fagus sylvatica and Picea abies. Can. J. Forage Res.* 31: 539-548.

Segui, E., Machado, H. and Martinez, J. 1984. Correlations between yields under two cultivation systems and their influence in the selection of *Panicum maximum* Jacq. *Pastos-y-Forrajes* 7(3): 331-341.

Sengul, S. 2003. Performance of some forage grasses or legumes and their mixtures under dry land conditions. *Eur. J. Agron.* 19: 401-109.

Senanayake, S.G.J.N. 2005. The effects of different light levels on the nutritive quality of four natural tropical grasses. *Trop. Grassl.* 29: 111-114.

Seresinhe, T., Hartwig, U.A., Kessler, W. and Noesberger, J. 1994. Symbiotic nitrogen fixation of white cloves in a mixed sward is not limited by height of repeated cutting. *J. Agron. and Crop Sci.* 172: 279-288.

Seresinhe, T. and Pathirana, K.K. 2000. Associate effects of tree legumes and effects of cutting height on the yield and nutritive value of *Panicum maximum* cv. Guinea. *Trop. Grassl.* 34: 103-109.

Seyed, Y.S., Motafakkerazat, R., Mosharraf, M., Hossain and Rahman, I.M.M. 2012. Water stress in plants: Causes, effects and responses [on-line]. Available: http://www.intechopen.com [11.09.2013].

Shahapurkar, P.R. and Patil, V.C. 1989. Intercropping studies in maize (*Zeamays*). *Korean J. Agric. Sci.* 2: 320-323.

Sharma, K.K., Khanna, P. and Gulati, A. 1996. The growth and yield of wheat and paddy as influenced by *Dalbergia sissoo* Roxb. boundary plantation. *Indian For.* 22: 1114-1126.

Sharma, P.C., Mishra, S.N., Singh, A. and Verma, J.S. 1988. Genetic variation and correlation in cowpea. *Ann. Agric. Res.* 9: 101-105.

Sheaffer, C.C., Peterson, P.R., Hall, M.H. and Stordahl, J.B. 1992. Drought effects on perennial forage legume yield and quality. *J. Prod. Agric.* 5: 556-561.

Sheaffer, K.M., Dunn, J.H., and Minner, D.D. 1988. Summer drought response and rooting depth of three cool- season turf grasses. *Hortic. Sci.* 22: 296 – 297.

Shekara, B.G., Sowmyalatha, B.S. and Baratkumar, C. 2012. Effect of phosphorus levels on forage yield of fodder cowpea. *J. Hortic. letters.* 2(1): 12-13.

Siddique, A.K.M.A.R. and Gupta, S.W. 1991. Genotypic and phenotypic variation for seed yield and other traits in cowpea (*Vigna unguiculata* (L.) Walp.). *Int. J. Trop. Agric.* 9: 144-148.

Sima, N.F., Mihai, G. and Sina, R.M. 2010. Evolution of the botanical composition and forage yield of several perennial fodder legume and grass mixtures in the year of establishment. *Notulae Botanicae Hortic. Agrobotanici Cluj- Napoca.* 38: 45-50.

Sima, N.F., Sima, R.M., Cuna, S., Cristea, G. and Mihal, V. 2011. Evaluation of the use of Carbon Isotope Discrimination as a selection Tool of Perennial Fodder Species for Temporary Pastures. *Not. Bot. Hortic. Agrobiol.* 39(2): 34-41.

Simpson, J.E., Adair, C.R., Kohler, G.D., Dawson, E.N., Debald, H.A., Kester, E.B. and Klick, J.T. 1965. *Quality Evaluation of Foreign and Domestic Rices. Tech. Bull.* No.13. USDA – ARS, North Carolina State University, Raleigh, 86p.

Simpson, J.R. and Pinkerton, A. 1989. Fluctuations in soil moisture and plant uptake of surface applied phosphate. *Fertil. Res.* 20: 101.

Singh, B. and Singh, G. 2004. Influence of soil water regime on nutrient mobility and uptake by *Dalbergia sissoo* seedlings. *Trop. Ecol.* 45 (2): 337-340.

Singh, B.B and Tarawali, S.A. 2011. Cowpea and its improvement: Key to sustainable mixed crop/livestock farming systems in West Africa. *Agrofor. Syst.* 2:34-41.

Silva, E.A., Silva, W.J. and Barreto, A.C. 2012. Dry matter yield, thermal sum and base temperatures in irrigated tropical forage plants. *Revista Brasiliera Zootecnia* 41 (3): 574-582.

Slama, I., Ghnaya, T., Savoure, A. and Abdelly, C. 2008. Combined effects of long-term salinity and soil drying on growth, water relations, nutrient status and proline accumulation of *Sesuvium portula-castrum*. *C.R. Biol.* 331: 442-451.

Slama, I., Tayachi, S., Jdey, A., Rouached, A. and Abdelly, C. 2011. Differential response to water deficit stress in alfalfa (*Medicago sativa*) cultivars: Growth, water relations, osmolyte accumulation and lipids peroxidation. *Agric. J. Biotechnol.* 10 (72): 16250-16259.

Slatyer, R.O. and Barrs, H.D. 1965. Modifications to the relative turgidity technique with notes on its significance as an index of the internal water status of leaves. *Arid zone Res.* 25: 331.

Sleugh, B., Moore, K.J., George, L.R. and Brummer, C.E. 2000. Binary legume-grass mixtures improve forage yield, quality and seasonal distribution. *Agron. J.* 92: 24-29.

Srinivasan, C. and Das, V.L.D. 1996. Correlation and path analysis for fodder yield in cowpea. *Madras Agric. J.* 83: 660-661.

Srivastava, R.C. and Bhatnagar, P.R. 1995. Feasibility of irrigation to pasture grasses during summer in Uttar Pradesh hills. *Indian J. Soil Conserv.* 23(3): 239-243.

Stur, W.W. 1991. Screening forage species for shade tolerance. A preliminary report. In: Shelton, H.M. and Stur, W.W. (eds.), *Proceedings of the Workshop on Forages for Plantation Crops*, ACIAR Proc. No.32, June 27-29, 1990, ACIAR, Melbourne, pp.78-81.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* 29: 259-260.

Subramaniam, K.S., Selvakumari, G., and Shanmugasundaram, V.S. 1993. Influence of irrigation and phosphorus levels on vegetable cowpea yield and water use efficiency. *S. Indian Hortic.* 41 (3): 139-143.

Surve, V.H., Patil, P.R. and Arvadia, M.K. 2012. Effect of row ratio in cereal-legume fodder under intercropping systems on biomass production and economics. In: *Proceedings of the International Conference on Agriculture, Science and Engineering*; September 30, 2012, Nigeria. Beverly Scientific Organization, Port Harcourt, Nigeria. pp.122-126.

Ta, T.C. and Faris, M.A. 1987. Effects of alfalfa proportions and clipping frequencies on Timothy alfalfa mixtures-competition and yield advantages. *Agron. J.* 79: 817-820.

Tayeb, E.M. 2006. Differential Responses of Pigments, Lipid Per-oxidation, Organic solutes, Catalase and Per-oxidase activity in the leaves of two *Vicia faba* L. Cultivars to Drought. *Int. J. Agric. and Biol.* 8(1): 116-122.

Thaware, B.L., Birari, S.P. and Bendale, V.W. 1992. Genetic analysis in forage cowpea. *Ann. Agric. Res.* 13: 188-190.

Tripathi, B.R. and Psychas, P.J. 1992. *The AFNETA Alley Farming Training Manual.* Vol.2. Source Book for Alley Farming Research. AFNETA (Alley Farming Network for Tropical Africa), International Institute of Tropical Agriculture, Ibadan, Nigeria, 218p.

Tripathi, R.K., Pradhan, L. and Rath, B.S. 1997. Performance of maize (*Zea mays*) and cowpea (*Vigna unguiculata)* forage intercropping system. *Indian J. Agron.* 42(1): 38-41.

Turken, I., Bor, M., Ozdemir, F. and Koca, H. 2005. Differential responses of lipid peroxidation and antioxidants in the leaves of drought-tolerant *P. acutifolius* Gray and drought-sensitive *P. vulgaris* L. subjected to polyethylene glycol mediated water stress. *Plant Sci.* 168: 223-231.

Ullah, M.A., Tariq, A.N. and Razzaq, A. 2007. Effect of rice bean (*Vigna umbellata*) intercropping on the yield of perennial grass, *Panicum maximum* cv. Gaton under rain-fed conditions. *J. Agric. Social Sci.* 3(2): 70-72.

Ushakumari, R. and Chandrasekharan, P. 1991. Genetic variability and correlation studies in fodder lablab (*Lablab purpureus* L.). *Forage Res.* 17: 1-5.

Varella, A.C., Moot, D.J., Lucas, R.J., McNeil, D.L., Peri, P.L. and Pollock, K.M. 2001. Different methods of artificial shade for agrosilvipastoral research. In: Gomide, J.A., Da Silva, S.C. and Mattos, W.R.S. (eds.), *Grassland Ecosystem: an Outlook into the 21st Century.* Proceedings of the XIX International Grassland Congress, 11-21 February 2001, Sao Pedro, Sao Paulo, Brazil. Brazilian Society of Animal Husbandry, 1097p.

Verbruggen, N. and Hermans, C. 2008. Proline accumulation in plants: a review. *Amino acids* 35: 753-759.

Viets, F.G. 1972. Water deficits and nutrient availability. In : Kozolowski, T.T. (ed.), *Water Deficit and Plant Growth.* Vol. III. Academic Press, New York, pp.217-240.

Vliegher, D.A. and Carlier, L. 2008. *Potential of Fodder Legumes under Intensive Farming Conditions in Flanders.* Crop Husbandry and Environment, ILVO, B-9820, Merelbeke, Belgium. 158p.

Voetberg, G.S. and Sharp, R.E. 1991. Growth of maize primary root at low water potential and role of increased proline deposition in osmotic adjustments. *Plant Physiol.* 96 : 1125 – 1230.

Volesky, J.D. and Berger, A.L. 2012. Forage production with limited irrigation. Neb Guide, University of Nebraska-Lincoln Extension, Institute of Agriculture and Natural Resources. Available: *http://extension.unl.edu/publications* [11.09.2013].

Watson, V.H., Hagedorn, C., Knight, W.E. and Pearson, H.A. 1984. Shade tolerance of grass and legume germplasm for use in the Southern Forest Range. USDA-ARS. *J. Range Manag.* 37(3): 229-232.

Weatherley, P.E. 1950. Studies on water relations of cotton plant. The field measurement of water deficit in leaves. *New Phytologist* 49: 81-97.

Whitehead, D.C. 1995. *Grassland Nitrogen.* CAB International, Wallingford, U.K., 387p.

Wilson, J.R. 1996. Shade-stimulated growth and nitrogen uptake by pasture grasses in a sub-tropical environment. *Aust. J. Agric. Res.* 47: 1075-1093.

Wilson, J.R., Hill, K., Cameron, D.M. and Shelton, H.M. 1990. The growth of *Paspalum notatum* under the shade of a *Eucalyptus grandis* plantation canopy and in full sun. *Trop. Grassl.* 24: 24-28.

Wong, C.C. 1991. Shade tolerance of tropical forages. A review. In: Shelton, H.M. Stur, W.W. (eds.), *Forages for Plantation Crops.* ACIAR Proceedings, 27-29 June 1990, Sanur Beach, Bali, Indonesia. Australian Centre for International Agricultural Research, Canberra, A.C.T., Australia, pp.64-69.

Wong, C.C. 1993. Strategies for Sustainable Production of Tropical Forages under shade. *Res. Bull.* No.21. MARDI, Kuala Lumpur, 285p.

Wong, C.C., Sharudin, M. and Rahim, H. 1985. Shade Tolerance Potential of some Tropical Forages for Integration in Plantations two legumes. *Res. Bull.* No.13. MARDI, Kuala Lumpur, 269p.

Xu, B., Shan, L., Zhang, S., Deng X. and Li, F. 2008. Evaluation of Switch grass and sainfoin intercropping under 2: 1 row replacement in semiarid region of north west China. *Afr. J. Biotechnol.* 7 (22): 4056-4067.

Yancy, P.H., Clark, M.E., Hand, S.C., Bowlus, R.D. and Somero, G.N. 1982. Living with water stress: evolution of osmolyte systems. *Science* 217: 1214-1223.

Yang, Z.B., Eticha, D., Rotter, B., Rao, I.M., and Horst, W.J. 2011. Physiological and Molecular analysis of polyethylene glycol- induced reduction of aluminium accumulation in the root tips of common bean (*Phaseolus vulgaris*). *New Phytologist* 192: 99-113.

Young, D.R. and Smith, W.K. 1980. Influence of sunlight on photosynthesis, water relations and leaf structure in the under-storey species *Arnica Cordifolia Ecol.* 61: 1380-1390.

Yousfi, N., Slama, I., Ghnaya, T., Savoure, A. and Abdelly, C. 2010. Effects of water deficit stress on growth, water relations and osmolytes accumulation in *Medicago truncatula* and *M. laciniata* populations. *C.R. Biol.* 333: 205-213.

Zimkova, M., Tisliar, E. and Michalee, M. 2002. Chemical and botanical composition of grass-legume mixtures in relationship to soil chemical composition. *Grassl. Sci. Eur.* 7: 102-103.

Zong, Q. and Brown, H.P. 2000. Soil potassium mobility and uptake by corn under differential soil moisture regimes. *Plant and Soil* 221: 121-134.

Zootec, R.B. 2012. Forage yield and nitrogen nutrition dynamics of warm-season forage genotypes under two shading levels and full sunlight. *R. Bras. Zootec.* 15: 16-35.

Appendices

APPENDIX – 1

Weather data during the cropping period (January 2012 to March 2013)

Standard Week number	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
1	30.7	20.8	99.0	60.4	0
2	30.3	23.0	98.6	67.6	0
3	29.4	19.2	98.1	55.3	5
4	30.3	19.9	98.7	57.4	0
5	31.3	21.2	97.1	55.9	0
6	30.8	23.5	97.6	71.6	0
7	30.8	22.9	97.7	65.3	0
8	31.6	21.6	96.4	51.7	0
9	31.5	23.2	94.3	62.1	0
10	31.2	24.7	88.6	66.3	0
11	31.4	21.0	98.3	69.1	0
12	32.2	24.0	93.7	63.6	0
13	32.2	23.6	93.4	61.6	0
14	32.6	24.7	89.9	64.9	1.5
15	32.7	24.7	92.6	65.9	11
16	33.0	25.9	85.3	68.0	9
17	30.1	25.0	92.3	79.9	93.4
18	30.6	25.4	92.9	73.6	19
19	31.0	25.5	88.1	72.7	8
20	31.5	26.1	91.4	74.3	22
21	31.5	25.8	91.7	72.1	0
22	31.5	26.1	90.0	70.6	1.0
23	31.3	24.7	91.4	71.1	14.5
24	30.4	23.9	93.6	72.4	35
25	29.4	24.3	94.4	77.0	10.5
26	29.8	23.8	87.0	74.0	30.0
27	29.5	23.9	95.1	78.3	37.0
28	29.6	24.0	88.9	72.9	31.5
29	29.9	24.6	92.3	76.4	16.0
30	30.0	24.5	94.4	74.7	11.5
31	30.2	24.6	94.0	75.0	0
32	30.3	23.7	87.7	72.9	3.0
33	29.7	23.5	91.3	73.3	85.0
34	29.8	23.9	92.6	75.0	2.0
35	28.9	23.5	94.7	85.3	98.0
36	29.8	23.8	89.9	74.9	28.5

37	29.7	24.1	94.4	76.1	14.0
38	30.7	24.2	87.9	69.3	9.0
39	30.7	24.3	87.1	70.1	0
40	31.2	23.5	89.6	66.6	0
41	31.4	24.1	90.3	72.9	19.0
42	29.4	23.4	94.4	79.6	53.5
43	30.1	23.9	94.6	76.9	37.5
44	29.8	23.3	91.9	73.4	12.5
45	30.1	23.0	96.9	77.3	94.6
46	30.3	23.2	95.6	68.6	3.0
47	30.5	23.1	98.6	72.3	1.0
48	30.6	22.7	99.0	67.7	0
49	30.5	22.6	99.0	66.3	0.5
50	30.6	22.1	99.0	62.4	0
51	31.1	22.8	91.4	60.3	0
52	30.5	23.5	99.0	71.9	40.0
1	30.6	23.4	95.4	72.0	17.5
2	30.0	22.6	96.4	74.6	24.0
3	30.1	20.8	96.0	75.1	0
4	30.5	21.3	96.1	73.6	0
5	30.4	20.8	94.3	75.4	0
6	31.2	22.9	93.3	74.3	5.0
7	32.0	23.0	92.4	75.7	33.0
8	31.4	21.8	89.9	74.9	0
9	32.0	21.4	91.3	67.4	0
10	32.1	24.3	94.7	80.6	21.0
11	32.3	23.9	93.4	81.3	34.0

APPENDIX – II

Weather data during the cropping period (March 2013 to March 2014)

Standard Week number	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
12	32.3	23.7	91.4	75.4	0
13	32.6	25.3	92.6	76.3	31
14	32.9	26.0	92.7	77.0	0
15	32.8	25.6	89.9	71.4	1.5
16	33.2	25.1	84.8	76.0	0
17	33.3	25.0	87.0	72.7	40.6
18	32.7	25.8	90.6	81.7	7.1
19	32.0	26.1	90.7	80.9	34.4
20	32.4	25.7	90.6	76.4	5.2
21	32.1	24.2	91.7	84.6	35.8
22	30.1	22.3	95.0	87.7	132.6
23	29.2	22.8	93.6	83.3	89.9
24	29.1	23.2	95.1	89.3	121.2
25	28.3	22.5	95.4	86.1	141.6
26	29.9	23.3	90.0	202.3	34.2
27	29.3	23.4	93.9	85.1	33.5
28	28.5	23.0	93.7	79.6	60.8
29	28.3	23.5	94.0	87.9	60.5
30	29.4	21.9	92.3	88.0	69.8
31	29.0	21.6	93.1	87.0	92.8
32	28.8	23.9	96.7	82.7	7.8
33	28.6	23.7	93.3	78.4	3.1
34	29.8	24.0	92.7	78.7	3.0
35	30.2	24.4	86.6	80.1	2.4
36	28.8	23.7	97.0	86.7	140.4
37	28.7	23.4	98.6	84.0	36.9
38	28.8	24.3	96.3	85.4	36.6
39	30.2	24.0	93.7	85.1	2.3
40	30.5	22.6	94.0	74.4	13.4
41	30.6	23.3	91.4	75.4	22.8
42	30.7	23.7	92.1	79.9	66.0
43	30.7	23.0	95.0	70.9	54.4
44	30.7	23.6	93.9	80.1	62.0
45	30.9	23.7	97.0	76.9	3.2
46	30.3	23.4	97.7	78.3	138.8
47	30.6	23.7	97.3	78.1	58.1

48	30.8	23.0	97.3	75.9	49.8
49	30.9	22.8	98.6	69.9	1.4
50	30.3	22.6	96.7	69.6	26.0
51	31.2	21.7	97.7	72.0	47.0
52	31.0	20.2	96.6	59.1	0
1	30.9	21.5	94.9	77.6	0
2	29.0	22.3	94.4	77.4	28.0
3	31.0	21.8	94.1	76.1	0
4	31.3	20.7	90.4	69.9	0.5
5	31.4	21.9	92.3	68.6	0
6	30.7	20.2	95.1	68.9	0
7	31.4	22.8	92.0	72.0	3.0
8	31.5	23.8	90.6	70.6	18.0
9	31.9	23.1	92.3	68.6	25.0
10	31.9	23.4	90.4	66.9	0
11	32.4	21.4	93.0	63.4	0
12	33.0	24.1	93.7	69.1	6.5
13	33.0	22.2	89.1	64.0	0

APPENDIX – III

Evaporation data, rainfall data and dates of various irrigation treatments

Date	Rainfall in mm	Evaporation in mm	Treatments irrigated
14.01.2012	0	3.6	Sowing
15.01.2012	0	2.8	
16.01.2012	0	2.4	Irrigation for germination &
17.01.2012	0	3.8	establishment (10days) (14.01.2012 to
18.01.2012	0	3.8	23.01.2012)
19.01.2012	0	3.2	
20.01.2012	0	2.5	
21.01.2012	0	3	
22.01.2012	0	2.8	
23.01.2012	0	3	
24.01.2012	0	3.2	
25.01.2012	0	3.6	
26.01.2012	0	3.4	
27.01.2012	0	3.6	
28.01.2012	0	4	
29.01.2012	0	3.4	
30.01.2012	0	3.8	
31.01.2012	0	4	
01.02.2012	0	4	
02.02.2012	0	3	IW/CPE = 0.8
03.02.2012	0	4.2	
04.02.2012	0	3.2	
05.02.2012	0	2	
06.02.2012	0	3	IW/CPE = 0.6
07.02.2012	0	3.4	

08.02.2012	0	2	
09.02.2012	0	2	
10.02.2012	0	2.2	
11.02.2012	0	4	
12.02.2012	0	4	
13.02.2012	0	3	
14.02.2012	0	3.8	IW/CPE = 0.8 & IW/CPE = 0.4
15.02.2012	0	2	
16.02.2012	0	3	Lifesaving irrigation
17.02.2012	0	4	
18.02.2012	0	4.2	
19.02.2012	0	3	
20.02.2012	0	4	
21.02.2012	0	3.4	IW/CPE = 0.6
22.02.2012	0	4	
23.02.2012	0	3.6	
24.02.2012	0	3.6	IW/CPE = 0.8
25.02.2012	0	3.4	
26.02.2012	0	4	
27.02.2012	0	4	
28.02.2012	0	4	
29.02.2012	0	4	
01.03.2012	0	4	
02.03.2012	0	3	
03.03.2012	0	4.2	
04.03.2012	0	3.2	
05.03.2012	0	2	IW/CPE = 0.8 & IW/CPE = 0.6
06.03.2012	0	3	IW/CPE = 0.4
07.03.2012	4	3.4	

08.03.2012	0	2	Lifesaving irrigation
09.03.2012	0	2	
10.03.2012	3	2.2	
11.03.2012	0	4	
12.03.2012	0	4	
13.03.2012	0	3	Harvest

FODDER PRODUCTION TECHNOLOGY UNDER LIGHT AND MOISTURE STRESS SITUATIONS

by

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ABSTRACT

The field experiment of the project entitled "Fodder production technology under light and moisture stress situations" was undertaken at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, during January 2012 to March 2014. The main objectives of the project were to identify drought tolerant varieties of fodder cowpea and their performance evaluation in varying proportions of grass legume mixtures under open and shaded conditions. The project comprised of two investigations. The Investigation-I entitled "Drought tolerance studies in fodder cowpea under open and shaded situations" was conducted during the summer season (January to March) of 2012. The Investigation-II on "Evaluation of grass-fodder cowpea mixtures under open and shaded situations" was conducted for two years from March 2012 to 2013 and from March 2013 to March 2014.

In Investigation-I, five fodder cowpea varieties (V_1-UPC-618, V_2-UPC-622, V_3-Bundel Lobia-1, V_4-COFC-8 and V_5-CO-5) were evaluated for their drought tolerance under four soil moisture stress levels (M_1 - pre sowing irrigation + life saving irrigation; M_2 - pre sowing irrigation + irrigation at IW/CPE ratio of 0.4; M_3 - pre sowing irrigation + irrigation at IW/CPE ratio of 0.6 and M_4 - pre sowing irrigation + irrigation at IW/CPE ratio of 0.8). The investigation was conducted as two separate experiments one in open and other in shade. Both the experiments were laid out in split plot design with four replication. Based on the results of this investigation, two drought tolerant fodder cowpea varieties were selected each under open and shaded situation, for conducting Investigation-II. The fodder cowpea varieties COFC-8 (V_4) and UPC-622 (V_2) which recorded significantly higher green fodder yield (24.21 t ha^{-1} & 21.36 t ha^{-1}, respectively), crude protein yield (0.79 t ha^{-1} & 0.66 t ha^{-1}, respectively) and net returns of Rs 44880 ha^{-1} and Rs 36011 ha^{-1}, respectively were selected for open condition. The fodder cowpea varieties COFC-8 (V_4) and UPC-618 (V_1) which recorded significantly higher green fodder

yield (11.50 t ha^{-1} and 11.00 t ha^{-1} respectively), crude protein yield of 0.41 t ha^{-1} & 0.34 t ha^{-1} respectively and net returns of Rs 13498 ha^{-1} and Rs 11873 ha^{-1} respectively were selected for shaded situation.

Investigation-II on the evaluation of grass-fodder cowpea mixtures were also conducted as two separate experiments, one in open and the other in shade. The experiments were laid out in RBD with three replications, comprising of two grasses [G_1-Hybrid napier (Suguna), G_2-Guinea grass (Harithasree), two best fodder cowpea varieties from the first investigation (V_1-COFC-8(open and shade), V_2-UPC-622 (open), UPC-618 (shade) and three grass legume row ratios (R_1-1:1, R_2 -1:2, R_3 -1:3). The results indicated the superiority of the grass legume mixture of hybrid napier cv. Suguna and with both the fodder cowpea varieties in the grass legume row ratio of 1:2 with respect to green fodder yield, crude protein yield and net returns.

Based on the results, it can be concluded that hybrid napier cv. Suguna intercropped with fodder cowpea varieties COFC-8 and UPC-622 in open condition and with COFC-8 and UPC-618 in partial shade (30 per cent) in the row ratio of 1:2 is the best for obtaining maximum yield, quality and net returns.