SHADE RESPONSE OF GUINEA GRASS (*Panicum maximum* J.) UNDER VARYING LEVELS OF POTASH

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Thesis submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2002

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DECLARATION

I hereby declare that this thesis entitled **"Shade response of Guinea grass (*Panicum maximum* J.) under varying levels of potash"** is a bonafide record of research work done by me during the course of research and that 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 **"Shade response of Guinea grass (*Panicum maximum* J.) under varying levels of potash"** is a record of research work done independently by **Mrs. Anita, M.R.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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AFFECTIONATELY DEDICATED

to

MY PARENTS, MY HUSBAND
***AND* MY DAUGHTER RIYA**

ACKNOWLEDGEMENT

With immense pleasure I wish to express my profound thanks and deep gratitude to Dr.(Mrs) S. Lakshmi, Associate Professor, Department of Agronomy and Chairman of the Advisory Committee, for her valuable guidance, timely advice and constant encouragement rendered to me throughout the period of my M.Sc. I am deeply indebted to her.

Grateful and sincere thanks are due to Dr. V. Muraleedharan Nair, Former Professor and Head, Department of Agronomy, for his sustained keen interest, constant encouragement, guidance and critical scrutiny of the manuscript amidst his busy schedule.

I wish to express my sincere and profound gratitude and obligations to Dr.S. Janardhanan Pillai, Professor and Head, Department of Agronomy for his constant, whole hearted help and valuable suggestions at various stages of investigation. I also place a deep sense of gratitude for the help offered by him during the collection of literature.

I express my profound gratitude to Dr. (Mrs.) P. Saraswathi, Professor and Head of the Department of Agricultural Statistics, for her valuable help and critical advice in planing of the study, analysis of the data and interpretation of the results of the research work.

I extend my sincere thanks to Smt. Sajitha Rani , Assistant professor, Department of agronomy, for her support and inspiring words throughout the preparation of thesis.

I always remember with much gratitude Dr.(Mrs.) Sumabai, Associate professor, Department of Plant Breeding and Genetics for whole hearted help *during the time of planting. I also place a deep sense of gratitude for the help offered by her throughout the period of my study.*

I am extremely thankful to Dr.(Mrs.) Geethakumari, Associate professor, and Dr. (Mrs.) Sheela, K.R, Associate professor, Department of Agronomy for their technical suggestions and expert advice. I also place a deep sense of gratitude for the help offered by them during my seminar.

I convey my heartiest gratitude to Dr. Prathapan, Assistant professor of Agronomy for the constant and valuable help while dealing with the instruments during the time of chemical analysis.

I extend my sincere thanks to all the teaching staff of the Department of Agronomy as well as to the non-teaching staff of the Department for their constant and whole hearted help rendered during the study.

My sincere thanks to Shri. C.E. Ajith Kumar, Programmer, Department of Agricultural Statistics, for his valuable assistance in the Statistical analysis of the data.

I am happy to record my sincere thanks to M/s. Athira Computers, Kesavadasapuram, Thiruvananthapuram for their untiring and timely help and flawless type setting of this manuscript.

I am deeply indebted to my best friends Sindhu and Sheena for their constant help, encouragement and co-operation. Also, I recall with gratitude the selfless help rendered to me by my friends Ranjini, Renu, Navas, Sreenivasan and Jacob, during the study.

I am profoundly grateful to Rakhi, Devi, Sindhu .K. Mathew and Sindhu for the constant help and inspiration extended to me during the completion of my thesis.

My grateful thanks to Geetha, Usha, Ameena, Sudha, Vidya and to all my juniors for their whole hearted co-operation during the study.

I express my sincere thanks to the authorities of Kerala Agricultural University for granting me KAU Research Fellowship and other facilities for the conduct of research work.

I owe a lot to Mr. Shaji for helping me in doing corrections. I gratefully acknowledge all the respondents for his co-operation.

Words fail to express my deep sense of gratitude and indebtedness to my parents, sisters, brother, Kavya and Riya for their undying love, unfailing moral support and constant encouragement, which enabled me to complete the work in time.

With a deep sense of affection, I wish to thank my husband, Mr.Sathyaraj, for his overwhelming support, unconditional help and constant inspiration throughout the preparation of the thesis.

Above all, I bow before the Almighty for all the blessings showered on me.

ANITA. M. R.

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LIST OF ABBREVIATIONS

%	-	per cent
@	-	at the rate of
^oC	-	degree Celsius
cc	-	cubic centimetre
cm	-	centimetre
cv	-	cultivar
DFY	-	dry fodder yield
Fig.	-	figure
FYM	-	farmyard manure
g	-	gram
ha	-	hectare
K	-	Potassium
kg	-	kilogram
kg ha^{-1}	-	kilogram per hectare
LAI	-	Leaf area index
m	-	metre
m^2	-	square metre
mg g^{-1}	-	milligram per gram
mm	-	millimetre
N	-	Nitrogen
NS	-	Non significant
P	-	Phosphorus
t	-	tonnes
t ha^{-1}	-	tonnes per hectare

INTRODUCTION

1. INTRODUCTION

The significance of livestock in Indian agriculture sector is well recognised. However the Indian livestock have very low productivity and fail to express their full genetic potential mainly due to the non availability of good quality fodder and feed resources. Currently the forages and feeds available in our country is sufficient to meet only 46.6 per cent of the requirement and the shortage is mainly due to the very limited area available for fodder cultivation. However, the possibility of diverting agricultural areas for fodder production is limited because of the increasing pressure on agricultural land for food production and for the cultivation of cash crops and plantation crops. Hence the only way to bridge the wide gap between demand and supply is to increase productivity from unit area and so a possible measure in Kerala is to raise fodder as intercrop in the partial shade of coconut trees in homesteads.

Research work on multiple cropping in coconut gardens was taken up only by 1970, though the practice of cultivating crops in the interspaces of coconut had been a common practice in Kerala. Early studies conducted at the CPCRI, Kasargode indicated that there is enough scope for intensifying intercropping in coconut garden as the coconut roots actively exploit only about 20 to 25 per cent of land area. Studies indicated that the amount of light that filters through the coconut canopy is markedly affected by the age of coconut palms. It has been estimated that light infiltration can range from as low as 10 per cent to as much as 70 per cent depending upon the age of the palm. Based on this indication, the general recommendation had been that multiple cropping in coconut garden can be taken up before the 10th year and after 20th year of planting.

Grass species suitable for the coconut understorey are relatively short, sod forming and shade tolerant. They should provide a moderate carrying capacity, easy to establish from cuttings, compete well with aggressive weeds and do not compete excessively with coconuts (Reynolds, 1988). Popular choices are cori grass (*Brachiaria miliformis*), paragrass (*Brachiaria mutica*), signal grass (*Brachiaria decumbens*) guinea grass (*Panicum maximum*) and congo signal grass (*Brachiaria ruziziensis*). Experiments conducted in AICRP on Forage Crops show that guinea grass is a suitable fodder crop for intercropping in coconut gardens. But its fodder yield is highly varying under partial shade. Shading has both direct and indirect effects on forage production in that it can alter morphological development and yield (Kephart and Buxton, 1996).

Guinea grass is found to respond to higher potash levels in shade and the content and uptake of potassium by guinea grass is higher in shade. Deficiency of potassium in soil not only affects production but also the quality of roughage. Optimum quantity of potash is required for the efficient utilisation of Nitrogen and Phosphorus for herbage production. Based on this study the suitability of guinea grass varieties for the different shade intensities and requirement of potash for different shade levels can be standardised. Keeping this in view, the present study entitled "Shade response of guinea grass (*Panicum maximum* J.) under varying levels of potash" was taken up with the following objectives.

1. To study the shade response of guinea grass varieties

2. To assess the optimum potash requirement for maximum fodder yield and quality under different shade intensities.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present investigation was undertaken with the object of studying the fodder production potential of guinea grass varieties grown under varying potash levels and shade intensities. The relative fodder production efficiencies of these varieties were also assessed in the open field and also under varying shade levels. The relevant literature on the performance of guinea grass as influenced by potash levels and shade levels are reviewed hereunder.

2.1 INFLUENCE OF SHADE ON THE PERFORMANCE OF FODDER CROPS

2.1.1 Influence of shade on growth characters

2.1.1.1 Height of the grass

Roberts and Struckmeyer (1939) observed an increase in height of plants due to shading. Subramonian *et al.* (1971) while studying the effects of N and P observed significant increase in plant height of ragi (*Eleusine coracana*) by incremental doses of Nitrogen, while Phosphorus failed to evoke any response in shade. According to Mullakoya (1982) maximum height was recorded under 50 per cent shade and the minimum under full sunlight in guinea grass var. Mackuenii.

Watson *et al.* (1984) found that plant height of marshall ryegrass reduced as the shade intensity increased. The plant height was 72cm under full sunlight whereas it was 38 cm and 31 cm under 50 per cent and 75 per cent shade. He also found that there is variation in the plant height of *Sericea lespedeza* grown under shade. At the first harvest plant height increased upto 78 cm under 50 per cent shade when compared to that under full sunlight. However, at the second harvest plants grown under shade were significantly shorter. At the second harvest the height of plants were 65 cm, 53 cm and 52 cm under full sunlight, 50 per cent shade and 75 per cent shade respectively.

According to Pillai (1986) guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) when grown under coconut shade recorded more height than those grown in open area. Benjamin *et al.* (1991) reported that shading reduces the growth of leucana although this plant has moderate tolerance to reduced light when compared with other tree legumes. 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 plants adapted to shade. Nandal and Singh (2001) reported that fodder crops of sorghum and oats showed greater tolerance to shade and so plant height was increased under agro-forestry systems.

2.1.1.2 Number of tillers

In guinea grass (*Panicum maximum*), Mullakoya (1982) obtained maximum number of tillers in full sunlight and the lowest with 75 per cent shade. Wong *et al.* (1985) reported that shading reduced tiller production, particularly in shade tolerant species. According to Pillai (1986) there was reduction in tiller production in guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) when grown under coconut shade. In the study undertaken by Wong (1993) involving 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. According to Nandal and Singh

(2001) tiller number of fodder sorghum and oats were reduced under agro-forestry systems, due to the influence of shade. Shading often reduces tillering of forages and slows the growth rate of forages (Buxton, 2001).

2.1.1.3 Leaf Area Index

The amount of carbohydrates that a plant can produce in a given time is dependant on the amount of sun's energy it can capture and convert to tissue. A plant maximizes radiation absorption by accumulating leaves (Ramus, 1995). A common expression that denotes the amount of leaf area a plant has is leaf area index (LAI). Mullakoya (1982) reported that leaf area decreased with increasing light intensities in guinea grass. The maximum leaf area was recorded in 75 per cent shade level. Watson *et al.* (1984) found that in case of *Sericea lespediza*, per cent leaves decreased significantly as level of shade increased in the first harvest whereas there is not much difference in per cent leaves in the second harvest as the level of shade increased. In the first harvest, the per cent leaves were 63.4 per cent, 56.6 per cent and 59.5 per cent under full sunlight, 50 per cent shade and 75 per cent shade respectively. In the second harvest, the per cent leaves were 63.0, 61.0 and 61.3 per cent under full sunlight, 50 per cent shade and 75 per cent shade respectively. According to Burt *et al.* (1986) beyond a LAI of 4, the production tend to decline somewhat. Pearson and Ison (1987) reported that perennial grasses with semi-erect leaves need larger leaf areas than legumes with horizontal leaves. Grasses may intercept virtually 95 per cent of radiation at LAI 6 to 9. According to Pillai (1986) LAI decreases under shaded situation in guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*). Shading increases leaf length and also leaf area. 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. These findings support earlier work using artificial shade (Wong and Wilson, 1990) as well as trees shade (Cameron *et al.* 1989). True shade tolerence in forage species is associated with a number of morphological and physiological adaptation of plants. These include higher leaf area ratios and specific leaf areas which inturn influence the efficiency of interception and use of radiation and therefore growth potential at low levels of radiation (Stur, 1991). 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 (*Panicum maximum*) grown under coconut shade. The increase in LA is attributed to maximise light interception and changes in physiological processes to enhance the efficiency of carbon utilization (Evans and Seemann, 1996).

2.1.1.4 Leaf/stem ratio

Mullakoya (1982) reported that shade levels had no significant effect on leaf/stem ratio of guinea grass (*Panicum maximum*). Wong *et al.* (1985) reported that shading increased specific leaf area and leaf/stem ratios, particularly in shade tolerant species. According to Pillai (1986) shading increased leaf/stem ratio of guinea grass (*Panicum maximum*) and Setaria grass (*Setaria sphacelata*) when grown under coconut shade. These findings support the earlier works using artificial shade (Wong and Wilson, 1980) as well as tree shade (Cameron *et al.* , 1989). Shading increases leaf/stem ratios particularly in shade tolerant species compared to plants grown in full sun (Wong, 1991). 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.

2.1.2 Influence of shade on yield

2.1.2.1 Green fodder yield

Shading does seem to effect the growth of tropical grasses more than legumes (Ludlow *et al.*, 1974). Screening trials conducted by Sahasranaman and Pillai (1976) at Kasargod showed that the fodder grass gautemala (*Tripsacum laxum*), hybrid Napier (*Pennisetum typhoides* x *Pennisetum purpureum*) and guinea grass (*Panicum maximum*) gave a green fodder yield of 50-60 t ha^{-1} under coconut shade. The shade tolerance and high yields of guinea grass (*Panicum maximum*) coupled with drought resistance and tolerance of less fertile soils have caused it to be used under coconut in a number of countries (Donald, 1979). Wong and Wilson (1980) from the studies on the effect of illumination at 100, 60 and 40 per cent of sunlight on the growth of siratro and green panic in pure and 50:50 mixture swards, defoliated every 4 (D4) or 3 (D3) weeks, observed that shading to 60 and 40 per cent of full sunlight increased the shoot yield of green panic in pure sward by 30 and 27 per cent respectively in the D3, but reduced it in the D4 treatment by 3 and 14 per cent. According to Mullakoya (1982) maximum yields were recorded in the treatment which received full sunlight, followed by 25 per cent, 50 per cent and 75 per cent shade levels. Watson *et al.* (1984) found that the green fodder yield of marshall ryegrass (*Lolium multiflorum*) reduced as the shade increased. Green fodder yield was reduced by 49 per cent under 50 per cent shade and reduced by 72 per cent under 75 per cent shade from the yield under full sunlight. Chen and Bong (1983) and Wong *et al.* (1985) found that cultivation of improved tropical grasses does not carry much economic value under rubber and oil palm because of their low yields and poor persistance. The yield reduction in pearl millet under *Acacia albida* and *Prosopis cineraria* trees was reported by Shankarnarayan *et al.* (1987). In a review to summarise pasture species for shaded environment, Shelton *et al.* (1987) commented that very few of the available high yielding grass species have shown genuine shade tolerance and they do not persist under grazing. Corigrass (*Brachiaria miliformis*) appears, in fact, to perform better in the shade than in the open (Reynolds, 1988). According to him, pasture herbage production and shade density are closely correlated. A reduction in pasture yield is likely in shaded conditions. Cameron *et al.* (1989) reported that *Eucalyptus grandis* planted in a Nelder fan design reduced pasture production below the canopy.

Some grasses and legumes are more shade tolerant than others. When light transmission values fall below 40 or 50 per cent then both production values and the range of species are 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 (Watson and Whiteman, 1981; Kaligis and Sumolong, 1991). Meerabai *et al.* (1993) obtained a green fodder yield of 108 t ha^{-1} for guinea grass (*Panicum maximum*) and 100 t ha^{-1} for congosignal grass (*Brachiaria ruziziensis*) when grown in coconut gardens. Shading has a greater effect on forage yield. For example, Kephart *et al.* (1992) and Kephart and Buxton (1993) found that imposing 63 per cent shade on some perennial forage grasses like reed canary grass (*Phalaris arundinacea*), orchard grass (*Dactylis glomerata*), timothy grass (*Phleum pratense*), smooth brome grass (*Bromus inermis*) etc. reduced yield by 43 per cent. Productivity was found to be increasing with fertilizer application under shaded condition. *Panicum 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 a highly productive grass like *Panicum 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 (Sato and Dalmacio, 1991; Sharma *et al.*, 1996) have also reported yield reduction in agroforestry due to reduction in solar radiation availability. George (1996) recorded a green fodder yield of 58 t ha^{-1} for guinea grass (*Panicum maximum*) grown in coconut garden.

2.1.2.2 Dry fodder yield

Eriksen and Whitney (1981) reported a decrease in dry matter yield in *Brachiaria brizantha*, *Brachiaria miliformis* and *Panicum maximum* when grown under shaded condition. According to Mullakoya (1982) maximum dry fodder yield of 32.14 t ha^{-1} was noted under full sunlight in guinea grass (*Panicum* *maximum*) var. Mackuenii and the dry fodder yield reduced under shaded conditions. Watson *et al.* (1984) found that the total dry matter yield of gulf ryegrass reduced significantly as the level of shade intensity increased. The total dry matter yield under 50 per cent shade was 77 per cent of the yield in full sunlight and the total dry matter yield under 75 per cent shade was only 46 per cent of the yield in full sunlight. Watson *et al.* (1984) found that there is not much variation in the dry matter yield of marshall ryegrass grown under 75 per cent and 50 per cent shade when compared to that grown in full sunlight. Watson *et al.* (1984) found that the total dry matter yield of *Sericea lespedeza* grown under shade decreased as the shade intensity increased. In the first year of harvest, under 50 per cent shade the total dry matter production was 81.3 per cent of the yield in full sunlight and under 75 per cent shade, it was 67.5 per cent of the yield in the full sunlight. Whereas, in the second year of harvest under 50 per cent shade the total dry matter yield was 68.7 per cent of the yield in full sunlight and under 75 per cent shade total dry matter yield was only 27.1 per cent of the yield in full sunlight. Chen and Othman (1983) and Mohamad (1986) found that due to diminishing light penetration, dry matter yield of forages drops from about 5500 kg ha^{-1} $year^{-1}$ to below 1000 kg ha^{-1} $year^{-1}$ when canopies close. The dry fodder yield of a local strain of guinea grass grown in the partial shade of coconut gardens by Pillai (1986) was 6.85 t ha^{-1} $year^{-1}$. He found that there was 8.9 per cent reduction in dry fodder yield in the case of guinea grass (*Panicum maximum*) and 14.9 per cent reduction in the case of setaria grass (*Setaria sphacelata*) when grown under partial shade. Decrease in dry matter yield of grasses was also reported by Schreiner (1987) wherein 25, 50 and 80 per cent shade decreased the dry matter yields by 5, 41 and 78 per cent respectively.

Wilson *et al.* (1990) found a 35 per cent increase in accumulated dry matter of a *Paspalum notatum* pasture under trees compared with that in the open pasture. These findings support earlier work on the performance of grasses using artificial shade (Wong and Wilson, 1980) as well as under trees shade (Cameron *et al.* , 1989). A study undertaken by Wong (1993) involving two tropical grasses

Paspalum malacophyllum and *Paspalum wettsteinii* showed that shade depressed total dry matter production, the depression as expected being proportional to the quantum of photosynthetic active radiation reduction.

2.1.3 Influence of shade on root growth

Light affects root growth indirectly through regulating plant dry matter production and its partitioning between shoot and root. Potted plants of sugarcane when grown under light conditions in a glass house, showed a high quantum of root production. When light was partially cut off through unbleached muslin, the root volume decreased to about 50 per cent. A further reduction in light intensity produced roots which were barely able to support the growth of the plants (Martin and Eckart, 1933). Root and bud growth are usually inhibited by low light intensities and this can lead to a reduction in assimilate flow to the root system (Nelson, 1964). Kawata and Saejima (1978) observed the production of more short unbranched roots by shading. Under subdued light, translocation of carbohydrates from the shoots to the root of rice plant appeared to be much reduced (Mengel and Viro, 1978) because of reduction in photosynthetic rate by 20-35 per cent in the middle and lower leaves (Sato and Kim, 1930). Wang *et al.*, (1981) reported that low light intensity damaged the roots more seriously than other organs in rice. Wong *et al.* (1985) reported that shading reduced leaf, stem, stubble and root yield, particularly in shade-tolerant species. He reported that shading increased shoot/root ratio, particularly in shade-tolerant species. In *Lolium perenne* grass, if light interception by the shoot system is made less effective due to shading, less photosynthate will be available for root growth (Gregory *et al.*, 1987). Wong (1991) reported that leaf, stem, stubble and root production are often reduced at low light in two shade tolerant grasses viz., *Paspalum malacophyllum* and *Paspalum wettsteinii.* He also reported that shading decreases root/shoot ratio in shade tolerant species. In an experiment to study the effect of defoliation, shading and competition on spotted knap weed (*Centaurea maculosa* Lam.) the foliage, root and crown growth increased significantly when plants received full, rather than half light (Kennett *et al.*, 1992). Growth and leaf physiology responses of container grown arkin carambola (*Averrhoea carambola* L.) trees to long term exposure of approximately 25, 50 and 100 per cent sunlight was studied. Trees in full sun had smaller total leaf area, canopy diameter and shoot/root ratio (Marler *et al.*, 1994). 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 44 cm^3 and root/shoot ratio of 0.38 for guinea grass var. Hamil under coconut shade. Jacob (1999) reported that root length of congosignal (*Brachiaria ruziziensis*) was 30.56 cm and root weight was 35.36 g $plant^{-1}$ when grown under coconut shade. Sunilkumar (2000) reported that root weight, root length and root shoot ratio decreased significantly with the advancement of shade level from 0 to 40 per cent in rice.

2.1.4 Influence of shade on biochemical aspects

2.1.4.1 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 increases with increase in shade intensity and the highest value was obtained at 75 per cent shade level is guinea grass (*Panicum 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. Nii and Kurowia (1988) studied the anatomical changes including chloroplast structure in peach leaves under different light intensities and found that chlorophyll content per unit leaf area and per dry weight increase with shading. 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). The chlorophyll concentration of rice leaves increased under shade (Janardhan and Murthy, 1980; Thangaraj and Sivasubramanian, 1990; Voleti *et al.*, 1991; Viji, 1995). George (1996) recorded a chlorophyll content of 2.5 in guinea grass (*Panicum maximum*) grown under coconut shade. According to Evans and Semann (1996) shade leaves have high chlorophyll per chloroplast. Sunil Kumar (2000) reported that total chlorophyll increased significantly with the advancement of shade level from 0 to 40 per cent. Anu (2001) reported a higher total chlorophyll content in rice leaves under partially shaded condition.

2.1.5 Influence of shade on quality aspects

2.1.5.1 Crude Protein Content

Growth and production of leaf biomass increases with increasing light. With increased biomass greater production of protein might be achieved with moderate to high light intensities (Blair, 1969). Myhr and Saebo (1969) observed that in some grass species crude protein contents were approximately doubled by shading. An increase in crude protein content was recorded with increasing levels of shade in guinea grass var. Mackuenii (Mullakoya, 1982). The crude protein content levels during spring season were highest due to rapid growth and more succulent tissues in three southern deer browses. As the leaves matured during summer, the levels of crude protein content declined significantly (Blair *et al.*, 1983). Crude protein content was greater in guinea grass (*Panicum maximum*) grown under 45 per cent shade than that grown under open (Pillai, 1986). Kephart and Buxton (1993) found that crude protein content concentration is much more responsive to shading than other quality characteristics. They found that 63 per cent shade increased crude protein concentration by 26 per cent in forage grasses like reed 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 (*Panicum maximum*) grown under partially shaded condition. Forages grown under shaded conditions usually has higher crude protein concentrations than unshaded forage (Buxton, 2001).

2.1.5.2 Crude fibre content

The fibre content varies since nutritive availability of the cell wall fraction varies among forages (Soest, 1967). Myhr and Saebo (1969) observed a reduction in crude fibre content in some grass species due to shading from 10 to 15 per cent of natural light. Ewen and Dietz (1965), Halls and Epps (1969) and Wolters found that crude fibre was higher in shaded vegetation than in open grown forage. However, in contrast Vallentine and Young (1959) and Wolters (1974) reported that crude fibre is lower in shaded herbaceous plants. Short and Regor (1970) and Short *et al.* (1974) found that shade favoured the production of fibre fractions in leaf tissues and it is widely recognized that fibrous cell-wall constituents limit the metabolic usefulness of forages. Mullakoya (1982) reported that crude fibre content was highest under full sunlight in guinea grass (*Panicum maximum*). Blair *et al.* (1983) found that leaves of three common palatable southern deer browses (flowering dog wood, yaupon, Japanese honey suckle) grown under shade have higher crude fibre content than those grown on full sunlight. According to them, relatively high fibre content associated with leaves grown in shade especially those in heavy shade might substantially reduce digestability, or metabolic availability of the relatively high protein, phosphorus and calcium fractions that appear to be prevelant in these tissues. Pillai (1986) found that guinea grass (*Panicum maximum* and Setaria grass (*Setaria sphacelata*) grown under coconut shade have less fibre content than in open. George (1996) recorded a crude fibre content of 31.9 per cent for guinea grass (*Panicum maximum*) grown under partially shaded situation.

2.1.6 Influence of shade on nutrient uptake

2.1.6.1 Nitrogen uptake

According to Wong and Wilson (1980) nitrogen accumulation in all the plant components of green panic was markedly improved by shading. Forage nitrogen content increased with decreasing light intensity from 1.0 to 1.6 and from 1.2 to 1.9 per cent without and with nitrogen respectively (Erikson and Whitney, 1981). Watson *et al.* (1984) found that the total nitrogen content in marshall rye grass (*Lolium multiflorum*) grown under shade increased when compared to that grown in full sunlight. The total nitrogen content under full sunlight was 0.8 per cent. Whereas it was 1.1 per cent each under 50 per cent and 75 per cent shade. According to Pillai (1986) nitrogen uptake in guinea grass (*Panicum maximum*) was more in open than under shaded condition. Schreiner (1987) reported that the concentration of nitrogen in grasses increased with increased shading. Wilson *et al.* (1990) found an increase in the proportion of nitrogen content of a *Paspalum notatum* pasture under the trees. These findings support earlier work using artificial shade (Wong and Wilson, 1980) as well as trees shade (Cameron *et al.*, 1989). Shading usually increase nitrogen concentration substantially, especially in leaves (Kephart and Buxton, 1996). George (1996) recorded a nitrogen uptake of 139 kg ha^{-1} $year^{-1}$ in guinea grass (*Panicum maximum*) under partially shaded situation. Jacob (1999) recorded a nitrogen uptake of 34.5 kg ha^{-1} in congosignal grass (*Brachiaria ruziziensis*) when grown under coconut shade.

2.1.6.2 Phosphorus uptake

Cook and Harris (1950); Vallentine and Young (1959) reported that phosphorus was higher in shade in some forages like flowering dogwood, yaupon and Japanese honey suckle. Hall and Epps (1969) found that leaves of forages beneath a forest canopy were lower in phosphorus but higher in calcium than in the open. Growth and production of leaf biomass increases with increasing light in forages. With increased biomass greater production of phosphorus might conceivably be achieved with moderate to high light intensities (Blair, 1969). Myhr and Saebo (1969) observed that in some grass species, phosphorus was increased under shade. Ewen and Dietz (1965) and Wolters (1973 and 1974) reported that phosphorus level was higher in shaded forages. Mayland and Grunes (1974) concluded that there was no difference in the phosphorus content of grasses between open and shaded sites. Phosphorus contents tended to be higher under shade and higher with applied nitrogen except of phosphorus (Erikson and Whitney, 1981). According to Mullakoya (1982) there was no significant difference in the phosphorus uptake in guinea grass (*Panicum maximum*) due to varying intensities of shade. Blair *et al.* (1983) found that leaves of three common palatable southern deer browses (flowering dogwood, yaupon and Japanese honey suckle) grown under shade have higher phosphorus content throughout the year especially in deep shaded leaves, but showed little difference in content between moderate shade or full sunlight. Watson *et al.* (1984) found that the phosphorus content in marshall rye grass (*Lolium multiflorum*) grown under shade increased as the shade intensity increased. The phosphorus content was 0.16 per cent under full sunlight whereas it was 0.25 per cent and 0.27 per cent under 50 per cent and 75 per cent shade respectively. Pillai (1986) has reported that phosphorus level in two forages viz. guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) grown under coconut shade were little higher than in open. George (1996) recorded a phosphorus uptake of 24.4 kg ha^{-1} yr^{-1} in guinea grass (*Panicum maximum*) var. Hamil when grown under coconut shade. Jacob (1999) recorded a phosphorus uptake of 4.76 kg ha^{-1} in congosignal grass (*Brachiaria ruziziensis*) when grown under coconut shade.

2.1.6.3 Potassium uptake

Cunningham and Lamb (1959) in bermuda grass (*Cynodon dactylon*) under shaded condition found 88.5 per cent increase in potassium content when compared to 45.5 per cent under unshaded condition. Myhr and Sacbo (1969) observed that in some grass species, potassium contents were approximately doubled under shade. Potassium contents tended to be higher under shade and higher with applied nitrogen except of phosphorus (Erikson and Whitney, 1981). The fodder potassium content increased with shade intensity and the maximum value was noted under 75 per cent shade level in guinea grass (*Panicum maximum*) (Mullakoya, 1982). Watson *et al.* (1984) has found that the potassium content in grass and legume species were increased significantly under shade than in full sunlight. He also found that the potassium content in marshall ryegrass (*Lolium 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) has found that under shaded conditions, the requirements of potassium was more in guinea grass (*Panicum 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 a *Paspalum notatum* pasture under trees compared with that in the open pasture. These findings support earlier work using artificial shade (Wong and Wilson, 1980) as well as trees shade (Cameron *et al.*, 1989). Meerabai *et al.* (1993) obtained maximum yield at potassium 90 kg ha^{-1} for guinea grass (*Panicum maximum*) and congosignal grass (*Brachiaria ruziziensis*) grown in coconut gardens. George (1996) reported that the potassium uptake was 131 kg ha^{-1} for guinea grass (*Panicum maximum*) grown under partially shaded conditions. Jacob (1999) recorded a potassium uptake of 28.4 kg ha^{-1} for congosignal grass (*Brachiaria ruziziensis*) when grown under coconut shade.

2.1.7 Influence of shade on NPK status of soil

Mullakoya (1982) reported that in guinea grass there was no significant influence of shade levels on available nitrogen in soil. According to him maximum soil phosphorus content was noted under 75 per cent shade intensity and minimum value for full sunlight. But shade levels had no significant influence in the available soil potassium content. In coconut garden the nitrogen content of soil was found to be higher than in the open area when two forage grasses were grown (Pillai, 1986). The phosphorus content in coconut garden soils was also found to be more than in the open area. But the potassium content in coconut garden soils was lesser than in the open area which is attributed to the luxury consumption of potassium by grasses in shade. George (1996) when working on 'Agronomic evaluation of biofarming techniques for forage production in coconut gardens' reported that the NPK content of the soil under partially shaded situation was found to be 193%, 27% and 64% respectively. Jacob (1999) reported that available NPK content of the soil under partially shaded condition was found to be 207%, 51% and 99% respectively.

2.2 EFFECTS OF POTASSIUM ON GROWTH AND YIELD OF FODDER CROPS

2.2.1 Effects of potassium on growth characters

Potassium is absorbed by forage grasses in large amounts than any other mineral element except N and in some cases, calcium. Potassium is required in plants as a catalyst and plays an essential role in the metabolic processes of plants and is required in adequate amounts in several enzymatic reactions. These are the energy carriers in the metabolic processes of both plants and animals. Potassium is also an essential key in the carbohydrate metabolism, a process by which energy is obtained from sugar. This is very important in forage grass survivability. This is the process by which carbohydrates are stored in the root system during the dormant months 95 an energy reserve. Application of potassium to the plants in absence of adequate K will counteract the ill effects of too much nitrogen, increase rate of photosynthesis, improve overall yield potential and quality, and have a balancing effect on both N and P (Phillips and Kee, 1998).

2.2.1.1 Height of grass

According to Mullakoya (1982) application of potash had shown linear increase in the plant height in guinea grass (*Panicum maximum*). In a field study with hybrid napier involving four levels of nitrogen (250, 500, 750 and 1000 kg ha^{-1} yr^{-1}), 2 levels of potassium (150 and 300 kg ha^{-1} yr^{-1}) and one level of phosphorus (200 kg ha^{-1} yr^{-1}), potassium levels did not show any significant influence on plant height (Yeh, 1988). Sakeena and Salam (1989) reported that there was considerable improvement in plant height with potassium application upto 35 kg ha^{-1} in rice. A similar trend was observed in dwarf napier grass also when varying levels of nitrogen and potassium were tested along with a fixed level of phosphorus (Hong and Hsu, 1993). Significant increase in plant height of rice was noted with potassium level of 60 kg ha^{-1} over 45 kg ha^{-1} at maximum tillering and harvest stages (Babu, 1996). Sonia (1999) found that application of potassium at 150 kg ha^{-1} significantly increased the plant height of signal grass (*Brachiaria decumbens*) at fourth harvest. Plant height in rice was significantly increased by the application of potassium at 60 and 90 kg K_2O ha^{-1} over absolute control (Singh *et al.*, 2000).

2.2.1.2 Number of tillers

Tillering capability is generally genetically controlled but is also much dependent on the nutrition and environmental factors. Among various plant hormones, cytokinins have been known to play important role in the growth of buds and tillers (Bruins, 1979). Therefore better K nutrition in fertilized plots resulted in significant increase in the number of tillers. According to Mullakoya (1982) maximum number of tillers were recorded with 100 kg K_2O ha^{-1} and minimum with 25 kg K_2O ha^{-1} in guinea grass (*Panicum maximum*). Linbao (1985) also reported similar effect of potassium on tillering in rice. Munegowda *et al.* (1987) observed that the number of leaves and nodes of hybrid napier grass (*Pennisetum typhoides*) var. NB-21 increased with increase in fertility levels upto 180:120:80 kg NPK ha^{-1}. According to Chand and Rao (1996) application of 75 kg K_2O ha^{-1} increased the number of tillers in lemongrass (*Cymbopogon flexuosus*). Sonia (1999) reported that potassium levels, cutting management as well as interaction effects were non-significant in tiller production in signal grass (*Brachiaria decumbens*).

2.2.1.3 Leaf/stem ratio

Leaf/stem ratio is an important parameter is fodder quality which inturn has a direct influence on palatability of fodder. The more the leafy portion, the more will be the acceptibility by cattle. Eventhough basically it is a genetic factor, it can be effectively managed by agronomic practices.

According to Mullakoya (1982) leaf/stem ratio is not influenced by potash levels in guineagrass (*Panicum maximum*). Yeh (1988) reported that potash rates had no effect on the leaf/stem ratio in hybrid napier. Yadav and Sharma (1989) opined that potassium rates did not influence the leaf/stem ratio of dinanath grass (*Pennisetum pedicellatum*). Williams and Hanna (1995) found a negative correlation between leaf/stem ratio and potash levels in elephant grass (*Pennisetum purpureum*). Sonia (1999) noticed that there was no marked difference between lower and higher levels of nitrogen and potassium with regard to leaf/stem ratio in signal grass (*Brachiaria decumbens*).

2.2.1.4 Leaf Area Index

According to Mullakoya (1982) maximum leaf area was noticed with 100 kg K_2O ha^{-1} and minimum with 25 kg K_2O ha^{-1} in guineagrass (*Panicum maximum*). According to Sonia (1999) potassium had a notable effect on LAI in the second harvest in signal grass (*Brachiaria decumbens*) and the highest dose of potassium (150 kg ha^{-1}) recorded higher LAI.

2.2.2 Effect of potassium yield and yield attributes

2.2.2.1 Green fodder yield

The yield of fodder maize was increased with increasing levels of exchangeable potassium in the soil (Mengel and Brauschwieg, 1972). But Smith (1979) working on Switch grass ((*Panicum virgatum*) reported that the vegetative growth was favoured by nitrogen fertilization, but not by potassium. Mullakoya (1982) obtained maximum green fodder yield for the highest level of potash in guinea grass (*Panicum maximum*). Krishnamoorthy *et al.* (1987) observed that a dose of 180-120-80 kg N-P_2O_5-K_2O ha^{-1} was found to be optimum for maximum fresh fodder yield of hybrid napier. In congosignal (*Brachiaria ruziziensis*) green fodder yield increased upto a fertilizer level of 90 kg K_2O ha^{-1}, was reported by Meerabai *et al.* (1993) in the red loam soils of Vellayani. Thakuria (1993) noticed no significant effect on green fodder yield of teosinte (*Euchlaena mexicana*) by potassium application. According to Yadav *et al.* (1993) good yield response to potassium was noted by the application of 60 kg K_2O ha^{-1} in cereals. Turf density and growth were increased as the rate of potassium application increased upto 350 kg K_2O ha^{-1} in perennial rye grass (*Lolium multiflorum*). A reduction in growth and potassium content was noted at higher potassium application rates (Razmjoo and Kaneko, 1993). Application of increasing levels of potash increased fodder yields of sorghum (Akolkar and Sonar, 1994). Application of potassium significantly increased green fodder yield of *Andropogon gayanus* (Tening *et al.*, 1995). According to Efimov *et al.* (1996) application of potassic fertilizers at rates of 90, 120 and 180 kg ha^{-1} increases the grass yield of rye grass by 69, 92 and 121 per cent respectively. The further increase of the potassium rate to 240 kg ha^{-1} gives no significant yield gain and results in excessive accumulation of K in the grass. According to the reports of Vasanthi *et al.* (1998) 10 t ha^{-1} of organic manure along with the recommended doses of N, P and K were necessary to attain maximum herbage yield from fodder maize, sorghum and pearlmillet. Phillips and Kee (1998) reported that potassium fertilization increased the green forage yield in hybrid Bermuda grass (*Cynodon dactylon*). According to Sonia (1999) a significant response of green fodder yield to potassium application was noticed in the second harvest in signal grass (*Brachiaria decumbens*). The green fodder yield increased as the harvests progressed. Jokela *et al.* (1999) reported that potassium fertilization gave significant yield increases in alfalfa and in some forage grasses.

2.2.2.2 Dry fodder yield

Arnold (1978) found that the highest dry matter yield was obtained in the medium potassium treatment in the fodder. According to Mullakoya (1982) potash levels did not have any significant influence in improving drymatter yield of guinea grass (*Panicum maximum*). Combined application of nitrogen, phosphorus and potassic fertilizers were found to increase the dry forage yield in *Bracharia decumbens* (Cautaruth *et al.*, 1985). Potassium application markedly increased the yield of fodder crops and enhanced K uptake and concentration (Tiwari and Nigam, 1985). Fernandes *et al.* (1985) observed an increase in dry matter yield of *Brachiaria decumbens* with increased levels of nitrogen in the presence of potassium. Vallejos (1986) revealed that there was significant effect of N x K interactions on drymatter production but phosphorus or potassium alone had no effect in increasing the dry matter yields of *Brachiaria decumbens*. Increasing rates of K_2O increased rye grass (*Lolium multiflorum*) dry matter production (Haby *et al.*, 1988). Satjipanon *et al.* (1989) reported that in congosignal grass (*Brachiaria ruziziensis*) maximum dry matter yield was obtained at application of 12 + 24 + 12 kg N + P + K ha^{-1}.

Berroteran (1989) working on dry matter production in gamba grass (*Andropogon gayanus*) reported that gamba grass did not respond to K application. Thakuria (1993) reported that application of potash did not give any significant response to dry fodder yield of teosinte (*Euchlaena mexicana*).

Meerabai *et al.* (1993) obtained maximum response for dry fodder yield for potassium upto 90 kg ha^{-1} for guinea grass (*Panicum maximum*) and congosignal grass (*Brachiaria ruziziensis*). According to Prakash *et al.* (1994) potassium application could not produce any significant response in dry matter yield in rhodes grass (*Chloris guayana*). The total dry herbage yield increased significantly with the application of 75 kg K_2O ha^{-1} in lemon grass (Chand and Rao, 1996). The dry fodder yield of berseem and sudan grass (*Sorghum vulgare* var. *sudanensis*) increased significantly upto 150 kg K_2O ha^{-1} application in the first cutting. In the subsequent harvests, dry matter yield of berseem increased upto 150 kg K_2O ha^{-1} whereas in sudan grass the increase was only upto 75 kg K_2O ha^{-1} (Rao *et al.*, 1999). Potassium had no significant influence in dry fodder yield in signal grass (Sonia, 1999).

2.2.3 Influence of potassium root characters

Weller (1928) showed that application of N, P and K resulted in an increased root growth in sugarcane. Potassium helps in root development and enhances the growth of rice plants (Vijayan and Sreedharan, 1972). The response of forage grasses to K fertilization is less. Potassium improves stand persistence due to a stronger root system (Keisling, 1978). He also reported that potassium aids in the building of root reserves for the production of growth of new shoots.

This large capacity for K absorption is certainly true for grasses. Among the fertilizers used for rice, Nitrogen was the most effective in increasing rooting activity, whereas potassium and phosphorus were less effective (Meerabai *et al.*, 1993).

2.2.4 Effect of potassium on biochemical aspects

2.2.4.1 Chlorophyll content

Thomson and Wier (1962) reported on the importance of potash in plastid development and it is presumed that high doses of potash application resulted in enhanced chlorophyll synthesis. Effect of potassium on the chlorophyll content and photosynthetic activity has been reported earlier (Ozbun *et al.*, 1965). Ray and Choudhary (1980) after detailed study concluded that the application of potassium increased the chlorophyll content in rice. According to Mullakoya (1982) application of different doses of potash had not shown any significant influence in improving the chlorophyll content of guinea grass (*Panicum maximum*). Increased potassium supply increased the leaf area and chlorophyll content of wheat leaves (Beringer, 1983). The increased chlorophyll synthesis at higher levels of nitrogen and potassium was reported by Sheela (1993) in rice. Anu (2001) reported that highest chlorophyll content was registered by 45 kg K_2O ha^{-1} in rice.

2.2.5 Effect of potassium on quality aspects

2.2.5.1 Crude protein

Potassium is involved in the formation of protein through the polymerization of amino acids and other primary units in plants (Webster and Varner, 1954). Higher level of potassium in the soil results in a consequent reduction in crude protein synthesis (Raheja, 1966). According to Chavan and Magar (1971) application of 40 kg K_2O ha^{-1} increased the protein content.

Bhuiya *et al.* (1979) working on rice reported that potassium had no significant effect on crude protein content. According to Mullakoya (1982) potash levels had no positive influence in improving the crude protein content of guinea grass (*Panicum maximum*). In teosinte (*Euchlaena mexicana*) potassium application @ 40 kg ha^{-1} were found to increase the crude protein content (Thakuria, 1993). Andrade *et al.* (1996) reported that the effect of potassium on crude protein content of *Brachiaria ruziziensis* was non significant. Jacob (1999) reported that K fertilizer had little effect on the crude protein content in congosignal grass (*Brachiaria ruziziensis*). Sonia (1999) observed an inverse relationship between levels of applied potassium and nitrogen content of signal grass (*Brachiaria decumbens*). Higher levels of applied potassium reduced the protein content of fodder.

2.2.5.2 Crude fibre

According to Mullakoya (1982) potash levels had no positive influence in improving the crude fibre content of guinea grass (*Panicum maximum*). Vineetha (1995) reported that crude fibre content was significantly reduced by nitrogen, phosphorus and potassium application in gamba grass (*Andropogon gayanus*). NxK interaction effects significantly influenced the crude fibre content in signal grass (*Brachiaria decumbens*) wherein the same dose of nitrogen combined with the three different levels of potassium resulted in increased crude fibre content with increase in potassium levels (Sonia, 1999). Crude fibre content of the congosingal grass (*Brachiaria ruziziensis*) remained almost unaltered by fertilizer application (Jacob, 1999).

2.2.6 Effect of potassium on nutrient uptake

2.2.6.1 Uptake of Nitrogen

Highest uptake values of nitrogen were recorded in two split doses of potassium in maize (Chattaraj *et al.*, 1985). Potassium application significantly influenced the uptake of nitrogen in maize (Yadav *et al.*, 1993). According to Patel *et al.* (1994) application of potassium significantly increased the uptake of nitrogen in fodder jowar. Sonia (1999) reported that higher levels of applied potassium reduced the nitrogen content of fodder in signal grass (*Brachiaria decumbens*). Jacob (1999) reported that potassium @ 50 kg ha^{-1} increased the uptake of nitrogen in congosignal grass (*Brachiaria ruziziensis*).

2.2.6.2 Uptake of phosphorus

Rathore and Vijayakumar (1978) obtained an increased uptake of phosphorus by increased levels of potassium in sorghum (*Sorghum bicolor*) and dinanath grass (*Pennisetum pedicellatum*). According to Mullakoya (1982) potassium levels had no significant influence on phosphorus content of guinea grass (*Panicum maximum*). In a two-row barley (*Hordeum vulgare*) potassium application failed to show any significant contribution in phosphorus uptake in straw (Misra *et al.*, 1982). Highest uptake values of phosphorus were recorded in two split doses of potassium in maize (Chattaraj *et al.*, 1985). Fernandes *et al.* (1985) noticed a decrease in phosphorus concentration in plants with increase in nitrogen levels in presence of potassium in signal grass (*Brachiaria decumbens*). Potassium application significantly influenced the uptake of phosphorus by maize. The maximum uptake of phosphorus was recorded at 30 ppm K (Yadav *et al.*, 1993). According to Patel *et al.* (1994) the addition of potassium significantly increased the uptake of phosphorus in fodder jowar. According to Andrade *et al.* (1996) forage phosphorus concentration was decreased by potassium application. Sonia (1999) reported that the phosphorus content of signal grass (*Brachiaria decumbens*) was not significantly different at various levels of potassium. Jacob (1999) reported that potassium @ 50 kg ha^{-1} increased the uptake of phosphorus by congosignal grass (*Brachiaria ruziziensis*).

2.2.6.3 Uptake of Potassium

Johnkutty (1981) working on ragi (*Eleusine coranana*) reported that the potassium content of straw in ragi was influenced by application of potash significantly. In a two-row barley (*Hordeum vulgare*) potassium application failed to show any significant contribution in potassium uptake in straw (Misra *et al.*, 1982). According to Mullakoya (1982) potassium application significantly increased the potassium content in guinea grass (*Panicum maximum*). Tiwari and Nigam (1985) investigated the response of important fodder crops to potassic fertilizers and reported that potassium application markedly enhanced potassium uptake and concentration. The total uptake of potassium was considerably enhanced with full dose in sorghum (Chattaraj *et al.*, 1985). Application of high levels of potassium caused an increase in potassium content in rye-grass (*Lolium multiflorum*), reported by Haby *et al.* (1988). Dampney (1992) observed that potash application increased the herbage potassium concentration. Similar observation was recorded by Hong and Hsu (1993) in dwarf napier grass. Application of increasing levels of potash increased the potassium uptake by fodder sorghum (Akolkar and Sonar, 1994). According to Patel *et al.* (1994) addition of potassium significantly increased the uptake of potassium in fodder jowar. Uptake of potassium was significantly increased by the higher levels of nitrogen in Gamba grass (*Andropogon gayanus*), while phosphorus and potassium did not have a significant influence (Vineetha, 1995). Forage crops generally require large quantities of potassium. Some of the tropical grasses on an average remove 25 kg N, P and K from soil for each tonne of dry forage production, of which more than 50 per cent is potassium alone (Patra, 1995). Rao *et al.* (1999) reported that the total potassium uptake by sudan grass (*Sorghum vulgare* var. *sudanensis*) in the two harvests varied from 21.93 to 34.57 kg ha^{-1}. Sonia (1999) reported that increase in potassium levels from 50 to 100 kg ha^{-1} significantly increased the potassium content of signal grass (*Brachiaria decumbens*). According to Jacob (1999) potassium @ 50 kg ha^{-1} increased the uptake of potassium by congosignal grass (*Brachiaria ruziziensis*).

2.2.7 Influence of potassium on soil N, P, K status

According to Mullakoya (1982), in guinea grass (*Panicum maximum*) potash levels had no significant influence on nitrogen and phosphorus content of soil. An increase in soil potash was noticed with every incremental dose of applied potash. Soil application of potassium resulted in 4 to 24 kg ha^{-1} increase in available potassium over the initial level in maize plots. But no significant influence on potassium treatment on available nitrogen and phosphorus levles in soil was seen (Chattaraj *et al.*, 1985). Geethakumari (1989) working on nutrient management for maize-fodder cowpea intercropping in rice fallows reported that the highest level of applied potassium recorded highest value for available nitrogen in the soil after the experiment. Available nitrogen in the soil decreased with the increasing levels of potassium upto 60 ppm, beyond which there was no significant effect in maize plots. Effect of potassium application on available soil phosphorus was inconsistent (Yadav *et al.*, 1993). Vineetha (1995) working on gamba grass (*Andropogon gayanus*) reported that increase in nitrogen and potassium fertilizer levels increased the potassium status of the soil. Sonia (1999) based on the studies on signal grass (*Brachiaria decumbens*) reported that potassium levels did not have any significant effect on available nitrogen status of the soil. Potassium application @ 100 kg ha^{-1} however increased the available phosphorus status of the soil. The available potassium status of the soil was improved by potassium application to a significant extent.

2.3.1 Varietal influence on growth characters of guinea grass

2.3.1.1 Plant height

Humphreys (1978) reported that guinea grass cv. colonia had a plant height of 3.5 m whereas queensland grows upto 2m height and gatton grows upto 1.7 m height. Mullakoya (1982) reported that guinea grass cv Mackuenii recorded a plant height of 1.43 m. According to Chatterjee and Das (1989) sabi and green panic varieties of guinea grass grow upto a height of 1.5 m. They reported that the plant height of another variety punjab guinea grass was 1.9 m. Babu (1996) reported that plant height of guinea grass cv. Haritha was 109.6 cm whereas Hamil gave a height of 110 cm (George, 1996). In an initial varietal trial conducted with PGG varieties of guinea grass showed that plant height of PGG-310, PGG-511, PGG-519, PGG-598, PGG-600, PGG-9 and PGG-14 were 14.9 cm, 135 cm, 145.4 cm, 132.3 cm, 150.4 cm, 122.6 cm and 132.4 cm respectively (KAU, 1995). In the advanced trial with PGG varieties, the plant height of PGG-101, PGG-489, PGG-518, PGG-552, PGG-570 and PGG-14 were 152.3 cm, 153 cm, 146.2 cm, 138 cm, 145 cm and 130.7 cm respectively (KAU, 1995). In the varietal trials with JHGG varieties of guinea grass showed that the plant height of JHGG 96-1, JHGG 96-2, JHGG 96-3 and JHGG 96-4 were 144.7 cm, 158.3 cm, 159 cm and 151.7 cm respectively (KAU, 1995). Fazlullahkhan *et al.* (2000) reported that Co-2 variety of guinea grass released by TNAU gave a height of 275 cm.

2.3.1.2 Number of tillers

Mullakoya (1982) reported that Mackuenii variety of guinea grass produced 17.9 tillers per plant. A tiller number of 40 was produced by the variety Punjab guinea grass 1 (Chatterjee and Das, 1989). Babu (1996) reported that guinea grass cv. Haritha gave a tiller number of 16 per hill. George (1996) reported that Haritha produced a tiller number of 12. Fazlullakhan *et al.* (2000) reported that Co-2 variety of guinea grass released by TNAU produced 80-100 tiller numbers per plant.

2.3.1.3 L:S Ratio

Mullakoya (1982) got a leaf/stem ratio of 2.14 in a guinea grass cv. Mackuenii. Babu (1996) reported that Haritha variety gave a leaf/stem ratio of 1.94. In an initial varietal trial conducted with PGG varieties of guinea grass showed that leaf/stem ratios of PGG-9, PGG-14, PGG-101, PGG-202, PGG-205, PGG-297, PGGG-489, PGG-518, PGG-552 and PGG-570 were 0.85, 0.81, 1.27, 3.07, 2.43, 1.09, 1.89, 1.89, 1.65, 1.56 and 1.43 respectively (KAU, 1995). In the varietal trials with JHGG varieties of guinea grass showed that JHGG 96-1, JHGG 96-2, JGHH 96-3 and JHGG 96-4 gave leaf/stem ratios of 0.88, 0.88, 1.03 and 1.00 respectively (KAU, 1995). Fazlullakhan *et al.* (2000) reported that Co-1 variety of guinea grass released by TNAU gave a leaf/stem ratio of 0.77.

2.3.1.4 Leaf Area Index (LAI)

Mullakoya (1982) reported that in Mackuenii the leaf area was found to be 107 cm^2. A leaf area index of 4.4 was observed in Haritha variety of guinea grass (Babu, 1996). According to George (1996) Hamil gave a leaf area index of 4.6.

2.3.2 Yield characters

2.3.2.1 Green Fodder Yield

Mullakoya (1982) reported that Mackuenii variety of guinea grass gave a green fodder yield of 109 t ha^{-1} yr^{-1}. According to Chatterjee and Das (1989) punjab guinea grass 1 gave a green fodder yield of 1075 q ha^{-1}. Babu (1996) reported that Haritha variety of guinea grass produced a green fodder yield of 23.6 t ha^{-1}. The green fodder yield of Hamil was found to be 27 t ha^{-1} (George, 1996). In an advanced varietal trial with PGG varieties of guinea grass showed that the green fodder yield of PGG-101, PGG-297, PGG-489, PGG-518, PGG-552, PGG-570, PGG-9 and PGG-14 were 19.3 t ha^{-1}, 17.7 t ha^{-1}, 16.8 t ha^{-1}, 13.7 t ha^{-1}, 13 t ha^{-1}, 12.3 t ha^{-1}, 8 t ha^{-1} and 13 t ha^{-1} respectively (KAU, 1995). In a varietal trial with JHGG varieties of guinea grass, the green fodder yield of JHGG 96-1, JHGG 96-2, JHGG 96-3 and JHGG 96-4 were 65.7 kg per 12 m^2, 70 kg per 12 m^2, 80 kg per 12 m^2 and 35 kg per 12m^2 respectively (KAU, 1995). Bryalian guine gave a green fodder yield of 32 t ha^{-1} and HGP2-M3 gave a green fodder yield of 24 t ha^{-1} (KAU, 1995). Fazlullakhan *et al.* (2000) reported that Co-1 variety of guinea grass released by TNAU gave a green fodder yield of 200 t ha^{-1} yr^{-1} and Co-2 variety gave a green fodder yield of 270 t ha^{-1} yr^{-1}.

2.3.2.2 Dry fodder yield

Mullakoya (1982) reported that Mackuenii gave a dry fodder yield of 27.9 t ha^{-1} yr^{-1}. A dry fodder yield of 5.14 t ha^{-1} was obtained from a guinea grass cv. embu (Chatterjee and Das, 1989). In an initial varietal trial conducted with PGG varieties showed that the dry fodder yield of PGG-101, PGG-297, PGG-489, PGG-518, PGG-552 and PGG-9 were 6.8 t ha^{-1}, 5.9 t ha^{-1}, 4.8 t ha^{-1}, 4.6 t ha^{-1} and 2.7 t ha^{-1} respectively (KAU, 1995). In another varietal trial conducted with JHGG varieties showed that the dry fodder yield of JHGG 96-4, JHGG 96-3, JHGG 96-2 and JHGG 96-1 were 24.2 kg per 12 m^2 plot, 23 kg per 12m^2 plot, 20 kg per 12 m^2 plot and 19.7 kg per 12m^2 plot respectively (KAU, 1995). Babu (1996) noticed that Haritha gave a dry fodder yield of 8.07 tha^{-1}. George (1996) reported that the dry fodder yield of Hamil was 8.92 tha^{-1}. Fazlullakhan *et al.* (2000) reported that Co-1 variety of guinea grass released by TNAU gave a dry fodder yield of 20.5 t ha^{-1} yr^{-1}.

2.3.3 Quality aspects

2.3.3.1 Crude Protein Content

The crude protein content of guinea grass cv. Mackuenii was found to be 7.54 per cent (Mullakoya, 1982). In Haritha, the crude protein content was observed as 9.17 per cent (Babu, 1996). George (1996) reported that crude protein content of Hamil was found to be 9.02 per cent. According to Fazlullakhan *et al.* (2000), the crude protein content of Co-1 and Co-2 were 8.1 per cent and 8.5 per cent respectively.

2.3.3.2 Crude fibre

The crude fibre content of Mackuenii was found to be 33.6 per cent (Mullakoya, 1982). Babu (1996) reported that Haritha has a crude fibre content of 29.69 per cent. The crude fibre content of Hamil is 32.4 per cent (George, 1996). The crude fibre content of Co-1 and Co-2 were 26.6 per cent and 26.3 per cent respectively (Fazlullakhan *et al.* , 2000).

2.3.4 Uptake studies

According to Mullakoya (1982) potassium content of Mackuenii was found to be 0.87 per cent and phosphorus content was 0.21 per cent. George (1996) reported that phosphorus and potassium content in Hamil was 0.24 per cent and 1.32 per cent respectively. In Hamil, nitrogen uptake was found to be 90.4 t ha^{-1} yr^{-1}, phosphorus uptake was 15.9 t ha^{-1} yr^{-1} and potassium uptake was 85.16 t ha^{-1} yr^{-1}.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was undertaken to study the shade response of guinea grass varieties and to assess the optimum potash requirement for maximum fodder yield and quality under different shade intensities and also to workout the economics of grass cultivation. 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, Trivandrum. The farm is located at 8.5°N latitude and 76.9°E longitude at an altitude of 29 m above mean sea level.

3.1.1 Climate and season

Wet tropical climate prevailed in the experimental location. The experiment was started in the month of May 2001 and continued up to May 2002. The data on meteorological parameters viz., minimum and maximum temperature, relative humidity, evaporation and rainfall during the crop period are furnished in Appendix I and presented graphically in Fig. 3.1.

3.1.2 Soil

The soil of the experimental site was red sandy clay loam (oxisol, Vellayani Series).

Prior to the conduct of the experiment, composite soil samples were drawn from 0-15 cm depth and analysed for physico-chemical properties. The data obtained is given in Table 3.1. The soil was low in available N and K and medium in available P, with an acidic pH.

Table 3.1. Soil physico-chemical properties of the experimental site

Particulars	Mean value	Method used
I. Physical properties		
1. Mechanical composition		
Coarse sand (per cent)	16.70	
Fine sand (per cent)	31.30	Bouyoucos Hydrometer method
Silt (per cent)	25.50	(Bouyoucos, 1962)
Clay (per cent)	26.50	
2. Bulk density (gcc^{-1})	1.375	Gupta and Dakshinamoorthi (1980)
3. Water holding capacity (per cent)	21.50	Gupta and Dakshinamoorthi (1980)
4. Porosity (per cent)	32.00	Gupta and Dakshinamoorthi (1980)
II. Chemical properties		
1. Soil reaction (pH)	5.1	Direct reading with pH meter in 1:2.5 soil suspension (Gupta and Dakshinamoorthi, 1980)
2. Organic carbon (per cent)	0.43	Walkely and Black's method (Jackson, 1958)
3. Available Nitrogen ($kg\ ha^{-1}$)	193	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
4. Available P_2O_5 ($kg\ ha^{-1}$)	47.3	Bray's colorimetric method (Jackson, 1958)
5. Available K_2O ($kg\ ha^{-1}$)	94.8	Flame photometric method (Jackson, 1958)

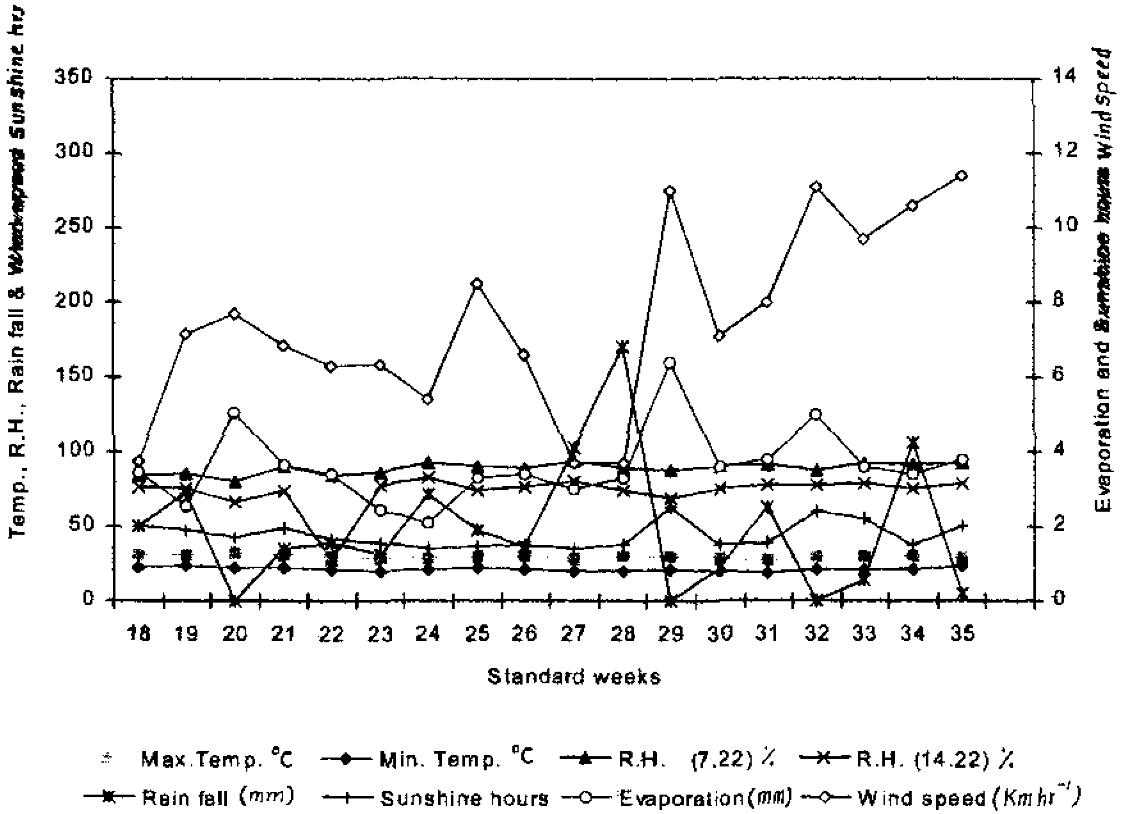

Fig. 1.a. Weather parameters during the crop period (April 30th 2001 to September 2nd, 2001)

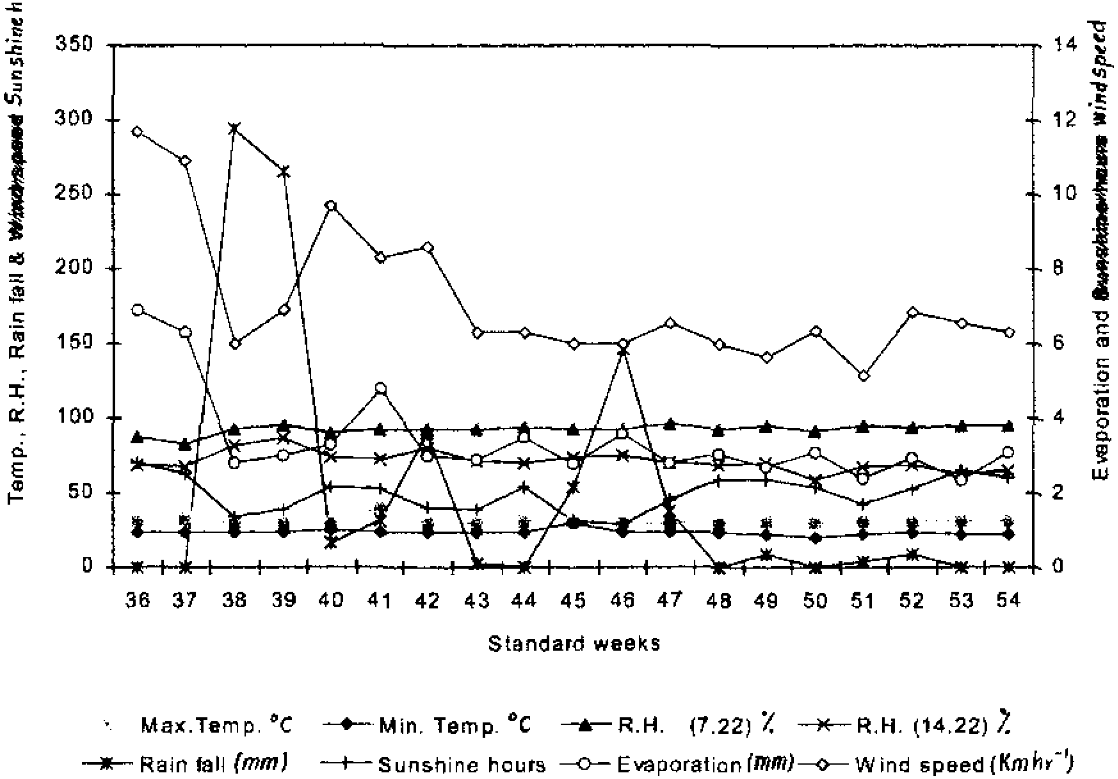

Fig. 1.b. Weather parameters during the crop period (September 3rd 2001 to January13 th, 2002)

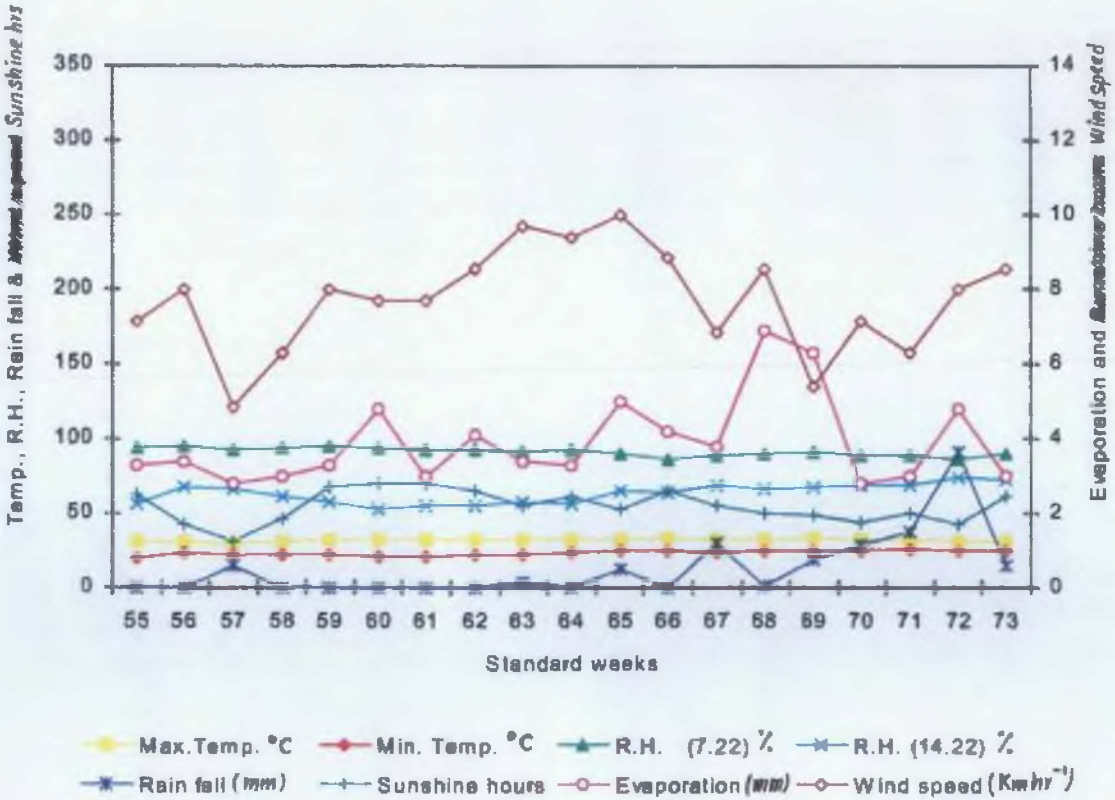

Fig. 1.c. Weather parameters during the crop period (January 14th 2002 to May 26th, 2002)

3.2 EXPERIMENTAL PROCEDURE

3.2.1 Layout and design

Test crop	:	*Panicum maximum* J.
Experimental design	:	Split-split plot
Replications	:	3
Spacing	:	40 x 20 cm

Plot size

Gross plot size	:	3 x 2.8 m
Net plot size	:	1.6 x 1.2 m
Total number of plots	:	54

Two rows of plants on all the sides of each plot were left as border crops.

3.2.2 Treatments

The lay out of experiment is given in Fig. 2. An overall view of experimental site is shown in plate.1.

Main plot treatments

A. Shade levels (main plot factor)

s_0	-	0 per cent shade
s_1	-	25 per cent shade
s_2	-	50 per cent shade

N
E

R-I

$s_1v_1k_3$	$s_0v_2k_2$	$s_2v_2k_1$
$s_1v_1k_1$	$s_0v_2k_1$	$s_2v_2k_2$
$s_1v_1k_2$	$s_0v_2k_3$	$s_2v_2k_3$
$s_1v_2k_3$	$s_0v_1k_1$	$s_2v_1k_2$
$s_1v_2k_2$	$s_0v_1k_2$	$s_2v_1k_1$
$s_1v_2k_1$	$s_0v_1k_3$	$s_2v_1k_3$

R-II

$s_0v_1k_2$	$s_2v_2k_1$	$s_1v_2k_2$
$s_0v_1k_1$	$s_2v_2k_2$	$s_1v_2k_3$
$s_0v_1k_3$	$s_2v_2k_3$	$s_1v_2k_1$
$s_0v_2k_2$	$s_2v_1k_1$	$s_1v_1k_2$
$s_0v_2k_3$	$s_2v_1k_3$	$s_1v_1k_1$
$s_0v_2k_1$	$s_2v_1k_2$	$s_1v_1k_3$

R-III

$s_2v_1k_3$	$s_1v_2k_2$	$s_0v_2k_1$
$s_2v_1k_2$	$s_1v_2k_1$	$s_0v_2k_3$
$s_2v_1k_1$	$s_1v_2k_3$	$s_0v_2k_2$
$s_2v_2k_2$	$s_1v_1k_1$	$s_0v_1k_2$
$s_2v_2k_3$	$s_1v_1k_2$	$s_0v_1k_3$
$s_2v_2k_1$	$s_1v_1k_3$	$s_0v_1k_1$

Fig. 2. Field layout of the experiment.

B. Varieties (sub plot factor)

v_1 - Hamil

v_2 - Haritha

C. Potash levels (sub-sub plot factor)

k_1 - 50 kg ha^{-1}

k_2 - 100 kg ha^{-1}

k_3 - 150 kg ha^{-1}

3.2.3. Treatment combinations - 18

Combinations of three levels of shade, two varieties and three levels of potassium formed 18 treatment combinations.

$s_1v_1k_1$	$s_2v_1k_1$	$s_3v_1k_1$
$s_1v_1k_2$	$s_2v_1k_2$	$s_3v_1k_2$
$s_1v_1k_3$	$s_2v_1k_3$	$s_3v_1k_3$
$s_1v_2k_1$	$s_2v_2k_1$	$s_3v_2k_1$
$s_1v_2k_2$	$s_2v_2k_2$	$s_3v_2k_2$
$s_1v_2k_3$	$s_2v_2k_3$	$s_3v_2k_3$

3.2.4 Details of cultivation

3.2.4.1 Field preparation

With the onset of south west monsoon, the experimental area was cleared off weeds, given two thorough diggings, stubbles were removed and the field was laid out into blocks and plots. The plots were dug and levelled.

PLATE 1

General view of the experimental site


Shade
Design
Replication
Treatments

3.2.4.2 Installation of shade nets

Shade was imposed on the day of plànting by using shade nets of the appropriate shade level.

3.2.4.3 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 @ 50 kg ha^{-1}. Nitrogen @ 200 kg ha^{-1} was given in two equal splits, one as basal and one after the second harvest. Potassium was applied according to the treatment in two equal splits, as basal and after the second harvest.

3.2.4.4 Planting

Healthy slips of guinea grass varieties as per treatments were planted at 40 x 20 cm spacing @ 2 slips $hill^{-1}$ on 4th May 2001.

3.2.4.5 After care

Light inter cultivation and hand weeding were done at 15 and 30 days after planting. Hand weedings were also done five days after the first and second fodder harvest. Irrigation was also given twice a week.

3.2.4.6 Harvest

Harvesting of the crop was done at a height of 15 cm from the base. Six cuts were taken, starting with the initial cut at 60 days after planting. Subsequent harvests were done at 45 days interval.

3.3 OBSERVATIONS RECORDED

Six observational plants were selected from each plot after avoiding the border rows. Observations on growth characters were recorded from the observational hills prior to each cut. From this the average of six cuts was worked out.

3.3.1 Biometric observations

3.3.1.1 Plant height

Height of the plant was measured in centimeters from the base of the plant to the tip of the longest leaf in all the observational hills. The mean heights were worked out.

3.3.1.2 Number of tillers hill^{-1}

Number of tillers in the observational plants in each plot were counted and the average was found out.

3.3.1.3 Leaf : stem ratio

The sample plants collected for recording dry matter production at each harvest 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.

3.3.1.4 Green fodder yield

The green matter yield from the net plot area was recorded after each harvest and the total green fodder yield in t ha^{-1} for the entire year was worked out.

3.3.1.5 Dry fodder yield

The six sample plants collected from each net plot on the day prior to each harvest were sun-dried and then oven dried to a constant weight at 70°C. The dry matter yield in t ha^{-1} was computed using the ratio between the fresh weight and oven dry weight of the sample plants at each harvest. From this, the total dry matter yield obtained during the entire crop period was worked out.

3.3.1.6 Root shoot ratio

Ratio of weight of dried roots and shoots of five plants are taken and the mean value calculated.

3.3.1.7 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 mesure of the volume of the root measured.

3.3.2 Physiolgical observations

3.3.2.1 Dry matter production

Four sample hills were uprooted from the net plot, washed, dried under sun, then oven dried at 80°C to constant weight and dry matter production expressed in t ha^{-1}.

3.3.2.2 Leaf area index

LAI is worked out using length width method suggested by Gomez (1972) and averages are worked out

LA = Leaf length x lead breadth x 0.75

$$LAI = \frac{LA}{\text{Land area}}$$

3.3.3 Biochemical studies

3.3.3.1 Chlorophyll content

Total chlorophyll content was estimated from the fully opened second leaf from the top at the tillering and panicle emergence stage by the method suggested by Arnon (1949). Total chlorophyll is expressed in mg g^{-1} of fresh weight 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 per cent acetone

w = Fresh weight of tissue extracted in 80 per cent acetone

3.3.4 Quality studies

3.3.4.1 Crude protein

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

3.3.4.2 Crude fibre

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

3.3.5 Uptake studies

3.3.5.1 Uptake of nitrogen

The nitrogen content was estimated by modified microkjeldal 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}.

3.3.5.2 Uptake of phosphorus

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

3.3.5.3 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}.

3.3.6 Soil studies

Soil samples were collected from the experimental area before and after the experiment. The air dried soil samples were analysed for available nitrogen, available phosphorus and available potassium contents.

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).

3.3.7 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.

Net income (Rs. ha^{-1}) = Gross income - Total expenditure

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

3.3.8 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

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala State during the period from May 2001 to May 2002 to find out the potash requirement for guinea grass varieties under varying shade levels. The results obtained during the cropping period are presented herein.

4.1 GROWTH CHARACTERS

Observations on growth characters like plant height, number of tillers and leaf:stem ratio were recorded and the results are presented below.

4.1.1 Plant height [Table 4.1.1.(a), (b) and (c)]

Plant height was significantly influenced by increasing shade levels from 0 to 50 per cent in all the harvests. 50 per cent shade level recorded the highest plant height followed by 25 per cent shade level. The lowest plant height was observed in open condition.

Significant difference in plant height between the varieties was observed only in the second harvest. Hamil recorded the highest plant height of 174.67 cm in second cut.

Application of potassium had a significant influence on the height of the plant at all the five harvests. In the first and second cuts, highest dose of potassium (150 kg ha^{-1}) recorded the highest plant height which was on par with k_2 treatment (100 kg ha^{-1}). In the third, fourth and fifth cuts, the highest dose of K_2O (k_3) recorded significantly higher plant height followed by k_2 treatment.

Table 4.1.1(a) Main effects of shade levels (S), varieties (V) and potassium (K) on plant height of guinea grass (cm)

Main effects of factors	I cut	II cut	III cut	IV cut	V cut
Shade levels					
s_0	164.43	167.96	116.22	117.93	164.35
s_1	172.08	174.29	127.68	131.82	169.67
s_2	178.35	180.90	138.58	141.83	176.18
$F_{2,4}$	62.37**	8036.00**	3892.92**	23718.86**	919.82**
SE	0.883	0.072	0.179	0.078	0.195
CD	3.466	0.283	0.704	0.306	0.767
Varieties					
v_1	172.45	174.67	127.33	130.41	170.33
v_2	170.79	174.10	127.65	130.65	169.80
$F_{1,6}$	NS	40.80**	NS	NS	NS
SE	0.921	0.062	0.202	0.191	0.150
CD	-	0.215	-	-	-
Potash levels					
k_1	169.18	171.75	126.83	129.99	169.62
k_2	171.77	175.67	127.03	129.18	169.70
k_3	173.91	175.73	128.61	132.42	170.89
$F_{2,24}$	5.21*	1002.00**	33.23**	77.86**	19.65**
SE	1.036	0.072	0.170	0.191	0.162
CD	3.023	0.211	0.495	0.557	0.474

* Significant at 5 per cent level ** Significant at 1 per cent level NS Not significant

Table 4.1.1(b) Interaction effects of shade levels, and potassium with varieties on plant height of guinea grass (cm)

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
s_0v_1	164.70	168.36	115.79	117.82	164.46
s_0v_2	164.16	167.57	116.64	118.03	164.24
s_1v_1	174.08	174.88	127.73	131.62	169.82
s_1v_2	170.09	173.71	127.62	132.02	169.52
s_2v_1	178.58	180.78	138.48	141.78	176.72
s_2v_2	178.12	181.02	138.68	141.89	175.64
$F_{2,6}$	NS	24.60**	NS	NS	NS
SE	1.596	0.108	0.350	0.332	0.259
CD	-	0.372	-	-	-
v_1k_1	169.44	172.17	126.23	129.69	170.27
v_1k_2	173.56	175.93	126.63	129.06	169.31
v_1k_3	174.36	175.91	129.13	132.48	171.42
v_2k_1	168.92	171.33	127.42	130.29	168.97
v_2k_2	169.99	175.41	127.43	129.30	170.09
v_2k_3	179.46	175.56	128.09	132.36	170.36
$F_{2,24}$	NS	NS	12.18**	NS	11.77**
SE	1.465	0.102	0.240	0.270	0.229
CD	-	-	0.700	-	0.670

** Significant at 1 per cent level NS Not significant

Table 4.1.1(c) Interaction effects of shade levels (S) and potassium (K) on plant height of guinea grass (cm)

Main effects of factors	I cut	II cut	III cut	IV cut	V cut
s_0k_1	162.00	164.75	115.28	116.32	163.23
s_0k_2	165.20	169.15	116.40	116.95	164.02
s_0k_3	166.08	169.98	116.97	120.52	165.80
s_1k_1	169.75	170.10	126.18	130.95	169.08
s_1k_2	170.72	176.05	126.83	130.53	169.05
s_1k_3	175.78	176.73	130.02	133.98	170.88
s_2k_1	175.80	180.40	138.02	142.70	176.53
s_2k_2	179.40	181.82	137.87	140.05	176.03
s_2k_3	179.85	180.48	138.85	142.75	175.98
$F_{4,24}$	NS	199.33**	14.29**	11.57**	8.70**
SE	1.794	0.125	0.294	0.331	0.281
CD	-	0.365	0.858	0.965	0.820

** Significant at 1 per cent level

The treatment k_1 (50 kg ha^{-1}) recorded significantly lower plant height in all the harvests.

S x V interaction was found to be significant only in second harvest. Under s_0 and s_1 shade v_1 registered a height increase in comparison with v_2 while no significant difference was observed under s_2.

V x K interaction was significant in third and fifth cuts. In the third cut k_2 treated v_1 plant where taller than k_0 and k_1 treated plants. But in case of v_2 no significant difference was observed.

S x K interaction was found to be significant in all harvests except at the first cut. When plants are raised under s_0 and s_1 a significant increase in plant height was observed with an increase in the level of potassium. But this trend was not seen under s_2. This was the result observed in second cut. In third cut under s_0, k_1 and k_2 were on par; under s_1, k_2 and k_3 were on par. While under s_3 no significant difference was seen. In the fourth cut under open condition and 25 per cent shade, k_3 treated plants recorded maximum height while under s_3, k_1 treated plants were the smallest. In fifth cut, an increase in potassium resulted in an increase in plant height when the plants were grown under s_0 and s_1. But under s_2, k_3 treated plants were smaller than k_1 and k_2 treated plants.

4.1.2 Number of tillers [Table 4.1.2 (a), (b) and (c)]

The number of tillers were the highest in open and was significantly superior to that under shade in first, second and fifth harvest. In third and fourth harvests, tillers were significantly higher under s_1.

Variety v_1 produced significantly higher number of tillers in all cuts except the fourth cut.

Table 4.1.2(a) Main effects of shade levels (S), varieties (V) and potassium (K) on number of tillers of guinea grass

Main effects of factors	I cut	II cut	III cut	IV cut	V cut
Shade levels					
s_0	27.24	29.08	22.06	21.51	26.95
s_1	24.59	27.34	23.56	23.44	22.91
s_2	21.18	21.66	20.20	19.68	20.76
$F_{2,4}$	17049.60**	30811.34**	2367.32**	5669.91**	3831.12**
SE	0.023	0.022	0.035	0.025	0.051
CD	0.091	0.087	0.136	0.098	0.199
Varieties					
v_1	24.67	26.59	22.15	21.57	23.96
v_2	24.01	25.46	21.72	21.52	23.13
$F_{1,6}$	195.87**	495.96**	121.43**	NS	40.31**
SE	0.033	0.036	0.028	0.029	0.092
CD	0.116	0.123	0.095	-	0.320
Potash levels					
k_1	22.21	23.84	22.26	21.89	22.14
k_2	25.15	26.75	21.53	21.52	23.47
k_3	25.66	27.48	22.02	21.22	25.01
$F_{2,24}$	2802.81**	2904.85**	152.39**	112.04**	175.82**
SE	0.035	0.036	0.030	0.032	0.108
CD	0.103	0.104	0.088	0.092	0.316

** Significant at 1 per cent level   NS Not significant

Table 4.1.2(b) Interaction effects of shade levels (S) and Potassium (K) with varieties (V) on number of tillers of guinea grass

Interaction effects of factor	I cut	II cut	III cut	IV cut	V cut
s_0v_1	27.90	29.72	22.60	21.48	27.93
s_0v_2	26.59	28.43	21.51	21.53	25.97
s_1v_1	24.99	27.77	23.50	23.63	23.03
s_1v_2	24.20	26.91	23.61	23.26	22.79
s_2v_1	21.12	22.28	20.36	19.60	20.90
s_2v_2	21.23	21.04	20.04	19.77	20.62
$F_{2,6}$	77.07**	7.30*	81.29**	16.04**	18.95**
SE	0.058	0.062	0.048	0.051	0.160
CD	0.200	0.214	0.165	0.176	0.554
v_1k_1	22.69	24.18	22.33	21.73	21.96
v_1k_2	25.51	27.22	21.72	21.53	23.93
v_1k_3	25.81	28.37	22.40	21.44	25.98
v_2k_1	21.73	23.51	22.19	22.04	22.32
v_2k_2	24.79	26.28	21.33	21.51	23.01
v_2k_3	25.50	26.60	21.64	21.00	24.04
$F_{2,24}$	21.67**	64.09**	25.83**	36.11**	28.29**
SE	0.050	0.050	0.043	0.045	0.153
CD	0.145	0.147	0.125	0.130	0.447

* Significant at 5 per cent level ** Significant at 1per cent level

Table 4.1.2(c) Interaction effects of shade levels (S) with Potassium (K) on number of tillers of guinea grass

Interaction effects of factor	I cut	II cut	III cut	IV cut	V cut
s_0k_1	24.72	26.13	22.50	21.60	24.82
s_0k_2	28.18	29.97	21.40	21.50	26.73
s_0k_3	28.83	31.13	22.27	21.42	29.30
s_1k_1	22.98	24.62	23.72	23.30	21.53
s_1k_2	24.92	28.35	23.85	23.78	22.50
s_1k_3	25.88	29.05	23.10	23.25	24.70
s_2k_1	18.93	20.78	20.57	20.77	20.07
s_2k_2	22.35	21.93	19.33	19.28	21.18
s_2k_3	22.25	22.27	20.70	19.00	21.03
$F_{4,24}$	64.92**	263.75**	116.96**	110.81**	26.43**
SE	0.061	0.062	0.052	0.055	0.188
CD	0.178	0.181	0.153	0.159	0.548

** Significant at 1per cent level

An enhancement of potassium levels resulted in an increase in tiller number in all cuts except at the third and fourth harvests. In the third and fourth harvests, lowest dose of K_2O (50 kg ha^{-1}) recorded highest tiller number.

In all the cuts except fourth cut v_1 produced more number of tillers under s_0. Under s_1 no significant difference was seen between v_1 and v_2 in tiller numbers under third, fourth and fifth cuts. v_1 produced more number of tillers in second, third and fifth cuts under s_2 .

In the first, second and fifth cuts number of tillers were more for v_1 and v_2 with an increase in potassium levels, but in third and fourth cuts this trend was not seen.

In first, second and fifth cuts in the open shade, higher doses of potassium produced more number of tillers; but a differential response was seen in third and fourth cuts.

4.1.3 Leaf:Stem ratio (Table 4.1.3)

There was a decline in L:S ratio with an increase in shade intensity. But at the open and 25 per cent shade conditions in the first and second cuts no significant difference was observed in leaf : stem ratio.

L:S ratio of the plant was not influenced neither by the varietal differences nor by the variations in the potassium levels.

None of the interactions were significant.

4.2 YIELD CHARACTERS

4.2.1 Green fodder yield [Table 4.2.1(a), (b) and (c)]

Significant increase in green fodder yield was obtained by shade levels, varieties and potassium application. In the first, second and fifth cuts a significant

Table 4.1.3. Main effects of shade levels, varieties and potassium on Leaf:Stem Ratio of guinea grass

Main effects of factors	I cut	II cut	III cut	IV cut	V cut
Shade levels					
s_0	1.26	1.24	1.05	1.01	1.14
s_1	1.26	1.24	1.03	0.97	1.12
s_2	1.24	1.21	1.01	0.96	1.10
$F_{2,4}$	18.65**	38.39**	NS	110.41**	43.89**
SE	0.003	0.003	0.008	0.003	0.004
CD	0.012	0.010	-	0.010	0.014
Varieties					
v_1	1.25	1.23	1.03	0.98	1.12
v_2	1.25	1.23	1.03	0.98	1.12
$F_{1,6}$	NS	NS	NS	NS	NS
SE	0.004	0.003	0.006	0.002	0.004
CD	-	-	-	-	-
Potash levels					
k_1	1.25	1.23	1.03	0.98	1.12
k_2	1.26	1.23	1.03	0.98	1.12
k_3	1.25	1.23	1.03	0.98	1.12
$F_{2,24}$	NS	NS	NS	NS	NS
SE	0.004	0.003	0.005	0.002	0.003
CD	-	-	-	-	-

** Significant at 1 per cent level NS Not significant

Table 4.2.1(a) Main effects of shade levels (S), varieties (V) and potassium (K) on green fodder yield of guinea grass (t ha^{-1})

Main effects of factors	I cut	II cut	III cut	IV cut	V cut	Total
Shade levels						
s_0	16.94	20.58	13.55	13.87	16.73	100.31
s_1	14.08	18.32	15.69	14.77	14.17	95.47
s_2	9.92	10.29	9.32	9.39	9.99	67.21
$F_{2,4}$	6567.66**	20335.38**	17280.00**	11318.93**	13544.86**	105185.40**
SE	0.044	0.038	0.025	0.027	0.029	0.055
CD	0.171	0.149	0.097	0.106	0.115	0.216
Varieties						
v_1	13.96	16.82	12.87	13.04	13.93	89.56
v_2	13.33	15.98	12.83	12.31	13.33	85.76
$F_{1,6}$	156.23**	332.02**	NS	662.27**	280.10**	2879.53**
SE	0.035	0.032	0.028	0.020	0.025	0.050
CD	0.122	0.112	-	0.069	0.086	0.173
Potash levels						
k_1	11.34	14.62	12.96	12.53	12.47	79.97
k_2	14.51	16.88	12.81	12.86	14.07	90.13
k_3	15.09	17.70	12.89	12.64	14.36	92.88
$F_{2,24}$	3767.80**	1472.29**	12.81**	38.82**	1237.72**	10140.76**
SE	0.033	0.042	0.025	0.027	0.029	0.068
CD	0.096	0.121	0.074	0.080	0.084	0.197

** Significant at 1 per cent level NS Not significant

Table 4.2.1(b) Interaction effects of shade levels and potassium with varieties on green fodder yield of guinea grass (t ha^{-1})

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut	Total
s_0v_1	17.38	21.43	13.69	14.52	17.37	103.66
s_0v_2	16.50	19.73	13.41	13.21	16.09	96.97
s_1v_1	14.70	18.71	15.72	15.27	14.41	92.72
s_1v_2	13.47	17.93	15.66	14.28	13.93	93.21
s_2v_1	9.80	10.31	9.21	9.33	10.00	67.31
s_2v_2	10.03	10.28	9.42	9.46	9.98	67.11
$F_{2,6}$	77.81**	110.13**	13.19**	236.82**	107.36**	725.08**
SE	0.061	0.056	0.048	0.035	0.043	0.087
CD	0.212	0.194	0.165	0.119	0.150	0.300
v_1k_1	11.94	14.86	13.14	12.94	12.78	81.52
v_1k_2	14.58	17.38	12.73	13.22	14.50	91.91
v_1k_3	15.36	18.22	12.74	12.96	14.50	95.26
v_2k_1	10.73	14.39	12.77	12.11	12.16	78.42
v_2k_2	14.43	16.38	12.89	12.50	13.63	88.36
v_2k_3	14.83	17.18	12.83	12.33	14.21	90.51
$F_{2,24}$	67.52**	14.94**	32.99**	3.72*	25.14**	39.24**
SE	0.047	0.059	0.036	0.039	0.041	0.095
CD	0.136	0.171	0.104	0.113	0.119	0.279

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 4.2.1(c) Interaction effects of shade levels with potassium on green fodder yield of guinea grass (t ha^{-1})

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut	Total
s_0k_1	13.27	17.77	13.65	13.63	14.38	89.10
s_0k_2	18.50	21.35	13.52	14.08	17.73	104.48
s_0k_3	19.05	22.63	13.48	13.88	18.07	107.45
s_1k_1	11.47	16.02	15.87	14.62	13.12	86.98
s_1k_2	14.88	19.03	15.58	14.98	14.50	97.82
s_1k_3	15.90	19.92	15.62	14.72	14.90	101.60
s_2k_1	9.28	10.08	9.35	9.33	9.90	63.93
s_2k_2	10.13	10.25	9.33	9.52	9.97	68.10
s_2k_3	10.33	10.55	9.27	9.33	10.10	69.60
$F_{4,24}$	562.51**	288.07**	NS	NS	384.63**	935.52**
SE	0.057	0.072	0.044	0.047	0.050	0.117
CD	0.166	0.210	-	-	0.146	0.341

** Significant at 1 per cent level NS Not significant

reduction in green fodder yield was seen with an increase in shade. But in third and fourth cuts a quadrate type of response was seen among the shade levels. Green fodder yield was significantly higher for lowest shade level (Zero per cent shade) in first, second and last cuts. In third and fourth cuts, 25 per cent shade level recorded significantly higher green fodder yield. Total green fodder yield was also 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}).

The green fodder yield of varieties also varied in all cuts except the third cut. Hamil recorded significantly higher green fodder yield compared to Haritha (89.56t ha^{-1}).

Potassium application had also significant influence on green fodder yield as evident from the mean values. The highest level of potassium (150 kg ha^{-1}) recorded significantly higher green fodder yield followed by k_2 (100 kg ha^{-1}) and then by k_1 (50 kg ha^{-1}). However, in third harvest lowest dose of potassium recorded higher green fodder yield followed by k_3 (150 Kg ha^{-1}). In fourth harvest, medium dose of potassium (100 Kg ha^{-1}) registered higher green fodder yield followed by k_3 and then by k_1.

Significant S x V interaction was noticed in all harvests. In the open and 25 per cent shade v_1 performed better than v_2 while for 50 per cent shaded conditions v_2 produced more fodder than v_1 in first, third and fourth cuts. While no significant difference was seen between v_1 and v_2 in second and fifth cuts.

Significant V x K interaction was observed in all harvests. In the first and second cuts an increase in green fodder yield was observed with an increase in potassium for v_1. In third cut green fodder yield was found to reduce at higher levels of potassium, a parabolic trend was seen at the fourth cut while no significant difference in green fodder yield was seen at higher level of potassium at the fifth cut. In the case of v_2 in first, second and fifth cuts green fodder yield increased with an increase in potassium. In third cut green fodder yield at k_2 was highest than that obtained at k_1. k_2 and k_3 were on par at fourth cut.

Significant S x K interaction was observed in first, second and last cuts. At s_0 and s_1 shade level similar response was seen in all cuts. The first, second and fifth cuts showed a positive response with an increase in potassium, but under s_2 differential response was observed. In the first cut proportionate increase was seen. In second and fifth cut no significant difference was seen at k_1 and k_2 levels of potassium. S x K interaction was absent in the case of third and fourth cut green fodder yields.

Total green fodder yield was also significantly influenced by shade levels, varieties and potassium application. Lower levels of shade recorded higher total green fodder yield. Among the varieties, Hamil recorded the highest green fodder yield compared to Haritha. The higher level of potassium (150 kg ha^{-1}) recorded the maximum total green fodder yield. Significant S x V interaction was noticed in the total green fodder yield. The treatment combination s_0v_1 (zero per cent shade level + Hamil) registered the highest total green fodder yield. Similarly, s_0k_3 (zero per cent shade level + 150 kg K_2O ha^{-1}) recorded highest total green fodder yield. V x K interaction was also significant. v_1k_3 combination recorded higher total green fodder yield.

4.2.2 Dry fodder yield [Table 4.2.2(a), (b) and (c)]

The shade levels, varieties and potassium application significantly influenced the dry fodder yield in all cuts. Significantly higher dry fodder yield was obtained with lower levels of shade in first, second and last cuts, whereas in third and fourth harvests, 25 per cent shade recorded significantly higher dry fodder yield.

Table 4.2.2 (a) Main effects of shade levels, varictics and potassium on dry fodder yicld of guinea grass (t ha^{-1})

Main effects of factors	I cut	II cut	III cut	IV cut	V cut	Total
Shade levels						
s_0	4.22	5.14	3.39	3.47	4.15	25.00
s_1	3.53	4.69	3.93	3.68	3.54	23.97
s_2	2.51	2.57	2.33	2.36	2.49	16.82
$F_{2,4}$	39595.64**	186006.50**	154500.40**	773787.50**	83872.80**	243636**
SE	0.004	0.003	0.002	0.003	0.003	0.009
CD	0.017	0.013	0.008	0.010	0.011	0.035
Varieties						
v_1	3.48	4.21	3.22	3.26	3.47	22.35
v_2	3.35	4.06	3.21	3.08	3.31	21.51
$F_{1,6}$	500.79**	803.35**	NS	2643.38**	1282.62**	2952**
SE	0.004	0.004	0.003	0.002	0.003	0.011
CD	0.014	0.013	-	0.008	0.011	0.038
Potash levels						
k_1	2.84	3.75	3.24	3.11	3.11	20.07
k_2	3.63	4.23	3.20	3.21	3.50	22.53
k_3	3.79	4.42	3.20	3.16	3.57	23.20
$F_{2,24}$	18424.92**	7881.00**	56.13**	217.50**	5008.55**	15826.11**
SE	0.004	0.004	0.003	0.004	0.004	0.013
CD	0.011	0.011	0.009	0.010	0.010	0.038

** Significant at 1 per cent level

Table 4.2.2(b) Interaction effects of shade levels and potassium with varieties on dry fodder yield of guinea grass (t ha^{-1})

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut	Total
s_0v_1	4.31	5.36	3.42	3.63	4.31	25.79
s_0v_2	4.12	4.93	3.36	3.30	3.99	24.21
s_1v_1	3.67	4.69	3.93	3.80	3.61	24.43
s_1v_2	3.38	4.69	3.92	3.55	3.47	23.52
s_2v_1	2.46	2.58	2.31	2.34	2.50	16.84
s_2v_2	2.56	2.56	2.36	2.38	2.47	16.80
F2,6	418.33**	666.80**	46.15**	1065.00**	383.31**	823.20**
SE	0.007	0.006	0.005	0.004	0.005	0.019
CD	0.024	0.072	0.019	0.015	0.019	0.066
v_1k_1	2.97	3.71	3.29	3.20	3.19	20.34
v_1k_2	3.63	4.36	3.19	3.31	3.60	22.97
v_1k_3	3.84	4.55	3.19	3.26	3.63	23.75
v_2k_1	2.70	3.78	3.20	3.02	3.03	19.79
v_2k_2	3.63	4.11	3.21	3.13	3.39	22.09
v_2k_3	3.73	4.29	3.22	3.08	3.52	22.65
$F_{2,24}$	349.92**	581.89**	129.87**	NS	65.52**	113.68**
SE	0.005	0.006	0.004	0.005	0.005	0.019
CD	0.016	0.016	0.012	-	0.014	0.054

** Significant at 1 per cent level NS Not significant

Table 4.2.2(c) Interaction effects of shade levels and potassium on dry fodder yield of guinea grass (t ha^{-1})

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut	Total
s_0k_1	3.30	4.44	3.41	3.38	3.56	22.15
s_0k_2	4.60	5.34	3.38	3.53	4.39	26.05
s_0k_3	4.74	5.65	3.39	3.48	4.51	26.78
s_1k_1	2.87	4.31	3.98	3.62	3.30	22.06
s_1k_2	3.73	4.78	3.89	3.73	3.62	24.48
s_1k_3	3.99	4.98	3.91	3.67	3.70	25.39
s_2k_1	2.33	2.50	2.34	2.34	2.48	15.99
s_2k_2	2.57	2.58	2.34	2.38	2.48	17.06
s_2k_3	2.63	2.63	2.32	2.36	2.51	17.43
$F_{4,24}$	2547.60**	1723.61**	22.84**	25.43**	1758.28**	1503.16**
SE	0.007	0.007	0.005	0.006	0.006	0.023
CD	0.019	0.020	0.015	0.018	0.018	0.066

** Significant at 1 per cent level

The dry fodder yield of the varieties varied significantly in all harvests except third, among which Hamil recorded the highest dry fodder yield.

Highest doses of potassium (150 kg ha^{-1}) registered significantly higher dry fodder yield in first, second and last cuts. However, in third cut lowest dose of potassium recorded higher dry fodder yield followed by k_2 and k_3. In fourth cut, medium dose of K_2O (100 Kg ha^{-1}) recorded higher dry fodder yield followed by k_3 and then by k_1.

In the first, fourth and fifth cuts v_1 registered high dry fodder yield in comparison with v_2 under s_0 and s_1. Under shade s_2, v_2 found better than v_1 in first, third and fourth cuts and no significant difference in second cut observed. In second and third cuts v_1 and v_2 were on par under s_1. In fifth cut under all shades v_1 produced better dry fodder yield than v_2.

In the first, second and fifth cuts a significant increase in dry fodder yield was seen with an increase in potassium for both v_1 and v_2 with exception that v_2k_2 and v_2k_3 were on par at first cut. In the third cut the higher doses of potassium produced more or less the same dry fodder yield in case of both v_1 and v_2. V x K interactions was absent in fourth cut.

In the first and second cuts under all shaded conditions an increase in potassium resulted in an increase in dry fodder yield. In third cut a reduction in dry fodder yield was seen with an increase in shade. But the reduction was not significant at k_2 and k_3 under s_0 and s_1. Dry fodder yield was on par with k_2 and k_3 under s_2. In the fourth cut a quadratic type of response in dry fodder yield was seen. In fifth cut under s_0 , s_1 and s_2 a significant reduction in dry fodder yield was seen with an increase in potassium, but this reduction was not significant at k_1 and k_2 levels under s_2.

4.3 ROOT CHARACTERS

4.3.1 Root volume [Table 4.3(a) and (b)]

The shade levels and potassium application significantly influenced the root volume of the plant. Lowest levels of shade (s_0) recorded significantly higher root volume of the plant followed by s_1 and s_2. Root volume of varieties recorded no variation.

With regard to K_2O application k_2 (100 kg K_2O ha^{-1}) recorded the maximum root volume while k_1 produced significantly lower root volume. A further increase in potassium from k_2 to k_3 resulted in a reduction of root volume.

Significant S x V interaction was noticed. In open condition v_1 recorded more root volume than v_2. While in s_1 and s_2 shades no significant difference between v_1 and v_2 was observed.

S x K and V x K interactions were absent.

4.3.2 Root shoot ratio (Table 4.3a)

Root shoot ratio was not increased by shade level, potassium levels and also by varietal difference.

4.4 PHYSIOLOGICAL CHARACTERS

4.4.1 Leaf Area Index [4.4(a), (b)]

Significant influence of shade levels on Leaf Area Index was noticed in all harvests. The Leaf Area Index was found to be significantly higher at zero per cent shade level followed by s_1 and s_2 in first, second and fifth cuts.

Table 4.3 (a) Main effects of shade levels, varieties and potassium on Root volume (cm^3) and Root:Shoot ratio

Main effects of factors	Root volume	Root:Shoot ratio
Shade levels		
s_0	78.02	0.97
s_1	74.32	0.98
s_2	72.65	0.98
$F_{2,4}$	405.12**	NS
SE	0.137	0.001
CD	0.536	-
Varieties		
v_1	75.04	0.98
v_2	74.96	0.97
$F_{1,6}$	NS	NS
SE	0.139	0.003
CD	-	-
Potash levels		
k_1	73.49	0.98
k_2	76.10	0.97
k_3	75.40	0.98
$F_{2,24}$	45.76**	NS
SE	0.200	0.003
CD	0.583	-

** Significant at 1 per cent level NS Not significant

Table 4.3 (b) Interaction effects of shade levels and varieties on Root volume (cm^3)

Interaction effects of factors	Root Volume
s_0v_1	78.61
s_0v_2	77.43
s_1v_1	74.07
s_1v_2	74.57
s_2v_1	72.43
s_2v_2	72.87
$F_{2,6}$	7.83*
SE	0.241
CD	0.832

* Significant at 5 per cent level

Table 4.4 (a) Main effects of shade levels, varieties and potassium on Leaf Area Index of guinea grass

Main effects of factors	I Cut	II Cut	III Cut	IV Cut	V Cut
Shade levels					
s_0	4.99	5.19	4.55	4.43	4.98
s_1	4.74	4.96	4.72	4.68	4.75
s_2	3.83	3.88	3.62	3.62	3.72
$F_{2,4}$	1295.70**	3195.69**	2085.64**	638.08**	3752.22**
SE	0.017	0.012	0.013	0.022	0.011
CD	0.067	0.048	0.051	0.086	0.043
Varieties					
v_1	4.60	4.77	4.35	4.23	4.51
v_2	4.44	4.59	4.25	4.26	4.45
$F_{1,6}$	28.97**	89.60**	23.02**	NS	9.20**
SE	0.021	0.014	0.015	0.017	0.014
CD	0.072	0.048	0.051	-	0.048
Potash levels					
k_1	4.16	4.26	4.15	4.05	4.13
k_2	4.68	4.87	4.36	4.41	4.69
k_3	4.73	4.91	4.38	4.28	4.63
$F_{2,24}$	219.40**	450.15**	43.05**	75.53**	249.70**
SE	0.022	0.017	0.020	0.021	0.019
CD	0.063	0.050	0.057	0.060	0.057

** Significant at 1 per cent level NS Not significant

Table 4.4 (b). Interaction effects of shade levels and potassium with varieties on Leaf Area Index of guinea grass

Interaction effects of factors	I Cut	II Cut	III Cut	IV Cut	V Cut
s_0k_1	4.48	4.70	4.38	4.25	4.50
s_0k_2	5.15	5.38	4.62	4.57	5.28
s_0k_3	5.35	5.50	4.65	4.47	5.15
s_1k_1	4.32	4.38	4.48	4.42	4.28
s_1k_2	4.97	5.18	4.83	4.87	4.98
s_1k_3	4.95	5.30	4.85	4.77	4.98
s_2k_1	3.67	3.68	3.58	3.48	3.60
s_2k_2	3.93	4.03	3.63	3.78	3.80
s_2k_3	3.90	3.93	3.65	3.60	3.75
$F_{4,24}$	20.31**	36.71**	6.68**	NS	28.78**
SE	0.037	0.030	0.034	0.036	0.034
CD	0.109	0.087	0.099	-	0.098

** Significant at 1 per cent level NS Not significant

i.e. an increase in shade resulted in an increase in leaf area. But in third and fourth cuts, significantly higher Leaf Area Index was recorded at 25 per cent shade level.

Leaf Area Index was significantly higher for Hamil (v_1) compared to Haritha (v_2) in all cuts except the fourth cut where it was on par

An increase in the level of potassium resulted in an increase in leaf area index. However increase in potassium from k_2 to k_3 did not produce any significant increase in leaf area index in first, second and third cuts. In fourth and fifth cuts a significant reduction in leaf area index was seen when potassium increased from k_2 to k_3.

In the first cut, under the open condition leaf area index was found to increase with the increase in the levels of potassium. This increase was seen under s_1 and s_2; but when potassium was increase from k_2 to k_3 a significant increase in leaf area index was not seen. In the second cut, under s_0 and s_1 a significant increase in leaf area index was observed with an increase in potassium while under s_2 a quadratic response was seen at the highest level of potassium. In the fourth cut under all shade levels the quadratic response to potassium was seen with the highest doses of potassium. S x K interaction was absent in fourth cut. In fifth cut under open condition a quadratic trend was seen with the levels of potassium. But under s_1 and s_2 the leaf area index was on par at k_2 and k_3 levels of potassium.

4.5 BIOCHEMICAL ASPECTS

4.5 Chlorophyll content [Table 4.5(a), (b) and (c)]

Shade levels, varieties and potassium application significantly influenced the chlorophyll content of the plant at all harvests. Chlorophyll content increased

Table 4.5 (a) Main effects of shade levels, varieties and potassium on chlorophyll content of guinea grass (mg g^{-1} of plant)

Main effects of factors	I Cut	II Cut	III Cut	IV Cut	V Cut
Shade levels					
s_0	2.16	2.15	2.15	2.12	2.13
s_1	3.76	3.76	3.72	3.76	3.65
s_2	4.30	4.21	4.25	4.26	4.17
$F_{2,4}$	81266.00**	693722.00**	703166.00**	247112.30**	78515.77**
SE	0.004	0.001	0.001	0.002	0.004
CD	0.015	0.005	0.005	0.009	0.015
Varieties					
v_1	2.98	2.91	2.93	2.91	2.86
v_2	3.83	3.83	3.81	3.85	3.77
$F_{1,6}$	30330.00**	224833.20**	113806.70**	42144.22**	24362.00**
SE	0.003	0.001	0.002	0.003	0.004
CD	0.012	0.005	0.006	0.011	0.014
Potash levels					
k_1	3.37	3.38	3.37	3.33	3.37
k_2	3.39	3.25	3.23	3.33	3.17
k_3	3.46	3.48	3.52	3.49	3.41
$F_{2,24}$	260.17**	1655.16**	3102.12**	1027.66**	599.61**
SE	0.003	0.003	0.003	0.003	0.005
CD	0.009	0.008	0.008	0.008	0.015

** Significant at 1 per cent level

Table 4.5 (b). Interaction effects of shade levels and potassium with varieties on chlorophyll content of guinea grass (mg g^{-1} of plant)

Interaction effects of factors	I Cut	II Cut	III Cut	IV Cut	V Cut
s_0v_1	1.75	1.68	1.67	1.59	1.65
s_0v_2	2.56	2.61	2.63	2.65	2.60
s_1v_1	3.09	3.07	3.06	3.09	2.96
s_1v_2	4.43	4.40	4.37	4.45	4.34
s_2v_1	4.09	3.98	4.07	4.05	3.97
s_2v_2	4.51	4.43	4.43	4.47	4.37
$F_{2,6}$	2936.25**	19500.00**	11195.33**	3673.18**	2342.93**
SE	0.006	0.002	0.003	0.006	0.007
CD	0.021	0.008	0.011	0.019	0.025
v_1k_1	2.65	2.65	2.70	2.63	2.67
v_1k_2	3.06	2.88	2.88	2.95	2.81
v_1k_3	3.22	3.20	3.22	3.15	3.11
v_2k_1	4.08	4.12	4.04	4.02	4.07
v_2k_2	3.71	3.62	3.57	3.71	3.54
v_2k_3	3.71	3.76	3.83	3.83	3.71
$F_{2,24}$	6338.00**	7399.16**	5471.29**	4561.45**	1805.64**
SE	0.005	0.004	0.004	0.004	0.007
CD	0.013	0.012	0.011	0.012	0.021

** Significant at 1 per cent level

Table 4.5 (c). Interaction effects of shade levels with potassium on chlorophyll content of guinea grass (mg g^{-1} of plant)

Interaction effects of factors	I Cut	II Cut	III Cut	IV Cut	V Cut
s_0k_1	1.86	1.92	1.98	1.96	1.96
s_0k_2	2.01	1.96	1.83	1.88	1.86
s_0k_3	2.60	2.56	2.65	2.52	2.56
s_1k_1	3.83	3.98	3.79	3.83	3.85
s_1k_2	3.96	3.65	3.73	3.85	3.61
s_1k_3	3.49	3.65	3.64	3.62	3.50
s_2k_1	4.40	4.25	4.34	4.20	4.30
s_2k_2	4.20	4.15	4.11	4.26	4.06
s_2k_3	4.30	4.23	4.29	4.33	4.17
$F_{4,24}$	3543.33**	2702.63**	3288.12**	2394.62**	913.49**
SE	0.006	0.005	0.005	0.005	0.009
CD	0.016	0.014	0.014	0.014	0.026

** Significant at 1 per cent level

significantly with increase in shade levels. s_2 treatment (50 per cent shade) recorded the maximum chlorophyll content in all harvests. Chlorophyll content was low in leaves of plants grown in open condition. Chlorophyll content increased when the intensity of shade increased.

Varieties also had significant influence on chlorophyll content of the plant. Haritha (v_2) recorded significantly higher chlorophyll content in all the harvests.

Application of potassium influenced chlorophyll content in all the harvests. Highest levels of potassium (150 kg ha^{-1}) resulted in significantly higher chlorophyll content of the plant. At lowest and highest levels of potassium, chlorophyll content was high.

Significant S x V interaction was observed in all harvests. Under the open and the two different shade levels, v_2 registered high chlorophyll content.

In case of v_1 an increase in potassium resulted in higher chlorophyll content while in case of v_2 an increase in potassium resulted in a reduction in chlorophyll content.

In the open shade, the effect of potassium was positive in all cuts. Under s_1 shade a negative response was seen with respect to chlorophyll content. Under s_2, lowest chlorophyll content was observed at k_2 level. It was high at k_1 and k_3 levels.

4.6 QUALITY ASPECTS

4.6.1 Crude protein [Table 4.6.1(a), (b) and (c)]

Crude protein content was significantly influenced by shade levels, varieties and potassium application. When the intensity of shade increased, the

Table 4.6.1(a). Main effects of shade levels, varieties and potassium on crude protein content and crude fibre content (per cent)

Main effects	Crude protein content	Crude fibre content
Shade levels		
s_0	8.06	32.08
s_1	8.09	31.67
s_2	8.14	31.53
$F_{2,4}$	157.33**	31.71**
SE	0.003	0.051
CD	0.013	0.200
Varieties		
v_1	8.08	31.94
v_2	8.11	31.58
$F_{1,6}$	29.14**	6.16**
SE	0.003	0.105
CD	0.011	0.362
Potash levels		
k_1	8.12	31.92
k_2	8.10	31.73
k_3	8.08	31.63
$F_{2,24}$	25.50**	NS
SE	0.003	0.115
CD	0.009	--

* Significant at 5 per cent level ** Significant at 1 per cent level

NS – Not significant

Table 4.6.1 (b). Interaction effects of shade levels and varieties on crude protein content of guinea grass (per cent)

Interaction effects of factors	Crude protein content
s_0v_1	8.04
s_0v_2	8.08
s_1v_1	8.08
s_1v_2	8.10
s_2v_1	8.13
s_2v_2	8.15
$F_{2,6}$	5.57*
SE	0.006
CD	0.019
v_1k_1	8.10
v_1k_2	8.08
v_1k_3	8.07
v_2k_1	8.13
v_2k_2	8.11
v_2k_3	8.09
$F_{2,24}$	4.50*
SE	0.004
CD	0.012

* Significant at 5 per cent level

Table 4.6.1 (c). Interaction effects of shade levels and potassium on crude protein content of guinea grass (per cent)

Interactive effects of factors	Crude Protein content
s_0k_1	8.08
s_0k_2	8.06
s_0k_3	8.06
s_1k_1	8.11
s_1k_2	8.09
s_1k_3	8.07
s_2k_1	8.16
s_2k_2	8.14
s_2k_3	8.13
$F_{4,24}$	3.00*
SE	0.005
CD	0.015

* Significant at 5 per cent level

crude protein content of the grass was also found to increase significantly with increase in shade levels. Protein content was higher in Haritha compared to Hamil. Crude protein content decreased with increase in potassium levels. Higher crude protein content was observed at the lowest dose of potassium.

Whatever be the shade levels crude protein was high in v_2 but this high content of crude protein in v_2 was more under open condition.

An increase in potassium resulted in a decrease in crude protein for both the varieties. But this decrease was not significant between k_2 and k_3 in $v_{[illegible]}$.

In general the effect of potassium at higher doses was negative for this character. But under open condition and 50 per cent shade crude protein content of grass was on par at k_2 and k_3 levels.

4.6.2 Crude fibre content [Table 4.6.1a)]

Shade levels and varieties significantly influenced the crude fibre content of the plant. Crude fibre content reduced significantly with increase in shade levels. Lowest fibre content was noticed at 25 per cent shade level which was on par with 50 per cent shade level. Among the varieties, Haritha (v_2) registered the lowest crude fibre content. Potassium had no influence on crude fibre content.

4.6.3 Crude protein yield [Tables 4.6.2(a), (b) and (c)]

Significant increase in crude protein yield was obtained by shade levels, varieties and potassium application. Crude protein yield was the highest for lowest shade level in first, second and last cuts. However, in third and fourth cuts, 25 per cent shade level recorded the maximum crude protein yield.

Table 4.6.2 (a). Main effects of shade levels, varieties and potassium on protein yield of guinea grass (t ha^{-1})

Main effects of factors	I Cut	II Cut	III Cut	IV Cut	V Cut
Shade levels					
s_0	0.34	0.42	0.27	0.28	0.34
s_1	0.30	0.39	0.33	0.31	0.30
s_2	0.21	0.22	0.20	0.20	0.21
$F_{2,4}$	3892.93**	8967.43**	205464.00**	119863.60**	48365.50**
SE	0.056	0.039	0.015	0.016	0.029
CD	0.220	0.153	0.058	0.065	0.116
Varieties					
v_1	0.29	0.35	0.26	0.27	0.29
v_2	0.28	0.34	0.27	0.26	0.28
$F_{1,6}$	89.26**	110.32**	89.55**	1423.71**	412.34**
SE	0.040	0.039	0.031	0.018	0.026
CD	0.137	0.134	0.107	0.064	0.092
Potash levels					
k_1	0.24	0.31	0.27	0.26	0.26
k_2	0.30	0.35	0.27	0.27	0.29
k_3	0.31	0.37	0.27	0.26	0.30
$F_{2,24}$	14137.50**	5556.70**	62.62**	145.09**	3878.12**
SE	0.035	0.037	0.028	0.033	0.032
CD	0.102	0.109	0.082	0.097	0.093

** Significant at 1 per cent level

Table 4.6.2 (b). Interaction effects of shade levels, varieties and potassium on protein yield of guinea grass (t ha^{-1})

Interaction effects of factors	I Cut	II Cut	III Cut	IV Cut	V cut
s_0v_1	0.35	0.43	0.27	0.29	0.35
s_0v_2	0.34	0.40	0.27	0.27	0.33
s_1v_1	0.31	0.39	0.33	0.32	0.30
s_1v_2	0.29	0.40	0.33	0.30	0.29
s_2v_1	0.21	0.22	0.19	0.20	0.21
s_2v_2	0.22	0.22	0.20	0.20	0.21
$F_{2,6}$	264.46**	354.87**	25.73**	1159.71**	281.17**
SE	0.069	0.067	0.054	0.032	0.046
CD	0.237	0.232	0.186	0.110	0.159
v_1k_1	0.24	0.31	0.27	0.26	0.26
v_1k_2	0.30	0.36	0.26	0.27	0.30
v_1k_3	0.31	0.37	0.26	0.27	0.30
v_2k_1	0.23	0.32	0.27	0.25	0.25
v_2k_2	0.30	0.34	0.27	0.26	0.28
v_2k_3	0.31	0.36	0.27	0.26	0.29
$F_{2,24}$	303.35**	420.94**	90.48**	NS	48.64**
SE	0.05	0.053	0.040	0.047	0.045
CD	0.145	0.154	0.116	-	0.132

** Significant at 1 per cent level NS Not significant

Table 4.6.2 (c). Interaction effects of shade levels with potassium on protein yield of guinea grass (t ha^{-1})

Interaction effects of factors	I Cut	II Cut	III Cut	IV Cut	V Cut
s_0k_1	0.27	0.36	0.28	0.27	0.29
s_0k_2	0.37	0.43	0.27	0.29	0.36
s_0k_3	0.38	0.46	0.27	0.28	0.36
s_1k_1	0.24	0.36	0.33	0.30	0.28
s_1k_2	0.31	0.40	0.33	0.31	0.30
s_1k_3	0.33	0.42	0.33	0.31	0.31
s_2k_1	0.20	0.21	0.20	0.20	0.21
s_2k_2	0.22	0.22	0.20	0.20	0.21
s_2k_3	0.22	0.22	0.20	0.20	0.21
$F_{4,24}$	1889.38**	1169.34**	20.55**	17.26**	1344.53**
SE	0.061	0.065	0.049	0.057	0.055
CD	0.177	0.189	0.142	0.167	0.162

** Significant at 1 per cent level

Varieties also had a significant effect on crude protein yield in all cuts. Hamil registered the highest crude protein yield in first, second and last cuts whereas in third and fourth cuts Haritha registered highest crude protein yield.

Potassium application also had significant influence on crude protein yield. The highest level of K_2O (150 kg ha^{-1}) recorded maximum crude protein yield in first, second and last cuts, while in fourth cut, lowest level of K_2O (50 kg ha^{-1}) registered highest crude protein yield and in third cut medium level of K_2O (100 kg ha^{-1}) registered highest crude protein yield.

Significant S x V interaction was noticed in all harvests. Under s_0 and s_1, v_1 registered high crude protein yield in first and fifth cut while v_2 grown under s_2 had high crude protein yield in all the cuts. In second and third cuts also v_2 registered high crude protein yield when the grass is grown under s_1. In the fourth cut, however v_1 had high crude protein yield under s_1.

In the first, second and fifth cuts there was an increase in crude protein yield of v_1 and v_2 with an increase in the level of potassium. But in the third cut, response of potassium was not significant with v_1 and v_2 except for the observation for v_1k_1. Interaction was not evident in case of fourth cut.

In the first cut under s_0, response to k_2 and k_3 was on par but the protein yield increased with an increase in potassium when the crop is grown under s_1 and s_2. In the second cut whatever be the levels of potassium there was a significant reduction in crude protein under s_2, though the response of potassium was positive. In the third cut k_2 and k_3 were on par at s_2 with respect to the character crude protein. In the fourth cut quadratic type of response was seen at the various levels of shade. In the fifth cut under s_0 , k_2 and k_3 were on par. Under s_1, proportionate increase with potassium levels was seen. Under s_2, k_1 and k_2 were on par.

4.7 NUTRIENT UPTAKE

4.7.1 Nitrogen uptake [Table 4.7(a), (b) and (c)]

Shade levels, varieties and potassium application had significant influence on nitrogen uptake by the plant. There was a significant increase in nitrogen uptake with a decrease in shade level. Highest nitrogen uptake was recorded at zero per cent shade level. Varieties also varied significantly in nitrogen uptake. Highest nitrogen uptake was observed in Hamil followed by Haritha.

Application of potassium also helped to increase the nitrogen uptake. Higher doses of potassium resulted in higher nitrogen uptake.

Significant S x V interaction was also observed. The uptake of nitrogen decreased with an increase in levels of shade for Hamil. In the absence of shade and under 25 per cent shade, nitrogen uptake by Hamil was significantly higher while in 50 per cent shade, the uptake of nitrogen by Haritha was more.

V x K interaction was also significant. A significant increase in nitrogen uptake was seen with an increase in potassium for both v_1 and v_2.

Significant S x K interaction was also noticed. Under all shaded conditions an increase in potassium resulted in an increase in nitrogen uptake.

4.7.2 Phosphorus uptake [Table 4.7(a), (b) and (c)]

A significant increase in phosphorus uptake with decrease in shade levels was observed. Varieties varied significantly in phosphorus uptake in first and second harvests. Hamil recorded the highest phosphorus uptake of 30.84 kg ha^{-1}. Application of potassium also had significant influence on phosphorus uptake. Phosphorus uptake was highest at k_3 level (30.38 kg ha^{-1}).

Significant S x V interaction was observed. The uptake of phosphorus decreased with an increase in levels of shade for both the varieties.

Table 4.7 (a). Main effects of shade levels, varieties and potassium on the uptake of nitrogen, phosphorus and potassium by guinea grass (kg ha^{-1})

Main effects of factors	N	P	K
Shade levels			
s_0	311.06	34.05	460.67
s_1	310.11	30.10	446.34
s_2	218.48	24.16	312.81
$F_{2,4}$	20358.20**	5716.82**	19948.75**
SE	0.373	0.067	0.577
CD	1.463	0.263	2.267
Varieties			
v_1	282.95	30.84	414.76
v_2	276.81	28.17	398.46
$F_{1,6}$	119.41**	979.35**	741.72**
SE	0.397	0.060	0.423
CD	1.373	0.209	1.464
Potash levels			
k_1	258.59	28.64	368.76
k_2	286.70	29.49	416.58
k_3	294.36	30.38	434.48
$F_{2,24}$	1220.85**	240.38**	2740.09**
SE	0.539	0.056	0.649
CD	1.573	0.164	1.895

** Significant at 1 per cent level

Table 4.7 (b). Interaction effects of shade levels and potassium with varieties on the uptake of nitrogen, phosphorus and potassium by guinea grass (kg ha^{-1})

Interaction effects of factors	N	P	K
s_0v_1	318.17	35.34	475.86
s_0v_2	303.94	33.16	445.48
s_1v_1	314.18	31.43	454.67
s_1v_2	306.03	28.77	438.02
s_0v_1	216.50	25.73	313.74
s_2v_2	220.47	22.58	311.88
$F_{2,6}$	90.77**	10.63*	189.41**
SE	0.687	0.105	0.733
CD	2.378	0.362	2.536
v_1k_1	259.74	30.01	373.60
v_1k_2	289.92	30.88	425.24
v_1k_3	299.18	31.62	445.42
v_2k_1	257.43	27.27	363.92
v_2k_2	283.48	28.10	407.91
v_2k_3	289.53	29.13	423.54
$F_{2,24}$	11.71**	NS	22.62**
SE	0.762	0.079	0.918
CD	2.225	-	2.679

* Significant at 5 per cent level ** Significant at 1 per cent level NS Not significant

Table 4.7 (c). Interaction effects of shade levels with potassium on the uptake of nitrogen, phosphorus and potassium by guinea grass (kg ha^{-1})

Interaction effects of factors	N	P	K
s_0k_1	277.93	32.45	404.65
s_0k_2	324.10	34.75	479.15
s_0k_3	331.13	35.55	498.20
s_1k_1	288.65	29.22	406.67
s_1k_2	315.12	30.13	453.90
s_1k_3	326.55	30.95	478.47
s_2k_1	209.18	24.25	294.97
s_2k_2	220.88	23.58	316.68
s_2k_3	225.38	24.63	326.78
$F_{4, 24}$	125.67**	71.76**	228.20**
SE	0.934	0.097	1.124
CD	2.725	0.284	3.282

** Significant at 1 per cent level

Significant S x K interaction was also noticed. Under open shade and under 25 per cent shade, an increase in potassium resulted in an increase in phosphorus uptake. However, under 50 per cent shade this increase was not significant at k_1 and k_2 levels.

V x K interaction was not significant.

4.7.3 Potassium uptake [Table 4.7 (a) and (b)]

Shade levels, varieties and potassium application significantly influenced the uptake of potassium by plant. Uptake of potassium was found to be significantly higher at zero per cent shade level. Among the varieties Hamil recorded highest potassium uptake of 414.76 Kg ha^{-1}. Application of potassium influenced the potassium uptake by plant. Higher doses of potassium resulted in significantly higher uptake of potassium.

Significant S x V interaction was also noticed. The uptake of potassium decreased with an increase in levels of shade for both the varieties.

In V x K interaction, a significant increase in potassium uptake was observed with an increase in potassium for both v_1 and v_2.

In S x K interaction, under all shaded condition an increase in potassium resulted in an increase in potassium uptake.

4.8 NUTRIENT STATUS OF SOIL AFTER THE EXPERIMENT

4.8.1 Available nitrogen (Table 4.8)

Shade levels, varieties and potassium application had no significant influence on available nitrogen status of the soil.

None of the interactions were significant.

Table 4.8 Main effects of shade levels, varieties and potassium on available nitrogen, phosphorus and potassium status of soil after the experiment (kg ha^{-1})

Main effects of factors	Nitrogen	Phosphorus	Potassium
Shade levels			
s_0	205.29	53.51	102.13
s_1	205.51	53.72	101.38
s_2	205.11	53.78	100.50
$F_{2,4}$	NS	NS	109.04**
SE	0.276	0.057	0.078
CD	-	-	0.306
Varieties			
v_1	205.30	53.67	101.36
v_2	205.30	53.67	101.32
$F_{1,6}$	NS	NS	NS
SE	0.509	0.042	0.059
CD	-	-	-
Potash levels			
k_1	205.26	53.22	98.13
k_2	205.51	53.73	101.56
k_3	205.15	54.05	104.33
$F_{2,24}$	NS	51.54**	1908.34**
SE	0.583	0.059	0.071
CD	-	0.171	0.208

** Significant at 1 per cent level NS Not significant

4.8.2 Available phosphorus (Table 4.8)

Shade levels, varieties are found to be non-significant. However, application of potassium significantly influenced the phosphorus status of the soil. Highest soil phosphorus status of 54.05 Kg ha^{-1} was recorded at k_3 level followed by k_2 and k_1.

None of the interactions were significant.

4.8.3 Available potassium (Table 4.8)

There was a significant reduction of potassium status of the soil with increase in shade levels. Various potassium levels significantly influenced the available K status of the soil. The highest dose of potassium (150 kg K_2O ha^{-1}) registered the highest available K status of soil which was significantly superior to that at the other two K_2O levels.

None of the interactions were significant.

4.9 RESPONSE SURFACE AND STANDARDISATION OF RESPONSE TO APPLIED POTASSIUM [Table 4.9]

The fitted quadratic response is as follows

Under zero per cent shade,

$$Y = 0.8656 + 109.0722\,x - 25.9196\,X^2$$

F for regression = 214.653

R^2 = 96.62 %

The physical and economic optimum dose of potassium under open condition was found to be 130 Kg ha^{-1} and 121 Kg ha^{-1} respectively.

Table 4.9. Optimum dose of potassium for guinea grass under different shade intensities

Item (K_2O)	Price (Rs)	Physical optimum dose ($Kg\ ha^{-1}$)	Economic optimum dose ($Kg\ ha^{-1}$)
0 Per cent shade	7.5 Kg^{-1}	130	129
25 Per cent shade	7.5 Kg^{-1}	149	143
50 Per cent shade	7.5 Kg^{-1}	152	150

Under 25 per cent shade,

$$Y = 0.8296 + 103.1753\,x - 24.4870\,X^2$$

F for regression = 223.583

R^2 = 96.75 %

The physical and economic optimum dose of potassium under 25 per cent shade was found to be 149 Kg ha^{-1} and 143 Kg ha^{-1} respectively.

Under 50 per cent shade,

$$Y = 0.5765 + 72.0418\,x - 17.1457\,X^2$$

F for regression = 258.726

R^2 = 97.18 %

The physical and economic optimum dose of potassium under 50 per cent shade was found to be 152 Kg ha^{-1} and 150 Kg ha^{-1} respectively.

Table 4.10(a). Effects of shade levels, varieties and potassium on net returns and Benefit:Cost ratio of guinea grass

Main effects of factors	Net returns (Rs ha^{-1})	Benefit:Cost ratio
Shade levels		
s_0	53502.33	2.24
s_1	44482.00	2.00
s_2	26498.84	1.71
$F_{2,4}$	553687.30**	22.57**
SE	18.475	0.056
CD	72.531	0.220
Varieties		
v_1	43935.33	2.06
v_2	39053.45	1.90
$F_{1,6}$	39276.00**	7.05*
SE	17.419	0.044
CD	60.278	0.153
Potash levels		
k_1	34998.50	1.78
k_2	42668.33	2.05
k_3	46816.33	2.11
$F_{2,24}$	172339.60**	9.98**
SE	14.44	0.055
CD	42.157	0.161

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 4.10(b). Interaction effects of shade levels, varieties and potassium on net returns and Benefit:Cost ratio of guinea grass

Interaction effect of factors	Net returns (Rs ha^{-1})	Benefit:Cost ratio
s_0v_1	58983.00	2.36
s_0v_2	48021.67	2.11
s_1v_1	46804.00	2.09
s_1v_2	42160.00	1.91
s_2v_1	26019.00	1.74
s_2v_2	26978.67	1.67
$F_{2,6}$	19538.50**	NS
SE	30.170	0.076
CD	104.405	-
v_1k_1	35762.67	1.79
v_1k_2	44255.33	2.11
v_1k_3	51788.00	2.29
v_2k_1	34234.33	1.77
v_2k_2	41081.33	1.98
v_2k_3	41844.67	1.94
$F_{2,24}$	23838.64**	NS
SE	20.425	0.078
CD	59.620	-

** Significant at 1 per cent level NS Not significant

4.10 Economics [Table 4.10(a), (b) and (c)]

The net returns was positive in all the treatments. Shade levels, varieties and potassium had significant influence on the net returns. The highest net returns and benefit:cost ratio was obtained with s_0 (zero per cent shade level) which was significantly superior to all other shade levels. Similarly the highest dose of K_2O fetched maximum net returns and benefit:cost ratio. Among the varieties, Hamil was more profitable which could be evidenced from the highest net returns and benefit:cost ratio.

S x V interaction significantly influenced the net returns. The maximum net income of Rs.58983 ha^{-1} was obtained for the treatment s_0v_1 (zero per cent shade level + Hamil) which was significantly superior to all other treatments.

Table 4.10(c). Interaction effects of shade levels with potassium on net returns and Benefit:Cost ratio of guinea grass

Interaction effects of factors	Net returns (kg ha^{-1})	Benefit:Cost ratio
s_0k_1	41343.00	1.90
s_0k_2	55731.50	2.45
s_0k_3	63432.50	2.37
s_1k_1	39673.50	1.88
s_1k_2	45914.00	1.95
s_1k_3	47858.50	2.17
s_2k_1	23979.00	1.58
s_2k_2	26359.50	1.75
s_2k_3	29158.00	1.79
$F_{2,24}$	34256.18**	NS
SE	25.016	0.095
CD	73.019	-

** Significant at 1 per cent level NS Not significant

V x K interaction significantly influenced the net income. The treatment v_1k_3 (Hamil + 150 kg K_2O ha^{-1}) fetched maximum net returns.

S x K interaction also positively influenced the economics of guinea grass cultivation. The highest net returns was realized for the treatment s_0k_3 (zero per cent shade + 150 kg K_2O ha^{-1}).

DISCUSSION

5. DISCUSSION

The present investigation was undertaken with the objective of working out an optimum potash requirement for guinea grass varieties under varying shade levels. The results of the experiment, presented in the previous chapter are discussed here under.

5.1 GROWTH CHARACTERS

5.1.1 Plant height

The results of the study revealed that the plant height increased as the shade intensity increased. This increase in plant height with increase in shade intensity was observed in all the five cuts. Maximum plant height was recorded under 50 per cent shade and the minimum under full sunlight (Plate 2, 3 and 4). It is a well known fact that plants grown in shade are always taller than those grown in full sunlight. In open, the phytochrome pigment will be in P_r form which prevents elongation and under shade it gets converted to P_{fr} form which enhances stem elongation and results in increase in internode length. Production of auxins are more under shaded conditions which results in strong apical growth, preventing side shoot sprouting and further development. The chlorophyll content was also higher in 50 percent shade compared to open which resulted in higher plant height. A similar result was also reported by Mullakoya (1982) in guinea grass cv. Mackuenii and by Pillai (1986) in guinea grass and setaria grass.

There was significant difference in plant height between the varieties only at the second harvest. Hamil recorded more plant height compared to Haritha.

PLATE 2

Treatment Combination which registered the highest green fodder and dry fodder yield

PLATE 3

Guinea grass cv. haritha grown under open condition


$S_0V_1K_3$


$S_0V_2K_3$

PLATE 4

Guinea grass varieties grown under 25 percent shade


S1V2K3


S1V1K3

PLATE 5

Guinea grass varieties grown under 50 percent shade


$S_2V_1K_3$


$S_2V_2K_3$

Similar results were also reported in Hamil by George (1996) and in Haritha by Babu (1996).

Application of potash had shown linear increase in the height of plant with increasing levels. Potash is essential for various metabolic activities of living cells. This function of potash in the plant might have stimulated grasses to grow taller under higher doses of potash applications. It is a well known fact that potassium promotes the growth of meristematic tissues (Tisdale *et al.*, 1995) which may increase the chlorophyll content of the plant. A similar linear increase in plant height due to potassium application was reported by Mullakoya (1982) in guinea grass cv. Mackuenii.

Among the interaction effects, S x K interaction was found significant in all harvests except the first cut. When higher levels of shade was combined with potassium, it resulted in an increase in plant height. Similar result was also reported by Mullakoya (1982) in guinea grass. Application of potassium was found to increase the chlorophyll content of the plant under shaded condition.

S x V interaction was significant only in second cut. When higher levels of shade was combined with Hamil or Haritha, it resulted in an increase in plant height. The chlorophyll content was higher in 50 percent shade compared to open which resulted in higher plant height.

V x K interaction was significant in third and fifth harvests. When higher levels of potassium was combined with Hamil, it resulted in an increase in plant height.

5.1.2 Number of tillers

The study revealed that shade has dominating influence on inhibition of tiller production. Tiller number declined with shading in first, second and fifth

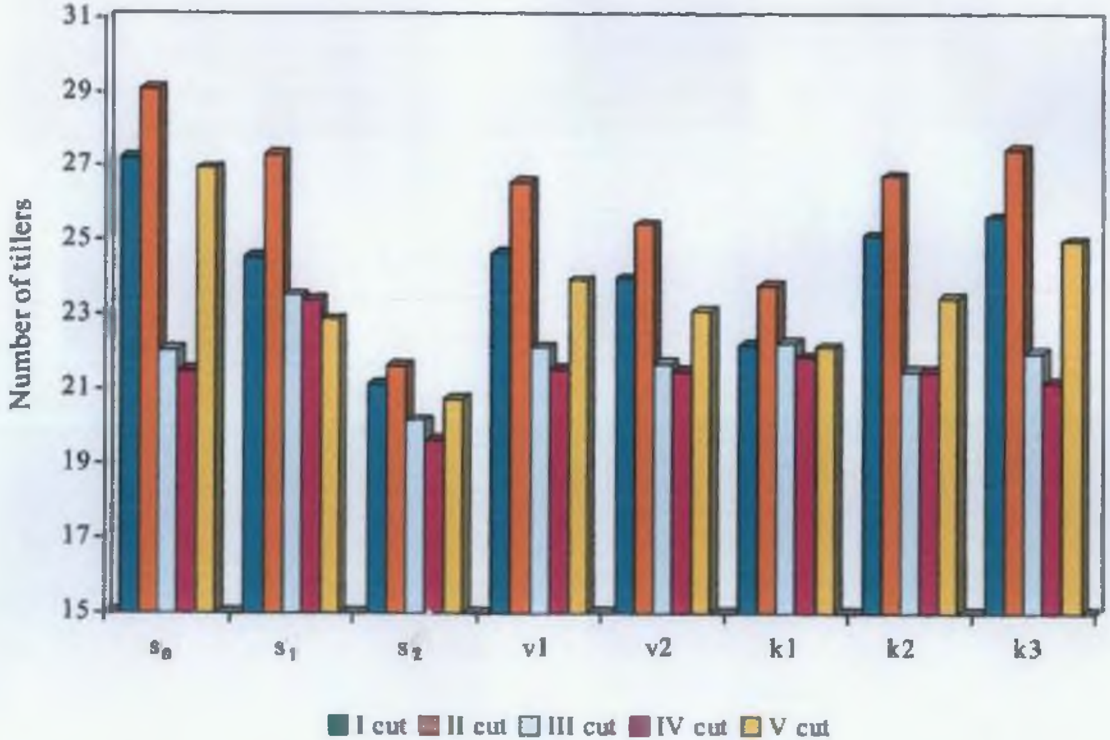

Fig. 3. Main effects of shade levels, varieties and potassium on number of tillers of guinea grass

cuts. Maximum number of tillers were recorded at zero per cent shade (Fig. 3). A similar decrease in the number of tiller production with increase in shade intensity was reported by Mullakoya (1982) in guinea grass cv. Mackuenii and by Pillai (1986) in guinea grass and setaria grass. The increase in number of tillers may be due to the higher leaf area index which might have resulted in more carbohydrate assimilation. These findings are also in agreement with the observations made by Buxton (2001) in forages and by Wong (1993) in two tropical grasses *Paspalum malacophyllum* and *Paspalum wettsteinii*.

However, in the third and fourth cuts tiller number increased under 25 per cent shade when compared to that under full sunlight. This reduction in tiller number under full sunlight may be due to the higher mean daily temperature prevailed during this period which may be above the optimum temperature required for growth of tropical grasses. Evaporation demand will be greatly reduced in the shaded environment and soil-water availability for the pasture will be maintained at a higher level than in the open (Wilson and Wild, 1991) through the combined effects of less evaporation from the soil and lower transpiration rates of the pasture. This is in conformity with the fact that temperature affects the growth rate and productivity of grasslands (Ramus, 1995) separately affecting each process of development as well as rates and direction of metabolic pathways associated with growth.

Tiller number was also significantly influenced by the varieties in all cuts except in the fourth cut. Among the varieties, highest tiller number was recorded by Hamil compared to Haritha as shown in Plate 2. Higher leaf area index recorded by this variety may have resulted in more carbohydrate production responsible for increased number of tillers. Similar result was also reported by Babu (1996) in Haritha and by George (1996) in Hamil.

Significant response for potash application was recorded in all cuts. Higher doses of potassium recorded the maximum tiller number. Similar increase in tiller number with application of potassium was reported by Mullakoya (1982) in guinea grass. Tillering capability is generally genetically controlled but is also much dependent on the nutrition and environmental factors. Among various plant hormones cytokinins, have been known to play important role in the growth of buds and tillers (Bruins, 1979). Therefore better potassium nutrition in fertilized plots resulted in significant increase in the number of tillers, probably through the increased chlorophyll content of leaves observed in this study.

S x V interactions were significant in all the harvests. Lower levels of shade combined with Hamil resulted in a significant positive response on the number of tillers in first, second and last cuts. This may be mainly due to the genetic superiority of this variety and also due to the increased vigour and growth under full sunlight. However, in third and fourth harvests Hamil recorded the highest tiller number at 25 per cent shade level. This may be due to the higher mean daily temperature that prevailed during this period which might have resulted in more evaporation from the open plots. In 25 per cent shade, light intensity and moisture availability would have been optimum for growth. Similar effects were also reported by Wilson and Wild (1991).

V x K interaction was found to be significant in all cuts. Hamil recorded highest tiller number at higher levels of potassium. This may be due to the genetic superiority of variety Hamil which performs better under optimum management practices. Hence tiller number was highest at all the levels of K for Hamil. However, in fourth cut, Haritha recorded highest tiller number at lower levels of potassium.

Tiller number was also significantly influenced by S x K interaction in all cuts. In the first, second and fifth harvests under optimum moisture availability, maximum response was obtained at 150 kg K_2O ha^{-1} in open condition whereas in the dry season, maximum number of tillers were produced with 100 kg K_2O ha^{-1} in 25 per cent shade level. This may be because in open condition the leaf area index was highest at k_3 level while at 25 per cent shade level maximum leaf area index responsible for more tillers was obtained at 100 kg K_2O ha^{-1}. This increase in leaf area might have resulted in better photosynthesis.

5.1.3 Leaf:stem ratio

Results on leaf:stem ratio showed that shade levels had significant influence in all harvests except in third cut. Leaf:stem ratio was higher in the open condition. The greater availability of sunlight in the open has greatly enhanced vigorous growth and higher tillering in grasses resulting in the higher production of larger leaves as evidenced by the high leaf area index under open. Leaf:stem ratio is a measure of the quality of fodder and hence determine its preference by animals. Similar improvement in forage leaf:stem ratio consequent to decrease in shade levels was reported by Pillai (1986) in guinea grass and setaria grass.

5.2 YIELD CHARACTERS

5.2.1 Green fodder yield

The green fodder production was 41.5 per cent, 50 per cent and 40.3 per cent lower in 50 per cent shade compared to open in first, second and last cuts respectively (Fig. 4). In the total green fodder yield there was an yield reduction of 4.8 per cent and 33.0 per cent in 25 per cent and 50 per cent shade respectively. Under 25 per cent shade the yield reduction compared to open was 16.8 per cent, 11.0 per cent and 15.3 per cent respectively for first, second and fifth harvests. The increased number of tillers, high root volume and high leaf area index in open may have contributed to the increased yield in open condition. In general, yield of forages is linearly related to the amount of light available, and in a coconut plantation with 50 per cent light transmission, the yield of a highly productive grass like *Panicum maximum* will be approximately 50 per cent of the yield achieved in full sunlight (Reynolds, 1995). Many workers (Sato and Dalmacio,

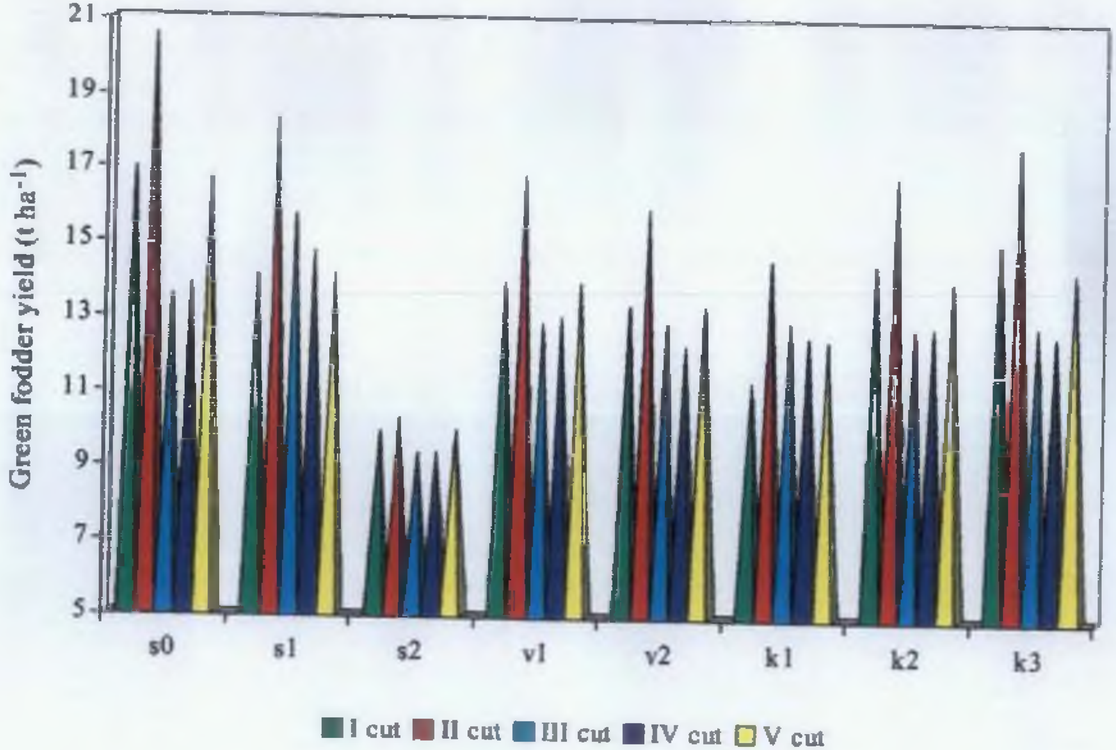

Fig. 4. Main effects of shade levels, varieties and potassium on green fodder yield (t ha^{-1}) of guinea grass

1991; Sharma *et al.*, 1996) have also reported yield reduction in agroforestry due to reduction in solar radiation availability. This is evident from the fact that a warm season C_4 plant continue the CO_2 uptake for photosynthesis at higher light levels closer to full sunlight and use the higher light intensity effectively (Gardener *et al.*,1985).

However, in the third and fourth cuts, green fodder yield increased to the tune of 15.7 per cent and 6.6 per cent under 25 per cent shade when compared to that under full sunlight. This reduction in green fodder yield under full sunlight may be due to the higher mean daily temperature that (Appendix 1) prevailed during this period which may be above the optimum temperature required for optimum growth for tropical grasses. This is in confirmity with the fact that temperature affects the growth rate and productivity of grasslands (Ramus, 1995) separately affecting each process of development as well as rates and direction of metabolic pathways associated with growth.

Among the varieties, Hamil (v_1) recorded 4.43 per cent increase in green fodder yield compared to Haritha (v_2). This might be due to the higher number of tillers produced by Hamil and better uptake of nutrients. This result is in confirmity with the findings of Babu (1996) in Haritha and George (1996) in Hamil.

The highest dose of potassium (150 kg ha^{-1}) recorded significantly higher green fodder yield in first, second and fifth harvests. An yield increase of 16.1 per cent and 12.7 per cent was obtained due to the application of 150 and 100 kg K_2O ha^{-1} over 50 kg K_2O ha^{-1}. Potassium increases the plant height, number of tillers, leaf area, number of stomata and its apertures, net photosynthesis and efficiency of carbondioxide assimilation owing to its role in many of the biochemical processes such as protein synthesis and carbohydrate metabolism and better potassium nourished plants grow vigorously (Jacob *et al.*, 1973). Here also application of K_2O @ 150 kg ha^{-1} was found to result in significantly higher plant

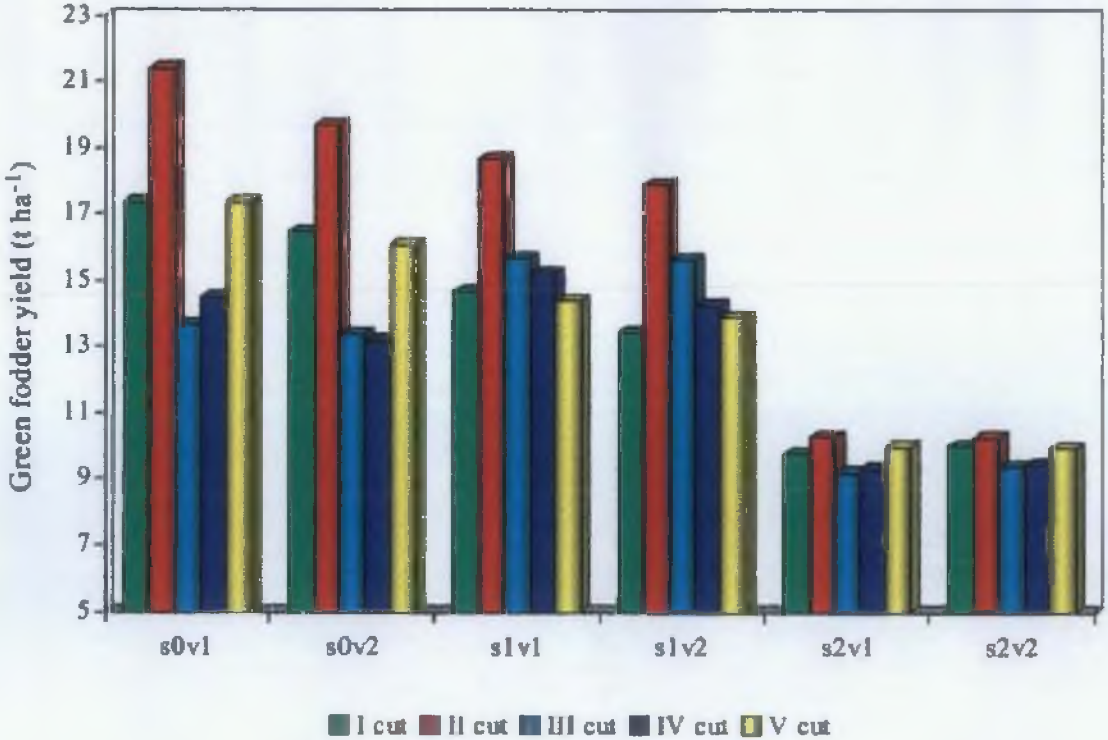

Fig. 5. Interaction effects of shade levels and varieties on green fodder yield (t ha^{-1}) of guinea grass

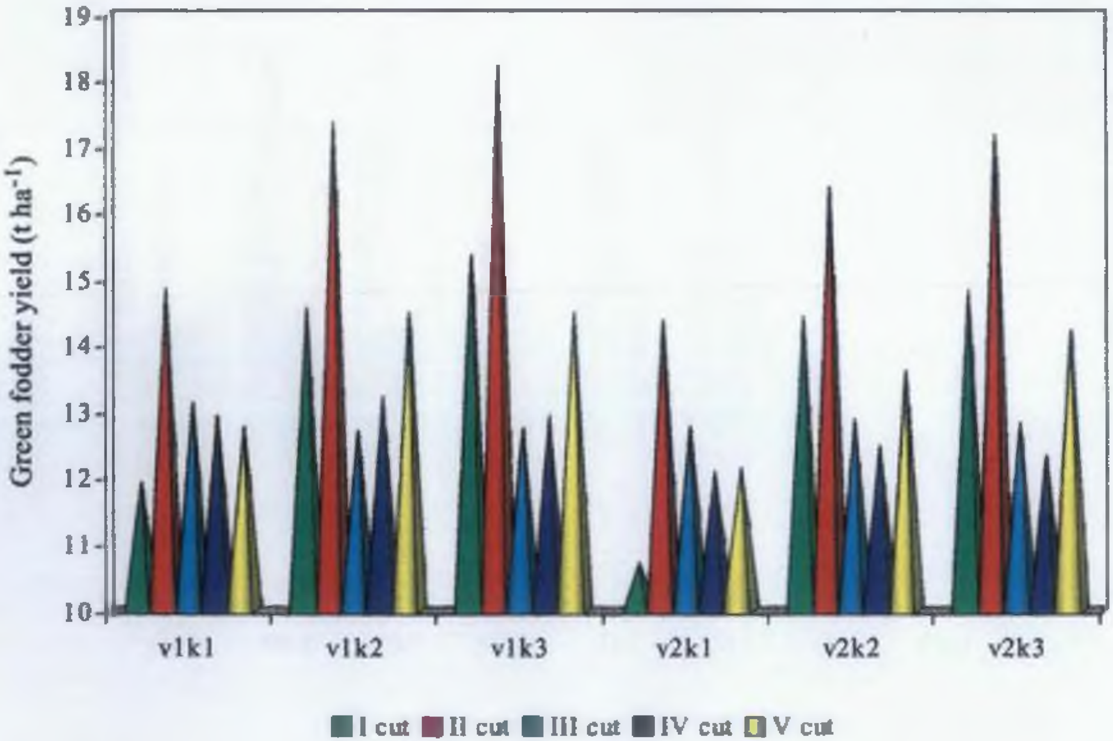

Fig. 6. Interaction effects of varieties and potassium on green fodder yield (t ha^{-1})

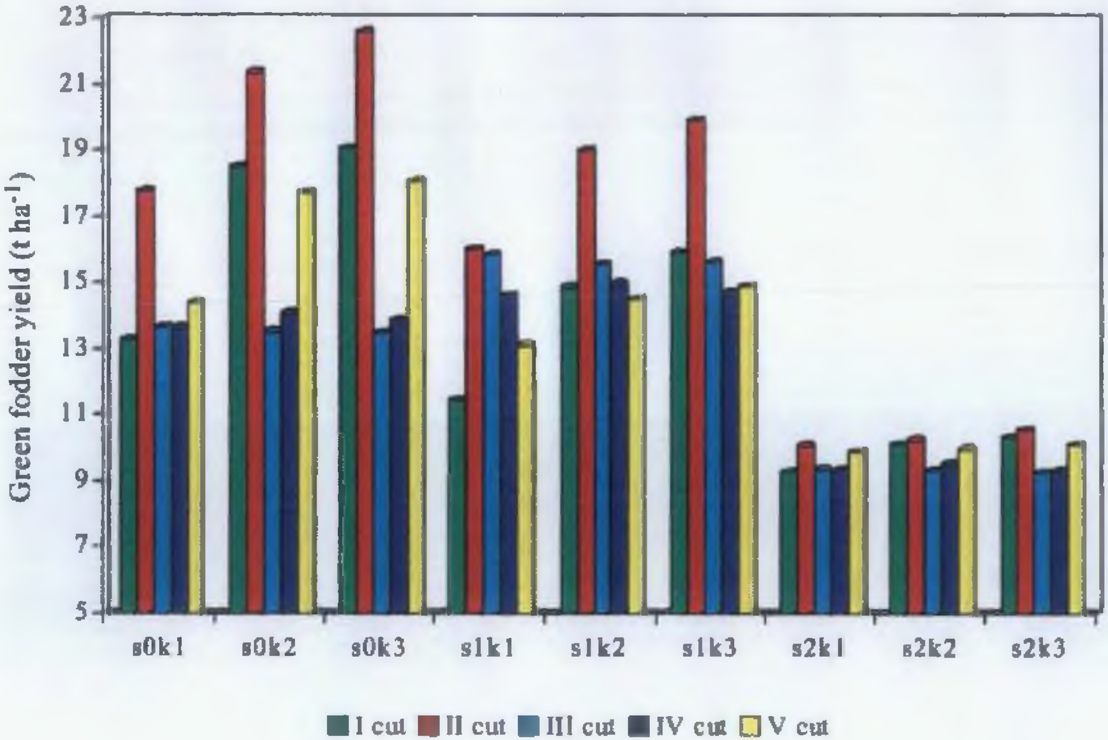

Fig. 7. Interaction effects of shade levels and potassium on green fodder yield (t ha^{-1})

height, number of tillers of the plant and root volume. Similar results were also reported in *Panicum maximum* by Mullakoya (1982) and in *Brachiaria decumbens* by Sonia (1999). Phillips and Kee (1998) also reported that potassium fertilization increased the green forage yield in hybrid bermuda grass. However, in third harvest lowest dose of potassium (k_1) recorded higher green fodder yield and in fourth harvest medium dose of potassium (k_2) recorded higher green fodder yield.

S x V interaction was significant in all harvests. Hamil recorded higher green fodder yield when grown under open conditions in first, second and fifth cuts (Fig. 5). This may be due to the good performance of this variety under full sunlight. However, in third and fourth harvests, Hamil recorded higher green fodder yield under 25 per cent shade level. This reduction in green fodder yield under full sunlight may be due to the higher mean daily temperature that prevailed during this period which may be above the optimum temperature required for optimum growth for tropical grasses. This is in confirmity with the fact that temperature affects the growth rate and productivity of grass lands (Ramus, 1995). When total green fodder yield is considered, variety Hamil in open condition (s_0v_1) yielded the highest followed by Hamil grown in 25 per cent shade (s_1v_1) whereas under 50 per cent shade both the varieties performed similarly. Hence it can be concluded that Hamil is suitable for open and less shaded situation (upto 25 percent shade) whereas Haritha can be recommended in more shaded situations ie., upto 50 per cent shade. The reason for this can be attributed to the increase in tillers which is almost same as that of Hamil under 50 per cent shade.

Significant V x K interaction was observed in first, second, third and last harvests (Fig. 6). For both the varieties application of K_2O at 150 kg ha^{-1} (k3) was found necessary for obtaining significant higher green fodder yield because at this levels of potash the tiller production was highest. However, in third harvest and fourth harvest Hamil recorded highest green fodder at lower levels of potassium of k_1 and k_2 respectively.

With regard to S x K interaction, the response of guinea grass to potash was found to be more in higher light intensity and a proportional decrease was seen with reduction in light intensities (Fig. 7). This can be attributed to the increased tiller production at higher light intensities at the same level of potash itself. At all the shade levels tried, k_3 (150 kg K_2O ha^{-1}) recorded significant higher green fodder yield. It can be inferred from this that application of K_2O @ 150 kg ha^{-1} is required for the optimum green fodder yield of guinea grass cv. Haritha and Hamil. Similar results were also reported by Mullakoya (1982) in guinea grass cv. Mackuenii.

5.2.2 Dry fodder yield

The shade levels, varieties and potassium application significantly influenced the dry fodder yield in all harvests. Compared to the open conditions there was a reduction of 4.1 per cent and 32.7 per cent in dry fodder yield in 25 per cent and 50 per cent shade respectively (Fig. 8). In shade, spongy tissues are developed in plants which may be responsible for lesser dry matter accumulation. This may be due to the partial reduction or absence of carbondioxide assimilation and reduced availability of constructive materials of plants as reported by Duggar (1903). A study undertaken by Wong (1993) involving the tropical grass *Paspalum malaco phyllum* and *Paspalum wettsteini* showed that shade depressed total dry matter production, the depression as expected being proportional to the quantum of photosynthetic active radiation reduction. In this aspect also under shade, the number of tillers and leaf area index are found to be significantly lower than that in open. The results are in confirmity with the findings of Mullakoya (1982) in guinea grass; Pillai (1986) in guinea grass and setaria grass and Eriksen and Whitney (1981) in *Brachiaria brizantha*.

However, in the third and fourth harvests, dry fodder yield increased under 25 per cent shade when compared to that under full sunlight. This reduction in dry fodder yield under full sunlight may be due to the higher mean daily

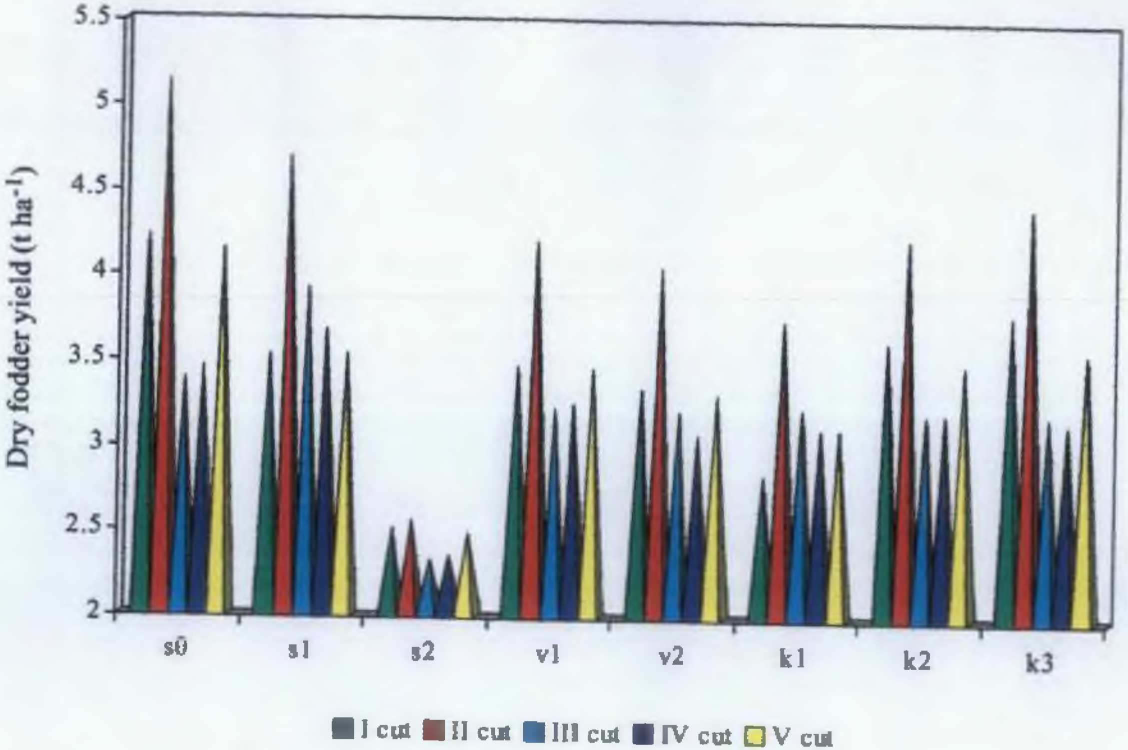

Fig. 8. Main effects of shade levels, varieties and potassium on dry fodder yield (t ha^{-1})

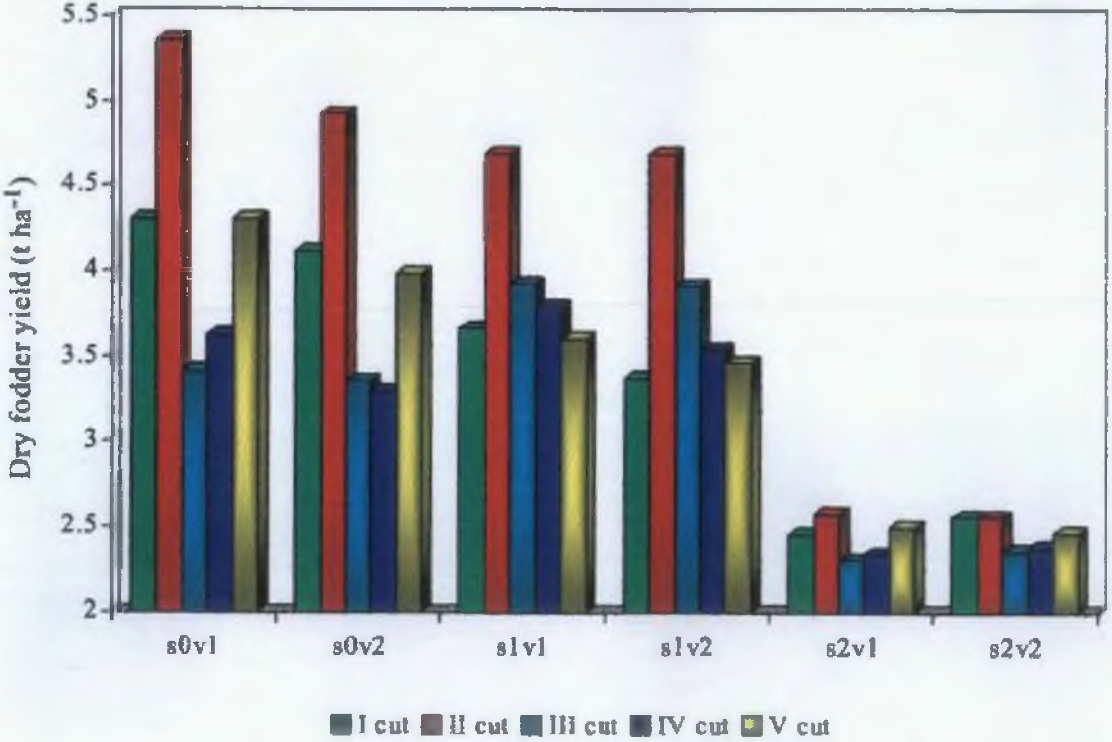

Fig. 9. Interaction effects of shade levels and varieties on dry fodder yield (t ha^{-1})

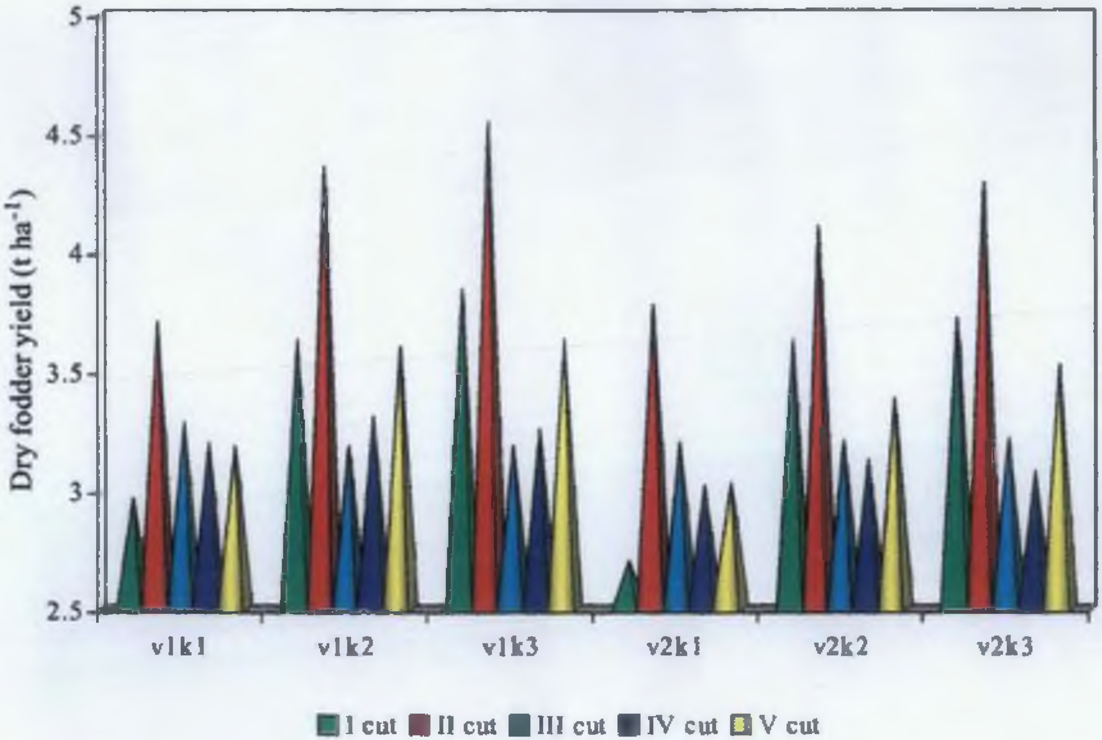

Fig. 10. Interaction effects of varieties and potassium on dry fodder yield (t ha^{-1})

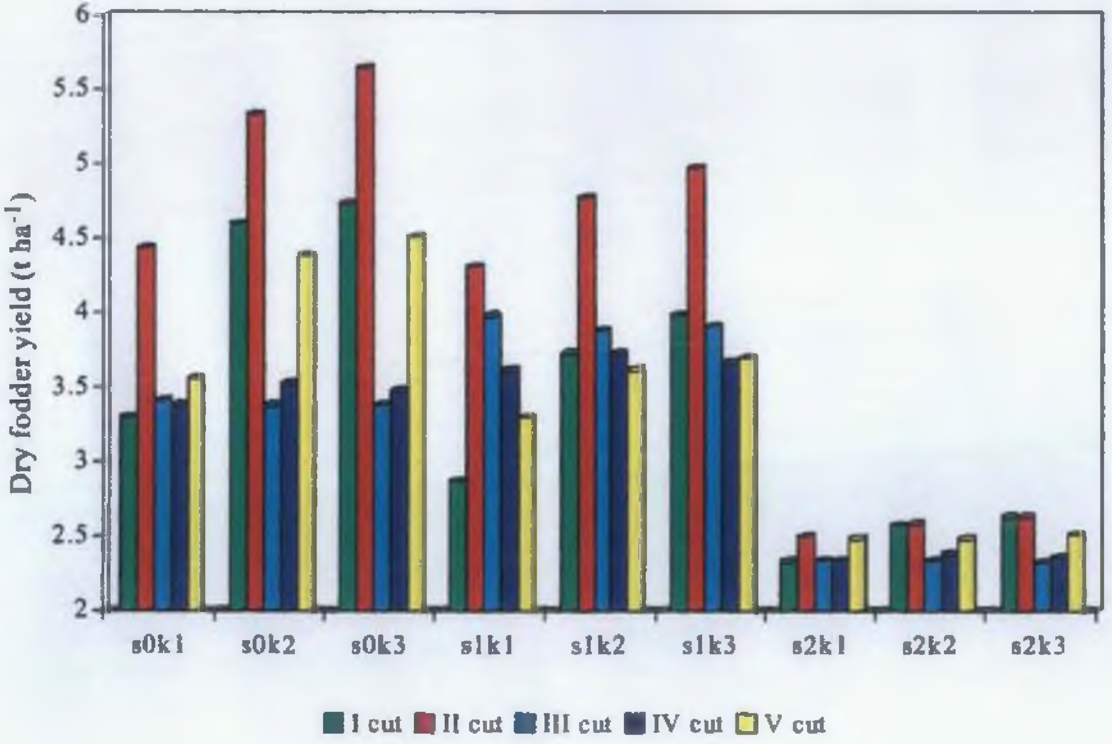

Fig. 11. Interaction effects of shade levels and potassium on dry fodder yield (t ha^{-1})

temperature that prevailed during this period which may be above the optimum temperature required for optimum growth of tropical grasses.

The dry fodder yield was significantly influenced by the varieties also. Hamil recorded the higher dry fodder yield compared to Haritha which is due to the higher green fodder production. This result is in confirmity with the findings of Babu (1996) in Haritha and George (1996) in Hamil.

The highest level of potassium gave maximum dry fodder yield in first, second and last cuts. This might be due to the greater translocation of photosynthates and assimilation of CO_2 at higher levels of potassium which in turn gave a higher dry fodder yield. Similar result was obtained in *Lolium multiflorum* by Haby *et al.* (1988) and in *Panicum maximum* and *Brachiaria ruziziensis* by Meerabai *et al.* (1993). However, in third cut lowest dose of potassium recorded higher dry fodder yield and in fourth cut medium dose of potassium recorded higher dry fodder yield.

S x V interaction was significant in all harvests. Hamil recorded significantly highest dry fodder yield under open conditions and in 25 per cent shade (Fig. 9). A linear reduction in dry fodder yield with decrease in light intensity was noticed which can be due to the same effect noticed in the case of green fodder yield. At 50 per cent shade both the varieties can be recommended for fodder production.

V x K interactions revealed that at all levels of potash, the dry fodder yield of Hamil was superior to Haritha and for both the varieties for maximum expression of yield in terms of dry fodder, application of 150 kg K_2O ha^{-1} was found to be ideal (Fig. 10).

S x K interaction was also significant. Reduction in light intensity recorded a negative response for potash application with respect to dry fodder yield. At all the three light intensities, application of 150 kg K_2O ha^{-1} was seen necessary for optimum dry fodder production in first, second and last cuts. However in third cut at all the light intensities lower levels of potassium recorded higher dry fodder yield and in fourth cut at all light intensities medium dose of potassium recorded higher dry fodder yield (Fig. 11). Similar results was also reported by Mullakoya (1982) in guinea grass.

5.3 ROOT CHARACTERS

5.3.1 Root volume

Lower levels of shade recorded the highest root volume of the plant. Root and bud growth are usually inhibited by low light intensities and this can lead to a reduction in assimilate flow to the root system (Nelson, 1964). Exposure to prolonged periods of shade causes most forages to modify proportioning of biomass among plants parts so that the potential for photosynthetically active radiation interception is maintained or increased and root growth is decreased (Kephart and Buxton, 1996). Similar results was obtained in *Lolium perenne* by Gregory *et al.* (1987) and in *Paspalum malacophyllum* and *Paspalum wettsteinii* by Wong (1991).

The medium level of potassium (100 kg ha^{-1}) recorded the maximum root volume followed by higher level of potassium (150 kg ha^{-1}). Potassium improves stand persistence due to stronger root system. Potassium aids in the building of root reserves for the production of growth of new shoots. This large capacity for potassium absorption is certainly true for grasses (Keisling, 1978). Similar result was also reported by Meerabai *et al.* (1993) in rice.

Significant S x V interaction was noticed, wherein Haritha at lower levels of shade recorded maximum root volume. This may be due to the reduced root growth at higher levels of shade.

5.3.2 Root : shoot ratio

Shade levels, varieties, potassium and interactions were non-significant.

5.4 PHYSIOLOGICAL CHARACTERS

5.4.1 Leaf area index

A significant influence of shade levels on leaf area index was noticed in all harvests. The leaf area index was found to be maximum at zero per cent shade level in first, second and fifth harvests as shown in Fig. 12. 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 maximises radiation absorption by accumulating leaves (Ramus, 1995). The increase in leaf area index under open condition may be due to the increase in plant height, number of tillers, root volume and number of leaves in full sunlight. Similar results were also reported by Mullakoya (1982) in *Panicum maximum* and by Pillai (1986) in guinea grass and *Setaria grass*.

However, in third and fourth harvests, higher leaf area index was recorded at 25 per cent shade level. This reduction in leaf area index under full sunlight may be due to the higher mean daily temperature that prevailed during this period which may be above the optimum temperature required for optimum growth for tropical grasses. Evaporation demand will be greatly reduced in the shaded environment and soil water availability for the pasture will be maintained at a higher level than in the open (Wilson and Wild, 1991) during this period through the combined effects of the evaporation from the soil and lower transpiration rates of the pasture.

Leaf area index was also significantly influenced by varieties in all cuts except in the fourth cut. Hamil recorded higher leaf area index compared to

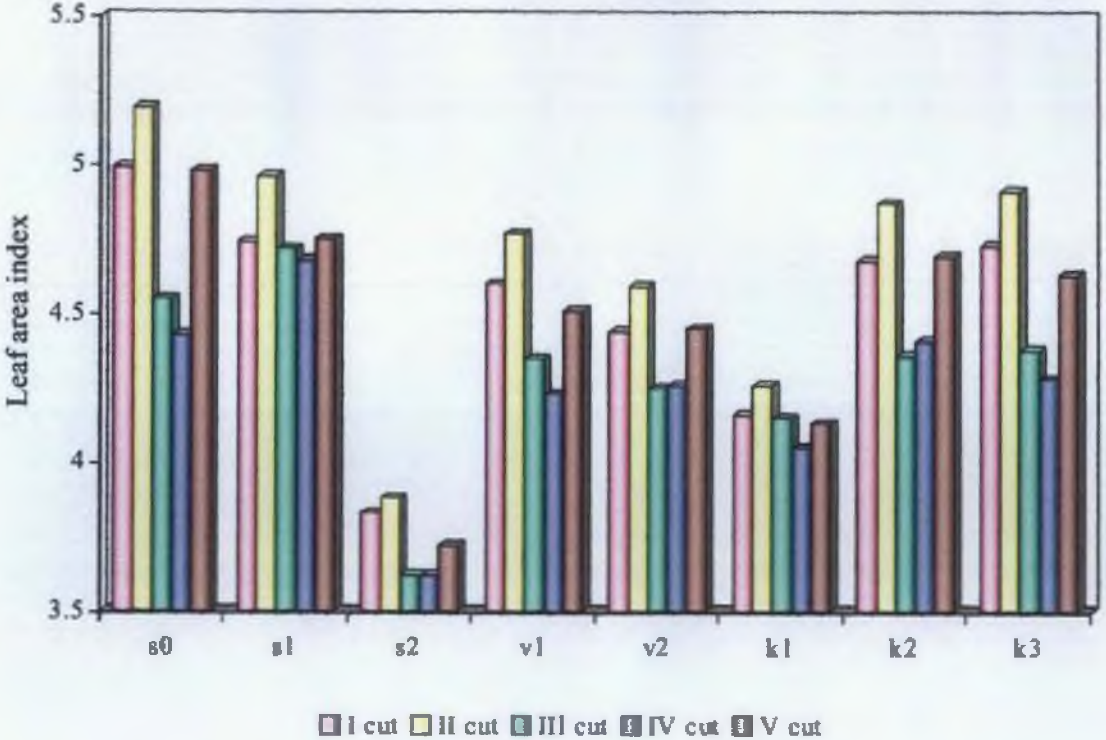

Fig. 12. Main effects of shade levels, varieties and potassium on Leaf Area Index of guinea grass

Haritha which is due to higher tiller number recorded by this variety which may have contributed to more number of leaves. Similar result was also reported by George (1996) in Hamil and Babu (1996) in Haritha due to the influence of increased number of tillers.

Higher levels of potassium registered higher leaf area index in first, second and third cuts. Potassium plays a crucial role in the meristematic growth through its effect on the synthesis of phytohormones which resulted in the production of more number of tillers, more number of leaves and significantly higher root volume. Increased potassium supply increased the leaf area of wheat leaves (Beringer, 1983). Similar result was also reported in *Panicum maximum* by Mullakoya (1982) and in *Brachiaria decumbens* by Sonia (1999). However in fourth and fifth cuts medium dose of potassium registered higher leaf area index.

S x K interaction significantly influenced leaf area index in first, second, third and fifth harvests. In open highest level of potassium (k_3) registered higher leaf index. This may be due to the increase in the number of leaves in full sunlight and also due to the increase in leaf area due to the application of potassium. In shaded situation k_2 (100 kg K_2O ha^{-1}) was sufficient to produce highest leaf area index. The tiller production was maximum at k_3 level in open and k_2 level in 25 per cent shade. Increase in number of tiller might have contributed to more number of leaves and hence leaf area index. Similar results were obtained by Mullakoya (1982) in guinea grass. However in third cut at 25 percent shade level highest level of potassium registered higher leaf area index. This may be due to the increase in the number of leaves at 25 percent shade during the period.

V x K and S x V interactions were non-significant.

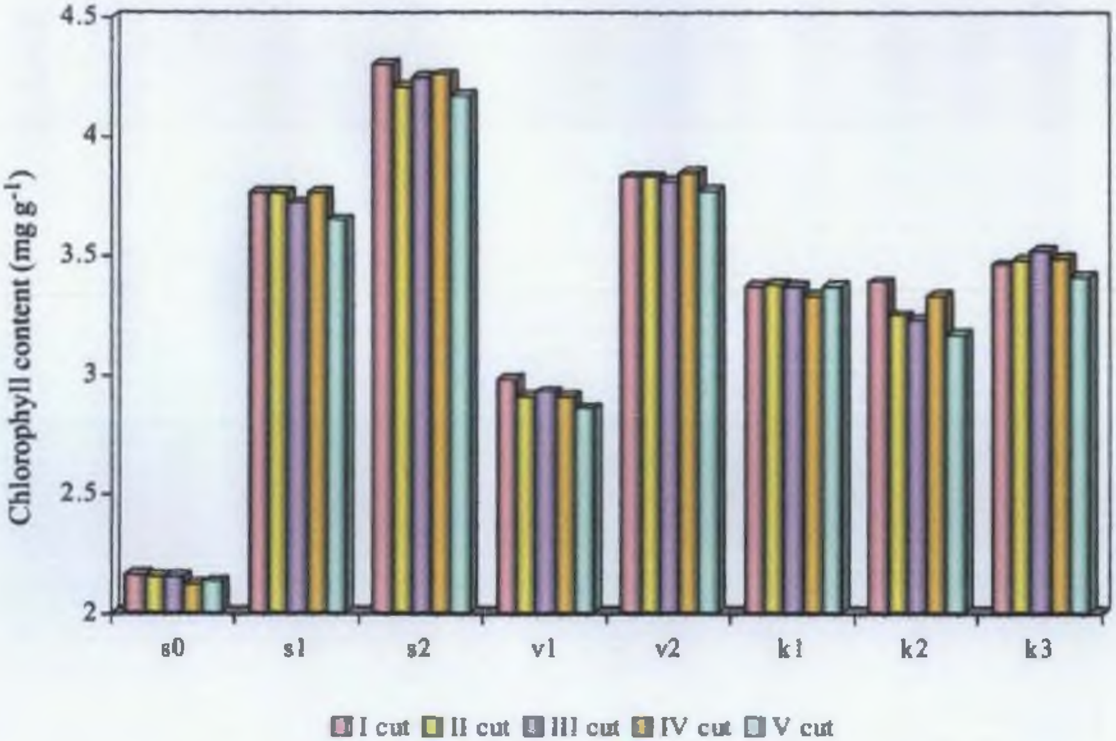

Fig. 13. Main effects of shade levels, varieties and potassium on chlorophyll content (mg g^{-1})

5.5 BIOCHEMICAL ASPECTS

5.5.1 Chlorophyll content

Shade levels, varieties and potassium application significantly influenced the chlorophyll content of the plant. Chlorophyll content increased significantly with increase in shade levels (Fig. 13). Fifty per cent shade level recorded the maximum chlorophyll content in all harvests. The increase in chlorophyll content under shaded conditions is an adaptive mechanism commonly observed in plants to maintain the photosynthetic efficiency (Attridge, 1990). The higher leaf content of chlorophyll was also apparant in the visual appearance of the crop and it looked distinctly green under shade than in the open. The greater light harvesting complex per area is the result of increased chlorophyll 'b'/ chlorophyll 'a' ratio. Chlorophyll 'b' absorbs short wave length compared to chlorophyll 'a'. So to maximise light absorption there will be more chlorophyll 'b' under shade. True shade tolerance in forage species is associated with high chlorophyll densities (Stur, 1991). Mullakoya (1982) also reported high chlorophyll content under 75 per cent shade level in *Panicum maximum*.

Varieties also had significant influence on chlorophyll content of plant. Haritha recorded highest chlorophyll content compared to Hamil. Haritha is a shade tolerant cultivar released by Kerala Agricultural University. Increased chlorophyll content is an adaptive mechanism for shade tolerant plant types to maintain the photosynthetic rate (Attridge, 1990).

Application of potassium also had significant influence on chlorophyll content in all harvests. Higher levels of K_2O (150 kg ha^{-1}) resulted in an increase in the chlorophyll content of the plant. Thomson and Weir (1962) reported on the importance of potash in plastid development and it is presumed that higher doses of potash application resulted in enhanced chlorophyll synthesis. A reduction in chlorophyll content has also been reported earlier due to lower levels of K_2O

supply (Hewitt, 1983; Huber, 1984). This might be due to certain abnormal changes occurring in the chloroplast structure or unavailability of certain other nutrients which may affect the chlorophyll synthesis (Hewitt, 1983). Similar results was also reported by Sheela (1993) and Anu (2001) in rice.

Significant S x V interaction was observed in all harvests. Under all the shade intensities Haritha recorded higher chlorophyll content and the highest was under 50 per cent shade level. This may be due to the higher content of chlorophyll 'b' in this variety under deep shade to maximise light absorption.

V x K interaction was also significant in all harvests. The maximum chlorophyll content was recorded by Haritha at all K_2O levels and higher chlorophyll content was seen at 50 kg K_2O ha^{-1}. This may be due to the higher content of chlorophyll 'b' in this variety which was more projected by the enhanced chloroplast synthesis by potassium at k_1 level.

S x K interaction results revealed the influence of higher shade intensity in increasing the chlorophyll content at different K_2O levels. Under 50 per cent shade, k_1 was found to produce the highest chlorophyll content except in third cut while in 0 per cent shade, application of k_3 resulted in significantly higher chlorophyll content. It may be due to the inherent ability of plants to maintain photosynthetic efficiency that increase in K_2O levels increased chlorophyll content in lower light intensities.

5.6 QUALITY ASPECTS

5.6.1 Crude protein

Crude protein content was significantly influenced by shade levels, varieties and potassium application in guinea grass. Crude protein content was found to increase significantly with increase in shade levels. Crude protein content concentration is much more responsive to shading than other quality characteristics. Plants adapted to shade had lower non-structural carbohydrate concentrations than those adapted to full sunlight (Kephart and Buxton, 1996). Increased concentration of nitrogenous compounds from shading is usually at the expense of soluble carbohydrates (Buxton, 2001). Mullakoya (1982) and Pillai (1986) also observed an increase in crude protein content by shading in guinea grass.

Among the varieties, Haritha reported higher crude protein content compared to Hamil. The genetic superiority of this variety in this character has been an added advantage in this respect. Similar result was also reported by Babu (1996) in Haritha and by George (1996) in Hamil.

Potassium levels significantly reduced the crude protein content. Higher crude protein content was observed at lowest dose of potassium (50 kg ha^{-1}). This might be due to a comparatively higher levels of K_2O in the soil which inturn reduced the uptake of N, resulting in a consequent reduction in crude protein synthesis (Raheja, 1966). Similar results were obtained by Sonia (1999) in signal grass.

Significant S x V interaction was also noticed. Haritha recorded highest crude protein content at higher levels of shade. Hence shading was found to be beneficial for improving the protein content of guinea grass.

In V x K interaction, there was a significant increase in the crude protein content for both Haritha and Hamil at lower levels of potassium.

S x K interaction revealed the influence of higher shade intensity in increasing the crude protein content at lower levels of potassium. This might be due to a comparatively higher levels of potassium in the soil which in turn reduce to the uptake of nitrogen, resulting in a consequent reduction in protein synthesis (Raheja, 1966). Similar result was also reported by Mullakoya (1982) in guinea grass.

5.6.2 Crude fibre content

Shade levels and varieties significantly influenced the crude fibre content of the plant. Crude fibre content reduced significantly with increase in shade levels. Lowest fibre content was noticed at 25 per cent shade level which was on par with 50 per cent shade level. Growing of forages in full sunlight causes changes in chemical composition of plant parts including that of cell walls. Forage cell walls, composed mostly of polysaccharides and lignin, limit forage consumption and digestability (Buxton, 2001). Most studies have reported that shading decreases cell wall concentration of forages. The hemicellulose fraction may be less sensitive to shading than cellulose and lignin fractions (Kephart and Buxton, 1996). Similar results were also reported by Mullakoya (1982) in *Panicum maximum* and by Pillai (1986) in guinea grass and setaria grass.

Among the varieties, Haritha registered the lowest crude fibre content compared to Hamil. Similar results were also reported by Babu (1996) in Haritha and George (1996) in Hamil.

Application of potassium had no influence on crude fibre content of guinea grass.

S x V, V x K and S x K interactions were non-significant.

5.6.3 Crude protein yield

The crude protein yield was found to be significantly higher at open followed by that at 25 per cent and 50 per cent shade levels (Fig. 14). This may be

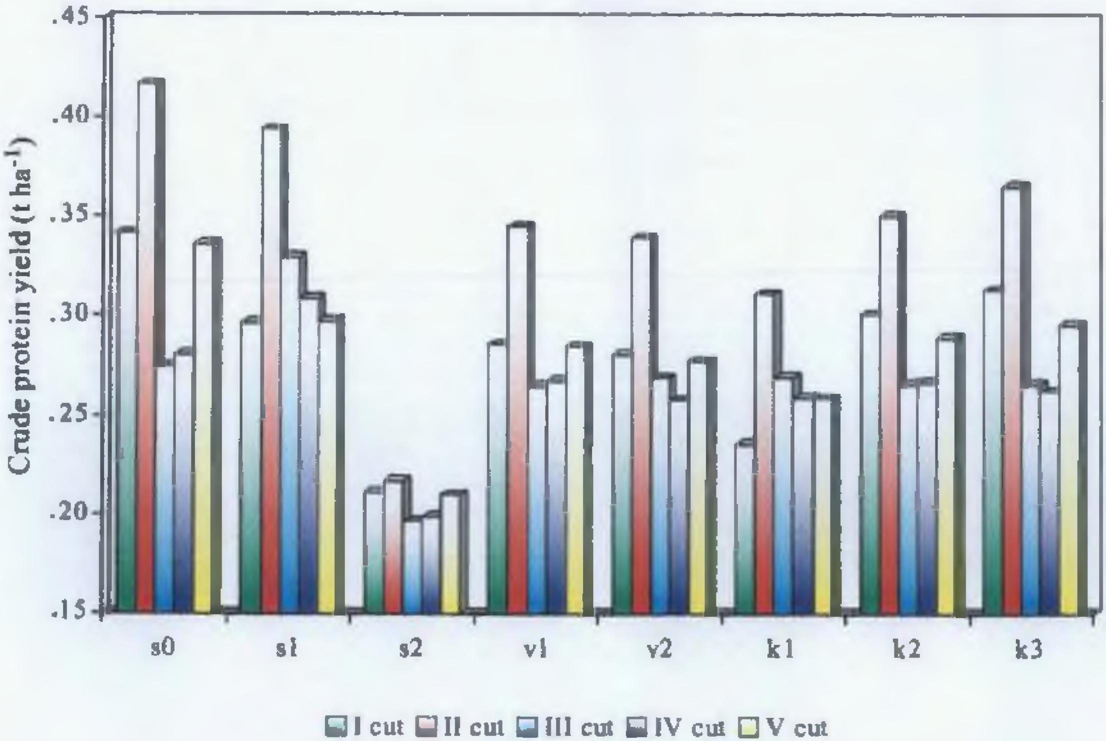

Fig. 14. Main effects of shade levels, varieties and potassium on crude protein yield (t ha^{-1})

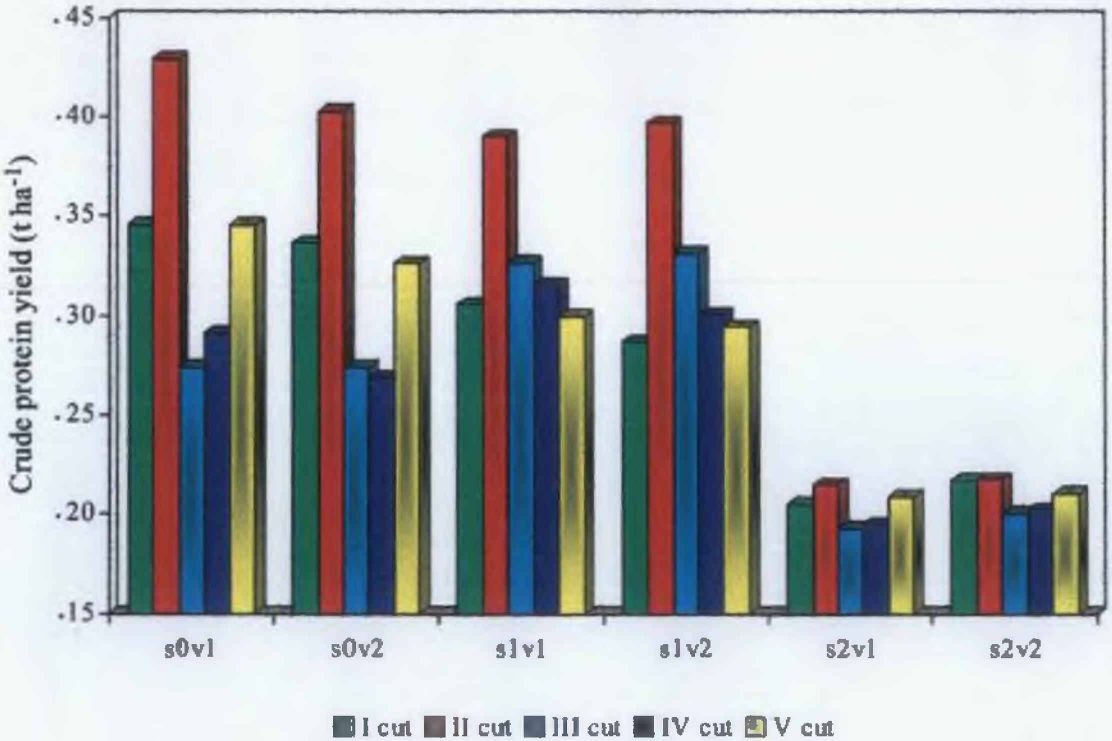

Fig. 15. Interaction effects of shade levels and varieties on crude protein yield (t ha^{-1})

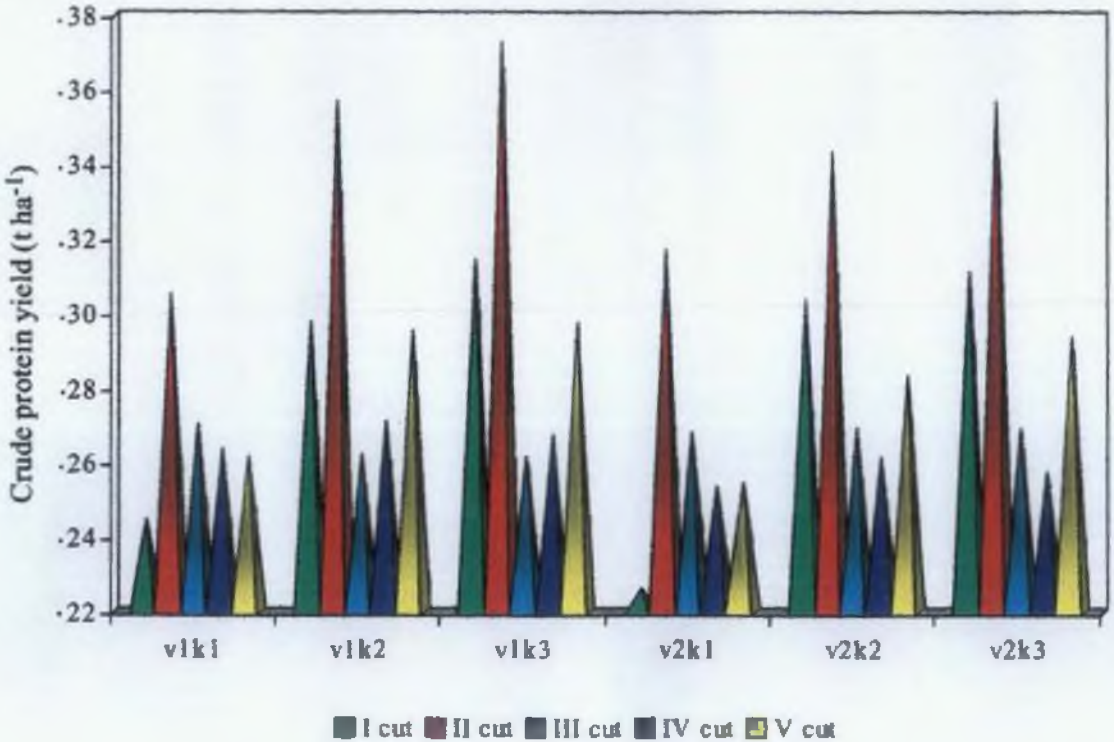

Fig. 16. Interaction effects of varieties and potassium on crude protein yield (t ha^{-1})

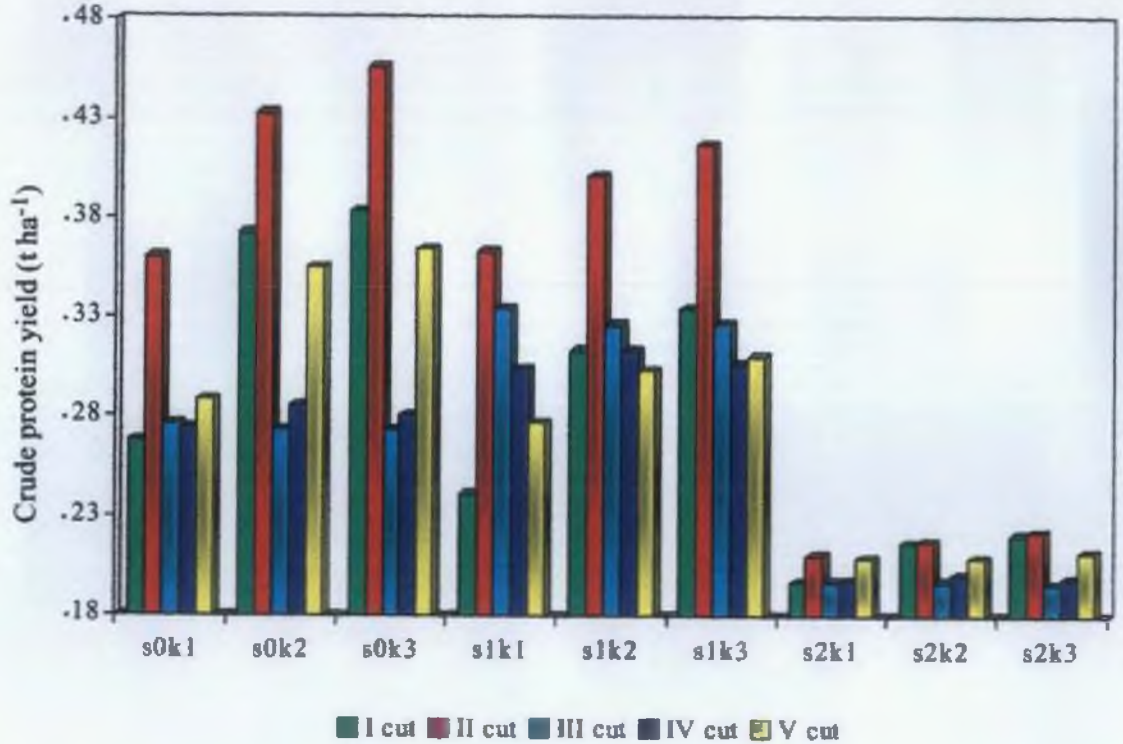

Fig. 17. Interaction effects of shade levels and potassium on crude protein yield (t ha^{-1})

due to the effect of dry fodder yield which was highest in the open and lowest in 50 per cent shade. The crude protein yield was reduced by 37.4 per cent and 1.4 per cent in 50 per cent and 25 per cent shade over open respectively. Similar result was also reported by Kepharat and Buxton (2001).

Among the varieties Hamil recorded significantly higher crude protein yield in first, second and last cuts which is also due to the higher dry matter production by this variety. However in third and fourth cuts Haritha registered higher crude protein yield.

Among the different K_2O levels, k_3 was found to produce higher crude protein yield followed by k_2 and k_1 in first, second and last cuts. Increased dry fodder yield at k_3 level may be the cause of significantly higher crude protein yield. However in third cut increased dry fodder yield at k_2 level (100 kg K_2O ha^{-1}) may be the cause of higher crude protein yield and in fourth cut increased dry fodder yield at k_1 level (50 kg K_2O ha^{-1}) may be the cause of higher crude protein yield.

S x V interaction was significant in all harvests. Hamil recorded significantly higher crude protein yield in open and in 25 per cent shade. At 50 per cent shade both the varieties were on par with respect to crude protein yield. This result is in accordance with that of dry fodder yield as seen in Fig. 15.

Influence of V x K interaction on crude protein yield was also in tune with that of the dry fodder yield. Hamil was found to be significantly superior to Haritha and for both varieties K_2O @ 150 kg ha^{-1} was required for obtaining maximum crude protein yield in first, second and last cuts. However in third cut Hamil at lowest dose of potassium recorded higher crude protein yield as shown in Fig. 16.

S x K interaction was also significant in all harvests. As in the case of dry fodder yield, reduction in light intensity recorded a negative response for K_2O application and protein yield was higher at higher K_2O levels as seen in Fig. 17.

5.7 NUTRIENT UPTAKE

5.7.1 Nitrogen uptake

Shade levels, varieties and potassium application had significant influence on nitrogen uptake by the plant as seen in Fig. 18. A marked increase in nitrogen uptake with decrease in shade levels was obtained. Highest N uptake was recorded at zero per cent shade level. The total nitrogen content increased under shade compared to open conditions. However, the N uptake was found to increase under open condition. This may be due to the increase in dry matter yield under full sunlight. Similar results were also reported by Pillai (1986) in guinea grass and Setaria grass.

Varieties also had significant influence on nitrogen uptake by the plant. Highest N uptake was observed in Hamil. This may be due to the higher dry matter yield registered by this variety. Similar result was also reported by Babu (1996) in Haritha and by George (1996) in Hamil.

Application of potassium also helped to increase the nitrogen uptake. Higher doses of potassium resulted in higher nitrogen uptake which was due to increased dry matter production. Similar results were also reported by Patel *et al.* (1994) in fodder jowar; Sonia (1999) in signal grass and Jacob (1999) in congosignal grass.

Significant S x V interaction was also observed which can be attributed to the increased dry matter production at full sunlight by Hamil variety.

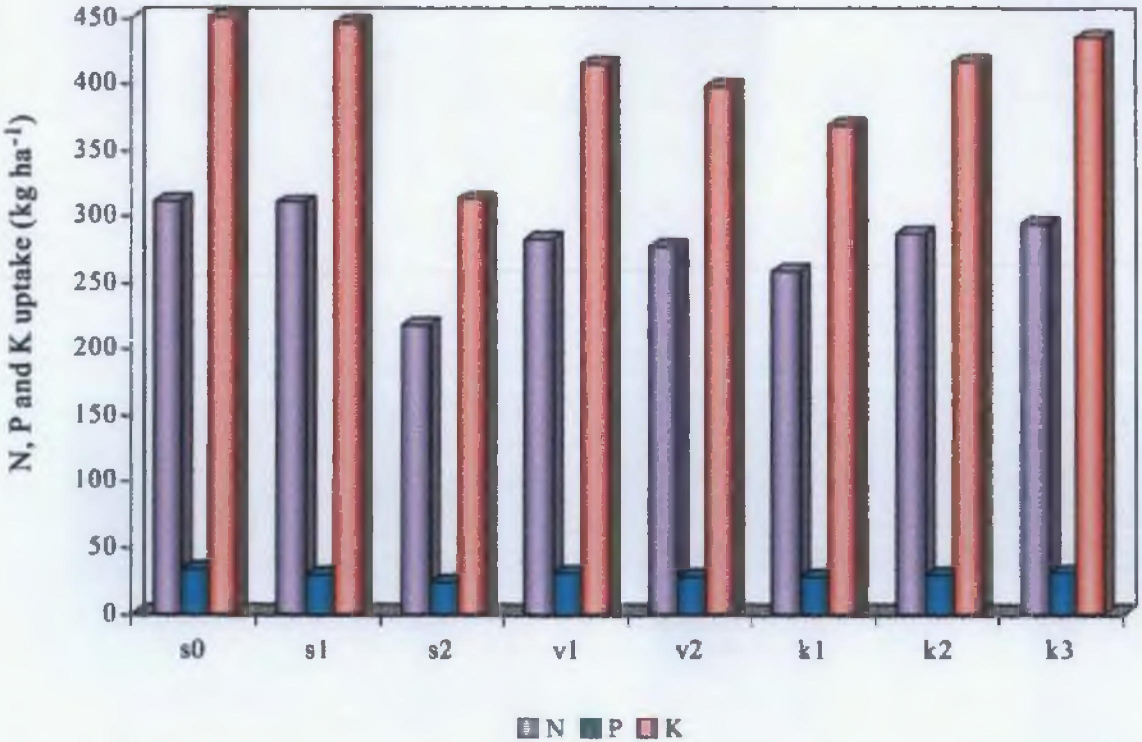

Fig. 18. Main effects of shade levels, varieties and potassium on N, P and K uptake (kg ha^{-1})

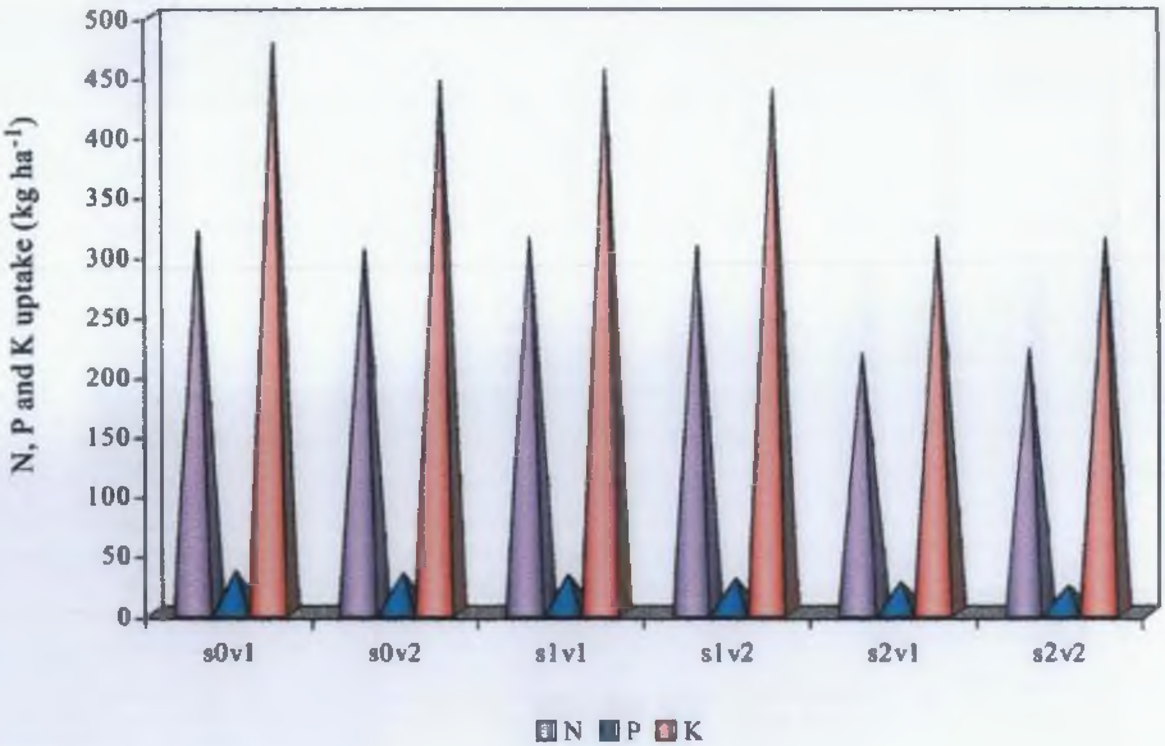

Fig. 19. Interaction effects of shade levels and varieties on N, P and K uptake (kg ha^{-1})

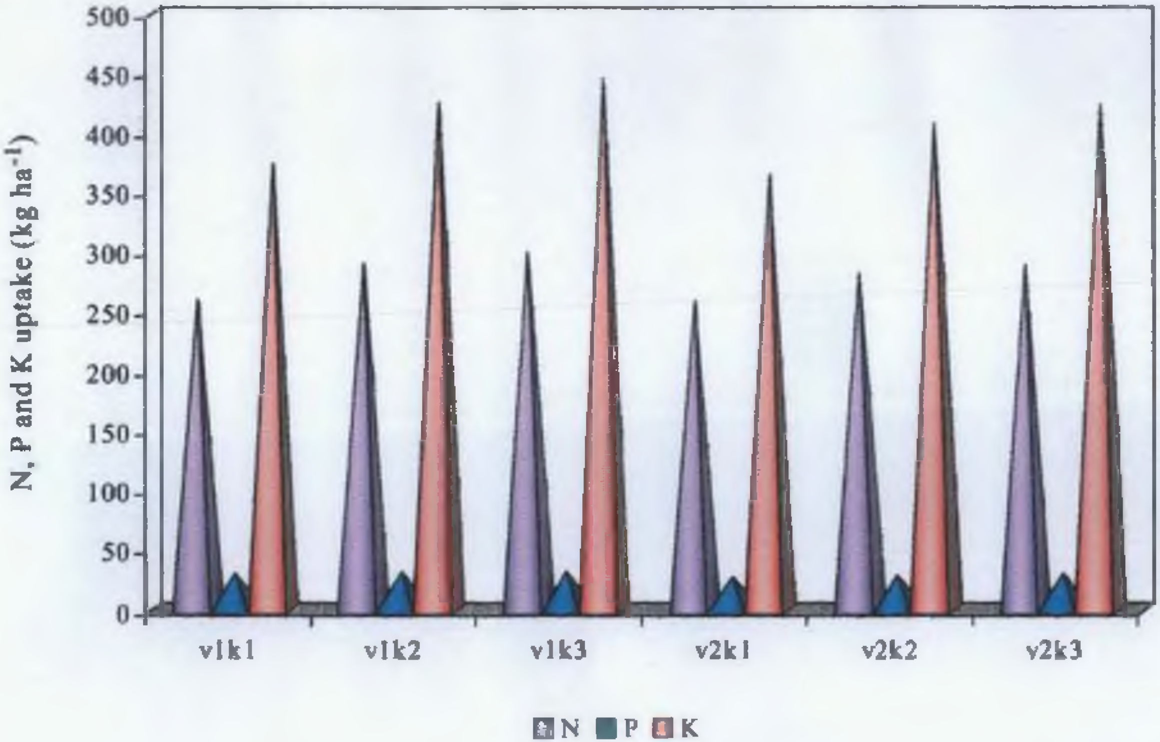

Fig. 20. Interaction effects of varieties and potassium on N, P and K uptake (kg ha^{-1})

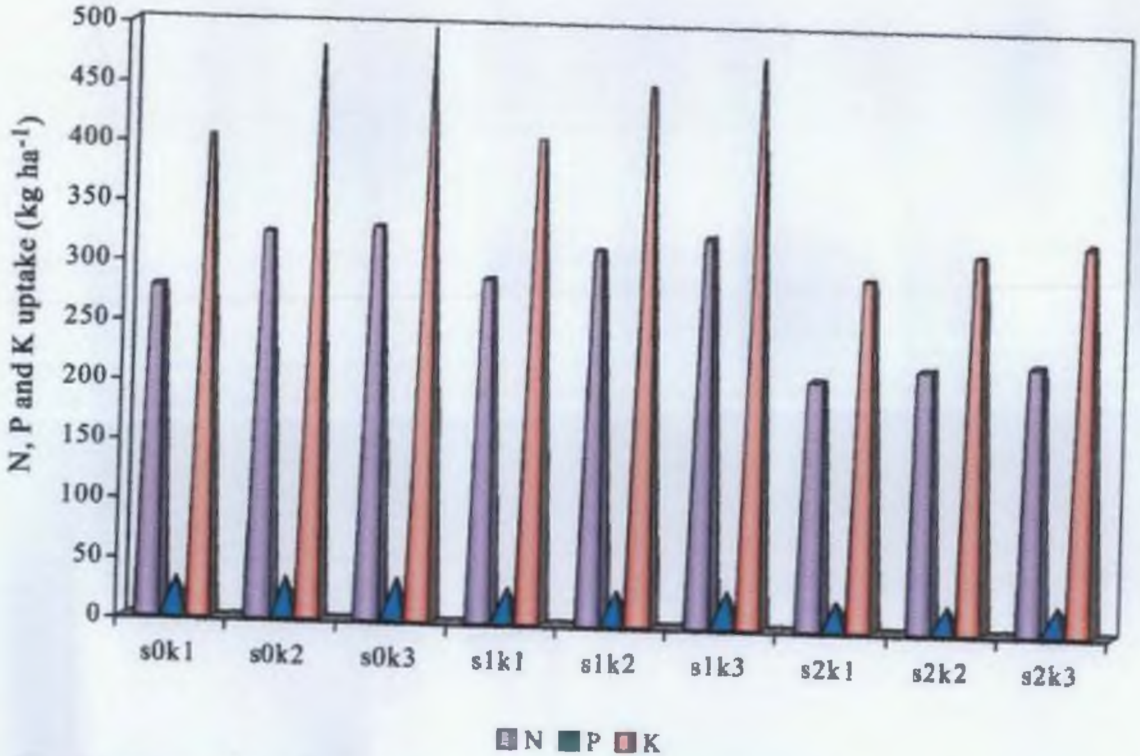

Fig. 21. Interaction effects of shade levels and potassium on N, P and K uptake (kg ha^{-1})

5.7.2 Phosphorus uptake

An increase in phosphorus uptake with decrease in shade levels was observed which may be due to the increase in dry matter yield under open conditions. However the phosphorus content was higher under shade situation as seen in Fig. 18. Similar results was also reported by Pillai (1986) in guinea grass and Watson *et al.* (1984) in marshall rye grass.

Varieties also had significant influence on phosphorus uptake. Hamil recorded the highest phosphorus uptake which was due to the increase in dry matter production by this variety. Similar result was also reported by Babu (1996) in Haritha and by George (1996) in Hamil.

Higher levels of potassium resulted in a significant increase in phosphorus uptake. This may be due to the increased root growth which enhanced the uptake of phosphorus. This is in confirmity with the findings of Patel *et al.* (1994) in fodder jowar.

5.7.3 Potassium uptake

Uptake of potassium was found to be highest at zero per cent shade level as seen in Fig. 18. Potassium contents were approximately doubled under shade (Myhr and Saebo, 1969). Eventhough the potassium content is high, due to the lower dry matter yields, the uptake was also found to be lower under shade. Similar results were also reported by Mullakoya (1982) in guinea grass, Pillai (1986) in guinea grass, Wilson *et al.* (1990) in *Paspalum notatum* and Watson *et al.* (1984) in marshall rye grass.

Varieties also had significant influence on potassium uptake. Hamil recorded the highest potassium uptake which was due to the increase in dry matter production by this variety. Similar result was also reported by Babu (1996) in Haritha and by George (1996) in Hamil

Higher doses of potassium resulted in an increased uptake of potassium. Tiwari and Nigam (1985) investigated the response of important fodder crops to potassic fertilizers and reported that potassium application markedly enhanced potassium uptake and concentration. Similar results were also reported by Mullakoya (1982) in guinea grass, Haby *et al.* (1988) in rye grass and Patra (1995) in some tropical forage grass.

S x V, S x K and V x K interactions significantly influenced the uptake of potassium. The uptake of K_2O at zero per cent shade level was significantly higher in variety Hamil. Higher doses of potassium registered highest potassium uptake by the plant.

5.8 NUTRIENT STATUS OF SOIL AFTER THE EXPERIMENT

5.8.1 Available nitrogen status

Shade levels, varieties and potassium application had no significant influence on available nitrogen.

None of the interactions were significant.

5.8.2 Available phosphorus status

Application of potassium and increase in light intensity significantly influenced the phosphorus status of the soil as seen in Fig. 19. This is in confirmity with the findings of Sonia (1999).

None of the interactions were significant.

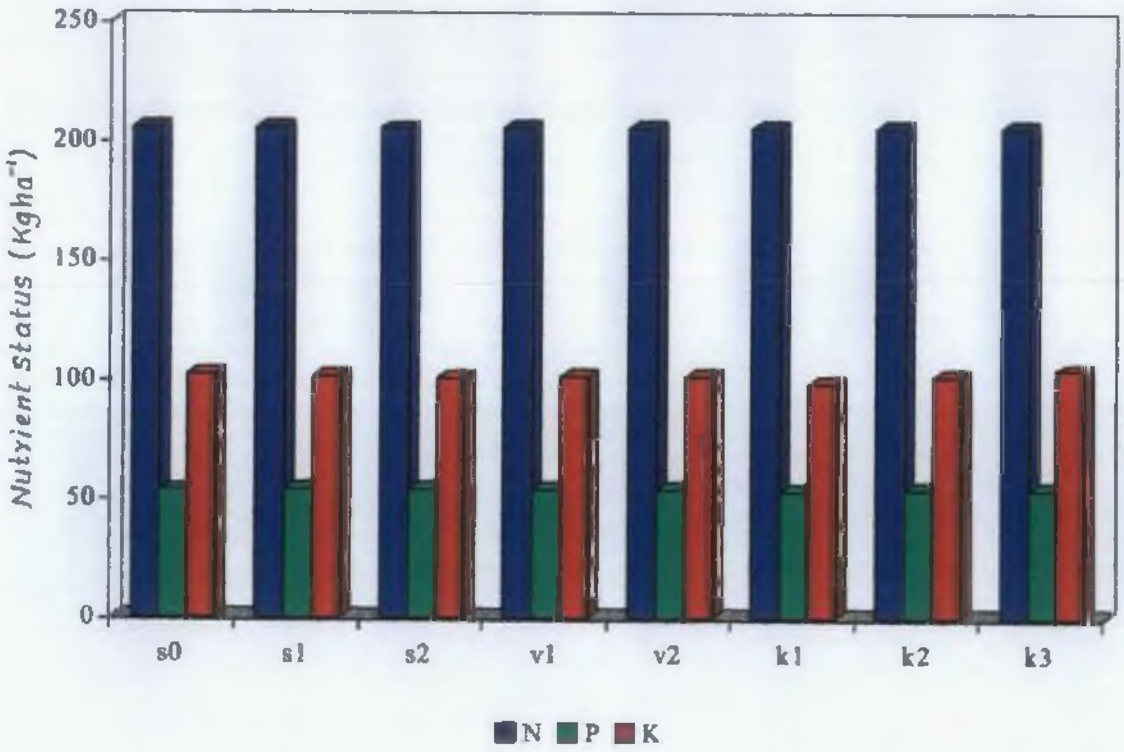

Fig. 22. Main effects of shade levels, varieties and potassium on nutrient status of soil after the experiment

5.8.3 Available potassium status

There was a significant reduction of potassium status of the soil with increase in shade levels which is attributed to the luxury consumption of potassium by grasses in shade. Similar results are also reported by Mullakoya (1982) and Pillai (1986).

Significant increase in available potassium status of the soil was observed with increase in potassium application. This might be due to increase potassium fixation which increased slowly available fixed form of K thereby increasing potassium status of soil (Johnkutty, 1981). The results are in confirmity with the findings of Vineetha (1985) in gamba grass and Sonia (1999) in signal grass.

5.9 RESPONSE SURFACE & STANDARDISATION OF RESPONSE TO APPLIED POTASSIUM

The relationship between applied potassium and green fodder yield was estimated by fitting a quadratic response surface. From this, the physical optimum and economic optimum doses of potassium were estimated. The economic optimum dose was estimated by computing the price of green fodder and cost of fertiliser. The physical and economic optimum doses estimated for potassium under open conditions were 130 kg ha^{-1} and 129 kg ha^{-1} respectively. Under 25 per cent shade, the physical and economic dose of potassium were 149 kg ha^{-1} and 143 kg ha^{-1} respectively. Under 50 per cent shade, the physical and economic optimum dose of potassium were 152 kg ha^{-1} and 150 kg ha^{-1} respectively.

The optimum potassium dose for guinea grass was found to increase with increase in shade intensity. This may be due to the increase in potassium content of the fodder at deep shade. Since the tiller number and green fodder yield of the

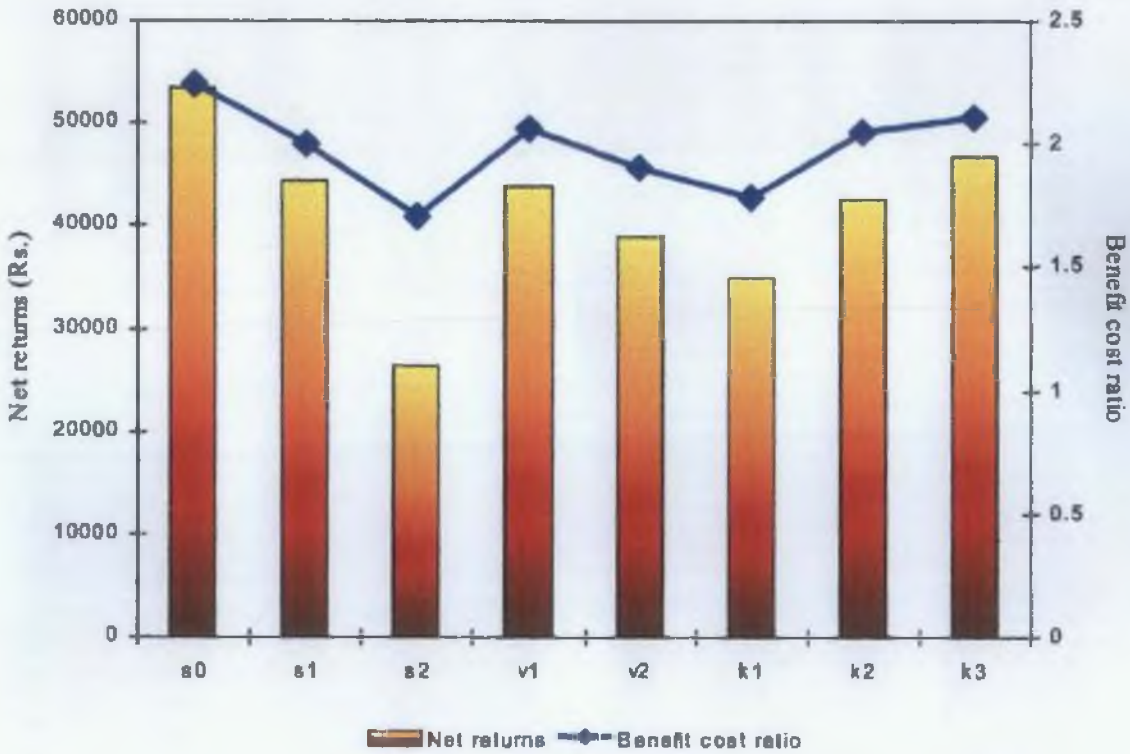

Fig. 23. Main effects of shade levels, varieties and potassium on ~~nutrient status of soil after the experiment~~
net returns and benefit cost ratio

crop increase with increase in potassium level, the economic optimum dose of potassium was also high.

5.10 ECONOMICS

Highest net returns and benefit : cost ratio was obtained for zero per cent shade and highest dose of potassic fertilizer as seen in Fig. 20. Guinea grass can be economically cultivated in shade intensities upto 50 per cent where the B:C ratio is 1.70 compared to 2.23 under open conditions. This is mainly due to the higher green fodder and dry fodder yields realized from the said treatments. Among the varieties, Hamil registered higher net returns and benefit : cost ratio compared to Haritha which is also due to the high fodder yield of the variety.

SUMMARY

6. SUMMARY

An investigation was under taken in the Instructional Farm, College of Agriculture, Vellayani to find out the potash requirement for guinea grass (*Panicum maximum* J.) varieties under varying shade levels. The experiment was laid out in split-split plot design with three replications. Combination of three levels of shade (0, 25, 50 %) two varieties (Hamil and Haritha) and three levels of potassium (50, 100 and 150 kg ha^{-1}) formed eighteen-treatment combinations.

The salient findings of the experiment are summarized below:

1. Plant height increased significantly as the shade intensity increased. Hamil recorded more plant height compared to Haritha. Application of potash had shown linear increase in the height of plant. When higher levels of shade was combined with potassium it resulted in an increase in plant height.

2. In general, tiller number, green fodder yield and dry fodder yield were significantly higher for lowest shade level and a linear decrease in yield with shading to the tune of 4.8 per cent and 33.0 per cent was observed in 25 per cent and 50 per cent shade respectively. Application of potassium at the rate of 150 kg ha^{-1} have maximum number of tillers, green fodder yield and dry fodder yield and the yield increase was 12.7 per cent and 16.1 per cent more at 100 and 150 kg K_2O ha^{-1} compared to 50 kg K_2O ha^{-1}. Among the varieties, Hamil recorded significantly higher yield compared to Haritha.

3. Interaction results indicate that the variety Hamil is suitable for open areas and upto 25 per cent shade while Haritha can be recommended in higher shade intensities of 50 per cent.

4. When individual harvests are considered, the green and dry fodder yield was higher at the open condition in the first, second and fifth harvests which coincide with the rainy season. In third and fourth harvests when the availability of rainfall is lesser, significantly higher yield was obtained at 25 per cent shade level.

5. Leaf: Stem ratio was reduced significantly with increasing shade levels. Varieties, potash levels and interactions were non significant.

6. Root volume was significantly higher for lowest shade level. Medium level of potassium recorded maximum root volume.

7. Leaf area index was significantly higher for lowest shade level in first, second and last cuts. However, in third and fourth cuts, 25 per cent shade levels recorded higher leaf area index. Higher levels of potassium registered higher leaf area index. Hamil recorded higher leaf area index compared to Haritha. The treatment combination s_0k_3 recorded significantly higher leaf area index in first, second and fifth harvests while in third harvest s_1k_3 was found to produce higher leaf area index.

8. Chlorophyll content increased significantly with increase in shade levels. Higher levels of potassium resulted in significantly higher chlorophyll content of the plant. Among the varieties Haritha recorded higher chlorophyll content compared to Hamil in all harvests. The treatment combinations s_2v_2, v_2k_1 and s_2k_1 recorded higher chlorophyll content.

9. Shading improved the quality of fodder. Crude protein content of the plant enhanced with increase in shade levels. Higher levels of applied potassium reduced the protein content of the fodder. Among the varieties protein content was higher in Haritha compared to Hamil. The treatment combination s_2v_2, v_2k_1 and s_2k_1 recorded higher crude protein content.

10. Crude fibre content reduced significantly with increase in shade levels. Among the varieties Haritha registered lowest crude fibre content. Potassium had no influence on crude fibre content.

11. Crude protein yield increased significantly with decrease in shade level in first, second and fifth cuts. However, in the third and fourth cuts 25 per cent shade level recorded higher protein yield. Higher doses of potassium resulted in higher protein yield in all harvests. Among the varieties, Hamil recorded higher protein yield. The treatment combinations s_0v_1, v_1k_3 and s_0k_3 recorded higher protein yield in first, second and fifth cuts. However, in third cut s_1v_2 and s_1k_1 recorded higher protein yield and in fourth cut s_1v_1, v_1k_2 and s_1k_2 recorded higher protein yield.

12. N uptake, P_2O_5 uptake and K_2O uptake increased significantly with decrease in shade levels. Among the varieties Hamil recorded higher nitrogen, phosphorus and potassium uptake. Higher doses of potassium resulted in higher uptake of nutrients. The treatment combination s_0v_1, v_1k_3 and s_0k_3 recorded higher nitrogen, phosphorus and potassium uptake.

13. Shade levels, varieties and potassium application had no significant influence on available nitrogen status of the soil after the experiment.

14. Application of potassium significantly increased the phosphorus status of the soil after the experiment.

15. There was a significant reduction of potassium status of the soil with increase in shade levels and the highest dose of potassium (150 kg ha^{-1}) registered highest available potassium status of the soil, after the experiment.

16. The optimum potassium dose for guinea grass was found to increase with increase in shade intensity.

17. The net returns and benefit cost ratio was positive for all the treatments. Guinea grass is economically viable in shade levels upto 50 per cent where the B:C ratio was 1.70 compared to 2.23 under open. Variety Haritha was found to have more net returns.

Future line of work

The present investigation confirms that guinea grass is a shade tolerant crop and economic yields are obtained upto 50 per cent shade levels. Further studies to ascertain its tolerant capacity in shade intensities above 50 per cent is to be conducted, so as to test its suitability under intense shade of crops like rubber. So also screening of other popular varieties of guinea grass and other cultivated grasses for shade tolerance may be promising. In this study a linear response for potash upto 150 kg ha^{-1} was obtained and hence higher levels of K_2O may also be evaluated for tapping the potential yield under shaded situation.

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* Originals not seen

APPENDIX

Appendix I : Weather parameters during the crop period (April 30th 2001 to May 26th, 2002) - Weekly averages

Standard week	Temperature (°C)		Rrelative Humidity (%)		Rainfall (mm)	Evaporation (mm)	Sunshine hours	Wind speed (km hr^{-1})
	Maximum	Minimum	7.22 am	2.22 pm				
18 (Apr30-May 6)	31.60	22.6	83.43	75.71	49.8	3.43	50.2	3.74
19 (May 7-May 13)	31.54	23.52	85.57	75.57	72.2	2.54	47.3	7.14
20 (May 14-May 20)	31.94	22.98	79.85	66.14	0.00	5.07	42.3	7.71
21 (May 21-May 27)	31.08	21.88	89.71	73.28	35.4	3.67	48.3	6.85
22 (May 28-June 3)	29.47	21.68	83.28	27.14	38.2	3.42	41.10	6.28
23 (June 4-June 10)	28.64	20.08	85.85	77.43	31.0	2.47	38.4	6.33
24 (June 11-June 17)	28.7	20.92	93.0	82.57	71.20	2.11	34.6	5.42
25 (June 18-June 24)	30.00	21.90	90.60	74.10	46.90	3.30	36.50	8.50
26 (June 25-July 1)	29.70	20.80	89.00	75.90	36.80	3.40	37.00	6.60
27 (July 2-July 8)	28.50	20.00	93.90	80.40	102.00	3.00	34.40	3.70
28 (July 9-July 15)	29.80	20.60	88.30	74.10	169.70	3.30	37.00	3.70
29 (July 16-July 22)	29.90	20.70	87.40	68.40	0.00	6.40	62.30	11.00
30 (July 23-July 29)	29.30	20.20	90.40	75.00	22.40	3.60	37.80	7.10
31 (July 30-Aug 5)	27.60	19.30	91.00	76.90	63.10	3.80	38.40	8.00
32 (Aug 6-Aug 12)	30.40	21.20	87.60	77.10	0.00	5.00	59.80	11.10
33 (Aug 13-Aug 19)	30.50	21.20	93.00	78.60	13.20	3.60	55.10	9.70
34 (Aug 20-Aug 26)	29.70	21.10	91.10	75.60	106.60	3.40	37.20	10.60
35 (Aug 27-Sep 2)	29.20	23.70	91.90	79.30	5.20	3.80	49.50	11.40

Appendix I : Continued

Standard week	Temperature (^{0}C)		Rrelative Humidity (%)		Rainfall (mm)	Evaporation (mm)	Sunshine hours	Wind speed (km hr^{-1})
	Maximum	Minimum	7.22 am	2.22 pm				
36 (Sep 3-Sep 9)	31.00	23.80	88.10	68.30	0.00	6.90	70.40	11.70
37 (Sep 10-Sep 16)	32.90	23.60	82.40	67.70	0.00	6.30	63.00	10.90
38 (Sep 17-Sep 23)	29.50	23.60	92.30	81.30	294.00	2.80	33.90	6.00
39 (Sep 24-Sep 30)	28.20	23.30	94.90	86.10	264.40	3.00	39.10	6.90
40 (Oct 1-Oct 7)	30.00	24.40	89.70	73.90	15.80	3.30	53.50	9.70
41 (Oct 8-Oct 14)	40.00	23.70	91.90	72.90	30.80	4.80	52.00	8.30
42 (Oct 15-Oct 21)	29.50	24.00	93.10	79.70	89.60	3.00	39.60	8.60
43 (Oct 22-Oct 28)	30.25	23.9	92.00	71.42	3.00	2.90	38.80	6.30
44 (Oct 29-Nov 4)	31.10	24.17	93.14	70.42	0.00	3.50	53.30	6.28
45 (Nov 5-Nov 11)	30.44	30.27	92.57	73.14	54.2	2.80	31.40	6.00
46 (Nov 12-Nov 18)	29.72	23.14	92.85	75.28	146.00	3.62	28.40	6.00
47 (Nov 19-Nov 25)	30.54	23.47	96.14	69.85	37.9	2.8	45.30	6.57
48 (Nov 26-Dec 2)	30.52	23.2	93.00	68.42	0.00	3.04	58.30	6.00
49 (Dec 3-Dec 9)	31.01	22.9	94.57	69.42	8.6	2.72	59.00	5.66
50 (Dec 10-Dec 16)	30.55	20.05	91.00	59.00	0.00	3.11	53.70	6.33
51 (Dec 17-Dec 23)	30.97	22.38	94.42	67.43	3.7	2.4	42.60	5.14
52 (Dec 24-Dec 30)	30.9	23.5	94.28	69.28	8.3	2.94	52.20	6.85
53 (Dec 31-Jan 6)	31.37	23.01	95.42	62.85	0.00	2.36	65.10	6.57
54 (Jan 7-Jan 13)	30.98	22.95	95.42	64.57	0.00	3.11	60.40	6.28

Appendix I : Continued

Standard week	Temperature (°C)		Rrelative Humidity (%)		Rainfall (mm)	Evaporation (mm)	Sunshine hours	Wind speed (km hr^{-1})
	Maximum	Minimum	7.22 am	2.22 pm				
55 (Jan 14-Jan 20)	30.72	19.45	94.28	55.85	0.00	3.30	62.30	7.14
56 (Jan 21-Jan 27)	31.21	23.37	94.71	67.85	0.00	3.40	42.40	8.0
57 (Jan 28-Feb 3)	30.24	23.0	92.85	66.14	15.00	2.80	31.00	4.85
58 (Feb 4-Feb 10)	31.22	22.7	93.42	61.28	0.00	3.00	46.60	6.28
59 (Feb 11-Feb 17)	32.0	22.37	94.57	57.14	0.00	3.30	67.10	8.0
60 (Feb 18-Feb 24)	32.27	21.52	94.0	52.42	0.00	4.80	69.80	7.7
61 (Feb 25-Mar 3)	32.28	21.78	92.71	54.57	0.00	3.00	69.80	7.71
62 (Mar 4-Mar 10)	33.11	22.88	92.14	55.14	0.00	4.10	64.50	8.57
63 (Mar 11-Mar 17)	32.85	23.02	91.71	57.85	3.8	3.41	55.20	9.71
64 (Mar 18-Mar 24)	32.81	23.55	92.0	56.28	0.00	3.30	61.20	9.42
65 (Mar 25-Mar 31)	33.1	25.22	90.42	65.14	12.9	5.00	53.00	10.00
66 (Apr 1-Apr 7)	33.24	24.84	86.57	63.42	0.00	4.20	64.50	8.86
67 (Apr 8-Apr 14)	33.08	24.31	89.14	69.14	30.00	3.80	55.30	6.85
68 (Apr 15-Apr 21)	32.97	24.91	89.57	66.85	1.2	6.90	50.20	8.57
69 (Apr 22-Apr 28)	33.15	24.8	90.71	67.57	18.4	6.30	48.80	5.42
70 (Apr 29-May 5)	32.47	25.35	88.42	68.71	28.7	2.80	43.30	7.14
71 (May 6-May 12)	32.67	25.92	88.42	69.0	38.0	3.00	49.40	6.28
72 (May 13-May 19)	30.68	24.45	86.42	73.57	91.2	4.80	42.10	8.0
73 (May 20-May 26)	31.42	24.71	90.42	72.42	15.6	3.0	60.70	8.57

SHADE RESPONSE OF GUINEA GRASS (*Panicum maximum* J.) UNDER VARYING LEVELS OF POTASH

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Abstract of the thesis submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2002

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9. ABSTRACT

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala State to find out the potash requirements for guinea grass (*Panicum maximum* J.) varieties under varying shade levels.

The influence of shade levels and potassium on growth parameters, fodder yield, quality of produce, uptake of nutrients, chemical properties of soil and economics was investigated.

Three levels of shade (0, 25, 50 %), three levels of potassium (50, 100, 150 kg ha^{-1}) and two varieties (Hamil and Haritha) were combined to from eighteen treatment combinations. The experiment was laid out in split-split plot design with three replications.

Results of the experiment revealed that lower levels of shade as well as higher levels of potassium had significant positive influence on improving the fodder production potential of guinea grass. Among the varieties, Hamil registered higher yield potential compared to Haritha. Lower levels of shade and higher doses of potassium significantly increased the growth parameters namely, number of tillers leaf: stem ratio, leaf area index and root volume.

Lower levels of shade and higher doses of potassium registered maximum green fodder yield in first, second and last harvests. However, in third and fourth cuts, 25 percent shade level registered maximum green fodder yield. Among the varieties, Hamil registered higher green fodder yield in all harvests. Similar results were obtained in the case of dry fodder yield also.

Quality parameters of the forage significantly improved as shade progresses. Maximum crude protein content was realized at lower level of potassium. Among the varieties, Haritha registered higher crude protein and chlorophyll contents.

The nutrient uptake showed a significant increase with lower levels of shade. Application of potassium significantly increased the uptake of nitrogen, phosphorus and potassium. Hamil registered higher N, P, K uptake in all harvests.

There was a significant reduction of potassium status of the soil with increase in shade levels. Application of potassium significantly increased the phosphorus and potassium status of the soil after the experiment.

The optimum potassium dose for guinea grass was found to increase with increase in shade intensity.

Lower levels of shade with higher dose of potassium registered highest net returns and benefit cost ratio. But economic yield was obtained in shade intensity up to 50 percent.