NUTRIENT MANAGEMENT OF GUINEA GRASS (*Panicum maximum* J.) UNDER OPEN AND SHADED CONDITIONS

LEKSHMI, P.

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

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2004

Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM-695 522

DECLARATION

I hereby declare that this thesis entitled "**Nutrient management of guinea grass (*Panicum maximum* J.) under open and shaded conditions**" 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
16-02-2005.

LEKSHMI, P.
(2002-11-02)

CERTIFICATE

Certified that this thesis entitled "**Nutrient management of guinea grass (*Panicum maximum* J.) under open and shaded conditions**" is a record of research work done independently by Mrs. Lekshmi, P. (2002-11-02) 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.

Vellayani,
16-02-2005.

Dr. S. LAKSHMI
(Chairman, Advisory Committee)
Associate Professor of Agronomy,
AICRP on Forage Crops,
College of Agriculture, Vellayani
Thiruvananthapuram.

Approved by

Chairman :

Dr. S. LAKSHMI
Associate Professor of Agronomy,
AICRP on Forage Crops,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

Members:

Dr. S. JANARDHANAN PILLAI
Associate Professor and Head,
Department of Agronomy,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

Dr. (Mrs.) P. SARASWATHI
Professor and Head,
Department of Agricultural Statistics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

Dr. (Mrs.) M. MEERABAI
Associate Professor,
Department of Agronomy,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

External Examiner :

Dr. A. MUTHUSANKARA NARAYANAN
Professor and Head,
Department of Agronomy,
Agricultural College and Research Institute,
Killikulam, Vallanadu-628 252.

ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to Dr. (Mrs) S. Lakshmi, Associate Professor, Department of Agronomy and Chairman of the Advisory Committee, for her inspiring guidance, valuable suggestions and constant encouragement during the course of this investigation. I am much obliged to her for friendly approach and affection which greatly facilitated the preparation of the thesis.

I extend my heartful indebtedness to Dr. S. Janardhanan Pillai, Associate Professor and Head, Department of Agronomy for his sustained interest and valuable help throughout the course of the research programme.

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 planning of the study, analysis of the data and interpretation of the results of the research work inspite of her busy schedule.

I am extremely thankful to Dr. (Mrs.) M. Meerabai, Associate Professor, Department of Agronomy for her valuable suggestions, immense help and timely advice rendered during the course of my study.

My heartful thanks to Dr. Roy Stephen (Department of Plant Physiology) Dr. Prathapan, (Department of Agronomy) and Dr. (Mrs.) Sumabai (Department of Plant Breeding and Genetics) for their valuable suggestions and timely help throughout the course of the investigation.

I wish to express each and every teaching and non-teaching staff members of Department of Agronomy for the help rendered me during the course of my study.

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

I am thankful to all the staff and labourers of the Instructional Farm, Vellayani for their whole hearted cooperation and sincere efforts for the successful completion of the research work.

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 take this opportunity to express my sincere and heartful thanks to my classmates Jayakiran and Seema for their selfless help, moral support and constant encouragement throughout the period of my study.

My grateful thanks to all my senior and junior students for their timely help and cooperation.

I sincerely thank Kishore and Biju for their active involvement, sincerity and rapid type setting of the thesis.

Words cannot express enough the love and gratitude I feel for my beloved father and mother. I am indebted to them for their undying love, constant encouragement, mental and physical support and blessings which have made this attempt a reality.

With a deep sense of affection, I wish to thank my parent in laws, brother, brother-in-law, all my relatives and my best friend, Sreedevi for their over whelming support, unconditional help and constant inspiration extended to me throughout the preparation of the thesis.

Last but not the least, I am proud in mentioning my husband, Mr. Radhakrishnan and my son Vishnu whose ardent love, affection, patience and magnanimous support sustained me from the start to the finish.

Above all, I bow before God Almighty for his eternal love and blessings showered upon me.

Lekshmi. P

CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF FIGURES CONTINUED

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	–	Per cent
°C	–	Degree Celsius
°E	–	Degree East
°N	–	Degree North
BCR	–	Benefit-cost ratio
CD	–	Critical difference
CGR	–	Crop growth rate
CFC	–	Crude fibre content
cm	–	Centimetre
CO_2	–	Carbon dioxide
CPC	–	Crude protein content
cv.	–	Cultivar
cvs.	–	Cultivars
DAS	–	Days after sowing
et al.	–	And others
Fig.	–	Figure
g cc^{-1}	–	Gram per cubic centimetre
g cm^{-2} day^{-1}	–	Gram per centimetre square per day
g m^{-2}	–	Gram per metre square
g m^{-2} day^{-1}	–	Gram per metre square per day
ha	–	Hectare
i.e.	–	That is
K	–	Potassium
K_2O	–	Potash
kg	–	Kilogram
kg ha^{-1}	–	Kilogram per hectare
kg ha^{-1} $harvest^{-1}$	–	Kilogram per hectare per harvest
kg ha^{-1} $year^{-1}$	–	Kilogram per hectare per year
LA	–	Leaf area
LAI	–	Leaf area index
L:S ratio	–	Leaf : Stem ratio
m	–	Metre
mg g^{-1}	–	Milligram per gram
mg g^{-1} day^{-1}	–	Milligram per gram per day
mg L^{-1}	–	Milligram per litre
mm	–	Millimetre
N	–	Nitrogen
NAR	–	Net assimilation rate
P	–	Phosphorus
P_2O_5	–	Phosphate
q ha^{-1}	–	Quintals per hectare
RGR	–	Relative growth rate
Rs. ha^{-1}	–	Rupees per hectare
S	–	Shade
spp.	–	Species
t ha^{-1}	–	Tonnes per hectare
t ha^{-1} $year^{-1}$	–	Tonnes per hectare per year
var.	–	Variety
viz.	–	Namely

INTRODUCTION

1. INTRODUCTION

The requirement of food and forages for the ever-increasing human and animal population has created an enormous pressure on 328.8 million hectares land of the country. As such the possibility of increasing area under good lands for forage production seems to be remote owing to preferential food need for human beings. The area required to meet out the projected fodder shortage of 40 percent is about 10 million ha and presently India has only 6.9 million ha of land under fodder production, which is about 4.7 percent of the total cultivated area. The possibility of increasing fodder supply by adopting latest forage production technologies on the available cultivated area is very limited.

The fodder production in India is not sufficient enough to meet even half of the requirement of the livestock population, and the forages produced are of poor quality. The inadequate supply of nutritious forages and feeds is one of the reasons for poor milk yields of cows and buffaloes in our country. The diversion of newer area for forage cultivation would not be possible because of preferential treatment of human food and other economic compulsions. Under such circumstances, the only way to bridge the wide gap between demand and supply is to ameliorate the forage resources through increased productivity from a unit area.

Due to the unique cropping systems followed, the scope for raising fodder as a sole crop is very limited in Kerala state. Farmers raise fodder crops mostly as border plants or as intercrops in orchards and coconut gardens. It has therefore become imperative that all efforts should be oriented to develop the fodder resources by introducing a judicious forage intercropping programme, suitable for partially shaded conditions existing in coconut gardens and homesteads. For this purpose suitable fodder species and their management practices have to be worked out.

Fertilizer management is the important aspect which helps in harnessing the potential yield and improving the quality of the forages. Soils of high fertility produce forages with higher nutritive value than inferior soils. Fertilizers also affect the quality of herbage by changing the chemical composition of the individual plant. The importance of N in forage production is well known. The application of nitrogen fertilizer tends to effect an increase in the protein content of plants. Likewise, applications of phosphorus promote a greater uptake of elements.

Phosphorus is an important element when considered from the point of view of both yield and quality of forage. Adequate amounts of available phosphorus in soils stimulate rapid growth and development of plants, hasten maturity and improve their quality. A high percentage of phosphorus in forages and pasture crops increases the feeding value of the forage crop and improves its palatability as shown by preference of the cattle for phosphated hay and pasture. But response of N in conjunction with varying doses of P and vice versa has not been assessed. Based on this study the suitability of guinea grass for the different shade intensities and requirement of nitrogen and phosphorus different shade levels can be standardized. Keeping this in view, the present study entitled "Nutrient management of guinea grass (*Panicum maximum* J.) under open and shaded conditions" was taken up with the following objectives.

1. To study the nutritional alterations under open and shade in guinea grass.
2. To assess the optimum nitrogen and phosphorus requirement of the crop in both the situations and the influence of nutrients on quality of fodder and nutrient uptake.
3. To work out the economics of cultivation in both open and shaded conditions.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present investigation was undertaken with the objective of studying the fodder production potential of guinea grass var. Hamil under varying nitrogen and phosphorus levels. The relative fodder production efficiency of this variety was also assessed in the open field as well as in 50 per cent shaded condition. The relevant literature on the performance of guinea grass as influenced by nitrogen and phosphorus levels and different 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

In a field study with guinea grass var. Mackueni, Mullakoya (1982) recorded maximum height under 50 per cent shade and the minimum under full sunlight. According to Pillai (1986) guinea grass (*Panicum maximum*) and Setaria grass (*Setaria sphacelata*) grown under coconut shade, recorded more height than that grown in open area. In general, internode length increased for forages grown in shade compared to that grown in full sun (Blanche, 1999). Buxton (2001) opined that 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 increased under agro-forestry systems. Anita (2002) found out that plant height of guinea grass (*Panicum maximum*) was significantly increased by increasing shade levels from zero to 50 per cent in all the five harvests. Bhatt *et al.* (2002) observed in tropical range grasses, plant height increased with decreasing light intensities being maximum at 50 per cent light intensity.

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. 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. Kephart and Buxton (1996) found out that shading often reduced tillering of forages. Bahmani *et al.* (2000) opined that number of tillers per plant for two cultivars of perennial rye grass (*Lolium perenne*) ('Ellett' and 'Grasslands Ruanui') were consistently reduced under shade (low light intensity and low red: far red ratio) compared with the control treatment. Dias-Filho (2000) observed that number of tillers of *Brachiaria brizantha* cv. Marandu and *B. humidicola* are higher in high light plants. Shading often reduced tillering of forages and slowed the growth rate of forages (Buxton, 2001). 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. Anita (2002) reported that number of tillers of guinea grass (*Panicum maximum*) declined with shading in first, second and fifth cuts. Maximum numbers of tillers were recorded at zero per cent shade.

2.1.1.3 Leaf / Stem Ratio

Anita (2002) recorded a decline in L: S ratio of guinea grass (*Panicum maximum*) with an increase in shade intensity upto 50 per cent shade.

However, according to Pillai (1986) shading increased leaf / stem ratio of guinea grass (*Panicum maximum*) and Setaria grass (*Setaria sphacelata*) when grown under coconut shade. Wilson *et al.* (1990) found an increase in the proportion of green leaf of a *Paspalum notatum* pasture under trees compared with that in the open pasture. Shading increased leaf / stem ratios particularly in shade tolerant species compared to plants grown in full sun (Wong, 1991).

Mullakoya (1982) opined that shade levels had no significant effect on leaf / stem ratio of guinea grass (*Panicum maximum*).

2.1.2 Influence of Shade on Yield

2.1.2.1 Green Fodder Yield

In a study conducted by Mullakoya (1982) with four shade levels (0, 25, 50 and 75 per cent), it was found out that green fodder yield of guinea grass (*Panicum maximum*) was highest at zero per cent shade level (full sunlight). Watson *et al.* (1984) reported that the green fodder yield of marshall rye grass (*Lolium multiflorum*) reduced as the shade intensity increased. The green fodder yield was reduced by 49 per cent under 50 per cent shade and 72 per cent under 75 per cent shade from the yield under full sunlight. The yield reduction in pearl millet under *Acacia albida* and *Prosopis cineraria* trees was reported by Shankaranarayan *et al.* (1987). In a review to summarise pasture species for shaded environments, 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*) perform better in the shade than in the open (Reynolds, 1988). According to him, pasture herbage production and shade intensity 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 production values and the range of species are severely reduced. 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). In general herbage production and carrying capacity is inversely proportional to light transmission values (Wong, 1991).

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. 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. 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). George (1996) recorded a green fodder yield of 58 t ha^{-1} for guinea grass (*Panicum maximum*) grown in coconut garden. 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 obtained yield reduction in agroforestry due to reduction in solar radiation availability. Anita (2002) reported that total green fodder yield of guinea grass (*Panicum maximum*) was highest in open (100.31 t ha^{-1}) followed by 25 per cent shade (95.46 t ha^{-1}) and then by 50 per cent shade (67.21 t ha^{-1}).

However, Bhatt *et al.* (2002) found out that trispecific hybrid, *Brachiaria mutica, Panicum maximum, Pennisetum polystachyon, Cenchrus ciliaris, Setaria sphacelata* produced higher forage yield (fresh biomass) under low light intensity exhibiting their shade adaptation.

2.1.2.2 Dry Fodder Yield

In a field study conducted by Mullakoya (1982) in guinea grass (*Panicum maximum*) var. Mackueni, maximum dry fodder yield of 32.14 t ha^{-1} was noted under full sunlight and the dry fodder yield reduced under shaded conditions. The dry fodder yield of a local strain of guinea grass grown in the partial shade of coconut garden obtained 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. Kaushal *et al.* (2000) reported that dry matter content of guinea grass decreased (average decrease 16.38 %) when grown under 25 per cent solar radiation. Anita (2002) also recorded a reduction in the dry fodder yield by 4.1 per cent and 32.7 per cent in guinea grass (*Panicum maximum* J.) in 25 per cent and 50 per cent shade respectively compared to the open condition. Carvalho *et al.* (2002) observed that dry matter yield of *Brachiaria brizantha* cv. Marandu, *Panicum maximum* cvs. Aruana, Makueni, Mombaca and Tanzania and *Cynodon dactylon* cv. Tifton 68 were reduced by shade of *Anadenanthera macrocarpa* trees.

In trispecific hybrid, *Brachiaria mutica, Panicum maximum, Pennisetum polystachyon, Cenchrus ciliaris and Setaria sphacelata,* Bhatt *et al.* (2002) recorded higher dry matter yield under low light intensity exhibiting their shade adaptation.

2.1.3 Influence of Shade on Physiological Observations

2.1.3.1 Leaf Area Index

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 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) observed in *Sericea lespediza*, a reduction in the per cent leaves with an increase in the level of shade only during early stages whereas there was not much difference in per cent leaves in the second harvest as the level of shade increased. According to Pillai (1986) LAI decreased under shaded situation both in guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*). Pearson and Ison (1987) pointed out that perennial grass with semi-erect leaves need larger leaf area than legumes with horizontal leaves. Grasses intercept virtually 95 per cent of radiation at LAI 6 to 9. Wilson *et al.* (1990) found an increase in the proportion of green leaf of a *Paspalam notatum* pasture under trees compared with that in the open pasture. True shade tolerance in forage species is associated with a number of morphological and physiological adaptations of plants. These include higher leaf area ratios and specific leaf areas, which in turn influence the efficiency of interception and use of radiation and therefore growth potential at low levels of radiation (Stur, 1991). A plant maximizes radiation absorption by accumulating leaves (Ramus, 1995). The increase in leaf area is attributed to maximize light interception and changes in physiological processes to enhance the efficiency of carbon utilization (Evans and Seemann, 1996). According to Kephart and Buxton (1996) shaded forage leaves are longer and thinner with higher water content than when grown in full sunlight. Anita (2002) commented that the leaf area index was found to be maximum at zero per cent shade level in first, second and fifth harvests while in third and fourth harvests, higher leaf area index was recorded at 25 per cent shade level.

However, Bhatt *et al.* (2002) reported that trispecific hybrid, *Brachiaria mutica, Panicum maximum, Pennisetum polystachyon, Cenchrus ciliaris, Setaria sphacelata* produced higher LAI under low light intensity exhibiting their shade adaptation.

2.1.3.2 Crop Growth Rate

Fukai *et al.* (1984) observed that reducing solar input to 32 per cent decreased the CGR in cassava to about half that of the control regardless of plant age. Fukai *et al.* (1984) also obtained a significant variation in elephant foot yam with higher CGR values recorded at medium and low shade during the first and second phases of growth respectively. Ramanujam and Jose (1984) opined that the CGR of cassava grown under shade reduced significantly compared to those plants grown under normal light. Tania and elephant foot yam recorded higher values of CGR at medium and low shade in the first and second growth phases respectively (Pushpakumari and Sasidhar, 1992). Viji (1995) reported a decrease in CGR of rice cultivars at 50 per cent shade. Sreelathakumary (2000) recorded a reduction in CGR in all shade tolerant and susceptible genotypes of *Capsicum annuum*, *C. frutescens* and *C. chinense* grown under 50 per cent shade than in open. Sunilkumar (2000) obtained highest CGR value of 8.86 gm^{-2} day^{-1} at zero per cent shade in rice.

However, shade-grown plants of cocoyam had greater CGR compared to sungrown plants (Valenzuela, 1990). Bhatt *et al.* (2002) reported that trispecific hybrid, *Brachiaria mutica, Panicum maximum, Pennisetum polystachyon, Cenchrus ciliaris* and *Setaria sphacelata* produced higher CGR under low light intensity exhibiting their shade adaptation.

2.1.3.3 Relative Growth Rate

In sweet potato, RGR tended to decline with increasing shade and lowest values were recorded in 73 per cent shade (Roberts-Nkrumah *et al.*, 1986). A decrease in RGR in shade tolerant compared to light demanding tree species was reported by Mori *et al.* (1990). Shaded plants of pepper had considerably lower relative growth rate during flowering and early fruit development stages compared to exposed plants (Jung *et al.*, 1994). The stress susceptible cultivars of pepper Shamrock recorded a larger reduction in relative growth rate under low light stress and partitioned less dry matter to reproductive structures and more to leaves than the more tolerant cultivars (Turner and Wein, 1994). Viji (1995) reported a decrease in RGR when rice cultivars were subjected to 50 per cent shade.

Dias-Filho (2000) pointed out that relative growth rate of *Brachiaria brizantha* cv. Marandu and *B. humidicola* are high in open than under 30 per cent shade.

Jadhav (1987) observed a positive correlation of shade with leaf area ratio and relative growth rate in rice. Sunilkumar (2000) obtained higher RGR value at 20 per cent shade (63.96 mg g^{-1} day^{-1}) than at 0 and 40 per cent shade in rice.

2.1.3.4 Net Assimilation Rate

Ramanujam and Jose (1984) found that NAR of cassava grown under shade was reduced significantly when compared to those plants grown under normal light. Similar observations of reduced NAR were also noticed in shaded plants of cucumber (Smith *et al.*, 1984) and sweet potato (Laura *et al.*, 1986) compared to those plants exposed to full sunlight. Jung *et al.* (1994) reported that shaded plants of pepper had considerably lower net assimilation rate during flowering and early fruit development stages compared to exposed plants. Turner and Wein (1994) observed that the stress susceptible cultivars of pepper Shamrock recorded a larger reduction in net assimilation rate under low light stress than the more tolerant cultivars. Viji (1995) recorded a decrease in NAR when rice cultivars were subjected to 50 per cent shade. In rice, the NAR at zero and 20 per cent shade were on par and 40 per cent shade was significantly inferior to (3.22 g cm^{-2} day^{-1}) the other two shade levels (Sunilkumar, 2000).

However, Yinghua and Jianzhen (1998) reported that net photosynthetic rate of pepper was highest under 30 per cent shade.

2.1.4 Influence of Shade on Biochemical Studies

2.1.4.1 Chlorophyll Content

Mullakoya (1982) opined that chlorophyll content increased with increase in shade intensity and the highest value was obtained at 75 per cent shade level in guinea grass (*Panicum maximum*) var. Mackueni. Liu *et al.* (1984) suggested high chlorophyll a + b and low a/b ratio as a selection parameter for efficient photosynthesis at low light. 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). According to Evans and Seemann (1996) shade leaves have high chlorophyll per chloroplast. George (1996) recorded a chlorophyll content of 2.5 mg g^{-1} fresh weight in guinea grass (*Panicum maximum*) grown under coconut shade. Anu (2001) obtained higher total chlorophyll content in rice leaves under partially shaded condition. In guinea grass (*Panicum maximum*), chlorophyll content was low in leaves of plants grown in open condition and chlorophyll content increased when the intensity of shade increased from 0 to 50 per cent (Anita 2002). Awada *et al.* (2003) pointed out that total chlorophyll content of C_4 big blue stem (*Andropogon gerardii*) and C_3 smooth brome grass (*Bromus inermis*) increased with shade of green ash (*Fraxinus pennsylvanica*). Jiang *et al.* (2004) observed a significant differences in canopy chlorophyll index in *Paspalum vaginatum* Swartz and hybrid bermuda grass (*Cynodon dactylon* L. x C. *transvaalensis* Butt Davy) under 70 and 90 per cent low light treatments (LL) compared to full sunlight control (FL).

However, Dias-Filho (2002) recorded in *Brachiaria humidicola* a significant reduction in chlorophyll a:b ratio by 30 per cent shading.

2.1.5 Influence of Shade on Quality Aspects

2.1.5.1 Crude Protein Content

An increase in crude protein content was recorded with increasing levels of shade in guinea grass var. Mackueni (Mullakoya, 1982). 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 is much more responsive to shading than other quality characteristics. They commented 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. Kaushal *et al.* (2000) reported in guinea grass an increased crude protein content (average increase 164 %) when grown under 25 per cent solar radiance. Forages grown under shaded condition usually have higher crude protein concentrations than unshaded forage (Buxton, 2001). Anita (2002) observed an increase in the crude protein content of guinea grass (*Panicum maximum*) with increase in shade levels.

2.1.5.2 Crude Fibre Content

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. Pillai (1986) recorded low fibre content in guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) grown under coconut shade compared to open. George (1996) obtained a crude fibre content of 31.9 per cent for guinea grass (*Panicum maximum*) grown under partially shaded situation. According to Kaushal *et al.* (2000), crude fibre content of guinea grass decreased (average decrease 9.01 %) when grown under 25 per cent solar radiance. Anita (2002) also reported that crude fibre content of guinea grass (*Panicum maximum* J.) 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.

2.1.6 Influence of Shade on Nutrient Content and Uptake

2.1.6.1 Influence of Shade on Nitrogen Content and 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 (Eriksen 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. Pillai (1986) reported that nitrogen uptake in guinea grass (*Panicum maximum*) was more in open than under shaded condition. Schreiner (1987) opined 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). George (1996) recorded a nitrogen uptake of 139 kg ha^{-1} $year^{-1}$ in guinea grass (*Panicum maximum*) under partially shaded situation. Shading usually increases nitrogen concentration substantially, especially in leaves (Kephart and Buxton, 1996). Jacob (1999) obtained a nitrogen uptake of 34.5 kg ha^{-1} in congosignal grass (*Brachiaria ruziziensis*) when grown under coconut shade. Anita (2002) reported that there was a significant increase in nitrogen uptake with a decrease in shade level for guinea grass (*Panicum maximum* J.). Highest nitrogen uptake was recorded at zero per cent shade level (311.06 kg ha^{-1}) followed by 25 per cent shade (310.11 kg ha^{-1}) and then by 50 per cent shade (218.48 kg ha^{-1}). Carvalho *et al.* (2002)

observed that N concentration in the leaves of *Brachiaria brizantha* cv. Marandu, *Panicum maximum* cvs. Aruana, Makueni, Mombaca and Tanzania and *Cynodon dactylon* cv. Tifton 68 increased significantly under shade of *Anadenanthera macrocarpa* trees in comparison to the full sunlight condition. Awada *et al.* (2003) pointed out that N content of the leaves of C_4 bigblue stem (*Andropogon gerardii*) and C_3 smooth brome grass (*Bromus inermis*) increased with shade of green ash (*Fraxinus pennsylvanica*).

2.1.6.2 Influence of Shade on Phosphorus Content and Uptake

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) 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} $year^{-1}$ in guinea grass (*Panicum maximum*) var. Hamil when grown under coconut shade. Jacob (1999) obtained a phosphorus uptake of 4.76 kg ha^{-1} in congosignal grass (*Brachiaria ruziziensis*) when grown under coconut shade. Anita (2002) also observed a significant increase in phosphorus uptake of guinea grass (*Panicum maximum* J.) with decrease in shade levels. Highest P uptake was in open (34.05 kg ha^{-1}) than at 25 per cent shade (30.10 kg ha^{-1}) and 50 per cent shade (24.16 kg ha^{-1}).

2.1.6.3 Influence of Shade on Potassium Content and Uptake

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 observed that the potassium content in marshall rye grass (*Lolium multiflorum*) grown under shade increased as shade intensity increased. The potassium content was 1.6 per cent under full sunlight whereas it was 2.1 per cent and 2.7 per cent under 50 per cent and 75 per cent shade respectively. Pillai (1986) reported 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) obtained an increase in the proportion of potassium content of a *Paspalum notatum* pasture under trees compared with that in the open pasture. Meerabai *et al.* (1993) recorded maximum yield at potassium level 90 kg ha^{-1} for both guinea grass (*Panicum maximum*) and congosignal grass (*Brachiaria ruziziensis*) grown in coconut garden. 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. Anita (2002) opined that uptake of potassium was significantly higher at zero per cent shade level for guinea grass (*Panicum maximum* J.). Highest uptake value was in open (460.67 kg ha^{-1}) followed by 25 per cent shade (446.34 kg ha^{-1}) and 50 per cent shade (312.81 kg ha^{-1}).

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 open area when two forage grasses were grown (Pillai, 1986). The phosphorus content in coconut garden soil was also found to be more than in the open area. But the potassium content in coconut garden soils was lesser 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 garden' reported that after guinea grass cultivation the NPK content of the soil under partially shaded situation was found to be 193, 27 and 64 kg ha^{-1} respectively. Jacob (1999) reported that available NPK content of the soil cropped with congosignal (*Brachiaria ruziziensis*) under partially shaded condition was found to be 207, 51 and 99 kg ha^{-1} respectively. Anita (2002) commented that shade levels had no significant influence on available nitrogen and phosphorus status of the soil. But there was a significant reduction of potassium status of the soil with increase in shade levels.

2.2 INFLUENCE OF NITROGEN ON THE PERFORMANCE OF FODDER CROPS

Nitrogen constitutes the backbone of intensive grassland management. Growth of crop plants is limited more often by deficiency of nitrogen than by any other plant nutrient (Bogdan, 1977). As the vegetative parts of grasses comprise the economic yield, undoubtedly nitrogen plays the most important role in the production of herbage. The effect of nitrogen on various aspects of forage production are given below.

2.2.1 Influence of Nitrogen on Growth Characters

2.2.1.1 Height of the Grass

Rai and Shankaranarayan (1981) obtained an increase in plant height in giant anjan (*Cenchrus ciliaris*) with nitrogen application upto 40 kg N ha^{-1}. Bhati and Singh (1982) reported that plant height of *Cenchrus setigerus* Vahl. was maximum at highest dose of N (90 kg ha^{-1}). In a field study with hybrid napier involving four levels of fertilizer nitrogen (250, 500, 750 and 1000 kg N ha^{-1} $year^{-1}$), two levels of potassium (150 and 300 kg K_2O ha^{-1} $year^{-1}$) and one level of phosphorus (200 kg P_2O_5 ha^{-1} $year^{-1}$) indicated that nitrogen rate was positively correlated with plant height (Yeh, 1988).

A similar trend was observed in dwarf Napier grass also when varying levels of N and K were tested along with a fixed level of P (Hong and Hsu, 1993). A significant increase in plant height by nitrogen application upto 100 kg ha^{-1} was reported by Krishnan (1993) in guinea grass (*Panicum maximum*). In signal grass application of the highest dose of 200 kg N ha^{-1} recorded the maximum plant height (Sonia, 1999). Purushotham *et al.* (2001) reported that plant height of guinea grass increased significantly with N levels upto 150 kg ha^{-1}. Singh *et al.* (2001) pointed out that plant height of two varieties (PGG-9 and PGG-14) of guinea grass (*Panicum maximum*) significantly increased with increment in nitrogen levels upto 120 kg ha^{-1}. Singh *et al.* (2002a) recorded that plant height of Napier Bajra hybrid increased with increasing levels of N upto 150 kg N ha^{-1}. Soratto *et al.* (2004) commented that plant height of two fall *Panicum* cultivars (*Panicum dichotomiflorum* Michx.) increased with increasing levels of N from 0 to 200 mg L^{-1}.

In general the plant height increased with nitrogen application in most of the important fodder grasses.

2.2.1.2 Number of Tillers

Reddy (1990) obtained an increase in the number of tillers of hybrid napier with increased nitrogen levels. Krishnan (1993) recorded significant influence of nitrogen applied at 100 kg ha^{-1} on number of tillers in guinea grass (*Panicum maximum* J.). In switch grass (*Panicum virgatum*) application of nitrogen after cutting increased the total number of tillers (Brejda *et al.*, 1994). Vineetha (1995) working in gamba grass (*Andropogon gayanus* Kunth) pointed out that there was a progressive increase in tiller number with incremental levels of nitrogen. Increasing levels of applied nitrogen increased tiller density, but reduced individual tiller vigour as reported by Mc Kenzie (1996) in *Lolium perenne*. Sonia (1999) observed in signal grass (*Brachiaria decumbens* Stapf), a significant increase in tiller number per hill at the second, third and fourth harvest when nitrogen application was increased from 100 to 150 kg ha^{-1}. Joaquin *et al.* (2001b) reported that in guinea grass (*Panicum maximum* Jacq.), number of tillers increased with nitrogen levels upto 150 kg ha^{-1}.

Singh *et al.* (2001) opined that number of tillers of two varieties (PGG-9 and PGG-14) of guinea grass (*Panicum maximum*) significantly increased with increment in N level upto 120 kg ha^{-1}. Soratto *et al.* (2004) found out that tillering in two fall *Panicum* cultivars (*Panicum dichotomiflorum* Michx.) increased with increasing levels of N from 0 to 200 mg L^{-1}.

However, Ramamurthy (2002b) reported that application of N to *Pennisetum* trispecific hybrid did not significantly influence the growth parameter like number of tiller / tussock.

The tiller production showed an increasing trend with application of nitrogen in majority of the experiments so far conducted.

2.2.1.3 Leaf Stem Ratio

Leaf stem ratio indicates the general succulence of the herbage. A ratio above 1.00 indicates more succulence.

Kothari and Saraf (1987) reported an increase in L: S ratio and moisture content with increased application of nitrogen.

However, Jayakumar (1997) noted a decrease in L:S ratio in hybrid napier grass with the application of nitrogen. Sonia (1999) reported that the leaf stem ratio of signal grass (*Brachiaria decumbens* Stapf.) decreased with increase in N from 100 to 150 kg ha^{-1}.

Nitrogen did not significantly influence the leaf: stem ratio of dinanath grass (Abraham, 1978). Pillai (1986) reported that nitrogen could not exert any influence on the leaf stem ratio of guinea grass and setaria grass under both open and shaded situations. Yeh (1988) noticed that nitrogen application had not much effect on L:S ratio of hybrid napier. Yadav and Sharma (1989) opined that various nitrogen levels did not influence the leaf: stem ratio of dinanath grass. Ramamurthy (2002b) reported that application of N to *Pennisetum* trispecific hybrid did not significantly influence leaf: stem ratio.

2.2.2 Influence of Nitrogen on Yield

2.2.2.1 Green Fodder Yield

Dwivedi *et al.* (1991) observed a significant increase in the herbage production of thin napier grass with higher doses of nitrogen. In congosignal, Meerabai *et al.* (1992) noted a profound increase in green fodder yield upto 100 kg N ha^{-1} beyond which the yield increase was non-significant. According to Vineetha (1995), in gamba grass (*Andropogon gayanus* Kunth.), green fodder yield at both the harvests were significantly increased by the application of nitrogen and the highest level of nitrogen (225 kg ha^{-1}) recorded the maximum fodder yield in both the harvests.

Cameron and Ross (1996) opined that yields with applied nitrogen were approximately 2.5 times more than those without nitrogen on established green pastures. Gupta *et al.* (1998) noted in *Setaria sphacelata*, green fodder yield was affected significantly upto 120 kg N ha^{-1} during first year of investigation whereas in the second year, increase in yield was affected significantly only upto 80 kg N ha^{-1}. Sonia (1999) observed a pronounced increase in green fodder yield of signal grass by increased application of nitrogen and the maximum green fodder yield was obtained with the highest dose of nitrogen (200 kg N ha^{-1}). Singh *et al.* (2000) reported that green forage yield of guinea grass (*Panicum maximum*) increased significantly upto 75 kg N ha^{-1}. According to Joaquin *et al.* (2001a), green matter yield of 146.9 kg ha^{-1} obtained with highest level of N (150 kg ha^{-1}) in guinea grass (*Panicum maximum* Jacq.). Purushotham *et al.* (2001) found out in guinea grass, application of 150 kg N ha^{-1} gave significant higher fodder yield (494.3 q ha^{-1}) compared with 100 kg N ha^{-1} (430.5 q ha^{-1}). Singh *et al.* (2001) commented that green fodder yield of two varieties (PGG-9 and PGG-14) of guinea grass (*Panicum maximum*) significantly increased with the increment in N level upto 120 kg ha^{-1}. In napier bajra hybrids, an application of 200 kg N ha^{-1} $year^{-1}$ recorded significantly higher green forage yield of 175.5 t ha^{-1} $year^{-1}$ over 100 kg N (168.7 t ha^{-1} $year^{-1}$) (Ramamurthy, 2002a). Ramamurthy (2002b) noticed in *Pennisetum* trispecific hybrid, the green fodder yield increased significantly with increasing levels of N upto 120 kg N ha^{-1}. Singh *et al.* (2002a) obtained higher herbage yield of Napier-Bajra hybrid with increasing N levels upto 150 kg ha^{-1}.

Nitrogen application in general, significantly favoured higher green fodder yield in all the fodder grasses tried.

2.2.2.2 Dry Fodder Yield

Pamo (1991) working on Congosignal (*Brachiaria ruziziensis*) reported that dry matter yield increased significantly with increasing nitrogen rate upto 80 kg N ha^{-1}. Highest dry forage yield (10.99 t ha^{-1}) was recorded with application of 60 kg N ha^{-1} in *Cenchrus ciliaris* x *Cenchrus setigerus* hybrid (Rai, 1991). Tripathi and Singh (1991) noticed significant effects of increasing levels of nitrogen on dry fodder yield of dinanath grass upto 90 kg ha^{-1}. In *Brachiaria* spp. the dry fodder yield increased with nitrogen rates (Carvalho *et al.*, 1992). In case of congosignal grass grown under coconuts, dry fodder yield increased significantly with the application of 100 kg N ha^{-1} over 50 kg N ha^{-1} beyond which the yield increase was non significant (Meerabai *et al.*, 1992). According to Hall (1993) dry matter yield of native pasture increased from 2050 to 3060 kg ha^{-1} by application of nitrogen. Hong and Hsu (1993) reported that in dwarf napier grass, dry fodder yield increased upto 920 kg ha^{-1} of applied nitrogen @ 120 kg ha^{-1} $harvest^{-1}$ to obtain high dry matter yields in Rhodes grass. Pieterse and Rethman (1995) found in *Digitaria eriantha*, the highest production efficiency was with 80 kg ha^{-1} nitrogen application, with efficiency decreasing at lower and higher levels of nitrogen. Vineetha (1995) obtained maximum dry fodder yield in gamba grass (*Andropogon gayanus* Kunth) at the highest level of nitrogen (225 kg ha^{-1}). In *Brachiaria ruziziensis*, the dry matter yield increased by about 31.9 per cent with increased nitrogen levels (Andrade *et al*., 1996). Kulhari and Katewa (1998) found out that in natural grassland with *Heteropogon contortus* and *Eremopogon foveolatus*, successive increment of N levels from 30 to 60 kg ha^{-1} caused significant increase in dry forage yield and maximum total dry forage yield (87.1 q ha^{-1}) was obtained with the application of 60 kg N ha^{-1} which was significantly higher by 52.3 per cent over 30 kg N ha^{-1}. While working in *Pennisetum* trispecific hybrid, Ramamurthy and Vinodshankar (1998) reported that application of 50 kg N ha^{-1} recorded significantly higher dry matter yield compared with 25 kg N ha^{-1} and the control, but it was on par with 75 kg N ha^{-1}. Kawata and Matsunaka (1999) commented that dry matter yield was greatest in orchard grass (*Dactylis glomerata*) followed by meadow fescue (*Festuca elatior*) and timothy (*Phleum pratense*) in the treatment given N @ 6 g m^{-2}. Singh (1999) opined that Guatemala gama grass (*Tripsacum laxum*), guinea grass (*Panicum maximum*) cv. Hamil, Gatton and Makueni responded upto 200 kg N ha^{-1}, while broom grass (*Thysanolaena maxima*), guinea grass cv. PGG-1, palm grass (*Setaria palmifolia*) and thin napier grass (*Pennisetum polystachyon*) produced maximum dry matter at 100 kg N ha^{-1}. Sonia (1999) noticed that nitrogen application upto 200 kg ha^{-1} remarkably increased the dry fodder yield of signal grass. Singh *et al*. (2000) reported in guinea grass (*Panicum maximum*) dry matter yield increased significantly upto 75 kg N ha^{-1}. Dry fodder yield of two varieties (PGG-9 and PGG-14) of guinea grass (*Panicum maximum*) significantly increased with increment in N level upto 120 kg ha^{-1} (Singh *et al*., 2001). Ramamurthy (2002b) reported in *Pennisetum* trispecific hybrid, the dry matter yield increased significantly with increasing levels of N upto 120 kg N ha^{-1}. Rocha *et al*. (2002) opined that increase in N doses upto 400 kg ha^{-1} as ammonium sulfate increased dry matter yield of grasses of the *Cynodon* genus.

However, Ezenwa *et al.* (1996) showed that 1.8 t ha^{-1} dry matter was produced by *Brachiaria ruziziensis* without nitrogen fertilizers than with nitrogen fertilizers (0.2 t ha^{-1}) when grown in pure stand or mixture under a mature oil palm.

2.2.3 Influence of Nitrogen on Physiological Observations

2.2.3.1 Leaf Area Index

Kawata and Matsunaka (1999) observed that maximum LAI values were obtained for orchard grass (*Dactylis glomerata*), timothy (*Phleum pratense*) and meadow fescue (*Festuca elatior*) at the highest level of N application ie., 6 gm^{-2}. Sonia (1999) concluded that in Signal grass (*Brachiaria decumbens* Stapf.), leaf area index increased with increase in nitrogen levels from 100 to 200 kg ha^{-1}. Illavska *et al.* (2001) reported that there were 52.9 and 64.3 per cent increase in LAI of a temporary grassland for N @ 90 kg ha^{-1} and N @ 180 kg ha^{-1} treatments respectively in comparison with the control. Singh *et al.* (2002a) commented that LAI of Napier Bajra hybrid increased with increasing levels of N upto 150 kg ha^{-1}. Wadi *et al.* (2003) noted that LAI of napier grass (*Pennisetum purpuream*) and king grass, the hybrid between napier grass and pearlmillet (*Pennisetum typhoides*) increased as the level of chemical (NPK) fertilization increased.

2.2.3.2 Crop Growth Rate

While working in an *Anthoxantho-Agrostietum* grassland, Gaborcik and Javorkova (1990) reported that increase in N rate upto 300 kg N ha^{-1} increased CGR most, followed by RGR, LAI and NAR with 3 cuts $year^{-1}$, whereas with 5 cuts, the sequence in response to N was CGR > NAR > LAI > RGR. Wadi *et al.* (2003) noted that CGR of napier grass (*Pennisetum purpurem*) and king grass, the hybrid between napier grass and pearl millet (*Pennisetum typhoides*) increased as the level of chemical (NPK) fertilization increased.

However, Singer (2002) observed that growth rates ranged from 8.60 to 1.54, 9.14 to 0.67 and 4.19 to 0.29 g dry matter (DM) m^{-2} day^{-1} in orchard grass (*Dactylis glomerata* L.), smooth brome grass (*Bromus inermis* Leyss) and timothy (*Phleum pratense* L.) with different N levels.

2.2.3.3 Relative Growth Rate

Gaborcik and Javorkova (1990) reported that in *Anthoxantho-Agrostietum* grassland, with 5 cuts, RGR was increased by 15 per cent across all N rates upto 300 kg N ha^{-1}. Kumar and Singh (2001) observed that RGR of maize hybrid Ganga-5 increased with increasing N rates upto 160 kg ha^{-1}.

2.2.3.4 Net Assimilation Rate

NAR is essentially an estimation of canopy photosynthesis per unit leaf area and can be used as a measure of photosynthetic efficiency. Its contribution to yield is not direct (Gauder *et al.*, 1988). Gaborcik and Javorkova (1990) observed in *Anthoxantho-Agrostietum* grassland, with 5 cuts, NAR was increased by 12 per cent across all N rates upto 300 kg N ha^{-1}. Illavska *et al.* (2001) noticed in a temporary grassland, there were 20.7 and 45.6 per cent rise in NAR values for N @ 90 kg ha^{-1} and N @ 180 kg ha^{-1} treatment respectively in comparison with the control. Kumar and Singh (2001) found out that NAR of maize hybrid Ganga-5 increased with increasing N rates upto 160 kg N ha^{-1}. In maize (*Zea mays* L.), nitrogen application @ 80 and 120 kg N ha^{-1} increased NAR significantly over control (Shivay *et al.*, 2002).

However, Kawata and Matsunaka (1999) reported in orchard grass (*Dactylis glomerata*), timothy (*Phleum pratense*) and meadow fescue (*Festuca elatior*) that N application had no great effect on the NAR.

2.2.4 Influence of Nitrogen on Biochemical Studies

2.2.4.1 Chlorophyll Content

Sudhakar *et al.* (1987) reported that application of N at 180 kg ha^{-1} increased the leaf chlorophyll content in rice. Singh *et al.* (1992) also observed a significant increase in the chlorophyll content of rice with N application upto 150 kg ha^{-1}. In rice, there was a marked increase in chlorophyll content with an increase in the level of N and highest level of N (80 kg N ha^{-1}) recorded the maximum chlorophyll content of 1.62 mg g^{-1} (Anu, 2001). Soratto *et al.* (2004) commented that chlorophyll content of two fall *Panicum* cultivars (*Panicum dichotomiflorum* Michx.) increased with increasing levels of N from 0 to 200 mg L^{-1}.

2.2.5 Influence of Nitrogen on Quality Aspects

2.2.5.1 Crude Protein Content

Dwivedi *et al.* (1980) obtained highest crude protein content with 90 kg N ha^{-1} in *Chrysopogon fulvus*. Studies conducted on *Cenchrus setigerus* revealed that crude protein increased by 153 per cent by the application of 90 kg N ha^{-1} over no N application (Ravikumar *et al.*, 1980). An increase in crude protein content with addition of nitrogen was reported in hybrid napier NB-21 Lucerne mixture by Shanmugasundaram (1985). In bajra-napier hybrid the crude protein content was increased from 8.41 to 9.90 per cent with the application of 150 kg N ha^{-1} (Govindaswamy and Manickam, 1988). Similar trend was observed in *Digitaria decumbens* and *Brachiaria mutica* (Tudsri and Sornprasiti, 1988), hybrid Napier (Yeh, 1988) and dwarf Napier grass (Hong and Hsu, 1993). Rai (1991) recorded the highest crude protein yield of 1.65 t ha^{-1} from pure stand with 60 kg N ha^{-1} in *Cenchrus ciliaris* x *Cenchrus setigerus* hybrid. Tripathi and Singh (1991) working on dinanath grass (*Pennisetum pedicellatum*) reported that crude protein yield increased with nitrogen levels upto 120 kg N ha^{-1}, although the magnitude of increase was lower beyond 90 kg N ha^{-1}. Nitrogen application was found to increase the crude protein yields of

Brachiaria ruziziensis (Andrade *et al.*, 1996). Pieterse *et al.* (1997) reported in guinea grass, the cv. Gatton recorded highest crude protein level of 11.75 per cent at 160 kg N ha^{-1}, while another cv. Vencidor recorded lowest crude protein content of 5.2 per cent with 320 kg N ha^{-1}. Kulhari and Katewa (1998) noted in a natural grassland with *Heteropogon contortus* and *Eremopogon foveolatus*, graded doses of N upto 60 kg ha^{-1} significantly improved the crude protein content of grasses by 28.5 and 29.3 per cent over 30 kg N ha^{-1} at both I and II cuts respectively. According to Singh *et al.* (2000), crude protein yield of guinea grass (*Panicum maximum*) increased significantly from 0 to 75 kg N ha^{-1}. Rocha *et al.* (2002) opined that increase of N doses upto 400 kg ha^{-1} as ammonium sulfate increased crude protein yield of grasses of *Cynodon* genus. Thakuria (2002) observed that application of 120 kg N ha^{-1} as ½ at 1st rain + ½ after 1st cut following 2 cut frequency is beneficial for higher crude protein content in *Setaria sphacelata* cv. Kazangula.

However, Sonia (1999) noticed an inverse relationship between applied nitrogen and crude protein content of Signal grass (*Brachiaria decumbens* Stapf.).

2.2.5.2 Crude Fibre Content

Caceres *et al.* (1986) in their trial applied 60 kg N ha^{-1} to guinea grass (*Panicum maximum* cv. Common, *Panicum maximum* cv. Likoni) and gamba grass (*Andropogon gayanus*) reported that crude fibre ranged from 37.1 to 38.0 per cent (DM basis) in the cut forage and from 38.1 to 40.5 per cent on the 4th day in gamba grass (*Andropogon gayanus*) and guinea grass (*Panicum maximum* cv. Common) respectively. Vineetha (1995) observed that crude fibre content of gamba grass (*Andropogon gayanus* Kunth) was significantly reduced by N application upto 225 kg ha^{-1}. Kulhari and Katewa (1998) reported that in a natural grassland with *Heteropogon contortus* and *Eremopogon foveolatus* due to the application of 60 kg N ha^{-1}, significant reduction in crude fibre content was reported over 45 and 30 kg N ha^{-1} by 6.4 and 10.8 per cent and 6.1 and 11.7 per cent at I and II cuts respectively. Sonia (1999) concluded that incremental levels of nitrogen reduced the crude fibre content to a significant extent in Signal grass. Rocha *et al.* (2002) commented that in grasses of *Cynodon* genus, increase in N doses upto 400 kg ha^{-1} as ammonium sulfate decreased crude fibre content to a considerable level.

2.2.6 Influence of Nitrogen on Nutrient Content and Uptake

2.2.6.1 Nitrogen Content and Uptake

Nitrogen and phosphorus fertilizers along with FYM were found to be effective in increasing the nitrogen uptake in *Cenchrus ciliaris*. Significant response was noted upto 30 kg N ha^{-1} (Bhati and Mathur, 1984). Singh (1987) observed that higher levels of applied nitrogen increased the forage nitrogen content in hybrid napier. Trials conducted in *Cenchrus ciliaris* revealed that the nitrogen concentration of fodder was increased by N fertilizers (Rai, 1989). Peake *et al.* (1990) reported that addition of nitrogen to green panic resulted in a slight reduction in nitrogen concentration whereas nitrogen content increased in buffel grass. Nitrogen concentration in Rhodes grass was significantly increased by nitrogen application (Prakash *et al.*, 1994). Vineetha (1995) observed in gamba grass (*Andropogon gayanus* Kunth.), uptake of nitrogen was significantly influenced by the levels of N and uptake was maximum (65.5 kg ha^{-1}) at the highest level of N (225 kg ha^{-1}). Soratto *et al.* (2004) opined that nitrogen content of two fall *Panicum* cultivars (*Panicum dichotomiflorum* Michx) increased with increasing levels of N from 0 to 200 mg L^{-1}.

An inverse relationship between applied levels of nitrogen and plant nitrogen content was reported by Fernandes *et al.* (1985) in *Brachiaria decembens*. In Signal grass (*Brachiaria decembens* Stapf.), the highest N content was recorded by the treatment receiving the lowest dose of nitrogen viz., 100 kg ha^{-1}. Further as the nitrogen application was increased there was a steady decline in the nitrogen content of the grass (Sonia, 1999).

2.2.6.2 Phosphorus Content and Uptake

Kulhari and Katewa (1998) opined that in a natural grassland of *Heteropogon contortus* and *Eremopogon foveolatus*, improvement in P content was recorded due to increasing levels of N but it could not attain the level of significance from 30 to 60 kg N ha^{-1} application. Belanger *et al.* (2002) observed that P concentration and uptake of timothy genotypes decreased under N stress. Coblentz *et al.* (2004) while working with Common Bermuda grass (*Cynodon dactylon*) which was harvested from two producer sites (Latta and Stephens), uptake of P was generally improved with N fertilization reaching 30 kg P ha^{-1} at Stephens site and 50.8 kg P ha^{-1} at Latta site.

But contradictory to these, Abraham *et al.* (1980) observed a decreasing trend in phosphorus content with nitrogen application in dinanath grass. Ravikumar *et al.* (1980) reported that an increasing level of N caused a decrease in P content of herbage of *Cenchrus setigerus*. Fernandes *et al.* (1985) found out decreasing P concentration in the plant with increasing nitrogen levels in presence of potassium in signal grass (*Brachiaria decembens*). Prakash *et al.* (1994) noticed a decrease in P concentration in Rhodes grass by increased N application. According to Andrade *et al.* (1996) forage P concentration was decreased by N and K application in Congo signal. Sonia (1999) obtained a decreasing trend of P uptake with increase in nitrogen application in Signal grass (*Brachiaria decembens* Stapf).

2.2.6.3 Potassium Content and Uptake

Abraham (1978) observed that there was a significant increase in the K content by nitrogen application in dinanath grass. A consistent rise in the uptake of potassium in dinanath grass (*Pennisetum pedicellatum*) due to nitrogen application was noticed by Rathore and Vijayakumar (1978).

According to Abraham *et al.* (1980), there was an increase in potassium content of dinanath grass (*Pennisetum pedicellatum*) due to the application of nitrogen.

Contradictory to these results, Vineetha (1995) reported that K content of gamba grass (*Andropogon gayanus* Kunth) was significantly reduced due to nitrogen application. In signal grass, the K content was not significantly influenced by the different levels of nitrogen (Sonia, 1999).

2.2.7 Influence of Nitrogen on NPK status of Soil

Abraham (1978) observed in dinanath grass, available nitrogen content of the soil increased progressively with increase in the level of applied N. Vineetha (1995) found in her field trial with gamba grass (*Andropogon gayanus* Kunth) that nitrogen fertilizer upto 225 kg/ha increased the nitrogen status of the soil but nitrogen fertilizer had no significant influence on soil P content. Sonia (1999) opined that in Signal grass (*Brachiaria decumbens* Stapf) an increase in nitrogen application resulted in an increase in available nitrogen status of the soil. She also reported that the different nitrogen levels did not produce any significant effect on available phosphorus status of soil. Also as the nitrogen dose was increased from 100 to 150 kg ha^{-1}, there was a significant decrease in available potassium status.

2.3 INFLUENCE OF PHOSPHORUS ON THE PERFORMANCE OF FODDER CROPS

The best response of crops to phosphorus was obtained in the early stage of crop growth but decreases gradually with the approach of maturity. Grasses generally show more response to nitrogen than phosphorus. Hence research results on phosphorus nutrition of grasses are comparatively less. The available literatures on phosphorus nutrition of grasses relevant to the present investigation are reviewed.

2.3.1 Influence of Phosphorus on Growth Characters

2.3.1.1 Height of the Plant

In guinea grass (*Panicum maximum* Jacq.), Setaria grass (*Setaria anceps* Stapf) and Congosignal (*Brachiaria ruziziensis*), plant height increased with increase in phosphorus application upto 120 kg P_2O_5 ha^{-1} (Chandini, 1980). Bhati and Singh (1982) reported highest plant height of *Cenchrus setigerus* at 30 kg P_2O_5 ha^{-1}. According to Purushotham *et al.* (1995) plant height of anjan grass (*Cenchrus ciliaris*) was significantly improved at 40 kg P_2O_5 ha^{-1} compared with 20 kg P_2O_5 ha^{-1}.

However, Rai and Shankaranarayan (1981) observed that the plant height was not affected by the application of phosphorus in giant anjan (*Cenchrus ciliaris*) either as soil application or as foliar spray. Pillai (1986) opined that application of phosphorus did not exert any significant influence on height of guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) under both open and shaded situations. According to Hernandez and Cardenas (1990) plant height of guinea grass cv. Likoni was not significantly different from the control over the 6 years with increasing dose of phosphorus upto 400 kg P_2O_5 ha^{-1}. Vineetha (1995) noticed that P application have no significant effect on plant height of gamba grass (*Andropogon gayanus* Kunth).

2.3.1.2 Number of Tillers

Chandini (1980) found out in guinea grass (*Panicum maximum* Jacq.), Setaria grass (*Setaria anceps*) and Congo signal (*Brachiaria ruziziensis*), the tiller number increased significantly with increase in the level of P_2O_5 upto 160 kg ha^{-1}. Bhati and Singh (1982) noticed that number of tillers per plant of *Cenchrus setigerus* was maximum at 30 kg P_2O_5 ha^{-1}. Bhati and Mathur (1984) observed a significant increase in number of tillers of *Cenchrus ciliaris* Linn. due to phosphorus application upto 30 kg ha^{-1}.

According to Rai and Shankaranarayan (1981) application of phosphorus did not produce any significant increase in number of tillers of giant anjan grass (*Cenchrus ciliaris*). Pillai (1986) commented that various phosphorus levels had no significant effect in tiller production of guinea grass and setaria grass. Krishnan (1993) opined that phosphatic fertilizers did not influence tiller production in guinea grass (*Panicum maximum* Jacq.). Purushotham *et al.* (1995) observed that the tillering capacity of anjan grass (*Cenchrus ciliaris*) did not differ due to P levels. In gamba grass (*Andropogon gayanus* Kunth), application of phosphorus did not produce any significant effect in number of tillers (Vineetha, 1995).

*2.3.1.3 **Leaf: Stem ratio***

Chandini (1980) reported an increase in leaf /stem ratio of guinea grass (*Panicum maximum* Jacq.), setaria grass (*Setaria anceps*) and congosignal (*Brachiaria ruziziensis*) with increasing levels of phosphorus upto 160 kg P_2O_5 ha^{-1}.

However, according to Pillai (1986) phosphorus could not exert any influence on the leaf: stem ratio of guinea grass and setaria grass (*Setaria anceps* cv. Kazangula) under both open and shaded situations.

2.3.2 Influence of Phosphorus on Yield

2.3.2.1 Green Fodder Yield

Grasses generally show great response to nitrogen and so, much studies have not been carried out on phosphorus fertilization of grasses. Application of 30 kg P_2O_5 ha^{-1} gave significant increase in fresh fodder yield in *Cenchrus ciliaris* (Bhati and Mathur, 1984). Herbage yield increased with increase in phosphorus rates in thin napier grass (*Pennisetum polystachyon*) (Dwivedi *et al.*, 1991). In Congo signal, green fodder yield increase upto 30 kg P_2O_5 ha^{-1} as reported by Meerabai *et al.* (1993) in the red loam soils of Vellayani. Purushotham *et al.* (1995) observed that the green fodder yield of anjan grass (*Cenchrus ciliaris*) was significantly higher (29.3 per cent) with 40 kg P_2O_5 ha^{-1} (58.9 q ha^{-1}).

Phosphorus fertilization had little effect on yield components as reported by Balasko (1977) in tall fescue forage. Chandini (1980) reported that phosphorus levels had no significant influence in increasing the green forage yield of guinea grass (*Panicum maximum* Jacq.), Congosignal (*Brachiaria ruziziensis*) and setaria grass (*Setaria anceps*). According to Ravikumar and Shankaranarayan (1980) P application did not significantly affect forage production of *Sehima nervosum* grassland. Vineetha (1995) opined that different phosphorus levels have no significant influence on green fodder yield of gamba grass (*Andropogon gayanus* Kunth.).

2.3.2.2 Dry Fodder Yield

Pillai (1986) observed that phosphorus given @ 60 kg ha^{-1} recorded highest dry matter yield in both guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*). Phosphorus application at the rate of 60 kg ha^{-1} increased the average dry matter yield of hybrid napier from 16.8 (without P) to 18.7 t ha^{-1} (Maiti *et al.*, 1988). Costa (1989) reported that *Andropogon gayanus, Brachiaria humidicola, Brachiaria decumbens, Brachiaria ruziziensis* and *Panicum maximum* showed an increased response to P_2O_5 upto 100 kg ha^{-1} with regard to the dry matter yields. According to Dias-Filho *et al.* (1989), dry matter production increased with P_2O_5 levels upto 100 kg ha^{-1} in *Brachiaria brizantha*. Shoot dry matter production increased with increasing phosphorus rate in gamba grass (*Andropogon gayanus*) (Paulino and Malavotta, 1989). Similar results were obtained by Paulino *et al.* (1989) in *Andropogon gayanus*. Drymatter yield of Perennial ryegrass (*Lolium perenne*) increased by 10 per cent with the application of P_2O_5 @ 100 kg ha^{-1} (Acuna and Wilman, 1993). Hall (1993) noticed that dry matter yields of native pasture increased to 3080 kg ha^{-1} by the application of superphosphate in the first year. Dry matter yields of perennial grasses were found to be responding positively to the freshly available P in the soil, from the most recent P application (Paynter and Dampney, 1996). Gelderman *et al.* (2002) found out that dry matter yield of an established cool-season grass was significantly increased by P fertilizer application upto 66 kg ha^{-1}.

Chandini *et al.* (1985) observed that P application did not influence the dry matter yield of *Panicum maximum*, *Brachiaria ruziziensis* and *Setaria anceps*. Hernandez and Cardenas (1990) opined that dry matter yield of guinea grass cv.Likoni was not significantly differed from the control upto highest level of phosphorus (400 kg P_2O_5 ha^{-1}). No significant response to P application was recorded by Prakash *et al.* (1994) in Rhodes grass. Vineetha (1995) noticed that in gamba grass (*Andropogon gayanus* Kunth), phosphorus did not have much influence on dry fodder yield.

2.3.3 Influence of Phosphorus on Physiological Observations

2.3.3.1 Leaf Area Index

Singh *et al.* (1993) reported that in Sorghum (*Sorghum bicolor*) P_2O_5 applied @ 40 kg ha^{-1} recorded significantly higher LAI over rest of lower levels. In maize (*Zea mays* L.), increasing level of phosphorus upto 80 kg P_2O_5 ha^{-1} significantly increased the LAI at 30, 60 and 90 DAS (Kumar and Singh, 2002).

2.3.3.2 Crop Growth Rate

Munda *et al.* (1984) observed that in hybrid pearl millet, at 30 DAS, application of 60 kg P_2O_5 ha^{-1} increased CGR by about 67.6 per cent over no application and at the pre-flowering stage (50 DAS), application of 60 kg P_2O_5 ha^{-1} increased CGR by about 48.3 per cent over no application. According to Kanno *et al.* (1999) CGR of *Brachiaria decumbens* cv. Basilisk and *Brachiaria brizantha cv.* Marandu increased by P supply upto 200 kg P_2O_5 ha^{-1}. Kumar and Singh (2002) noticed an increase in the CGR of maize (*Zea mays* L.) with increasing dose of phosphorus upto 80 kg P_2O_5 ha^{-1} at 30 and 90 DAS.

Pillai (1986) reported that in guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*), effect of P application on CGR was not significant in open area but it significantly increased the CGR under partial shaded situations.

2.3.3.3 Net Assimilation Rate

Kanno *et al.* (1999) reported that in *Brachiaria decumbens* cv. Basilisk and *Brachiaria brizantha* cv. Marandu, the effect of P supply on NAR was less that on leaf area.

2.3.4 Influence of Phosphorus on Quality Aspects

2.3.4.1 Crude Protein Content

Chandini (1980) found an increase in the crude protein content of *Panicum maximum*, *Brachiaria ruziziensis* and *Setaria anceps* with increasing levels of P_2O_5 upto 120 kg P_2O_5 ha^{-1}. Dwivedi *et al.* (1980) opined that application of phosphorus showed slight increase in crude protein content with increasing levels of phosphorus from 0 to 40 $kgha^{-1}$. Ravikumar and Shankaranarayan (1980) obtained increase in crude protein content in the case of *Sehima nervosum* with phosphorus levels of 30, 60 and 90 kg P_2O_5 ha^{-1}. According to Bhati and Singh (1982) crude protein yield of *Cenchrus setigerus* was maximum at 30 kg P_2O_5 ha^{-1}. Bhati and Mathur (1984) reported that there was 22.7 per cent increase in crude protein yield of *Cenchrus ciliaris* Linn. with the application of 30 kg P_2O_5 ha^{-1}. The crude protein content in herbage of green panic and verano stylo remained unaffected by P but crude protein yield of green panic and verano stylo was significantly influenced by P application and P increased total crude protein yield by 96 per cent (Singh, 1984). Pillai (1986) noticed an increase in the crude protein content of guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) in open as well as in partial shade due to P application. Tripathi and Singh (1991) working on dinanath grass (*Pennisetum pedicellatum*) reported that phosphorus application significantly increased crude protein content and yield over 0 and 20 kg P_2O_5 ha^{-1}. Solanki and Patel (1998) reported that crude protein content of alfalfa linearly increased with increase in P from 60 to 120 kg P_2O_5 ha^{-1}.

2.3.4.2 Crude Fibre Content

Chandini (1980) reported that in *Panicum maximum, Setaria anceps* and *Brachiaria ruziziensis*, there was significant reduction in the crude fibre content with increase in the level of P_2O_5 from 80 to 120 kg ha^{-1}. Pillai (1986) noticed that increase in P application significantly reduced crude fibre content of guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) in open. Vineetha (1995) observed that crude fibre content of gamba grass (*Andropogon gayanus* Kunth.) was significantly reduced by application of P_2O_5 upto highest level (100 kg P_2O_5 ha^{-1}).

2.3.5 Influence of Phosphorus on Nutrient Content and Uptake

2.3.5.1 Nitrogen Content and Uptake

Pillai (1986) reported that P application significantly increased the N uptake of guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) in both open and shaded situations. Kamaraj *et al.* (2002) noticed an increased nitrogen uptake in rice variety TRY-1 with increasing levels of P and the highest nitrogen uptake was associated with 60 kg P_2O_5 ha^{-1} as coated diammonium phoshate while the lowest was with treatment receiving no fertilizer application.

According to Vineetha (1995) in gamba grass (*Andropogon gayanus* Kunth.), nitrogen content was not significantly influenced by different levels of P.

2.3.5.2 Phosphorus Content and Uptake

Bhati and Mathur (1984) reported that higher uptake of P (39.4 per cent) in *Cenchrus ciliaris* Linn. was obtained with highest dose of phosphorus (30 kg ha^{-1}). Pillai (1986) noted that the P content and uptake of guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) was significantly increased by the application of phosphorus both in open and partial shade. Hazra and Tripathi (1989) reported that the uptake of P by sweet clover was progressively increased with each successive increase in level of P upto higher level (90 kg P_2O_5 ha^{-1}). Hernandez and Cardenas (1990) observed that the highest herbage P content for guinea grass cv. Likoni was obtained with 400 kg P_2O_5 ha^{-1} (0.37 and 0.36 per cent for the wet and dry seasons respectively). In gamba grass (*Andropogon gayanus* Kunth.), P content was highest at the highest levels of P (100 kg ha^{-1}) but P did not have much effect on P uptake (Vineetha, 1995). Gelderman *et al.* (2002) commented that forage P concentration of an established cool-season grass was significantly increased by P fertilizer upto 66 kg ha^{-1}. Kamaraj *et al.* (2002) noticed that in rice var. TRY-1, P uptake was consistently increased with increasing levels of P and the highest P uptake was associated with 60 kg P_2O_5 ha^{-1} as coated diammonium phosphate while the lowest with treatment receiving no fertilizer application.

2.3.5.3 Potassium Content and Uptake

In hybrid pearl millet, potassium uptake was increased by 40.5 per cent due to 60 kg P_2O_5 ha^{-1} over no application of phosphorus (Munda *et al.*, 1984). Pillai (1986) reported that P application significantly increased the K content and uptake of guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) in both open and shaded situations. Kamaraj *et al.* (2002) observed an increase in the K uptake of rice var. TRY-1 with increasing levels of P and the highest K uptake was associated with 60 kg P_2O_5 ha^{-1} as coated diammonium phosphate while the lowest was with treatment receiving no fertilizer application.

2.3.6 Influence of P on NPK Status of Soil

In a field trial with *Panicum maximum, Setaria anceps* and *Brachiaria ruziziensis*, Chandini (1980) reported that there was significant increase in the nitrogen content of the soil due to the application of 120 kg P_2O_5 ha^{-1}. P levels also had significant influence in increasing the P content of the soil upto 120 kg P_2O_5 ha^{-1} recording 104.389 kg P ha^{-1}. But P levels had no significant influence in the available K content of the soil. Pillai (1986) in his field trial with guinea grass (*Panicum maximum*) and setaria grass (*Setaria sphacelata*) noted that in P applied plots (P_{60}), there was significant reduction of soil N but P content of soil was enriched by P fertilization. He also reported that P application significantly increased the K content in open while in partial shade the effect was not significant but same trend was noted. Hazra and Tripathi (1989) reported that in Sweet clover cultivation, the available N status of soil was greatly improved with P application and such increases were of the order of 12.5 and 27.5 and 31.0 kg N ha^{-1} under open and 2.5, 19.0 and 22.0 kg N ha^{-1} under tree canopy with the application of 30, 60 and 90 kg P_2O_5 ha^{-1} respectively. He also reported that available P content of soil at crop harvest was greatly influenced by P application rates and the additional values of available P were 6.5, 9.5 and 12.5 kg P_2O_5 ha^{-1} under open and 4.5, 8.0 and 14.0 kg P_2O_5 ha^{-1} under trees with the application of 30, 60 and 90 kg P_2O_5 ha^{-1} respectively. Vineetha (1995) reported in gamba grass (*Andropogon gayanus* Kunth.), that various P levels significantly increased the nitrogen and phosphorus status of the soil.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was undertaken to study the shade response of guinea grass and to assess the optimum nitrogen and phosphorus requirement for maximum fodder yield and quality under different shade intensities and also to work out the economics of grass cultivation. The materials and methods adopted for the study are detailed below.

3.1 EXPERIMENTAL SITE

The experiment was conducted in the upland area of the Instructional Farm of College of Agriculture, Vellayani, Thiruvananthapuram. The farm is located at 8.5° 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 2003 and continued upto March 2004. The data on meteorological parameters *viz.*, minimum and maximum temperature, relative humidity, evaporation, rainfall, sunshine duration and windspeed during the crop period are furnished in Appendix I and presented graphically in Fig. 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

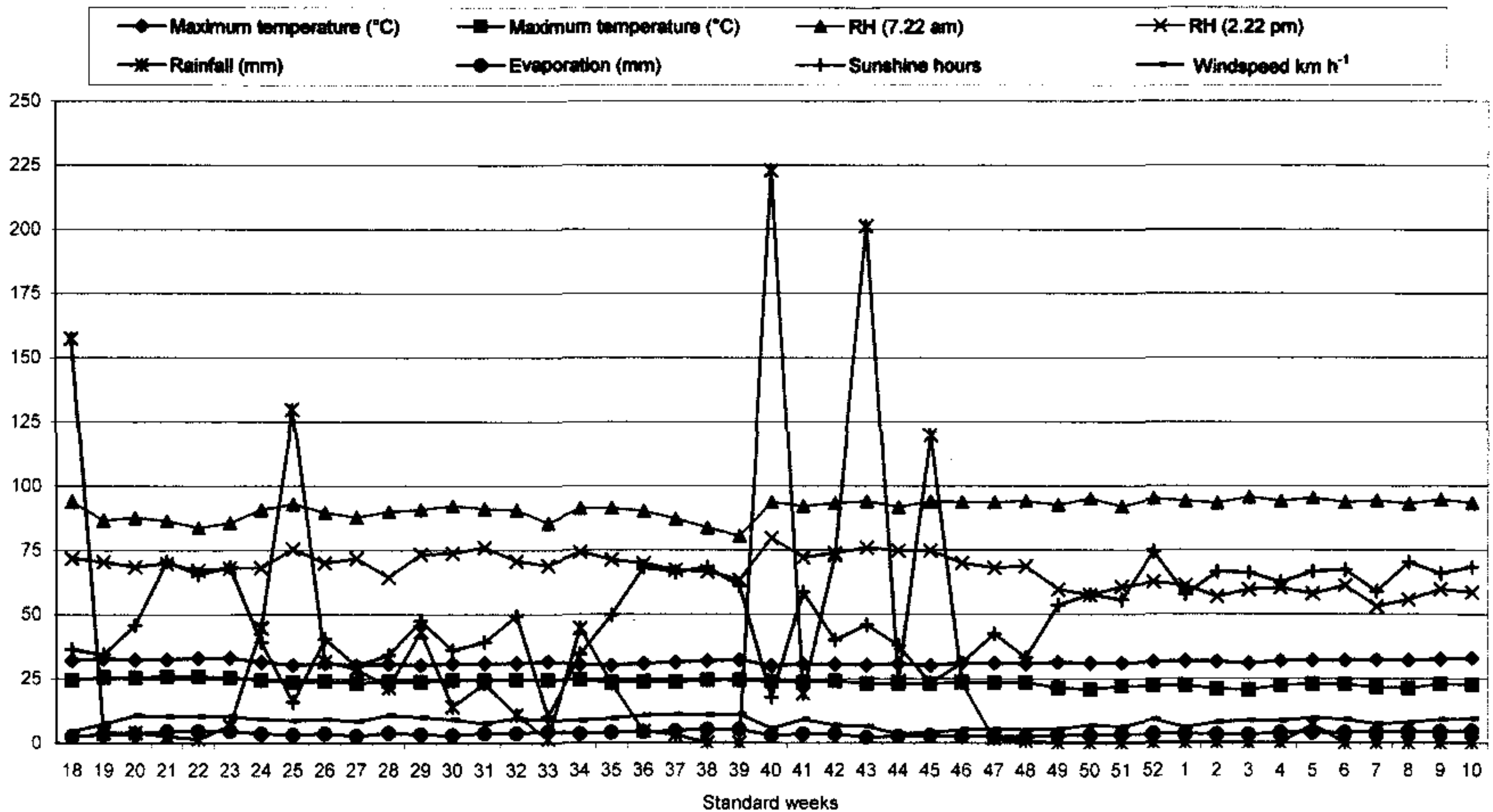


Fig. 1. Weather parameters during the crop period (April 30th 2003 to March 10th 2004)

and the data obtained is given in Table 1. (The soil was low in available N and K and medium in available P, with an acidic pH).

Table 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	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Fine sand (per cent)	31.30	
Silt (per cent)	25.50	
Clay (per cent)	26.50	
2. Bulk density (g cc^{-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 Dakshninamoorthi (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, 1973)
3. Available nitrogen (kg ha^{-1})	204.43	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
4. Available P_2O_5 (kg ha^{-1})	24.02	Bray's colorimetric method (Jackson, 1973)
5. Available K_2O (kg ha^{-1})	59.18	Flame photometric method (Jackson, 1973)

3.2 EXPERIMENTAL PROCEDURE

3.2.1 Layout and Design

Test crop : Guinea grass(*Panicum maximum* J.)

Experimental design : Split plot

Replications : 3

Spacing : 40 x 20 cm

Plot size

Gross plot size : 3.0 x 2.8 m

Net plot size : 2.8 x 1.2 m

Total number of plots : 54

Variety : Hamil

3.2.2 Treatments

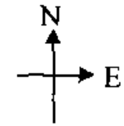
The layout of experiment is given in Fig. 2. An overall view of experimental site is shown in Plate 1.

A. Main plot treatments

Shade levels

s_0 – 0 per cent shade

s_1 – 50 per cent shade



s_0	T_3	T_8	T_9	T_6	T_4	T_7	T_5	T_2	T_1	R_2
s_1	T_{17}	T_{13}	T_{11}	T_{16}	T_{14}	T_{12}	T_{10}	T_{15}	T_{18}	
s_0	T_{18}	T_{16}	T_{12}	T_{14}	T_{17}	T_{15}	T_{11}	T_{13}	T_{10}	R_1
s_1	T_9	T_6	T_2	T_4	T_5	T_7	T_1	T_3	T_8	
s_0	T_2	T_5	T_7	T_1	T_3	T_6	T_8	T_4	T_9	R_3
s_1	T_{12}	T_{15}	T_{17}	T_{10}	T_{13}	T_{16}	T_{18}	T_{11}	T_{14}	

Fig. 2 Field layout of the experiment

Plate 1. General view of the experimental site

B. Sub plot treatments

Combinations of N and P

a. Nitrogen levels

n_1 – 100 kg ha^{-1}

n_2 – 200 kg ha^{-1}

n_3 – 300 kg ha^{-1}

b. Phosphorus levels

p_1 – 25 kg ha^{-1}

p_2 – 50 kg ha^{-1}

p_3 – 75 kg ha^{-1}

3.2.3 Treatment Combinations – 18

Combinations of two levels of shade, three levels of nitrogen and three levels of phosphorus formed 18 treatment combinations.

T_1 - $s_0n_1p_1$	T_7 - $s_0n_3p_1$	T_{13}- $s_1n_2p_1$
T_2 - $s_0n_1p_2$	T_8 - $s_0n_3p_2$	T_{14}- $s_1n_2p_2$
T_3 - $s_0n_1p_3$	T_9 - $s_0n_3p_3$	T_{15}- $s_1n_2p_3$
T_4 - $s_0n_2p_1$	T_{10}- $s_1n_1p_1$	T_{16}- $s_1n_3p_1$
T_5 - $s_0n_2p_2$	T_{11}- $s_1n_1p_2$	T_{17}- $s_1n_3p_2$
T_6 - $s_0n_2p_3$	T_{12}- $s_1n_1p_3$	T_{18}- $s_1n_3p_3$

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 individual plots were dug and levelled.

3.2.4.2 Installation of Shade Nets

Shade was imposed on the day of planting in the plots alloted for 50 per cent shade 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 potassium @ 130 kg ha^{-1} was given as basal, uniformly in all plots. Nitrogen was applied according to the treatments in two equal splits, as basal and after the second harvest. Phosphorus was applied as per the treatment as basal.

3.2.4.4 Planting

Healthy slips of guinea grass variety Hamil obtained from AICRP on Forage Crops centre, College of Agriculture, Vellayani were planted at 40 x 20 cm spacing @ 2 slips $hill^{-1}$ on 2^{nd} June 2003.

3.2.4.5 After Care

Light intercultivation 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 at flower emergence stage. Five 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

Ten observational plants were selected from each plot after avoiding the border rows and destructive sample 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 centimetres 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 the destructive rows on the day prior to each harvest were sun-dried and then oven dried to a constant weight at 70°C. The dry fodder yield in t ha^{-1} was computed by multiplying the green fodder yield with 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.

3.3.2 Physiological Observations

3.3.2.1 Leaf Area Index

LAI was worked out using length width method suggested by Gomez (1972) and averages were worked out.

LA = leaf length x leaf breadth x 0.75

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

3.3.2.2 Crop Growth Rate (CGR)

CGR was computed using the formula of Watson (1958) and expressed in g m^{-2} day^{-1}. It was calculated for the period between fourth and second cut.

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

W_1 and W_2 – Whole plant dry weight at t_1 and t_2

$t_2 - t_1$ – Time interval in days

P – Ground area on which W_1 and W_2 have been estimated.

3.3.2.3 Relative Growth Rate (RGR)

The RGR was determined based on the formula of Williams (1946) and expressed in mg g^{-1} day^{-1}. It was calculated for the period between fourth and second cut.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

where, W_1 and W_2 – Plant dry weight at time t_1 and t_2 respectively

$t_2 - t_1$ – Time interval in days

3.3.2.4 Net Assimilation Rate (NAR)

The method proposed by Gregory (1917) and modified by Williams (1946) was employed for calculating the NAR on leaf dry weight basis and the values were expressed as g m^{-2} day^{-1}. It was calculated for the period between fourth and second cut.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

where, W_1 and W_2 – Plant dry weight at t_1 and t_2 respectively

L_1 and L_2 – Leaf area at t_1 and t_2 respectively

$t_2 - t_1$ – time interval in days

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 time of recording observation before each harvest by the method suggested by Hiscox and Israelstam (1979). Total chlorophyll is expressed in mg g^{-1} of fresh weight of leaf.

$$\text{Total chlorophyll} = \frac{[20.2\ A_{645} + 8.02\ A_{663}] \times V}{W}$$

A = Absorbance at specific wavelengths

V = Volume of dimethyl sulfoxide used (DMSO)

W = Fresh weight of tissue extracted in dimethyl sulfoxide (DMSO)

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).

3.3.4.3 Total Protein Yield

Protein yield was estimated by multiplying the dry fodder yield with the protein content of the samples at each harvest and computing the total for the five harvests.

3.3.5 Nutrient Content and Uptake Studies

3.3.5.1 Content and 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 Content and Uptake of Phosphorus

Phosphorus content was determined by Vanadomolybdo-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 Content and Uptake of Potassium

The potassium content in the plant samples was 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 nitrogen, phosphorus and 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 was 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 2003 to March 2004 to find out the nutrient requirement of guinea grass 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 2 and 3)

Plant height was significantly influenced by shade levels in all the harvests except at third harvest. Fifty per cent shade level recorded the highest plant height and the lowest plant height was observed in open condition.

Application of nitrogen had a significant influence on the height of the plant at all the five harvests. In the first cut, n_2 (200 kg ha^{-1}) recorded highest plant height (146.05 cm), which was on par with n_3 (300 kg ha^{-1}). In the first, second and fourth cuts, no significant difference were observed in plant height at n_2 and n_3 levels. In the third cut, plant height did not differ significantly at n_1 (100 kg ha^{-1}) and n_2 (200 kg ha^{-1}) levels but a significant increase was observed at n_3 level. In the fifth cut, plant height increased with increasing levels of nitrogen.

Plant height was significantly influenced by phosphorus application and it increased with an increase in P levels. This was visible at all cuts.

In the absence of shade, plant height did not differ significantly in first cut at the various levels of applied nitrogen. In the second cut, plant

Table 2. Main effects of shade (S), nitrogen (N) and phosphorus (P) 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	137.49	82.51	135.98	81.64	67.46
s_1	152.53	106.26	146.84	121.65	121.06
$F_{1, 2}$	519.57**	54.06*	8.82^{ns}	24.94*	440.00**
SE	0.466	2.284	2.586	5.664	1.807
CD	2.839	13.899	-	34.468	10.997
Nitrogen levels					
n_1	144.09	88.13	137.77	91.32	86.37
n_2	146.05	96.49	139.99	103.18	93.67
n_3	144.88	98.52	146.47	110.44	102.74
$F_{2, 34}$	5.25*	9.07**	14.05**	11.02**	14.74**
SE	0.430	1.828	1.206	2.909	2.136
CD	1.235	5.247	3.462	8.352	6.133
Phosphorus levels					
p_1	136.48	85.62	136.52	90.16	83.02
p_2	143.98	93.44	141.86	102.72	95.47
p_3	154.57	104.08	145.85	112.07	104.29
$F_{2, 34}$	446.32**	25.69**	15.07**	14.28**	25.04**
SE	0.430	1.828	1.206	2.909	2.136
CD	1.235	5.247	3.462	8.352	6.133

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

ns - not significant

Table 3. Interaction effects of S x N, S x P and N x P on plant height of guinea grass, cm

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
s_0n_1	134.21	69.11	133.53	66.20	57.00
s_0n_2	141.70	84.46	133.38	83.36	66.68
s_0n_3	136.56	93.96	141.02	95.38	78.69
s_1n_1	153.97	107.16	142.00	116.43	115.73
s_1n_2	150.40	108.53	146.60	123.00	120.67
s_1n_3	153.21	103.08	151.91	125.51	126.79
$F_{2, 34}$	43.93**	15.66**	0.97^{ns}	2.99^{ns}	1.55^{ns}
SE	0.608	2.585	1.706	4.114	3.021
CD	1.747	7.421	-	-	-
s_0p_1	132.91	72.42	130.60	69.76	55.43
s_0p_2	136.99	82.47	136.64	81.76	67.79
s_0p_3	142.57	92.63	140.69	93.42	79.14
s_1p_1	140.04	98.82	142.43	110.56	110.60
s_1p_2	150.97	104.42	147.07	123.68	123.14
s_1p_3	166.57	115.52	151.01	130.71	129.44
$F_{2, 34}$	97.22**	0.41^{ns}	0.13^{ns}	0.17^{ns}	0.45^{ns}
SE	0.608	2.585	1.706	4.114	3.021
CD	1.747	-	-	-	-
n_1p_1	132.37	78.10	133.10	77.50	77.23
n_1p_2	146.12	84.97	137.47	95.28	87.20
n_1p_3	153.78	101.33	142.73	101.17	94.67
n_2p_1	140.38	89.78	136.55	95.90	82.93
n_2p_2	142.70	95.63	140.68	99.60	93.90
n_2p_3	155.07	104.07	142.73	114.03	104.18
n_3p_1	136.68	88.98	139.90	97.07	88.88
n_3p_2	143.12	99.73	147.42	113.27	105.30
n_3p_3	154.85	106.83	152.08	121.00	114.03
$F_{4, 34}$	15.44**	0.87^{ns}	0.60^{ns}	0.59^{ns}	0.35^{ns}
SE	0.745	3.166	2.089	5.039	3.700
CD	2.139	-	-	-	-

** Significant at 1 per cent level   ns- not significant height increased in proportion to an increase in applied nitrogen. However, in third, fourth and fifth cuts, no significant interaction was observed. In the presence of shade in the first cut, n_1 and n_3 applied plots produced more or less plants with the same height. In the second cut, no significant difference was observed. In the third, fourth and fifth cuts, no significant interaction were seen at the first two doses.

S x P interaction was observed only at first cut. The plant height increased with increasing levels of P, but the rate of increase was less in open compared to shade.

N x P interaction was also observed only at first cut. At lower dose of phosphorus (p_1), a quadrate response to N was noticed. When N was combined with p_2, there was a reduction in plant height with increasing levels of N and when combined with p_3, no significant difference was seen at the three levels of nitrogen.

4.1.2 Number of Tillers (Table 4 and 5)

A marked decrease in the number of tillers was observed when the plants were grown in shade. This was seen at all the cuts.

The response of nitrogen was not significant at the first, second and fifth cuts. During third and fourth cuts, an increase in number of tillers was seen at the highest dose of nitrogen (n_3).

An increase in the number of tillers was seen with an increase in the level of phosphorus. However, in the first cut this was not significant at p_2 and p_3 levels.

S x N interaction was not significant at first, second and fifth cuts. In the absence of shade, tiller number was more or less same at n_1 and n_2 levels and less than that observed at n_3 in third and fourth cuts. In the presence of shade, no significant difference in tiller number was seen at any of the cuts.

S x P interaction was significant at fourth cut alone. In the absence of shade a significant increase in tiller number was seen at the

Table 4. Main effects of shade (S), nitrogen (N) and phosphorus (P) 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	12.47	13.86	19.72	18.55	26.44
s_1	7.56	8.63	9.22	11.08	11.68
$F_{1, 2}$	153.38**	29.03*	50.70*	172.17**	24.23*
SE	0.280	0.686	1.042	0.402	2.120
CD	1.704	4.177	6.343	2.449	12.900
Nitrogen levels					
n_1	9.68	10.93	14.39	14.31	17.80
n_2	9.80	10.49	13.22	14.44	18.11
n_3	10.57	12.31	15.80	15.69	21.27
$F_{2, 34}$	1.45^{ns}	2.86^{ns}	5.99**	3.92*	3.18^{ns}
SE	0.401	0.562	0.527	0.384	1.076
CD	-	-	1.514	1.102	-
Phosphorus levels					
p_1	8.67	9.38	11.73	12.17	15.24
p_2	10.50	11.21	14.28	14.61	19.04
p_3	10.88	13.14	17.40	17.67	22.89
$F_{2, 34}$	8.72**	11.25**	28.97**	51.56**	12.62**
SE	0.401	0.562	0.527	0.384	1.076
CD	1.150	1.612	1.514	1.102	3.088

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

ns – not significant

Table 5. Interaction effects of S x N, S x P and N x P on number of tillers of guinea grass

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
s_0n_1	12.20	13.29	19.18	18.98	24.51
s_0n_2	12.20	12.87	17.67	17.40	24.71
s_0n_3	13.00	15.42	22.31	19.27	30.09
s_1n_1	7.16	8.58	9.60	9.64	11.09
s_1n_2	7.39	8.11	8.78	11.49	11.51
s_1n_3	8.13	9.20	9.29	12.11	12.44
$F_{2, 34}$	0.03^{ns}	0.59^{ns}	4.41*	5.09*	1.36^{ns}
SE	0.567	0.794	0.746	0.543	1.521
CD	-	-	2.141	1.558	-
s_0p_1	11.07	11.49	16.04	15.38	21.71
s_0p_2	13.22	14.00	19.67	18.02	26.58
s_0p_3	13.11	16.07	23.44	22.24	31.02
s_1p_1	6.27	7.27	7.42	8.96	8.78
s_1p_2	7.78	8.42	8.89	11.20	11.51
s_1p_3	8.64	10.20	11.36	13.09	14.76
$F_{2, 34}$	0.39^{ns}	0.62^{ns}	2.76^{ns}	3.70*	0.62^{ns}
SE	0.567	0.794	0.746	0.543	1.521
CD	-	-	-	1.558	-
n_1p_1	8.70	9.10	12.83	11.13	15.07
n_1p_2	10.13	11.17	14.33	14.30	16.90
n_1p_3	10.20	12.53	16.00	17.50	21.43
n_2p_1	8.53	9.03	10.67	11.90	13.50
n_2p_2	10.07	9.77	13.67	14.07	19.17
n_2p_3	10.80	12.67	15.33	17.37	21.67
n_3p_1	8.77	10.00	11.70	13.47	17.17
n_3p_2	11.30	12.70	14.83	15.47	21.07
n_3p_3	11.63	14.23	20.87	18.13	25.57
$F_{4, 34}$	0.33^{ns}	0.33^{ns}	3.38*	0.47^{ns}	0.30^{ns}
SE	0.694	0.973	0.913	0.665	1.863
CD	-	-	2.622	-	-

* Significant at 5 per cent level   ns – not significant

highest dose of P. The number of tillers were less under s_1 and also this much marked difference was not seen at the highest dose of P (p_3).

N x P interaction was visible only at third cut. An increase in tiller number was seen at p_3 when combined with N. But this increase was very high when combined with n_3.

4.1.3 Leaf: Stem Ratio (Table 6 and 7)

There was a significant reduction in L: S ratio under shade. This was observed in all the cuts.

A significant increase in L: S ratio in proportion to an increase in the levels of applied N was seen in all cuts except in second cut where no significant difference was seen. The same trend was seen in the case of phosphorus also.

S x N interaction was present in first cut only. In open condition the response of N was linear with respect to the levels of nitrogen. But in the presence of shade, no significant difference was seen at all the levels of nitrogen.

Similarly, S x P interaction was also present during the first cut. In the absence of shade ie, in open a linear response was seen with P. In the presence of shade, though the L:S ratio increased with an increase in P this was not significant at the second and third levels of P.

L: S ratio was not influenced by the N x P interaction. This was true in all cuts.

4.2 YIELD CHARACTERS

4.2.1 Green Fodder Yield (Table 8, 9a and 9b)

Green fodder yield was significantly low when the grass was grown under shade.

Green fodder yield significantly increased with an increase in the N and P levels.

No interaction between S and N was seen in the green fodder yield in all cuts except in third cut. Either in the presence or absence of shade

Table 6. Main effects of shade (S), nitrogen (N) and phosphorus (P) 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	1.34	2.17	2.78	1.96	1.86
s_1	0.74	1.76	1.71	1.24	1.14
$F_{1, 2}$	1527.20**	25.59*	718.02**	1883.55**	420.16**
SE	0.011	0.057	0.026	0.012	0.025
CD	0.066	0.349	0.159	0.071	0.151
Nitrogen levels					
n_1	1.02	1.98	2.25	1.55	1.45
n_2	1.04	2.00	2.28	1.60	1.50
n_3	1.06	1.91	2.31	1.66	1.55
$F_{2, 34}$	16.82**	1.00^{ns}	10.20**	27.34**	24.45**
SE	0.005	0.044	0.009	0.010	0.010
CD	0.015	-	0.027	0.029	0.028
Phosphorus levels					
p_1	0.99	1.93	2.24	1.56	1.45
p_2	1.05	1.95	2.28	1.60	1.50
p_3	1.07	2.01	2.32	1.65	1.55
$F_{2, 34}$	59.10**	0.75^{ns}	17.51**	20.01**	28.91**
SE	0.005	0.044	0.007	0.010	0.010
CD	0.015	-	0.027	0.029	0.028

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

ns – not significant

Table 7. Interaction effects of S x N, S x P and N x P on Leaf: Stem Ratio of guinea grass

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
s_0n_1	1.30	2.22	2.75	1.91	1.81
s_0n_2	1.33	2.24	2.75	1.95	1.86
s_0n_3	1.37	2.04	2.80	2.03	1.92
s_1n_1	0.76	1.73	1.75	1.20	1.10
s_1n_2	0.74	1.76	1.78	1.24	1.15
s_1n_3	0.75	1.78	1.82	1.29	1.18
$F_{2, 34}$	4.05*	1.94^{ns}	0.35^{ns}	0.82^{ns}	0.64^{ns}
SE	0.007	0.063	0.013	0.014	0.014
CD	0.021	-	-	-	-
s_0p_1	1.31	2.15	2.73	1.92	1.81
s_0p_2	1.34	2.14	2.79	1.96	1.86
s_0p_3	1.36	2.22	2.82	2.01	1.91
s_1p_1	0.67	1.72	1.75	1.20	1.09
s_1p_2	0.76	1.76	1.78	1.24	1.15
s_1p_3	0.78	1.80	1.82	1.29	1.19
$F_{2, 34}$	10.95**	0.09^{ns}	0.44^{ns}	0.03^{ns}	0.08^{ns}
SE	0.007	0.063	0.013	0.014	0.014
CD	0.021	-	-	-	-
n_1p_1	0.97	1.92	2.21	1.53	1.41
n_1p_2	1.03	1.97	2.25	1.55	1.45
n_1p_3	1.05	2.05	2.29	1.59	1.50
n_2p_1	1.00	1.94	2.24	1.56	1.44
n_2p_2	1.05	2.00	2.29	1.60	1.51
n_2p_3	1.07	2.06	2.32	1.64	1.55
n_3p_1	1.01	1.95	2.28	1.59	1.49
n_3p_2	1.07	1.87	2.32	1.66	1.55
n_3p_3	1.09	1.92	2.34	1.72	1.61
$F_{4, 34}$	0.06^{ns}	0.43^{ns}	0.14^{ns}	0.92^{ns}	0.48^{ns}
SE	0.009	0.077	0.016	0.017	0.017
CD	-	-	-	-	-

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

ns – not significant

Table 8. Main effects of shade (S), nitrogen (N) and phosphorus (P) 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	13.55	9.56	21.28	11.86	10.34	66.63
s_1	11.03	7.09	13.83	9.61	6.47	48.02
$F_{1,2}$	124.37**	35.21*	221.15**	11.26^{ns}	24.14*	228.18**
SE	0.160	0.295	0.355	0.475	0.558	0.871
CD	0.973	1.797	2.157	-	3.396	5.303
Nitrogen levels						
n_1	10.04	7.41	15.51	9.52	7.42	49.90
n_2	13.11	8.10	16.81	10.44	8.16	56.67
n_3	13.72	9.46	20.34	12.25	9.64	65.41
$F_{2,34}$	87.42**	56.44**	110.81**	45.99**	22.42**	278.08**
SE	0.211	0.139	0.237	0.204	0.239	0.466
CD	0.606	0.399	0.682	0.587	0.685	1.339
Phosphorus levels						
p_1	10.50	7.08	15.49	9.47	6.92	49.46
p_2	12.51	8.17	17.76	10.63	8.54	57.65
p_3	13.87	9.72	19.42	12.11	9.76	64.88
$F_{2,34}$	64.66**	90.91**	68.95**	41.68**	35.70**	273.60**
SE	0.211	0.139	0.237	0.204	0.239	0.466
CD	0.606	0.399	0.682	0.587	0.685	1.339

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

ns –not significant

Table 9a. Interaction effects of S x N, S x P and N x P 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_0n_1	11.46	8.66	20.09	10.71	9.17	60.08
s_0n_2	14.04	9.52	20.58	11.20	10.02	65.45
s_0n_3	15.16	10.52	23.18	13.68	11.84	74.38
s_1n_1	8.63	6.16	10.94	8.33	5.66	39.72
s_1n_2	12.18	6.69	13.04	9.68	6.30	47.89
s_1n_3	12.29	8.41	17.51	10.81	7.44	56.45
$F_{2, 34}$	1.85^{ns}	1.66^{ns}	13.45**	2.82^{ns}	0.93^{ns}	2.65^{ns}
SE	0.299	0.197	0.336	0.289	0.338	0.660
CD	-	-	0.964	-	-	-
s_0p_1	11.40	8.05	19.79	10.43	8.11	57.77
s_0p_2	14.00	9.57	21.03	12.08	10.56	67.33
s_0p_3	15.27	11.07	23.02	13.08	12.36	74.80
s_1p_1	9.60	6.12	11.18	8.52	5.72	41.14
s_1p_2	11.02	6.77	14.48	9.18	6.52	47.96
s_1p_3	12.48	8.37	15.82	11.14	7.16	54.95
$F_{2, 34}$	2.29^{ns}	2.91^{ns}	4.90*	1.90^{ns}	8.84**	3.46*
SE	0.299	0.197	0.336	0.289	0.338	0.660
CD	-	-	0.964	-	0.969	1.893
n_1p_1	7.72	6.54	13.89	8.28	6.08	42.51
n_1p_2	10.17	7.60	15.57	9.56	7.75	50.65
n_1p_3	12.23	8.10	17.08	10.72	8.42	56.55
n_2p_1	12.23	6.92	15.19	9.44	6.84	50.61
n_2p_2	13.18	7.87	17.25	10.27	8.39	57.09
n_2p_3	13.94	9.52	17.98	11.62	9.25	62.30
n_3p_1	11.55	7.80	17.38	10.70	7.83	55.25
n_3p_2	14.17	9.04	20.45	12.06	9.48	65.21
n_3p_3	15.45	11.55	23.19	13.98	11.60	75.78
$F_{4, 34}$	4.29**	6.45**	4.19**	0.76^{ns}	1.24^{ns}	8.30**
SE	0.366	0.241	0.411	0.354	0.414	0.808
CD	1.050	0.691	1.181	-	-	2.319

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

ns – not significant

Table 9b. Interaction effects of shade, nitrogen and phosphorus levels (S x N x P) 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
$s_0n_1p_1$	8.44	7.54	18.89	9.39	6.96	51.23
$s_0n_1p_2$	12.02	8.86	19.67	11.08	9.66	61.28
$s_0n_1p_3$	13.91	9.57	21.70	11.64	10.90	67.73
$s_0n_2p_1$	12.88	7.98	19.58	10.34	8.12	58.89
$s_0n_2p_2$	14.12	9.31	20.54	11.19	10.41	65.84
$s_0n_2p_3$	15.13	11.26	21.61	12.07	11.53	71.61
$s_0n_3p_1$	12.87	8.63	20.91	11.56	9.23	63.20
$s_0n_3p_2$	15.85	10.53	22.89	13.97	11.63	74.87
$s_0n_3p_3$	16.76	12.39	25.73	15.52	14.65	85.06
$s_1n_1p_1$	7.00	5.53	8.89	7.17	5.20	33.80
$s_1n_1p_2$	8.33	6.34	11.46	8.04	5.84	40.01
$s_1n_1p_3$	10.55	6.63	12.45	9.79	5.94	45.36
$s_1n_2p_1$	11.58	5.87	10.80	8.54	5.55	42.34
$s_1n_2p_2$	12.23	6.43	13.96	9.34	6.37	48.33
$s_1n_2p_3$	12.74	7.77	14.34	11.17	6.97	52.99
$s_1n_3p_1$	10.23	6.96	13.85	9.84	6.42	47.30
$s_1n_3p_2$	12.49	7.55	18.01	10.15	7.34	55.55
$s_1n_3p_3$	14.14	10.71	20.65	12.44	8.56	66.50
$F_{4, 34}$	0.69^{ns}	1.26^{ns}	0.15^{ns}	0.84^{ns}	0.25^{ns}	0.38^{ns}
SE	0.517	0.341	0.582	0.501	0.585	1.142
CD	-	-	-	-	-	-

ns – not significant

an increase in fodder yield was seen with an increase in the levels of N in first, second, fourth and fifth cuts. But in third cut, in the absence of shade there was no significant difference in fodder yield at the first two levels (n_1 and n_2) of nitrogen.

S x P interaction was found to influence the fodder yield in the third and fifth cuts. In the third cut the fodder yield was not significantly different at the first two levels (p_1 and p_2) of phosphorus when grown in open but in shade a proportionate increase in fodder yield was seen with an increase in P application. In the fifth cut, green fodder yield increased with an increase in P under both open and shaded condition.

N x P interaction was significant at first three cuts. In the first and third cuts when P was combined with the lowest level of N and highest level of N an increase in fodder yield was recorded with an increase in the levels of P, but when P was combined with second level (n_2) of nitrogen, the yield increase was not significant at p_2 and p_3 levels. In the second cut, no significant difference in fodder yield was recorded at p_2 and p_3 levels of P combined with n_1 level of N, but a proportionate increase in fodder yield was recorded at the levels of P when combined with n_2 and n_3.

4.2.2 Dry Fodder Yield (Table 10, 11a and 11b)

There was a significant reduction in dry fodder yield when the grass was grown under shade. However this difference was not significant at fourth cut.

An increase in dry fodder yield was recorded with an increase in N and P levels.

S x N interaction was visible only in third cut. In the open condition, no significant difference in dry fodder yield was seen at n_1 and n_2 levels, but significant increase occurred at n_3 level. In shaded condition, N showed a linear response with an increase in N application.

Table 10. Main effects of shade (S), nitrogen (N) and phosphorus (P) on dry 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	3.41	2.41	5.35	2.98	2.60	16.76
s_1	2.77	1.79	3.47	2.41	1.63	12.08
$F_{1,2}$	134.73**	43.44*	210.82**	11.40^{ns}	24.25*	252.36**
SE	0.039	0.067	0.092	0.120	0.140	0.208
CD	0.0238	0.406	0.558	0.728	0.854	1.268
Nitrogen levels						
n_1	2.52	1.86	3.90	2.39	1.87	12.56
n_2	3.29	2.04	4.22	2.62	2.05	14.25
n_3	3.46	2.39	5.11	3.08	2.43	16.45
$F_{2,34}$	88.57**	60.38**	112.40**	46.99**	22.50**	279.35**
SE	0.053	0.035	0.059	0.051	0.060	0.117
CD	0.152	0.100	0.170	0.148	0.172	0.335
Phosphorus levels						
p_1	2.64	1.79	3.89	2.38	1.74	12.44
p_2	3.15	2.06	4.46	2.67	2.15	14.50
p_3	3.49	2.45	4.88	3.04	2.46	16.32
$F_{2,34}$	65.15**	89.34**	69.88**	41.58**	35.98**	278.23**
SE	0.053	0.035	0.059	0.051	0.060	0.117
CD	0.152	0.100	0.170	0.148	0.172	0.335

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

ns – not significant

Table 11a. Interaction effects of S x N, S x P and N x P 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_0n_1	2.89	2.18	5.05	2.69	2.31	15.13
s_0n_2	3.53	2.40	5.17	2.82	2.52	16.45
s_0n_3	3.82	2.65	5.84	3.45	2.98	18.70
s_1n_1	2.16	1.55	2.75	2.09	1.42	10.00
s_1n_2	3.06	1.68	3.27	2.43	1.58	12.05
s_1n_3	3.09	2.14	4.39	2.72	1.87	14.19
$F_{2, 34}$	1.83^{ns}	2.19^{ns}	12.80**	2.73^{ns}	0.88^{ns}	2.84^{ns}
SE	0.075	0.049	0.084	0.073	0.085	0.165
CD	-	-	0.241	-	-	-
s_0p_1	2.87	2.03	4.98	2.62	2.04	14.52
s_0p_2	3.53	2.41	5.28	3.04	2.66	16.95
s_0p_3	3.84	2.79	5.79	3.29	3.11	18.81
s_1p_1	2.41	1.56	2.80	2.14	1.44	10.35
s_1p_2	2.77	1.71	3.63	2.30	1.64	12.05
s_1p_3	3.13	2.10	3.97	2.80	1.86	13.83
$F_{2, 34}$	2.36^{ns}	3.64*	5.04*	1.89^{ns}	8.84**	3.57*
SE	0.075	0.049	0.084	0.073	0.085	0.165
CD	-	0.141	0.241	-	0.243	0.473
n_1p_1	1.94	1.64	3.50	2.08	1.53	10.70
n_1p_2	2.56	1.91	3.91	2.40	1.95	12.75
n_1p_3	3.07	2.04	4.29	2.69	2.12	14.24
n_2p_1	3.07	1.74	3.81	2.37	1.72	12.73
n_2p_2	3.31	1.98	4.33	2.58	2.11	14.35
n_2p_3	3.50	2.39	4.52	2.92	2.33	15.66
n_3p_1	2.91	1.99	4.36	2.69	1.97	13.88
n_3p_2	3.57	2.28	5.14	3.04	2.39	16.40
n_3p_3	3.89	2.91	5.83	3.52	2.92	19.07
$F_{4, 34}$	4.31**	6.12**	4.35**	0.76^{ns}	1.28^{ns}	8.70**
SE	0.092	0.060	0.103	0.089	0.104	0.202
CD	0.263	0.173	0.295	-	-	0.579

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

ns – not significant

Table 11b. Interaction effects of shade, nitrogen and phosphorus levels (S x N x P) 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
$s_0n_1p_1$	2.13	1.90	4.75	2.36	1.75	12.90
$s_0n_1p_2$	3.03	2.23	4.93	2.78	2.43	15.44
$s_0n_1p_3$	3.50	2.41	5.45	2.93	2.74	17.05
$s_0n_2p_1$	3.24	2.01	4.91	2.60	2.05	14.81
$s_0n_2p_2$	3.55	2.34	5.16	2.82	2.62	16.54
$s_0n_2p_3$	3.80	2.84	5.43	3.04	2.90	17.99
$s_0n_3p_1$	3.23	2.17	5.26	2.91	2.32	15.86
$s_0n_3p_2$	3.99	2.65	5.76	3.52	2.92	18.86
$s_0n_3p_3$	4.22	3.12	6.48	3.91	3.69	21.39
$s_1n_1p_1$	1.76	1.39	2.24	1.80	1.31	8.51
$s_1n_1p_2$	2.09	1.59	2.88	2.02	1.47	10.06
$s_1n_1p_3$	2.64	1.66	3.13	2.45	1.49	11.43
$s_1n_2p_1$	2.90	1.47	2.71	2.14	1.39	10.65
$s_1n_2p_2$	3.07	1.62	3.50	2.34	1.60	12.16
$s_1n_2p_3$	3.20	1.95	3.60	2.81	1.75	13.33
$s_1n_3p_1$	2.58	1.81	3.46	2.48	1.62	11.89
$s_1n_3p_2$	3.15	1.91	4.52	2.56	1.85	13.94
$s_1n_3p_3$	3.56	2.69	5.18	3.13	2.16	16.75
$F_{4, 34}$	0.69^{ns}	1.24^{ns}	0.15^{ns}	0.84^{ns}	0.26^{ns}	0.44^{ns}
SE	0.130	0.085	0.145	0.126	0.147	0.285
CD	-	-	-	-	-	-

ns – not significant

S x P interaction was seen at second, third and fifth cuts. In the second and third cuts, the rate of increase in dry fodder yield at p_2 and p_3 levels of P when the grass was grown in open was different from that when the grass was grown in shade. In the fifth cut, the dry fodder yield was not significantly different at p_1 and p_2 levels of P and also at p_2 and p_3 levels of P, when the grass was grown in shade. But in the open, the response exhibited a linear trend.

N x P interaction was also registered at the first three cuts. In the first and third cuts, an increase in dry fodder yield was recorded with an increase in P combined with n_1 and n_3 but when P was combined with n_2, this increase was not significant at n_2p_2 and n_2p_3. In the second cut, the proportionate increase in dry fodder yield was registered when P was combined with n_2 and n_3. The dry fodder yield was not significantly different at n_2p_2 and n_2p_3.

4.3 PHYSIOLOGICAL CHARACTERS

4.3.1 Leaf Area Index (Table 12 and 13)

In all cuts except fourth, LAI was significantly low when grass was grown in shaded condition.

N levels significantly influenced the LAI at all the harvests. With regard to P levels also, significant difference in LAI was noticed in all harvests except fourth harvest.

N interacted with shade. This was seen in all cuts. In the first cut, LAI was same at n_1 level under open and n_3 level under shade. In all the cuts the LAI was less at the lowest level of N under shade. Maximum LAI was recorded at the highest N level (n_3) under open and shaded situation. In the fourth cut LAI was on par at n_1 and n_2 applied plots under open and in the fifth cut all the plots under shade registered lower LAI.

S x P interaction was not significant in all cuts except third cut. A significant reduction in LAI was seen under shade even with the highest doses of P.

Table 12. Main effects of shade (S), nitrogen (N) and phosphorus (P) 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	4.64	4.62	4.45	4.23	4.47
s_1	4.07	4.18	4.04	4.09	3.98
$F_{1, 2}$	12879.82**	2667.25**	442.06**	8.83^{ns}	110.88**
SE	0.004	0.006	0.014	0.032	0.033
CD	0.021	0.037	0.084	-	0.200
Nitrogen levels					
n_1	4.04	4.07	3.97	4.03	3.97
n_2	4.39	4.40	4.21	4.15	4.28
n_3	4.63	4.73	4.56	4.30	4.43
$F_{2, 34}$	3985.70**	5167.67**	464.99**	41.06**	171.60**
SE	0.005	0.005	0.014	0.021	0.018
CD	0.014	0.013	0.039	0.061	0.050
Phosphorus levels					
p_1	4.23	4.31	4.08	4.15	4.16
p_2	4.34	4.39	4.26	4.15	4.23
p_3	4.49	4.50	4.41	4.19	4.29
$F_{2, 34}$	732.91**	476.50**	144.20**	1.05^{ns}	13.72**
SE	0.005	0.005	0.014	0.021	0.018
CD	0.014	0.013	0.039	-	0.050

** Significant at 1 per cent level   ns – not significant

Table 13. Interaction effects of S x N, S x P and N x P on Leaf Area Index of guinea grass

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
s_0n_1	4.42	4.22	4.20	4.14	4.28
s_0n_2	4.65	4.63	4.43	4.17	4.47
s_0n_3	4.84	5.01	4.73	4.38	4.67
s_1n_1	3.66	3.93	3.74	3.92	3.67
s_1n_2	4.14	4.17	4.00	4.13	4.09
s_1n_3	4.42	4.44	4.39	4.23	4.18
$F_{2, 34}$	346.94**	230.08**	5.60**	4.45*	10.22**
SE	0.007	0.006	0.019	0.030	0.025
CD	0.019	0.018	0.056	0.086	0.071
s_0p_1	4.52	4.52	4.35	4.20	4.41
s_0p_2	4.62	4.61	4.46	4.23	4.47
s_0p_3	4.77	4.73	4.54	4.26	4.54
s_1p_1	3.95	4.10	3.80	4.10	3.91
s_1p_2	4.06	4.17	4.05	4.07	3.99
s_1p_3	4.21	4.28	4.28	4.11	4.04
$F_{2, 34}$	1.07^{ns}	2.64^{ns}	28.05**	0.82^{ns}	0.07^{ns}
SE	0.007	0.006	0.019	0.030	0.025
CD	-	-	0.056	-	-
n_1p_1	3.92	3.99	3.74	4.06	3.90
n_1p_2	4.02	4.09	4.01	4.01	3.99
n_1p_3	4.18	4.14	4.17	4.03	4.04
n_2p_1	4.25	4.34	4.02	4.13	4.22
n_2p_2	4.42	4.40	4.19	4.15	4.29
n_2p_3	4.50	4.47	4.42	4.17	4.33
n_3p_1	4.53	4.59	4.47	4.26	4.36
n_3p_2	4.58	4.69	4.58	4.29	4.41
n_3p_3	4.78	4.90	4.63	4.36	4.51
$F_{4, 34}$	18.98**	49.76**	10.69**	0.84^{ns}	0.37^{ns}
SE	0.008	0.008	0.024	0.037	0.030
CD	0.023	0.023	0.068	-	-

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

ns – not significant

N x P interaction was present at the first three cuts. The rate of increase in LAI was more when P was combined with n_2 level of N than that observed when combined with n_1 and n_3 levels of N.

4.3.2 Crop Growth Rate (Table 14 and 15)

Plants grown in shade registered a significantly low CGR compared to those grown in open.

An increase in either N or P resulted in an increase in CGR.

Though S x N interaction was absent, S x P interaction was present. The rate of increase in CGR with increase in P was at a higher rate under open compared to shaded situation.

N x P interaction was also present. In combination with n_1 and n_2 levels, the CGR increased with an increase in P, but when combined with p_2 and p_3 the CGR was more or less same.

4.3.3 Relative Growth Rate (Table 14 and 15)

There was a significant reduction of 50 per cent in RGR when the plants were raised in shade.

RGR increased with an increase in N and also in P.

All the interactions were significant. The plants grown with n_3 level of N under shade gave a better RGR than the plants grown at the lowest level of N under open. Maximum RGR was seen with the n_3 treated plots in open. A similar trend was observed in the case of P also.

When P was combined with the lowest level of N, a quadrate response was observed while when combined with the n_2 and n_3 levels RGR was found to increase with an increase in both N and P.

4.3.4 Net assimilation Rate (Table 14 and 15)

NAR was significantly low under shaded condition.

In open and shaded condition NAR was same at the highest level of N, while it was low under shaded condition at n_1 and n_2 levels.

Table 14. Main effects of shade (S), nitrogen (N) and phosphorus (P) on CGR (g m^{-2} day^{-1}), RGR (mg $g^{-1}day^{-1}$) and NAR (g m^{-2} day^{-1}) of guinea grass

Main effects of the factors	CGR	RGR	NAR
Shade levels			
s_0	2.67	14.29	0.42
s_1	2.16	7.71	0.38
$F_{1,2}$	978.29**	1178.65**	605.63**
SE	0.012	0.136	0.00
CD	0.071	0.825	0.01
Nitrogen levels			
n_1	2.20	6.19	0.16
n_2	2.25	10.88	0.48
n_3	2.79	15.93	0.55
$F_{2,34}$	1831.08**	5239.22**	4651.79**
SE	0.008	0.067	0.00
CD	0.022	0.193	0.01
Phosphorus levels			
p_1	2.27	7.83	0.36
p_2	2.46	11.25	0.39
p_3	2.51	13.92	0.44
$F_{2,34}$	286.46**	2056.79**	194.18**
SE	0.008	0.067	0.00
CD	0.022	0.193	0.01

** Significant at 1 per cent level

Table 15. Interaction effects of S x N, S x P and N x P on CGR (g m^{-2} day^{-1}), RGR (mg g^{-1}day^{-1}) and NAR (g m^{-2} day^{-1}) of guinea grass

Interaction effects of factors	CGR	RGR	NAR
s_0n_1	2.46	7.47	0.20
s_0n_2	2.50	15.97	0.50
s_0n_3	3.06	19.43	0.55
s_1n_1	1.93	4.92	0.12
s_1n_2	2.01	5.79	0.46
s_1n_3	2.53	12.42	0.55
$F_{2, 34}$	2.21^{ns}	811.08**	37.86**
SE	0.011	0.095	0.00
CD	-	0.273	0.01
s_0p_1	2.43	9.36	0.37
s_0p_2	2.77	14.70	0.41
s_0p_3	2.81	18.81	0.47
s_1p_1	2.10	6.30	0.35
s_1p_2	2.15	7.81	0.36
s_1p_3	2.22	9.02	0.42
$F_{2, 34}$	106.96**	628.01**	4.57*
SE	0.011	0.095	0.00
CD	0.031	0.273	0.01
n_1p_1	2.06	4.78	0.09
n_1p_2	2.23	7.16	0.16
n_1p_3	2.30	6.65	0.23
n_2p_1	2.11	8.23	0.45
n_2p_2	2.28	9.03	0.48
n_2p_3	2.37	15.38	0.51
n_3p_1	2.63	10.49	0.53
n_3p_2	2.88	17.57	0.53
n_3p_3	2.87	19.72	0.59
$F_{4, 34}$	4.97**	454.34**	13.81**
SE	0.013	0.116	0.01
CD	0.019	0.334	0.02

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

ns – not significant

p_1 under open and p_2 under shade also gave similar results. p_2 under open was on par with p_3 under shade.

Proportionate increase in NAR was seen with N x P combination at n_1 and n_2 levels combined with P; but no significant difference was seen when P was combined with n_3.

4.4 BIOCHEMICAL ASPECTS

4.4.1 Chlorophyll Content (Table 16 and 17)

Chlorophyll content was high in grass grown under shade. This was observed in all cuts.

Application of N and P was also found to influence the chlorophyll content.

In general, both in open and shade, plants treated with the highest N level (n_3) recorded highest chlorophyll content.

However with an increase in P the chlorophyll content was found to increase under both the conditions in all the cuts. But in the fifth cut at p_1 and p_2 levels under open registered similar results.

N x P interaction was significant. The chlorophyll content at n_2 level was significantly low in combination with P at all cuts. Highest chlorophyll content was recorded with n_3p_3 treated plants except with a difference at n_2p_2 in second cut.

4.5 QUALITY ASPECTS

4.5.1 Crude Protein Content (Table 18 and 19)

Crude protein content was significantly high when the crop was grown in shade.

Crude protein content was found to increase with an increase in either N or P levels.

S x N interaction was significant. In the open, the highest level of N (n_3) recorded highest crude protein content and was significantly superior to the other two lower N levels, n_1 and n_2.

Table 16. Main effects of shade (S), nitrogen (N) and phosphorus (P) on chlorophyll content (mg g^{-1} of plant) of guinea grass

Main effects of factors	I cut	II cut	III cut	IV cut	V cut
Shade levels					
s_0	2.38	2.02	3.46	2.12	3.39
s_1	2.63	3.50	4.39	3.07	4.20
$F_{1, 2}$	4567.00**	9617.31**	12814.47**	5856.96**	1712.61**
SE	0.003	0.011	0.006	0.009	0.014
CD	0.016	0.065	0.035	0.054	0.084
Nitrogen levels					
n_1	2.45	2.73	3.65	2.35	3.85
n_2	2.12	2.45	3.83	2.41	3.39
n_3	2.95	3.12	4.29	3.03	4.14
$F_{2, 34}$	3412.43**	1609.21**	1291.17**	1388.23**	1364.79**
SE	0.007	0.008	0.009	0.010	0.010
CD	0.020	0.024	0.026	0.029	0.029
Phosphorus levels					
p_1	1.97	2.62	3.58	2.24	3.58
p_2	2.35	2.90	3.98	2.64	3.98
p_3	3.21	2.77	4.21	2.91	3.82
$F_{2, 34}$	7873.86**	279.34**	1219.09**	1104.90**	382.74**
SE	0.007	0.008	0.009	0.010	0.010
CD	0.020	0.024	0.026	0.029	0.029

** Significant at 1 per cent level

Table 17. Interaction effects of S x N, S x P and N x P on chlorophyll content (mg g^{-1} of plant) of guinea grass

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
s_0n_1	2.03	2.01	3.00	2.24	3.20
s_0n_2	2.02	1.75	3.51	1.62	3.14
s_0n_3	3.09	2.31	3.86	2.49	3.83
s_1n_1	2.86	3.44	4.30	2.46	4.49
s_1n_2	2.22	3.15	4.15	3.19	3.64
s_1n_3	2.81	3.92	4.72	3.57	4.45
$F_{2, 34}$	1528.15**	47.45**	343.53**	1129.79**	439.78**
SE	0.010	0.012	0.013	0.014	0.014
CD	0.029	0.034	0.037	0.041	0.041
s_0p_1	1.87	1.65	3.25	1.41	3.51
s_0p_2	2.10	2.13	3.27	1.95	3.53
s_0p_3	3.18	2.30	3.85	2.99	3.13
s_1p_1	2.07	3.60	3.90	3.07	3.65
s_1p_2	2.60	3.68	4.69	3.33	4.42
s_1p_3	3.23	3.23	4.58	2.82	4.52
$F_{2, 34}$	251.20**	975.39**	526.79**	2368.14**	969.29**
SE	0.010	0.012	0.013	0.014	0.014
CD	0.029	0.034	0.037	0.041	0.041
n_1p_1	2.01	2.32	3.36	1.78	4.06
n_1p_2	2.31	2.66	3.54	2.07	3.59
n_1p_3	3.04	3.19	4.05	3.21	3.89
n_2p_1	1.49	2.70	3.22	2.05	2.95
n_2p_2	1.95	2.23	4.17	2.85	4.22
n_2p_3	2.93	2.43	4.10	2.33	3.02
n_3p_1	2.41	2.85	4.16	2.90	3.74
n_3p_2	2.79	3.81	4.23	3.00	4.12
n_3p_3	3.65	2.68	4.48	3.20	4.57
$F_{4, 34}$	69.79**	1346.76**	261.11**	680.36**	994.18**
SE	0.012	0.014	0.016	0.018	0.018
CD	0.035	0.041	0.046	0.050	0.051

** Significant at 1 per cent level

Table 18. Main effects of shade (S), nitrogen (N) and phosphorus (P) on crude protein content (%), crude fibre content (%) and total protein yield (t ha^{-1}) of guinea grass

Main effects of the factors	CPC	CFC	Total protein yield
Shade levels			
s_0	8.18	32.08	1.37
s_1	8.65	31.59	1.05
$F_{1, 2}$	647.90**	856.00**	186.39**
SE	0.013	0.012	0.017
CD	0.080	0.073	0.102
Nitrogen levels			
n_1	8.29	32.59	1.04
n_2	8.38	31.78	1.19
n_3	8.56	31.13	1.40
$F_{2, 34}$	54.48**	11951.00**	354.76**
SE	0.019	0.007	0.010
CD	0.054	0.019	0.028
Phosphorus levels			
p_1	8.31	32.31	1.03
p_2	8.46	31.79	1.22
p_3	8.47	31.41	1.38
$F_{2, 34}$	22.99**	4582.72**	316.71**
SE	0.019	0.007	0.010
CD	0.054	0.019	0.028

** Significant at 1 per cent level

Table 19. Interaction effects of S x N, S x P and N x P on crude protein content (%), crude fibre content (%) and total protein yield (t ha^{-1}) of guinea grass

Interaction effects of factors	CPC	CFC	Total protein yield
s_0n_1	8.14	32.88	1.23
s_0n_2	8.14	31.95	1.34
s_0n_3	8.25	31.42	1.55
s_1n_1	8.45	32.30	0.84
s_1n_2	8.63	31.61	1.04
s_1n_3	8.88	30.85	1.26
$F_{2, 34}$	18.24**	111.71**	8.71**
SE	0.026	0.009	0.014
CD	0.076	0.027	0.040
s_0p_1	8.11	32.70	1.18
s_0p_2	8.20	32.04	1.39
s_0p_3	8.23	31.51	1.55
s_1p_1	8.51	31.92	0.88
s_1p_2	8.73	31.54	1.05
s_1p_3	8.70	31.30	1.21
$F_{2, 34}$	2.82^{ns}	454.14**	1.54^{ns}
SE	0.026	0.009	0.014
CD	-	0.027	-
n_1p_1	8.16	32.95	0.87
n_1p_2	8.38	32.58	1.06
n_1p_3	8.35	32.24	1.18
n_2p_1	8.28	32.14	1.05
n_2p_2	8.47	31.85	1.21
n_2p_3	8.40	31.35	1.31
n_3p_1	8.49	31.83	1.17
n_3p_2	8.54	30.94	1.39
n_3p_3	8.66	30.63	1.64
$F_{4, 34}$	3.06*	229.50**	11.57**
SE	0.032	0.012	0.017
CD	0.093	0.033	0.048

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

ns – not significant

S x P interaction was not significant but N x P interaction was significant. When P was combined with n_1 and n_2 levels of N, no significant difference was seen in crude protein content at the highest levels of N, but when P was combined with n_3, the crude protein content was on par at n_3p_1 and n_3p_2 levels and was significantly lower than that observed at n_3p_3.

4.5.2 Crude Fibre Content (Table 18 and 19)

Crude fibre content was significantly low under shade.

A quadrate response was seen with both N and P.

All the interactions were significant though the crude fibre content decreased with an increase in either N or P, the rate of decrease was little high in open. The crude fibre content was found to decrease when P was combined with higher levels of N.

4.5.3 Total Protein Yield (Table 18 and 19)

Total protein yield was found to reduce when the crop was grown in shade.

An increase in either N or P was found to increase total protein yield.

Both in shade and open condition this trend was seen for both N and P though there was a difference in the rate of reduction under shade and open. P combined with higher doses of N resulted in higher values of total protein yield.

4.6 NUTRIENT CONTENT AND UPTAKE

4.6.1 Nutrient Content

4.6.1.1 NPK Content (Table 20 and 21)

Nitrogen content was significantly high when grown in shade.

An increase in both N and P was found to increase in N content. Though under both shade and open, N content was found to increase with an increase in N, the rate of increase was low in open.

Table 20. Main effects of shade (S), nitrogen (N) and phosphorus (P) on NPK content (%) of guinea grass

Main effects of the factors	N content	P content	K content
Shade levels			
s_0	1.31	0.21	1.51
s_1	1.38	0.22	1.71
$F_{1,2}$	662.82**	15.02^{ns}	80.69*
SE	0.002	0.002	0.016
CD	0.012	-	0.098
Nitrogen levels			
n_1	1.33	0.21	1.52
n_2	1.35	0.21	1.60
n_3	1.37	0.23	1.71
$F_{2, 34}$	105.86**	67.29**	38.29**
SE	0.002	0.001	0.016
CD	0.006	0.004	0.046
Phosphorus levels			
p_1	1.33	0.20	1.45
p_2	1.35	0.21	1.61
p_3	1.36	0.23	1.78
$F_{2, 34}$	76.69**	79.48**	104.54**
SE	0.002	0.001	0.016
CD	0.006	0.004	0.046

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

ns – not significant

Table 21. Interaction effects of S x N, S x P and N x P on NPK content (%) of guinea grass

Interaction effects of factors	N content	P content	K content
s_0n_1	1.30	0.20	1.39
s_0n_2	1.31	0.21	1.52
s_0n_3	1.33	0.22	1.62
s_1n_1	1.36	0.21	1.64
s_1n_2	1.38	0.22	1.68
s_1n_3	1.41	0.23	1.81
$F_{2, 34}$	14.32**	1.93^{ns}	1.97^{ns}
SE	0.003	0.002	0.023
CD	0.008	-	-
s_0p_1	1.30	0.19	1.35
s_0p_2	1.31	0.21	1.51
s_0p_3	1.33	0.22	1.67
s_1p_1	1.36	0.21	1.56
s_1p_2	1.40	0.22	1.70
s_1p_3	1.40	0.23	1.89
$F_{2, 34}$	10.40**	0.06^{ns}	0.32^{ns}
SE	0.003	0.002	0.023
CD	0.008	-	-
n_1p_1	1.31	0.19	1.38
n_1p_2	1.34	0.20	1.55
n_1p_3	1.35	0.22	1.63
n_2p_1	1.33	0.20	1.46
n_2p_2	1.35	0.21	1.59
n_2p_3	1.36	0.23	1.75
n_3p_1	1.36	0.22	1.52
n_3p_2	1.37	0.23	1.68
n_3p_3	1.39	0.24	1.95
$F_{4, 34}$	0.67^{ns}	0.21^{ns}	3.60*
SE	0.003	0.002	0.028
CD	-	-	0.079

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

ns – not significant

Though a similar trend was seen in P applied plots also, no significant difference was seen at p_2 and p_3 levels of P in shade.

N x P interaction was not significant.

Similar results were seen in P and K contents. None of the interactions influenced P content. But N x P interaction influenced K content. Though in general, the K content was found to increase with an increase in either N or P or their combination, the rate of increase was not similar.

4.6.2 Nutrient Uptake

4.6.2.1 N uptake (Table 22 and 23)

Nitrogen uptake was significantly low in shaded condition. Nitrogen uptake increased with an increase in both N and P. S x N interaction also influenced N uptake. The nitrogen uptake estimated at the lowest level of N under open condition was on par with the N uptake at the highest level of N in shaded condition. At the other levels of N, N uptake was significantly low in shaded condition. S x P interaction was absent while N x P interaction was present. Though an increase in both N and P resulted in an increase in N uptake the rate of increase was significantly high when P was combined with N at the highest level (n_3).

4.6.2.2 P Uptake (Table 22 and 23)

P uptake was also low in shaded condition. Increase in both N and P also helped in an increase in P uptake. S x N interaction influenced P uptake. The P uptake estimated at n_2 level in the open was more or less similar to that observed under n_3 in shaded condition. Maximum P uptake was observed with n_3 treated plants under open. S x P interaction was absent while N x P interaction was present. Though both N and P helped to enhance the P uptake the rate of increase was high when P was combined with the highest level of N.

Table 22. Main effects of shade (S), nitrogen (N) and phosphorus (P) on total NPK uptake (kg ha^{-1}) of guinea grass

Main effects of the factors	N uptake	P uptake	K uptake
Shade levels			
s_0	220	36	258
s_1	168	27	211
$F_{1, 2}$	255.66**	534.47**	15.86^{ns}
SE	2.327	0.264	8.343
CD	14.160	1.607	-
Nitrogen levels			
n_1	167	26	189
n_2	191	30	229
n_3	225	38	284
$F_{2, 34}$	400.67**	397.16**	117.30**
SE	1.458	0.307	4.393
CD	4.187	0.881	12.611
Phosphorus levels			
p_1	165	26	179
p_2	196	31	323
p_3	222	37	291
$F_{2, 34}$	382.13**	363.15**	160.39**
SE	1.458	0.307	4.393
CD	4.187	0.881	12.611

** Significant at 1 per cent level   ns – not significant

Table 23. Interaction effects of S x N, S x P and N x P on total NPK uptake of guinea grass, kg ha^{-1}

Interaction effects of factors	N uptake	P uptake	K uptake
s_0n_1	197	31	213
s_0n_2	216	34	253
s_0n_3	249	42	307
s_1n_1	136	21	166
s_1n_2	167	27	204
s_1n_3	201	33	261
$F_{2, 34}$	6.28**	4.36*	0.05^{ns}
SE	2.062	0.434	6.213
CD	5.921	1.246	-
s_0p_1	189	30	197
s_0p_2	223	36	259
s_0p_3	250	42	317
s_1p_1	141	22	162
s_1p_2	169	27	206
s_1p_3	194	33	264
$F_{2, 34}$	1.97^{ns}	1.39^{ns}	1.48^{ns}
SE	2.062	0.434	6.213
CD	-	-	-
n_1p_1	140	21	145
n_1p_2	169	26	194
n_1p_3	191	31	230
n_2p_1	168	25	184
n_2p_2	193	30	228
n_2p_3	212	35	273
n_3p_1	187	31	209
n_3p_2	224	37	275
n_3p_3	263	46	368
$F_{4, 34}$	11.45**	8.45**	8.22**
SE	2.526	0.532	7.609
CD	7.251	1.527	21.844

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

ns – not significant

4.6.2.3 K Uptake **(Table 22 and 23)**

K uptake was not significantly different under either shade or open condition. But the N and P application helped to increase the K uptake. Neither S x N nor S x P interaction influenced the K uptake. But N x P interaction influenced the K uptake. The rate of increase in K uptake was significantly high when P was combined with higher levels of N.

4.7 NUTRIENT STATUS OF SOIL AFTER THE EXPERIMENT

4.7.1 Available Nitrogen (Table 24 and 25)

When the experiment was raised under either shade or open, available N was not affected. An increase in both N and P influenced the available N content. None of the interactions were present.

4.7.2 Available Phosphorus (Table 24 and 25)

The soil in shade registered high available P. Increase in both N and P also resulted in higher available P content. All the interactions were significant. In the open condition highest available P was registered at n_2 level of N. But in the shade condition highest available P was registered at n_1 level of N. Available P increased with an increase in applied P at p_3 level. But the available P was not significantly different at p_3 level in both open and shaded condition. When P was combined with the lowest level (n_1) of N, proportionate increase in available P was observed with an increase in applied P. But when P was combined with n_2 a significant reduction was seen at n_2p_2. Available P was also significantly low at n_3p_1 and n_3p_2 but increased at n_3p_3.

4.7.3 Available Potassium (Table 24 and 25)

Available K content of the soil was not significantly different when the plant was grown either in open or shade. But an increase in the level of N resulted in a decrease in available K, which was on par at n_2 and n_3 levels. A quadrate nature of response was seen with an increase in applied P. All the interactions were present. Maximum available K of

Table 24. Main effects of shade (S), nitrogen (N) and phosphorus (P) on available N, P and K status of soil after the experiment, kg ha^{-1}

Main effects of the factors	Available N	Available P_2O_5	Available K_2O
Shade levels			
s_0	204.21	26.64	57.17
s_1	203.97	29.08	49.87
$F_{1, 2}$	1.60^{ns}	32.74*	17.14^{ns}
SE	0.152	0.301	1.248
CD	-	1.834	-
Nitrogen levels			
n_1	203.69	29.74	61.82
n_2	203.64	28.14	48.90
n_3	204.94	25.71	49.83
$F_{2, 34}$	5.19*	19.49**	44.94**
SE	0.321	0.460	1.075
CD	0.921	1.321	3.086
Phosphorus levels			
p_1	203.52	26.83	52.67
p_2	203.85	26.12	58.50
p_3	204.91	30.64	49.39
$F_{2, 34}$	5.06*	27.89**	18.42**
SE	0.321	0.460	1.075
CD	0.921	1.321	3.086

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

ns – not significant

Table 25. Interaction effects of S x N, S x P and N x P on available N, P and K status of soil after the experiment, kg ha^{-1}

Interaction effects of factors	Available N	Available P_2O_5	Available K_2O
s_0n_1	203.42	26.05	75.72
s_0n_2	204.09	30.34	49.08
s_0n_3	205.13	23.54	46.72
s_1n_1	203.97	33.44	47.93
s_1n_2	203.19	25.93	48.73
s_1n_3	204.75	27.88	52.94
$F_{2, 34}$	1.28^{ns}	44.31**	70.34**
SE	0.454	0.651	1.520
CD	-	1.868	4.365
s_0p_1	203.85	25.82	59.65
s_0p_2	203.97	23.97	64.75
s_0p_3	204.82	30.14	47.11
s_1p_1	203.19	27.84	45.69
s_1p_2	203.73	28.27	52.24
s_1p_3	205.00	31.14	51.67
$F_{2, 34}$	0.34^{ns}	3.38*	22.94**
SE	0.454	0.651	1.520
CD	-	1.868	4.365
n_1p_1	203.50	25.95	61.52
n_1p_2	203.17	29.51	71.14
n_1p_3	203.40	33.78	52.82
n_2p_1	202.59	31.49	51.65
n_2p_2	203.73	24.39	47.99
n_2p_3	204.62	28.53	47.08
n_3p_1	204.48	23.03	44.84
n_3p_2	204.64	24.48	56.38
n_3p_3	205.70	29.62	48.27
$F_{4, 34}$	0.54^{ns}	17.58**	8.80**
SE	0.556	0.797	1.862
CD	-	2.288	5.346

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

ns – not significant

soil was registered in open and treated with the lowest level of N (n_1). With an increase in N, there was a decrease in available K. Available K was high in p_2 treated plots both in open and shaded condition. But the available K content was not significantly different at p_2 and p_3 levels under shaded condition. N x P interaction was significant when P was combined with n_1 and n_3 levels, available K was found to increase at p_2 level. But when combined with n_2, available K was found to decrease with an increase in P.

4.8 ECONOMICS (Table 26 and 27)

Shade levels, nitrogen and phosphorus application had significant influence on the net returns and B: C ratio. The highest net return and benefit cost ratio was obtained in open condition, s_0 (16843 Rs ha^{-1} and 2.02 respectively), which was significantly superior to shaded condition, s_1 (11179 Rs.ha^{-1} and 1.86 respectively).

The n_3 level of nitrogen was found to be significantly superior with respect to net returns (17098 Rs ha^{-1}) and B: C ratio (2.09).

Application of p_3 level of P_2O_5 recorded the highest net return of 17351 Rs.ha^{-1}, which was significantly higher than that at p_2 level (14151 Rs.ha^{-1}). The B: C ratio was significantly higher at p_3 (2.13).

S x N interaction significantly influenced the net return and benefit cost ratio. The maximum net return of 19628 Rs ha^{-1} was obtained for the treatment s_0n_3 (zero per cent shade + 300 kg ha^{-1}), which was significantly superior to all other treatments and it had benefit cost ratio of 2.11. At s_1 also, n_3 recorded significantly higher net returns (14567 Rs.ha^{-1}) and B: C ratio (2.06).

N x P interaction also positively influenced the economics of guinea grass cultivation. Significantly higher net returns and B: C ratio was realized for the treatment n_3p_3 (21836 Rs.ha^{-1} and 2.36 respectively) and it was significantly superior to all other combinations.

Table 26. Main effects of shade (S), nitrogen (N) and phosphorus (P) on net returns (Rs. ha^{-1}) and Benefit : Cost ratio of guinea grass

Main effects of the factors	Net returns (Rs.ha^{-1})	BCR
Shade levels		
s_0	16843	2.02
s_1	11179	1.86
$F_{1, 2}$	88.72*	28.55*
SE	425.242	0.021
CD	2587.752	0.127
Nitrogen levels		
n_1	11244	1.80
n_2	13691	1.92
n_3	17098	2.09
$F_{2, 34}$	160.97**	95.77**
SE	231.703	0.015
CD	665.186	0.042
Phosphorus levels		
p_1	10531	1.73
p_2	14151	1.95
p_3	17351	2.13
$F_{2, 34}$	216.86**	190.96**
SE	231.703	0.015
CD	665.186	0.042

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

Table 27. Interaction effects of S x N, S x P and N x P on net returns (Rs. ha^{-1}) and Benefit : Cost ratio of guinea grass

Interaction effects of factors	Net returns (Rs. ha^{-1})	BCR
s_0n_1	14653	1.95
s_0n_2	16249	1.98
s_0n_3	19628	2.11
s_1n_1	7835.7	1.65
s_1n_2	11133	1.86
s_1n_3	14567	2.06
$F_{2, 34}$	4.64*	19.17**
SE	327.678	0.021
CD	940.715	0.060
s_0p_1	12913	1.81
s_0p_2	17192	2.04
s_0p_3	20425	2.20
s_1p_1	8149.2	1.65
s_1p_2	11110	1.86
s_1p_3	14277	2.07
$F_{2, 34}$	2.84^{ns}	0.90^{ns}
SE	327.678	0.021
CD	-	-
n_1p_1	8024	1.59
n_1p_2	11557	1.82
n_1p_3	14152	1.99
n_2p_1	11108	1.78
n_2p_2	13901	1.94
n_2p_3	16064	2.06
n_3p_1	12460	1.82
n_3p_2	16996	2.08
n_3p_3	21836	2.36
$F_{4, 34}$	8.35**	6.92**
SE	401.322	0.025
CD	1152.136	0.073

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

ns – not significant

DISCUSSION

5. DISCUSSION

The investigation was undertaken with the objective of working out an optimum nitrogen and phosphorus requirement for guinea grass under zero and 50 per cent shade levels. The results of the experiment, presented in the previous chapter are discussed hereunder.

5.1 GROWTH CHARACTERS

5.1.1 Plant Height

The results of the study revealed that the plant height increased as the intensity of shade increased (Fig. 3). This increase in plant height with increase in shade intensity was observed in all the cuts. Maximum plant height was recorded under 50 per cent shade and the minimum under full sunlight. 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 Pr form, which prevents elongation and under shade it gets converted to Pfr form mediated through increased level of sensitivity to gibberellin 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 (Morelli and Ruberti, 2000). The chlorophyll content was also higher in 50 per cent shade compared to open, which resulted in higher plant height. Similar results were also reported by Mullakoya (1982) in guinea grass cv. Mackueni, Pillai (1986) in guinea grass and setaria grass, Blanche (1999), Buxton (2001) and Anita (2002) in guinea grass.

Application of nitrogen had a significant influence on the height of the plant at all the five harvests. In the first harvest, n_2 treatment (200 kg N ha^{-1}) recorded highest plant height, which was on par with n_3 treatment (300 kg N ha^{-1}). In second and fourth cuts, highest level of

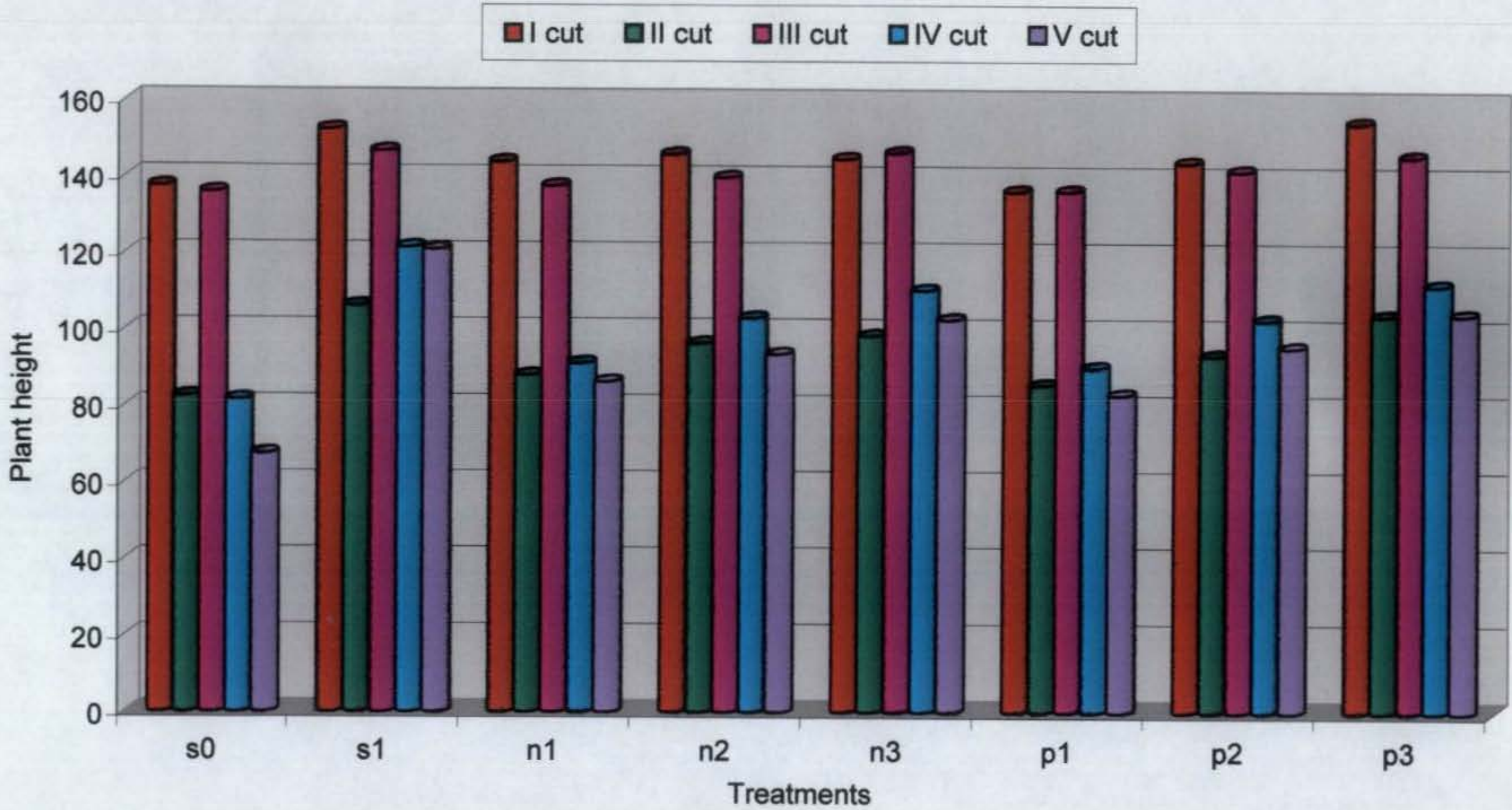


Fig. 3. Main effects of shade levels, nitrogen and phosphorus on plant height of guinea grass, cm

nitrogen (300 kg ha^{-1}) recorded more plant height, which was on par with n_2 treatment. In third and fifth cuts, highest level of nitrogen recorded more plant height, which was significantly superior to n_1 (100 kg ha^{-1}) and n_2 (200 kg ha^{-1}). In general, plant height showed a linear increase with increase in nitrogen levels. The increase in plant height due to enhanced N application might be due to increase in cell division and cell elongation, which is also a function of nitrogen (Tisdale *et al.*, 1985). Application of nitrogen resulted in increase in plant height also reported by Thomas (1978) in hybrid napier, Rai and Shankaranarayan (1981) in giant anjan, Krishnan (1993) in guinea grass, Vineetha (1995) in gamba grass and Sonia (1999) in signal grass.

Application of phosphorus also had a significant influence on the height of the plant at all the five harvests. In all the cuts, plant height showed a linear increase with increase in phosphorus levels upto p_3 (75 kg ha^{-1}). Height being a character dependent on nutrient, increased application of phosphorus would have encouraged the root growth which inturn resulted in higher nutrient absorption which was manifested in the increase in plant height. A similar increase in plant height by phosphorus application was reported by Chandini (1980) in guinea grass, setaria grass and congosignal.

S x N interaction found to be significant in first two cuts only. Under open condition, highest level of nitrogen (300 kg ha^{-1}) registered highest plant height in second cut while n_2 treatment (200 kg ha^{-1}) registered highest plant height in first cut. While under shade, even though plant height was more compared to open N levels did not influence this character.

Under both open and 50 per cent shaded situation, maximum plant height was attained when higher levels of phosphorus (75 kg ha^{-1}) were given. Increased application of phosphorus might have encouraged the root growth which inturn resulted in higher rate of nutrient absorption which was manifested in the increase in plant height under open and shaded situation.

Significant N x P interaction was found only in first cut. Under all levels of nitrogen, highest level of phosphorus (75 kg ha^{-1}) recorded maximum plant height. Treatment combination n_2p_3 (200 kg N ha^{-1} + 75 kg P_2O_5 ha^{-1}) recorded highest plant height which was on par with n_1p_3 (100 kg N ha^{-1}+ 75 kg P_2O_5 ha^{-1}) and n_3p_3 (300 kg N ha^{-1}+ 75 kg ha^{-1}). Similarly a non-significant increase in plant height with increase in levels of nitrogen and phosphorus was reported by Vineetha (1995) in gamba grass.

5.1.2 Number of Tillers

The study revealed that shade has dominating influence in inhibition of tiller production. Tiller number declined with shading in all the five cuts and maximum number of tillers was recorded at zero per cent shade (Fig. 4). A similar decrease in tiller production with increase in shade intensity was reported by Mullakoya (1982) in guinea grass cv. Mackuenii, Pillai (1986) in guinea grass and Setaria grass, Kephart and Buxton (1996); Buxton (2001) and Anita (2002) in guinea grass. The increase in number of tillers in open 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.

Application of nitrogen had significant influence on number of tillers in third and fourth cuts. In both cuts, highest level of nitrogen (300 kg ha^{-1}) registered higher number of tillers. It is a well known fact that nitrogen is the most important nutrient element for the vegetative growth of plants. Increased availability of this element would have contributed to higher tiller production in the grass. Similar results were obtained by Rai and Shankaranarayan (1981) in giant anjan grass, Sangakkara (1988) and Krishnan (1993) in guinea grass, Vineetha (1995)

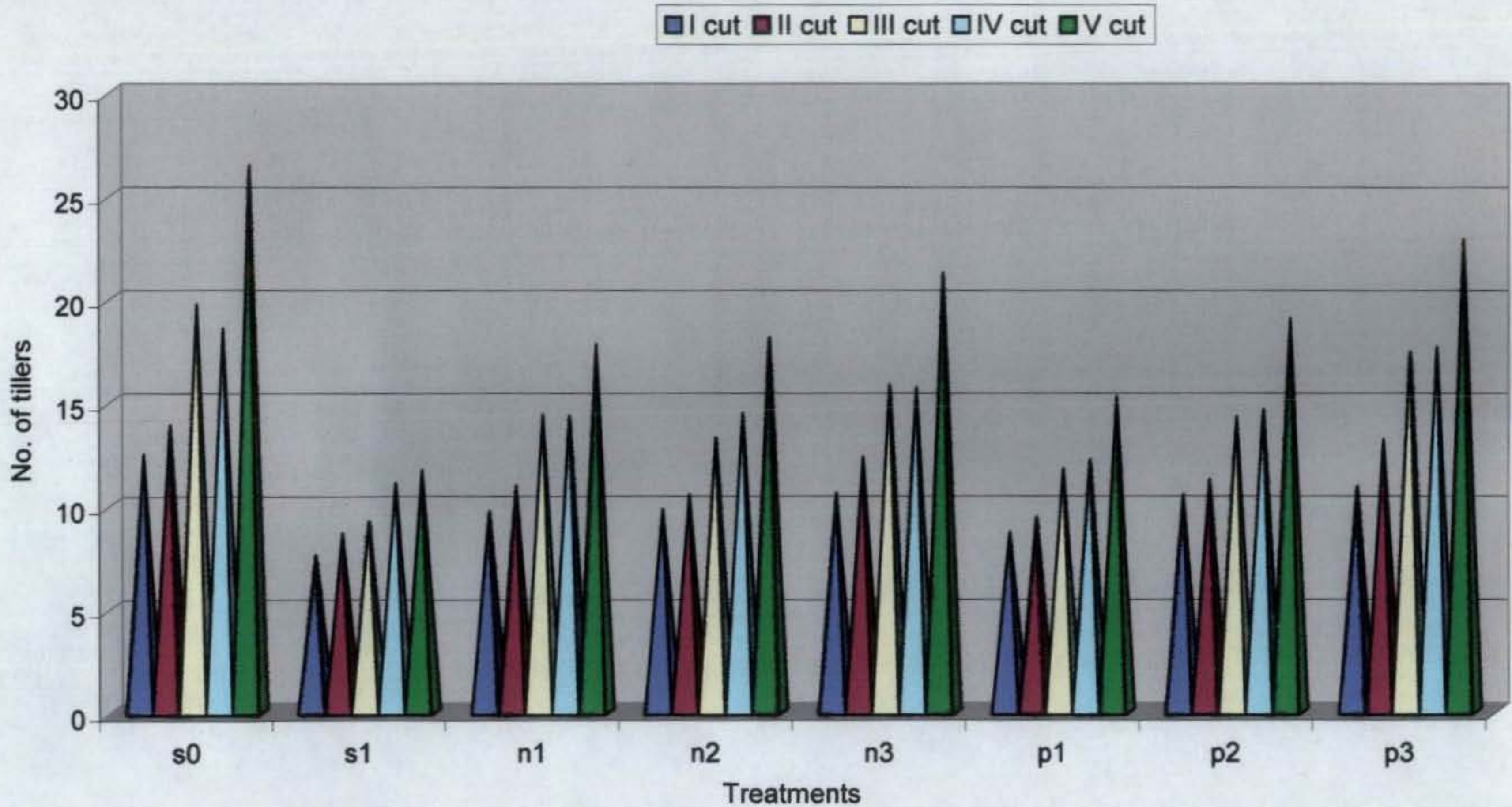


Fig. 4. Main effects of shade levels, nitrogen and phosphorus on number of tillers of guinea grass

in gamba grass, Sonia (1999) in signal grass and Parihar and Agarwal (2002) in spear grass.

Phosphorus levels had significant influence on number of tillers in all the five harvests. In all the cuts, maximum number of tillers were registered at the highest level of phosphorus (75 kg ha^{-1}) followed by 50 kg and 25 kg P_2O_5 ha^{-1}. Higher levels of phosphorus increased root growth, which resulted in higher rate of nutrient absorption resulting in increased number of tillers. Chandini (1980) observed similar results in guinea grass, setaria grass and congosignal.

In general, in both shade levels number of tillers were maximum at highest level of nitrogen. Increased availability of the element would have contributed to higher tiller production in the grass, as reported by Pillai (1986) in guinea grass and setaria grass.

Significant S x P interaction was noted in fourth cut. Under open and 50 per cent shaded condition, highest level of P (75 kg ha^{-1}) registered maximum number of tillers. Pillai (1986) reported that in guinea grass and setaria grass, the effect of phosphorus application was not significant in tiller production, but it has numerically increased the number of tillers under open and shaded conditions which indicates the decisive role of phosphorus in enhancing tiller production both in open and shaded condition.

When lowest level of nitrogen (100 kg ha^{-1}) was given, number of tillers at different phosphorus levels were on par. Under n_2 (200 kg N ha^{-1}), p_3 (75 kg P_2O_5 ha^{-1}) registered highest number of tillers but it was on par with p_2 (50 kg ha^{-1}). The highest level of nitrogen combined with highest level of phosphorus recorded maximum tiller number. Adequate supply of phosphorus is required for the efficient utilization of nitrogen as it helps in development of extensive root system for better use of soil moisture and nutrients (Bajpai and Gupta, 1979; Yadav *et al.*, 1984). Similar result was also reported by Vineetha (1995) in gamba grass.

5.1.3 Leaf: Stem Ratio

Results on leaf: stem ratio indicated the significant influence of shade intensity in all harvests. Leaf: stem ratio was higher in the open condition (Fig. 5). 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. Reduction in leaf: stem ratio with increase in shade levels was reported by Wong (1991) and Anita (2002) in guinea grass.

Application of nitrogen had a significant influence on leaf: stem ratio in all the five cuts except second cut. Leaf: stem ratio improved markedly due to N application. N improved the leaf: stem ratio owing to enhanced production of leafy material compared to stem, as observed by Kothari and Saraf (1987) in fodder sorghum.

Phosphorus levels also had a significant influence on leaf: stem ratio in all the five cuts except second cut. An increasing trend of leaf: stem ratio with incremental doses of phosphorus has been observed. Incremental doses of phosphorus resulted in higher proportion of leaf that accounted for the higher dry matter yield. Similar finding was also reported by Chandini (1980) in guinea grass, setaria grass and congosignal.

Significant S x N interaction was found only in first cut. N levels had no significant influence on the leaf stem ratio both under open and shade. Reduction in L: S ratio with higher doses of nitrogen was reported by Pillai (1986) in guinea grass under both open and shade.

S x P interaction was found to be significant only in first cut. Under open and shaded situation higher levels of phosphorus registered higher L:S ratio but the increase was not significant. Hence the different levels of P_2O_5 were equally effective in deciding L:S ratio. Similar trend of non-significant

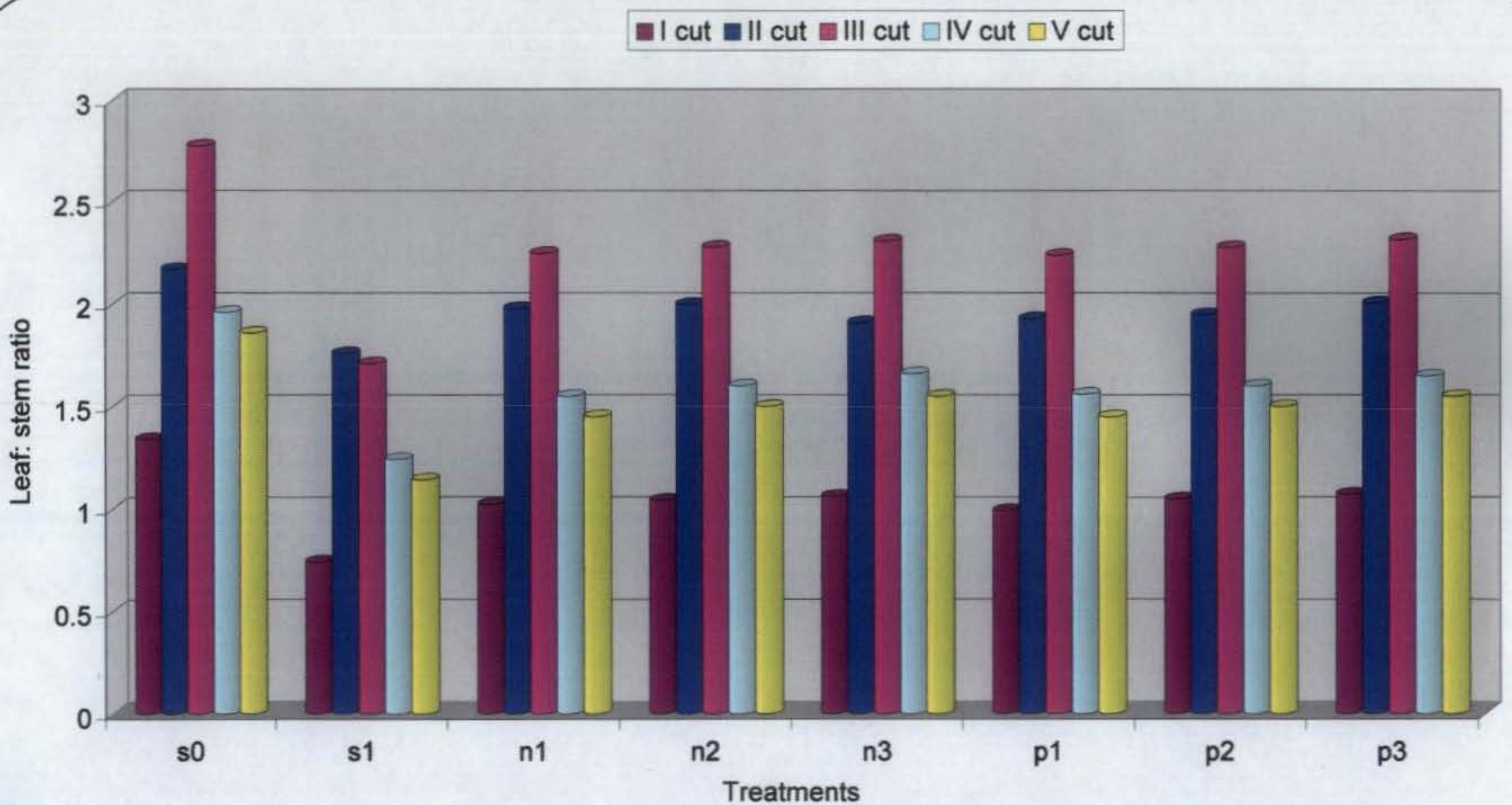


Fig. 5. Main effects of shade levels, nitrogen and phosphorus on leaf: stem ratio of guinea grass

influence of P_2O_5 in L:S ratio was reported by Pillai (1986) under both open and shade in guinea grass and setaria grass.

5.2 YIELD CHARACTERS

5.2.1 Green Fodder Yield

The green fodder production was 18.6 per cent, 25.8 per cent, 35 per cent and 37.4 per cent lower in 50 per cent shade compared to open in first, second, third and fifth cuts respectively (Fig. 6). In the total green fodder yield there was a yield reduction of 27.9 per cent in 50 per cent shade. The higher number of tillers and high leaf area index in open might have contributed to the increased yield in open condition. Many workers (Sato and Dalmacio, 1991; Sharma *et al.*, 1996) have also reported yield reduction in agro forestry due to reduction in solar radiation availability. This is evident from the fact that a warm season C_4 plant continues 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). This result is in conformity with the findings of Kephart and Buxton (1996) and Anita (2002) in guinea grass.

A perusal of the data on green fodder yield clearly indicated that with increase in nitrogen levels up to 300 kg ha^{-1}, green fodder yield significantly increased till fifth harvests. The highest level of nitrogen recorded 36.7 per cent, 27.7 per cent, 31.1 per cent, 28.7 per cent and 29.9 per cent increase in green fodder yield compared to lowest level of N in first, second, third, fourth and fifth cuts respectively. The total green fodder yield also registered 31.1 per cent increase with 300 kg N ha^{-1} over 100 kg N ha^{-1}. This increase in green fodder yield due to application of nitrogen is a reflection of the growth attributes *viz*., increased plant height, tiller number and L: S ratio as a result of increased nitrogen availability. An adequate supply of nitrogen which is associated with vigorous vegetative growth, might have contributed to this increased green fodder yield in the present study (Tisdale *et al.*, 1985). Similar

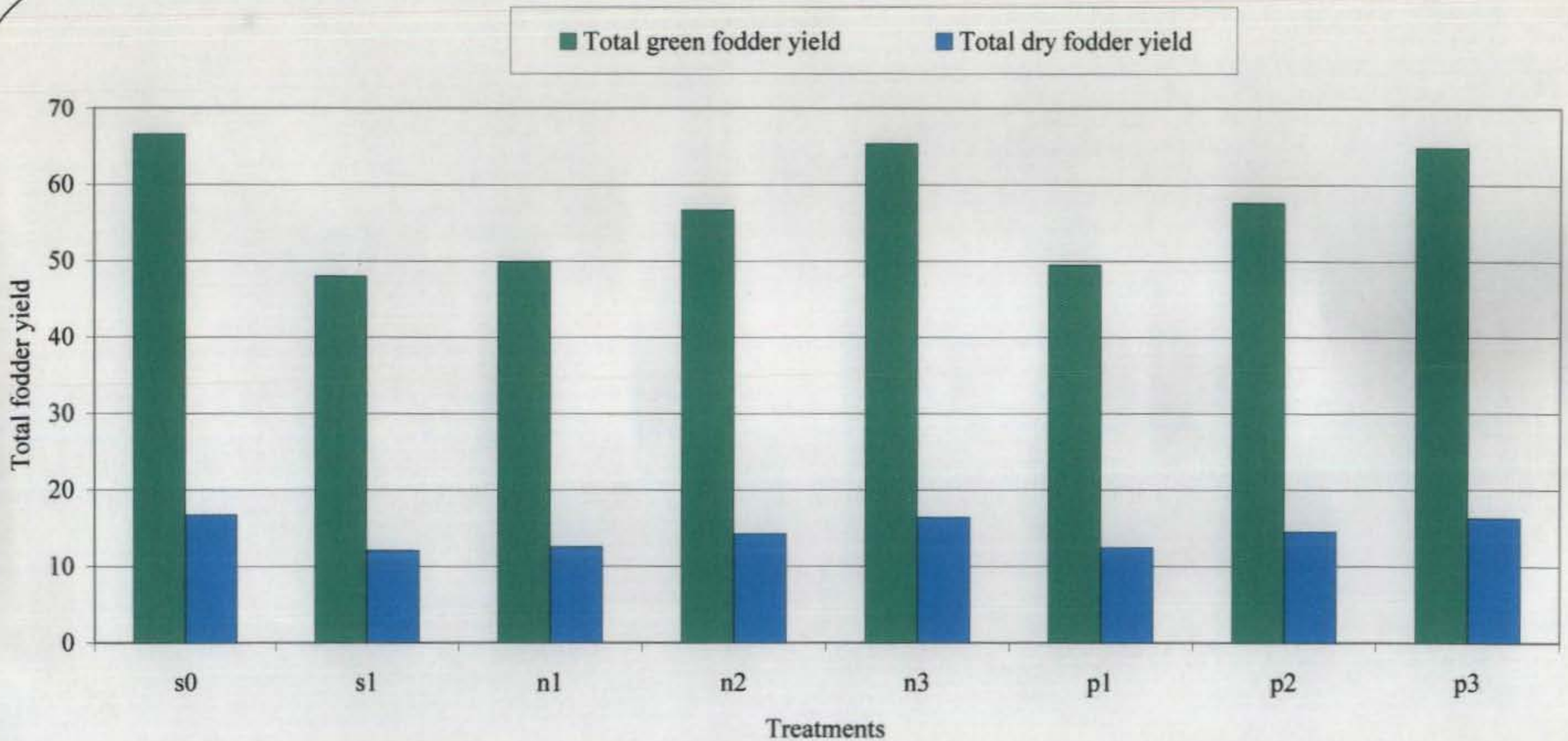


Fig. 6. Main effects of shade levels, nitrogen and phosphorus on total green fodder yield and total dry fodder yield of guinea grass, t ha^{-1}

enhancement in herbage production by increased nitrogen levels was reported by Dwivedi *et al*. (1991) in thin napier grass, Vineetha (1995) in gamba grass, Sonia (1999) in signal grass, Digvijay *et al*. (2000) in napier bajra hybrids and Agrawal *et al*. (2002) in guinea grass.

Application of phosphorus had significant effect on green fodder yield. The highest level of phosphorus (75 kg ha^{-1}) registered 32.1 per cent, 37.3 per cent, 25.4 per cent, 27.9 per cent and 41.0 per cent increase in green fodder yield over lowest level of P (25 kg ha^{-1}) in first, second, third, fourth, and fifth cuts respectively. Total green fodder yield also registered 31.2 per cent increase with highest phosphorus level over lowest level. Tomer *et al*. (1974) reported that the improvement in yield with phosphorus application is the result of improved growth resulting from increase in cell division, better root development and high microbial activity, which supplied adequate nutrients to the plants. This was in agreement with the findings of Chandini (1980) in guinea grass, setaria grass and congosignal, Dwivedi *et al.* (1991) in thin napier grass and Meerabai *et al*. (1993) in guinea grass and congosignal.

Significant S x N interaction was found in third cut only. Under open and 50 per cent shaded situation, green fodder yield increased with each successive dose of nitrogen upto 300 kg N ha^{-1} (Fig. 7). An adequate supply of nitrogen, which is associated with vigorous vegetative growth, might have contributed to this increased green fodder yield under open and 50 per cent shade (Tisdale *et al*., 1985).

Significant S x P interaction was observed in third and fifth cut. Total green fodder yield also had significant S x P interaction. In both shade levels, significantly higher green fodder yield was obtained from highest level of phosphorus (Fig. 8). Higher levels of P_2O_5 are required under 50 per cent shade compared to open for getting equal yields.

N x P interaction was significant in the first three cuts. At n_1 (100 kg ha^{-1}), n_2 (200 kg ha^{-1}) and n_3 (300 kg ha^{-1}), highest level of phosphorus (75 kg ha^{-1}) registered maximum green fodder yield (Fig. 9).

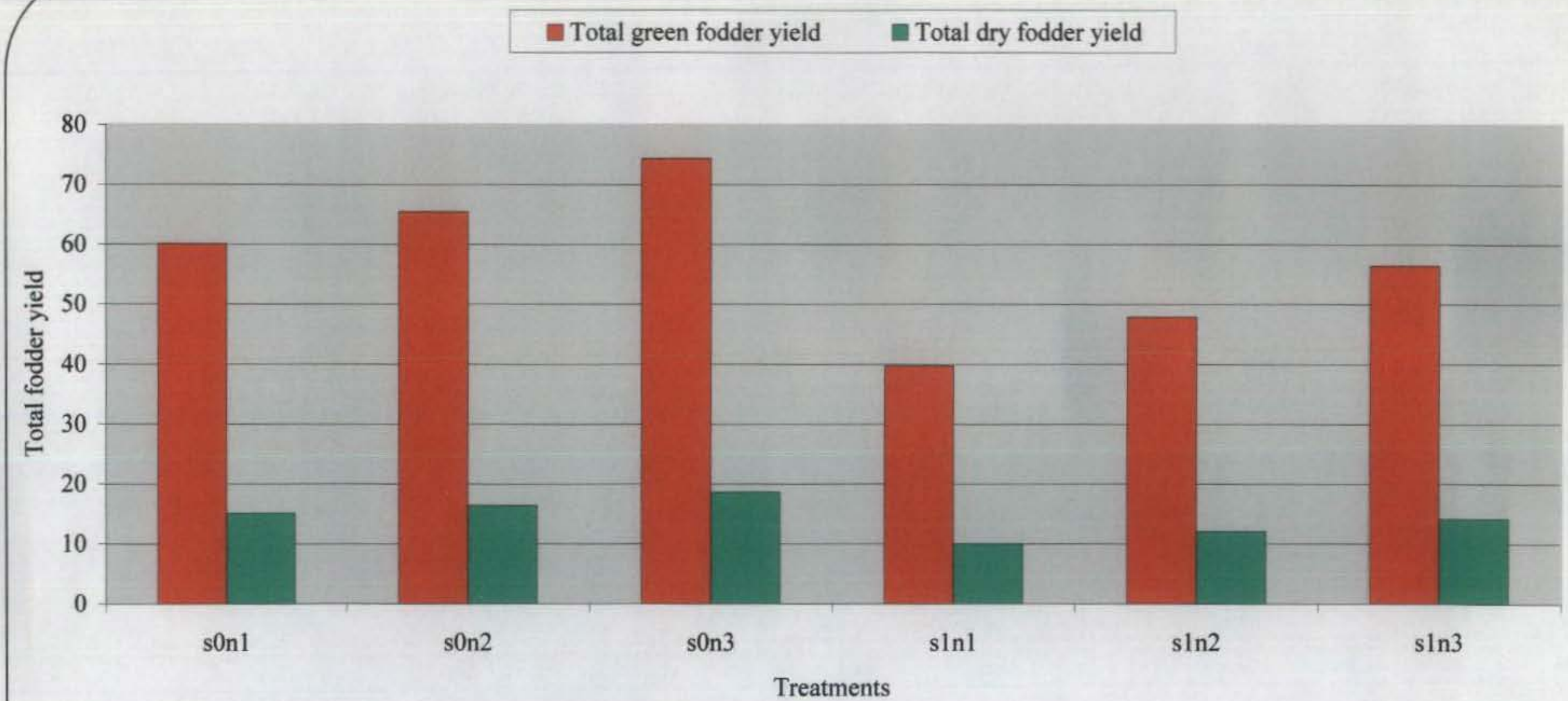


Fig. 7. Interaction effects of shade levels and nitrogen on total green fodder yield and total dry fodder yield of guinea grass, t ha^{-1}

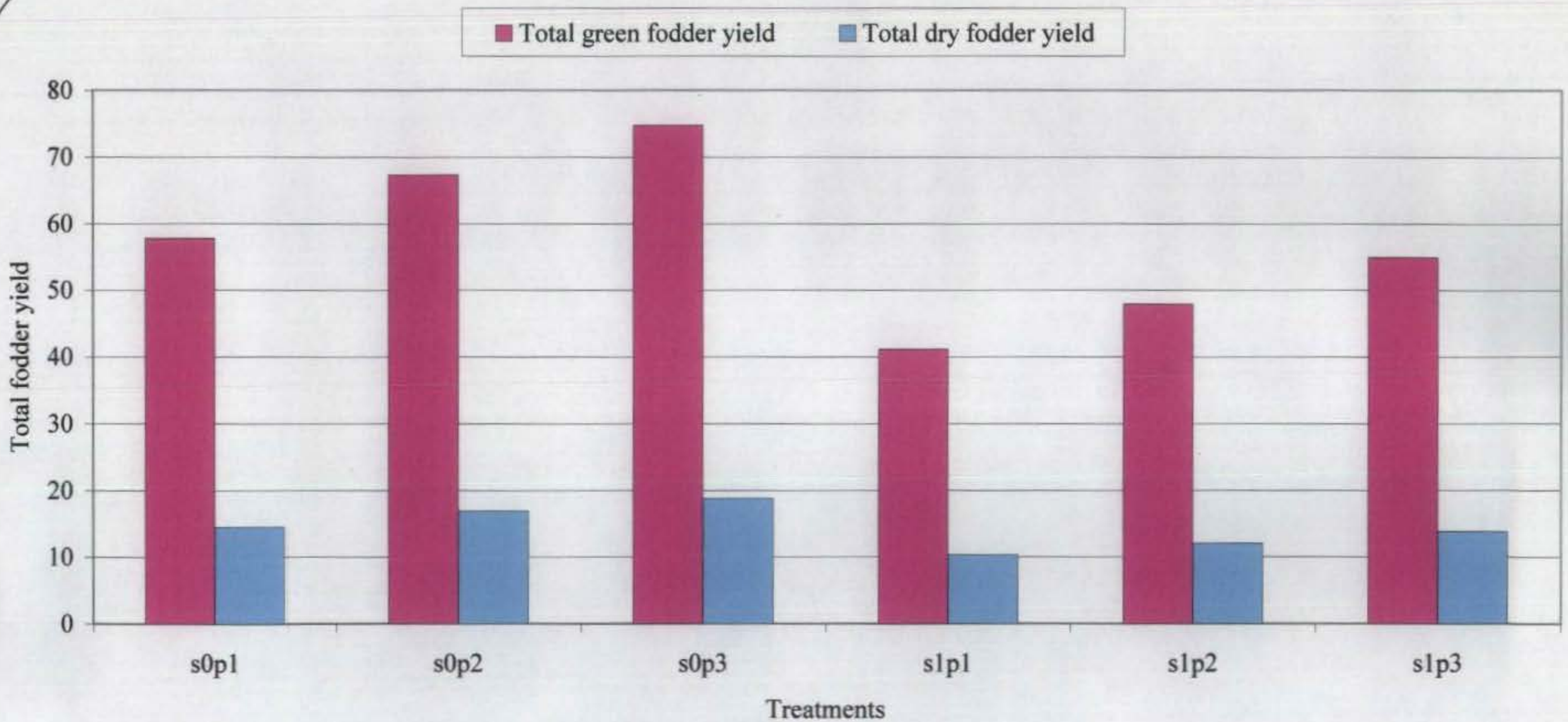


Fig. 8. Interaction effects of shade levels and phosphorus on total green fodder yield and total dry fodder yield of guinea grass, t ha^{-1}

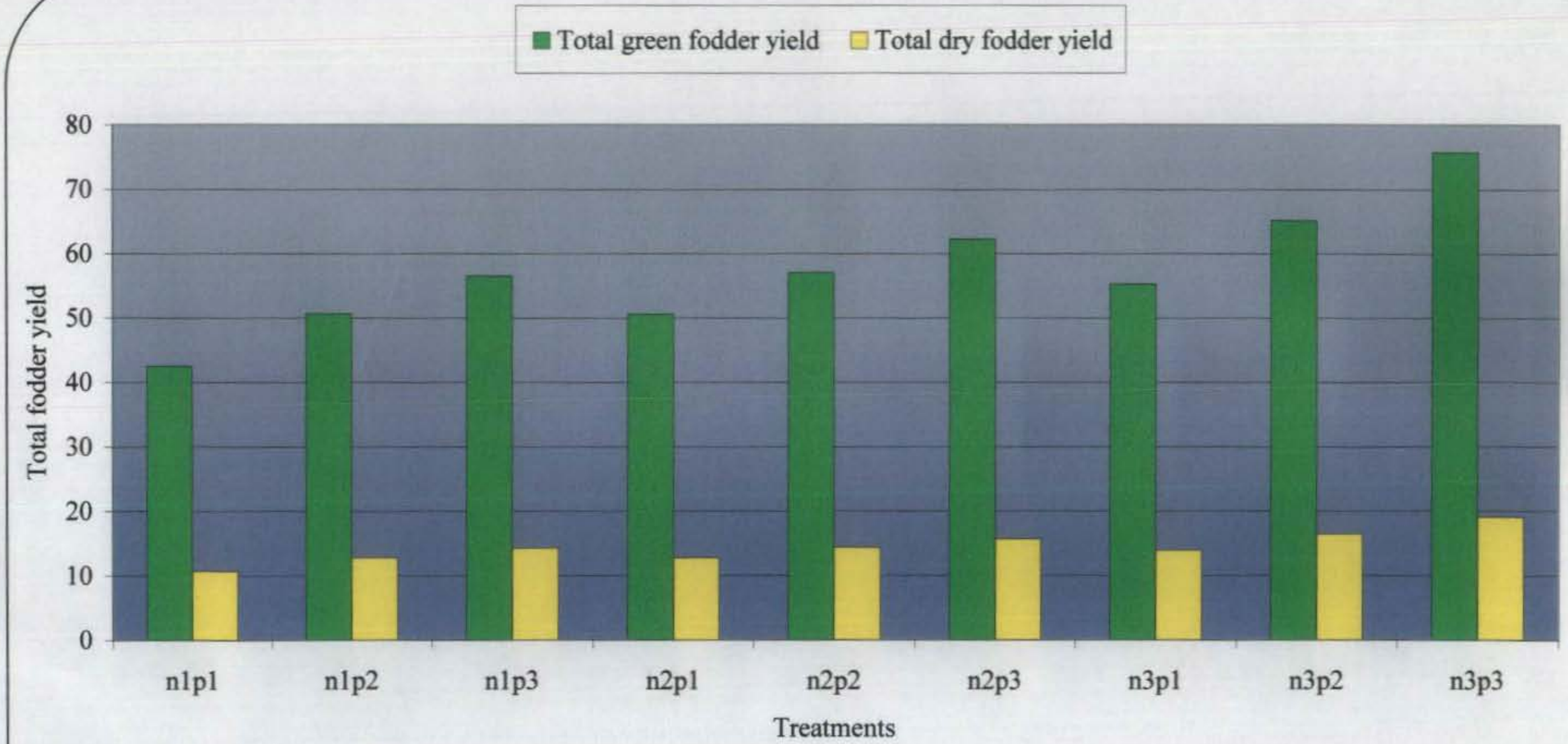


Fig. 9. Interaction effects of nitrogen and phosphorus on total green fodder yield and total dry fodder yield of guinea grass, t ha^{-1}

Total green fodder yield also had significant N x P interaction. Highest total green fodder yield of (75.78 t ha^{-1}) was obtained at the highest level of phosphorus and nitrogen (Plate 2 and 3). Similar improvement in green fodder yield with increase in nitrogen and phosphorus was reported by Vineetha (1995) in gamba grass, which may be due to the improved vegetative growth and root growth.

5.2.2 Dry Fodder Yield

Shade levels significantly influenced the dry fodder yield in all harvests except fourth cut. Compared to the open condition, there was a reduction of 18.8 per cent, 25.7 per cent, 35.1 per cent and 37.3 per cent in dry fodder yield in 50 per cent shade in first, second, third and fifth cuts respectively. Total dry fodder yield was also reduced by 27.9 per cent in 50 per cent shade compared to open condition (Fig. 6). 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 carbon dioxide assimilation and reduced availability of constructive materials of plants as reported by Duggar (1903). Under shade, the number of tillers and leaf area index were found to be significantly lower compared to open. The results are in conformity with the findings of Eriksen and Whitney (1981) in *Brachiaria brizantha*, Mullakoya (1982) in guinea grass, Pillai (1986) in guinea grass and setaria grass and Anita (2002) in guinea grass.

The dry fodder yield was significantly influenced by nitrogen in all the cuts. The highest level of nitrogen (300 kg ha^{-1}) resulted in 37.3 per cent, 28.5 per cent, 31.0 per cent, 28.9 per cent and 29.9 per cent increase in dry fodder yield over the lowest level (100 kg ha^{-1}) in the first, second, third, fourth and fifth cuts respectively. Highest level of nitrogen also registered 31.0 per cent increase in total dry fodder yield over lowest level of nitrogen. Increase in dry matter yield with increase in nitrogen level might be due to the increased cell division, enlargement

Plate 2. Best treatment combination identified under open condition

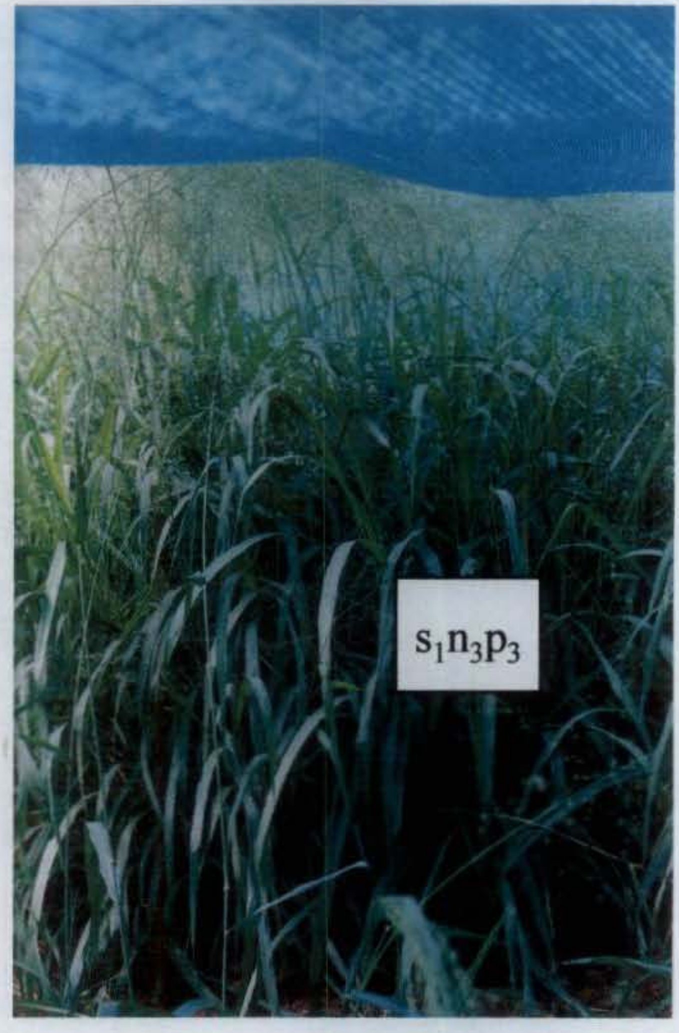


Plate 3. Best treatment combination identified under 50 per cent shade

and chlorophyll synthesis resulting in better growth and yield (Nehra *et al.*, 1981). Nitrogen compounds constitute 40 to 50 per cent of the dry matter of protoplasm and because of this, at higher nitrogen levels, more dry matter production occurs. Similar results were observed by Pillai (1986) in guinea grass and setaria grass, Tripathi and Singh (1991) in dinanath grass, Prakash *et al.* (1994) in Rhodes grass, Vineetha (1995) in gamba grass, Sonia (1999) in signal grass, Parihar and Agarwal (2002) in spear grass and Singh *et al.* (2002b) in *Iseilema laxum*.

The highest level of phosphorus gave maximum dry fodder yield in all the cuts. Total dry fodder yield also registered 31.2 per cent increase with highest level of phosphorus over lowest level. Tomer *et al.* (1974) reported that the improvement in yield with phosphorus application is the result of improved growth resulting from increase in cell division, better root development and high microbial activity, which supplied adequate nutrients to the plants, which is same as that obtained in guinea and setaria grass by Pillai (1986) and in guinea grass and congosignal by Meerabai *et al.* (1993).

S x N interaction was significant in third cut only. Under open and 50 per cent shade, N levels did not influence the dry matter yield significantly (Fig. 7). This result is in conformity with the findings of Pillai (1986) in guinea grass and setaria grass.

S x P interaction was significant in second third and fifth cuts. Total dry fodder yield was maximum (18.81 t ha^{-1} and 13.83 t ha^{-1}) with 75 kg P_2O_5 ha^{-1} under open and 50 per cent shade respectively (Fig. 8), which is in agreement with the finding of Pillai (1986) in guinea grass and setaria grass.

N x P interactions revealed that at all levels of nitrogen, the dry fodder yield recorded was maximum with highest level of phosphorus (75 kg ha^{-1}) (Fig. 9), as reported by Pillai (1986) in guinea grass and setaria grass. Treatment combination n_3p_3 (300 kg N ha^{-1} + 75 kg P_2O_5 ha^{-1}) registered highest dry fodder yield.

5.3 PHYSIOLOGICAL CHARACTERS

5.3.1 Leaf Area Index

A significant influence of shade levels on leaf area index was noticed in all harvests except fourth cut. The leaf area index was found to be maximum at zero per cent shade level (Fig. 10). The amount of carbohydrates that a plant can produce in a given time is dependent on the amount of sun's energy it can capture and convert to tissue. A plant maximizes radiation absorption by accumulating leaves (Ramus, 1995). The increase in leaf area index under open condition may be due to the increase in number of tillers, which in turn contributed to increase in number of leaves in full sunlight. Similar results of increased leaf area index under open compared to shade were also reported by Mullakoya (1982) in guinea grass, Pillai (1986) in guinea grass and setaria grass and Anita (2002) in guinea grass.

Leaf area index was significantly influenced by nitrogen application in all cuts. Highest level of nitrogen (300 kg ha^{-1}) recorded maximum leaf area index in all cuts. As the nitrogen supply increased the extra protein produced might have allowed the plant leaves to grow larger and hence to have more surface area available for photosynthesis (Russel, 1973). Increasing levels of nitrogen increased the LAI and CGR. This may be done due to the presence of adequate nitrogen supply, resulting in better utilization of carbohydrates to form more protoplasm. The cells produced under such conditions tend to be large with thin walls (Black, 1968), which may cause increase in leaf area. Increase in leaf area index with incremental doses of nitrogen was reported by Pillai (1986) in guinea grass and setaria grass and by Sonia (1999) in signal grass.

Higher levels of phosphorus registered higher leaf area index in all cuts except fourth cut. Increased availability of phosphorus might have increased the supply of nitrogen for leaf expansion and thereby resulting in higher leaf area. Thus enhanced production of leaves and

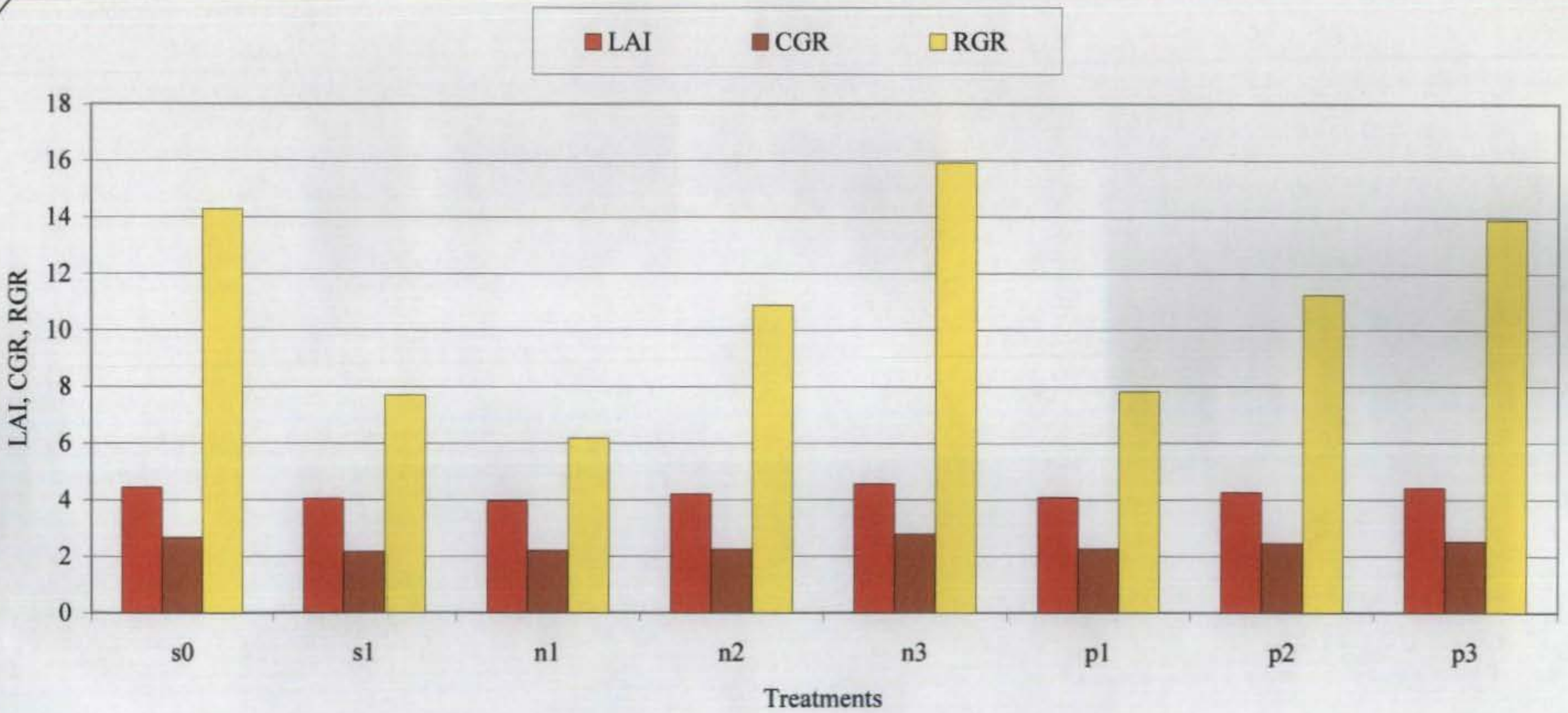


Fig. 10. Main effects of shade levels, nitrogen and phosphorus on leaf area index (3rd cut), CGR (g m^{-2} day^{-1}) and RGR (mg g^{-1} day^{-1}) of guinea grass

increased longevity of leaves exhibited by plants receiving high levels of nutrients might have increased the leaf area index of the crop as reported by Sonia (1999) in signal grass and Rani (2001) in bajra and sorghum.

S x N interaction significantly influenced the leaf area index in all the cuts. Under open and 50 per cent shade, n_2 (200 kg ha^{-1}) recorded maximum leaf area index (Fig. 11). The tiller production was maximum at n_3 level in open and 50 per cent shade. Increase in number of tillers might have contributed to more number of leaves and hence higher leaf area index. Similar results were obtained by Pillai (1986) in guinea grass and setaria grass.

Leaf area index exhibited significant S x P interaction in third cut only. Under open and 50 per cent shade, highest level of phosphorus (p_3) registered higher leaf area index which was on par with p_1 and p_2 in all other cuts. Increased availability of phosphorus might have increased the supply of nitrogen for leaf expansion and thereby resulting in higher leaf area under open and shaded condition.

N x P interaction was found to be significant in first three cuts. Under all levels of nitrogen, highest level of phosphorus (p_3) registered higher leaf area index in first, second and third cuts (Fig. 12). The LAI was significantly higher at n_3p_3 in the three cuts. The influence of nitrogen and phosphorus on increasing leaf area index had already been noted. The significant interaction effects may be due to their main treatment effects, as reported by Thakral *et al.* (1997) in *Brassica* sp.

5.3.2 Crop Growth Rate

Shade levels, nitrogen and phosphorus had significant influence on crop growth rate. Maximum crop growth rate was recorded at open (Fig. 10). Low light intensities pose stress on plants because irradiance limits photosynthesis and thus net carbon gain and plant growth. Higher dry matter production and leaf area index might have contributed to higher crop growth rate under open. The reduced crop performance as

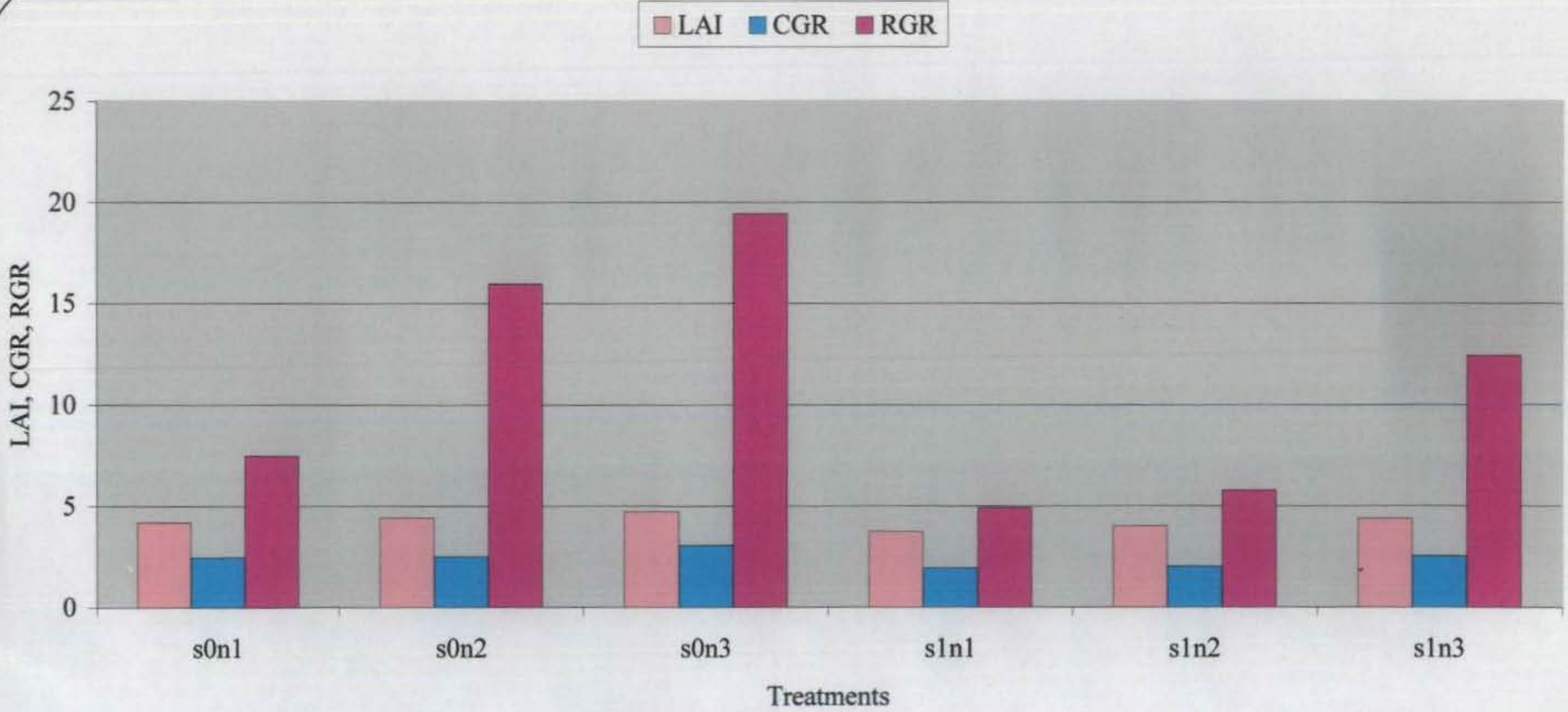


Fig. 11. Interaction effects of shade levels and nitrogen on LAI (3rd cut), CGR (g m^{-2} day^{-1}) and RGR (mg g^{-1} day^{-1}) of guinea grass

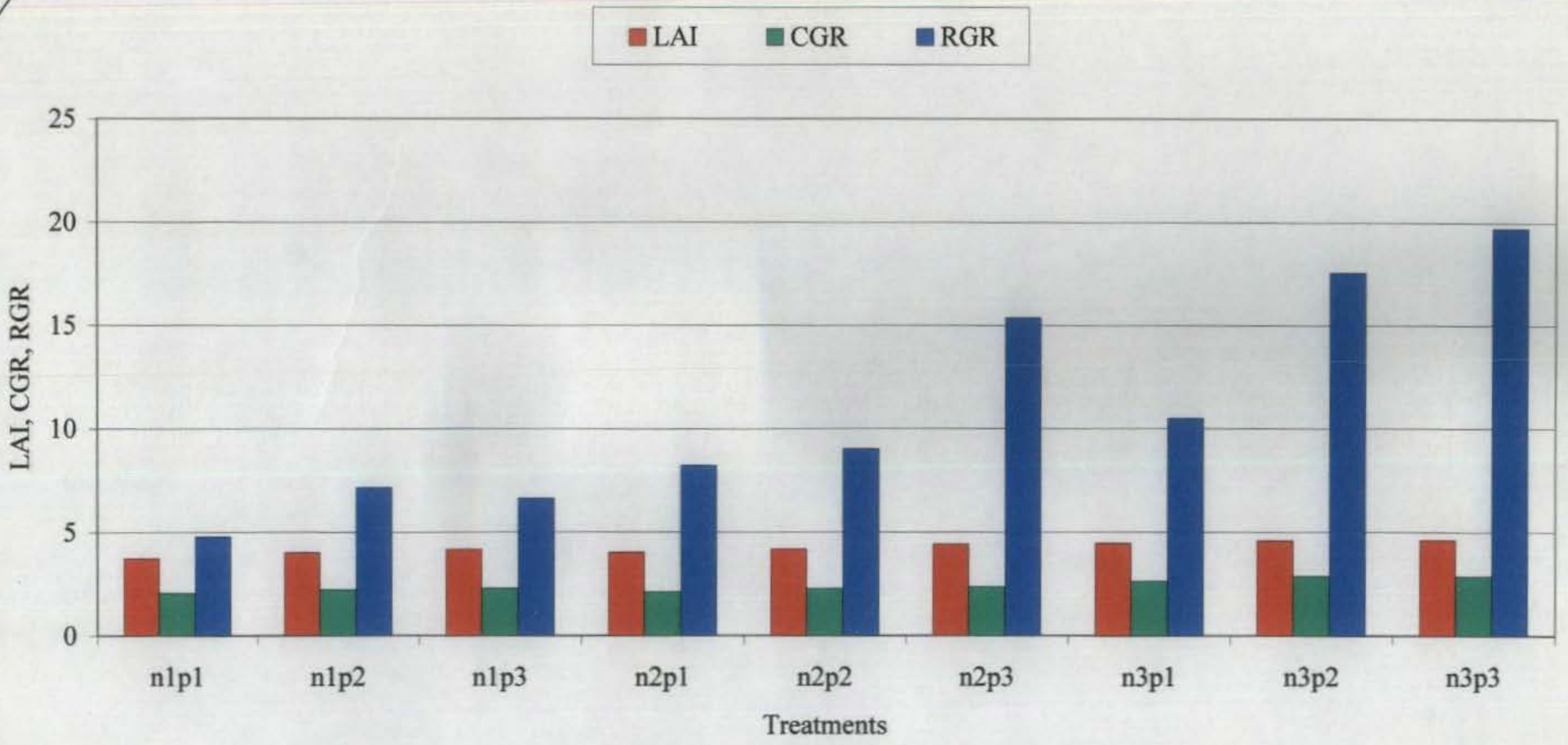


Fig. 12. Interaction effects of nitrogen and phosphorus on leaf area index (3rd cut), CGR ($g\ m^{-2}\ day^{-1}$) and RGR ($mg\ g^{-1}\ day^{-1}$) of guinea grass

reflected in LAI and tiller production was all responsible for the reduced crop growth under shade. This is in accordance with the findings of Pillai (1986) in guinea grass and setaria grass and Bhatt *et al.* (2002) in trispecific hybrids, *Brachiaria mutica, Panicum maximum, Pennisetum polystachyon, Cenchrus ciliaris* and *Setaria sphacelata.*

Nitrogen application had significant influence on crop growth rate. Crop growth rate increased significantly with increase in nitrogen levels upto 300 kg ha^{-1}. The higher LAI attained at the highest level of nitrogen resulted in greater rate of dry matter production per unit ground area which contributed to increased crop growth rate at highest level of nitrogen. Hence it can be concluded that N tended to increase the crop growth rate as evidenced by Pillai (1986) in guinea grass and setaria grass, Suja (2001) in white yam, Chakraborty *et al.* (2002) in finger millet and Kumar and Singh (2002) in maize. Increasing level of nitrogen increased the LAI and CGR. This may be due to the presence of adequate N supply, resulting in better utilization of carbohydrates to form more protoplasm. The cells produced under such condition tend to be large with thin walls (Black, 1968) which may cause increase in leaf area.

Crop growth rate attained maximum value of 2.51 g m^{-2} day^{-1} at the highest level of phosphorus (75 kg ha^{-1}). P supply increased dry weight and crop growth rate mainly through enlargement of leaf area. Similar results were also reported by Pillai (1986) in guinea and setaria grass, Oommen (1989) in sweet potato, Kanno *et al.* (1999) in *Brachiaria decumbens* cv. Basilisk and *B.brizantha* cv. Marandu, Archana (2001) in coleus and Kumar and Singh (2002) in maize.

Crop growth rate had significant S x P interaction. Under open and shaded condition, highest level of phosphorus (75 kg ha^{-1}) recorded maximum crop growth rate. Increased phosphorus levels resulted in higher LAI and dry weight which contributed to higher crop growth rate as reported by Pillai (1986) in guinea and setaria grass.

N x P interaction was found to be significant for crop growth rate. Maximum crop growth rate was obtained at higher levels of nitrogen and phosphorus (Fig. 12). Higher values of crop growth rate was obtained when n_3 (300 kg N ha^{-1}) level combined with p_2 (50 kg P_2O_5 ha^{-1}) which was on par with p_3 (75 kg P_2O_5 ha^{-1}). The significant interaction effects may be due to their main treatment effects. Similar finding was reported by Ajithkumar (1999) in ginger.

5.3.3 Relative Growth Rate

Shade levels, nitrogen and phosphorus application had significant influence on relative growth rate. Maximum value for relative growth rate was recorded at open and minimum at 50 per cent shade (Fig. 10). Higher dry matter production and leaf area index might have contributed to higher relative growth rate under open. This is in conformity with the findings of Dias-Filho (2000) in *Brachiaria brizantha* cv. Marandu and *B.humidicola*, Viji (1995) and Sunilkumar (2000) in rice.

Maximum relative growth rate (15.93 mg $g^{-1}day^{-1}$) was obtained at highest level of nitrogen (300 kg ha^{-1}) followed by n_2 (200 kg ha^{-1}) and n_1 (100 kg ha^{-1}). The higher LAI attained at the highest level of nitrogen contributed to higher rate of dry matter accumulation per unit original plant material which resulted in increase in RGR at the highest level of nitrogen. This can be related to the findings of Enyi (1973) in *Dioscorea esculenta*, Gaborcik and Javorkova (1990) in Anthoxantho-Agrostietum grassland, Kumar and Singh (2001) in maize and Suja (2001) in white yam.

Phosphorus levels also had significant influence on relative growth rate. Maximum value of 13.92 mg g^{-1} day^{-1} was attained at the highest level of phosphorus (75 kg ha^{-1}). Increasing levels of phosphorus tends to increase root growth which result in higher rate of nutrient absorption resulting in high dry matter production. This fact might have contributed to higher relative growth rate. Similar finding was reported by Ajithkumar (1999) in ginger.

Relative growth rate exhibited significant S x N interaction. Increasing level of nitrogen upto 300 kg ha^{-1} resulted in increased relative growth rate (Fig. 11). An adequate supply of nitrogen which is associated with vigorous vegetative growth (Tisdale *et al.*, 1985) contributed more number of tillers and LAI which resulted in higher dry matter production leading to higher relative growth rate at higher level of nitrogen under both open and shaded situation.

S x P interaction was significant for relative growth rate. Under open and 50 per cent shade, highest level of phosphorus resulted in maximum relative growth rate. Relative growth rate of 18.81 and 9.02 mg g^{-1} day^{-1} was attained at highest level of phosphorus under open and 50 per cent shade respectively.

Significant N x P interaction was found in relative growth rate. RGR increased with increasing levels of nitrogen and phosphorus and attained highest value of 19.72 mg g^{-1} day^{-1} when n_3 (300 kg N ha^{-1}) level was combined with p_3 (75 kg P_2O_5 ha^{-1}) (Fig. 12). The additive effect of the individual nutrients might have resulted in the significant effects of the interactions.

5.3.4 Net Assimilation Rate

Shade levels had significant effect on net assimilation rate. Under open, NAR attained maximum value than under 50 per cent shade. NAR is essentially an estimation of canopy photosynthesis per unit leaf area and can be used as a measure of photosynthetic efficiency. Its contribution to yield is not direct (Gauder *et al.*, 1988). According to Okoli and Owasu (1975), high NAR at low shade was due to high rate of photosynthesis. Similar finding was reported by Viji (1995) and Sunilkumar (2000) in rice.

Application of nitrogen had significant effect on NAR. NAR attained maximum value of 0.55 g m^{-2} day^{-1} at the highest level of nitrogen (300 kg ha^{-1}). The higher LAI attained at the highest level of nitrogen resulted in greater rate of dry matter production per unit photosynthesizing area which contributed to higher NAR as reported by Gaborcik and Javorkova (1990) in Anthoxantho-Agrostietum grassland, Illavska *et al.* (2001) in a temporary grassland and Suja (2001) in white yam.

Phosphorus levels also had significant influence on NAR. Highest level of phosphorus (75 kg ha^{-1}) resulted in maximum NAR (0.44 g m^{-2} day^{-1}). Increase in LAI and dry weight with increasing levels of phosphorus had already been mentioned. This might have contributed to higher NAR at higher level of phosphorus. Results conforming to this were obtained by Nayar (1986) in cassava, Archana (2001) in coleus and Tiwari *et al.* (2001) in linseed.

NAR had significant S x N interaction. Highest level of nitrogen recorded maximum net assimilation rate under open and 50 per cent shade. Increasing levels of nitrogen resulted in increased leaf area and dry weight that contributed to higher NAR with highest level of nitrogen under open and shaded situation.

Significant S x P interaction was found in case of NAR. Under open and 50 per cent shade, higher NAR value was obtained with the highest level of phosphorus (75 kg ha^{-1}). Influence of phosphorus in increasing leaf area and dry weight had already been mentioned. This might have contributed to higher NAR with increasing phosphorus levels.

N x P interaction was found to be significant. Maximum value for NAR (0.59 g m^{-2} day^{-1}) was obtained at higher levels of nitrogen and phosphorus. Role of nitrogen and phosphorus in increasing the leaf area and dry weight explained earlier, might be the reason for higher

NAR at higher levels of nutrients. Similar finding was reported by Ajithkumar (1999) in ginger.

5.4 BIOCHEMICAL ASPECTS

5.4.1 Chlorophyll Content

Shade levels, nitrogen and phosphorus 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 apparent in the visual appearance of the crop which 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 maximize light absorption there will be more accumulation of chlorophyll 'b' under shade (Bhatt and Sinha, 1990). True shade tolerance in forage species is associated with high chlorophyll densities, which indicate the photosynthetic efficiency (Stur, 1991). The shade leaves have larger grana, which contain major part of the chlorophyll, and Lambers *et al.*, (1998) reported that this high chlorophyll concentration allows efficient light capture per unit biomass invested in leaves at low irradiance. Mullakoya (1982) also reported high chlorophyll content under 75 per cent shade level in *Panicum maximum*. Similar findings were also reported by Sunilkumar (2000) in rice, Anita (2002) in guinea grass and Tiwari *et al.* (2002) in *Panicum maximum, Pennisetum polystachyon* and *Brachiaria mutica*.

Application of nitrogen had significant influence on chlorophyll content in all harvests. Higher levels of nitrogen (300 kg N ha^{-1}) resulted in an increase in the chlorophyll content of the plant. It is a

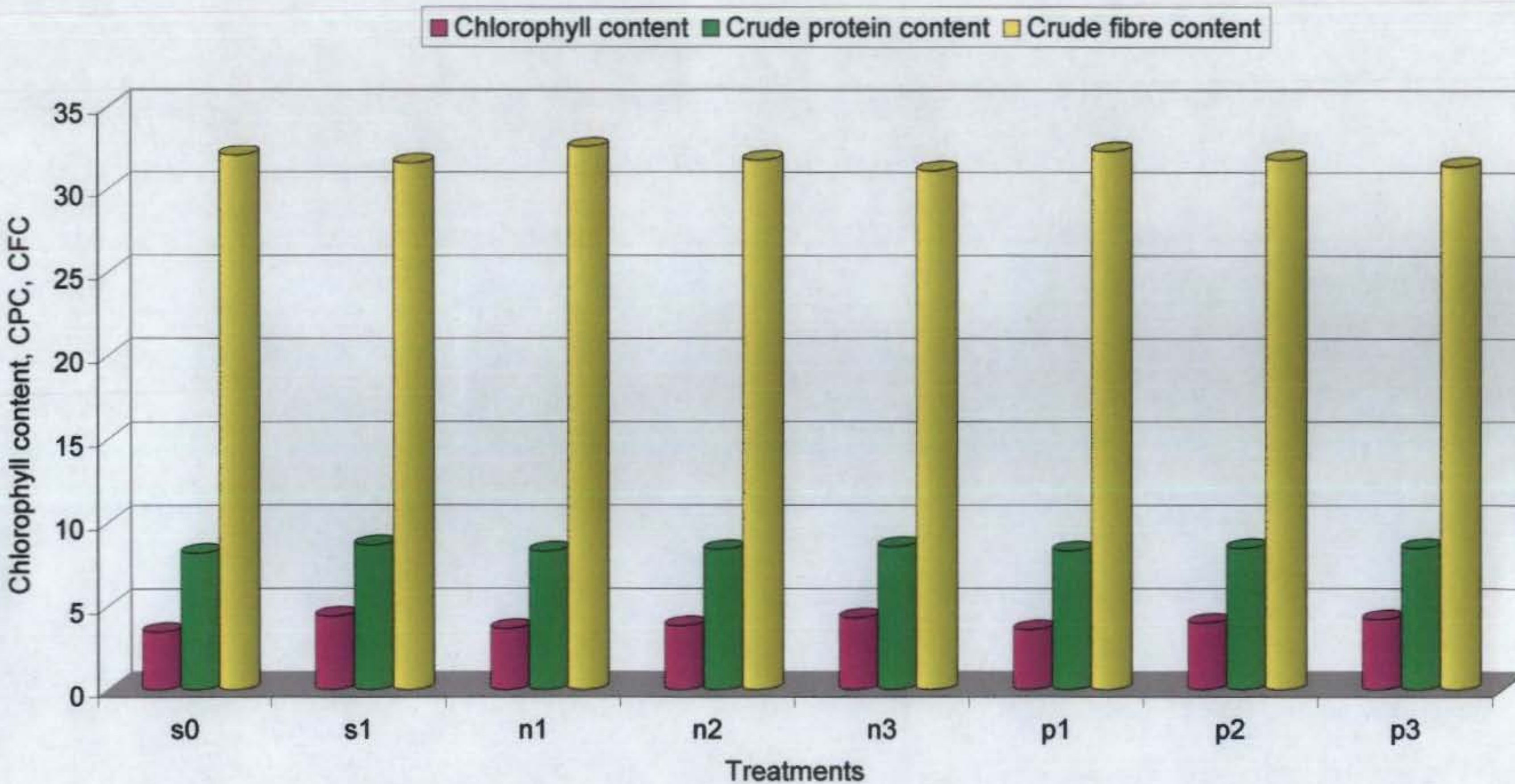


Fig. 13. Main effects of shade levels, nitrogen and phosphorus on chlorophyll content of plant (3rd cut) mg g^{-1}, crude protein content (%) and crude fibre content (%) of guinea grass

known fact that nitrogen is an integral part of the porphyrin ring system, the basic unit of chlorophyll structure (Tisdale *et al.*, 1995). Hence nitrogen supply tended to enhance the chlorophyll content as reported by Sudhakar *et al.* (1987), Singh *et al.* (1992), Anu (2001) in rice and Soratto *et al.* (2004) in *Panicum dichotomiflorum* Michx.

Phosphorus levels produced significant influence on chlorophyll content in all harvests. Higher levels of P_2O_5 (75 kg ha^{-1}) resulted in an increase in the chlorophyll content of the plant. It had been noted that phosphorus increases the nitrogen content in the plant thereby indirectly increasing chlorophyll content. P is an essential element for plant growth and is a part of metabolic energy transfer system (Reid and Jung, 1974). Malik and Srivastava (1985) reported the presence of a cofactor pyridoxal phosphate in the chlorophyll synthesis. This might be the reason for increased chlorophyll content with increasing phosphorus levels, which confirms to the earlier findings of Ajithkumar (1999) in ginger, Davaria *et al.* (2001) in mustard and Dayal and Goswami (2003) in cluster bean.

Significant S x N interaction was observed in all harvests. Under open condition, higher levels of nitrogen (300 kg ha^{-1}) resulted in an increase in the chlorophyll content. Under 50 per cent shade, higher level of nitrogen (300 kg ha^{-1}) registered maximum chlorophyll content in second, third and fourth cut while n_2 (200 kg ha^{-1}) registered maximum chlorophyll content in first and fifth cuts (Fig. 14). The role of nitrogen in increasing chlorophyll content had already been mentioned.

Chlorophyll content also had significant S x P interaction. It was seen that p_2 (50 kg P_2O_5 ha^{-1}) registered maximum chlorophyll content in fifth cut under open and in second, third and fourth cut under 50 per cent shade. While p_3 (75 kg P_2O_5 ha^{-1}) registered higher chlorophyll content in first, second, third and fourth cut under open and in first and fifth cut under 50 per cent shade (Fig. 15).

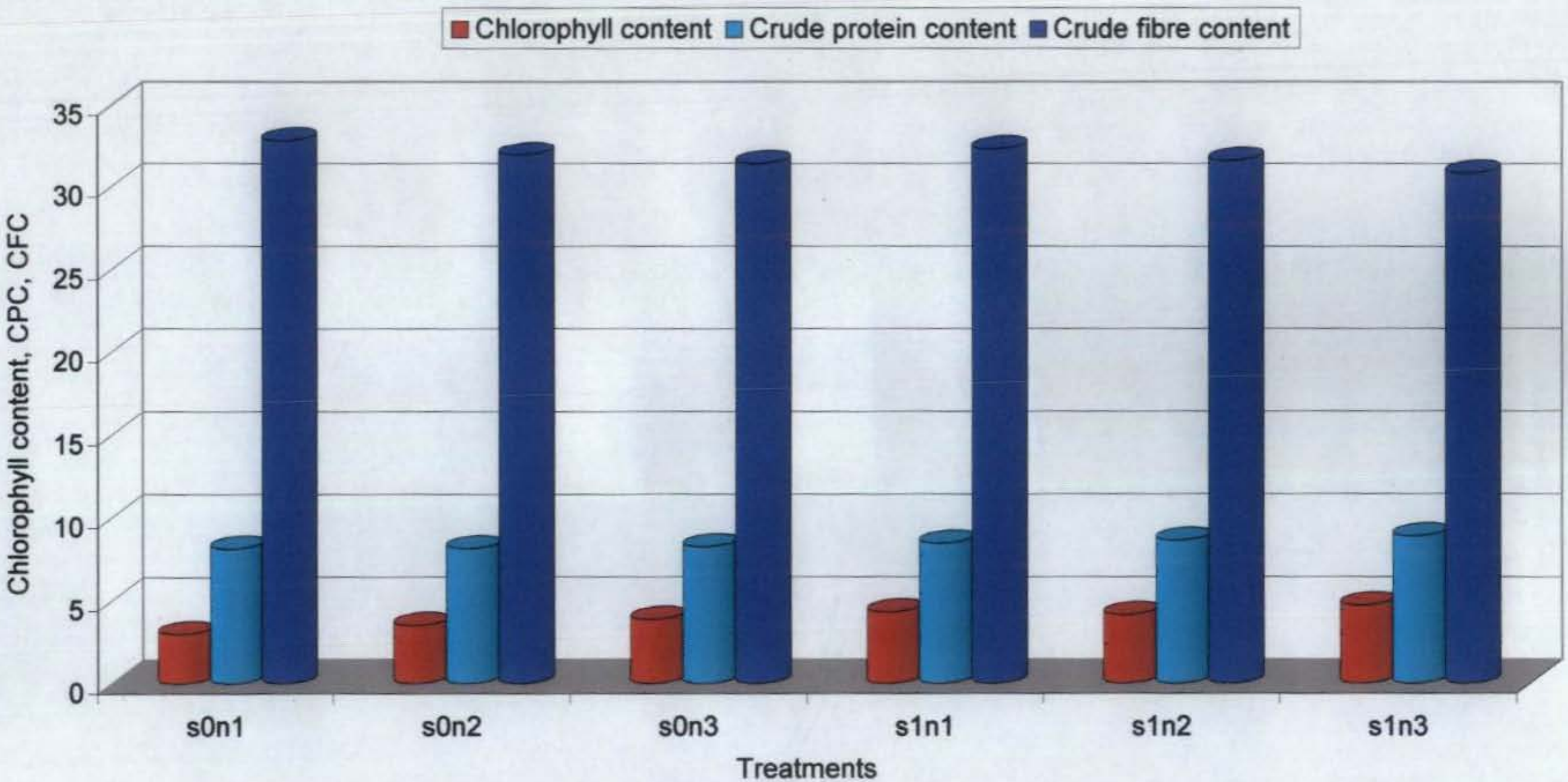


Fig .14. Interaction effects of shade levels and nitrogen on chlorophyll content of plant (3rd cut) (mg g^{-1}), crude protein content (%) and crude fibre content (%) of guinea grass

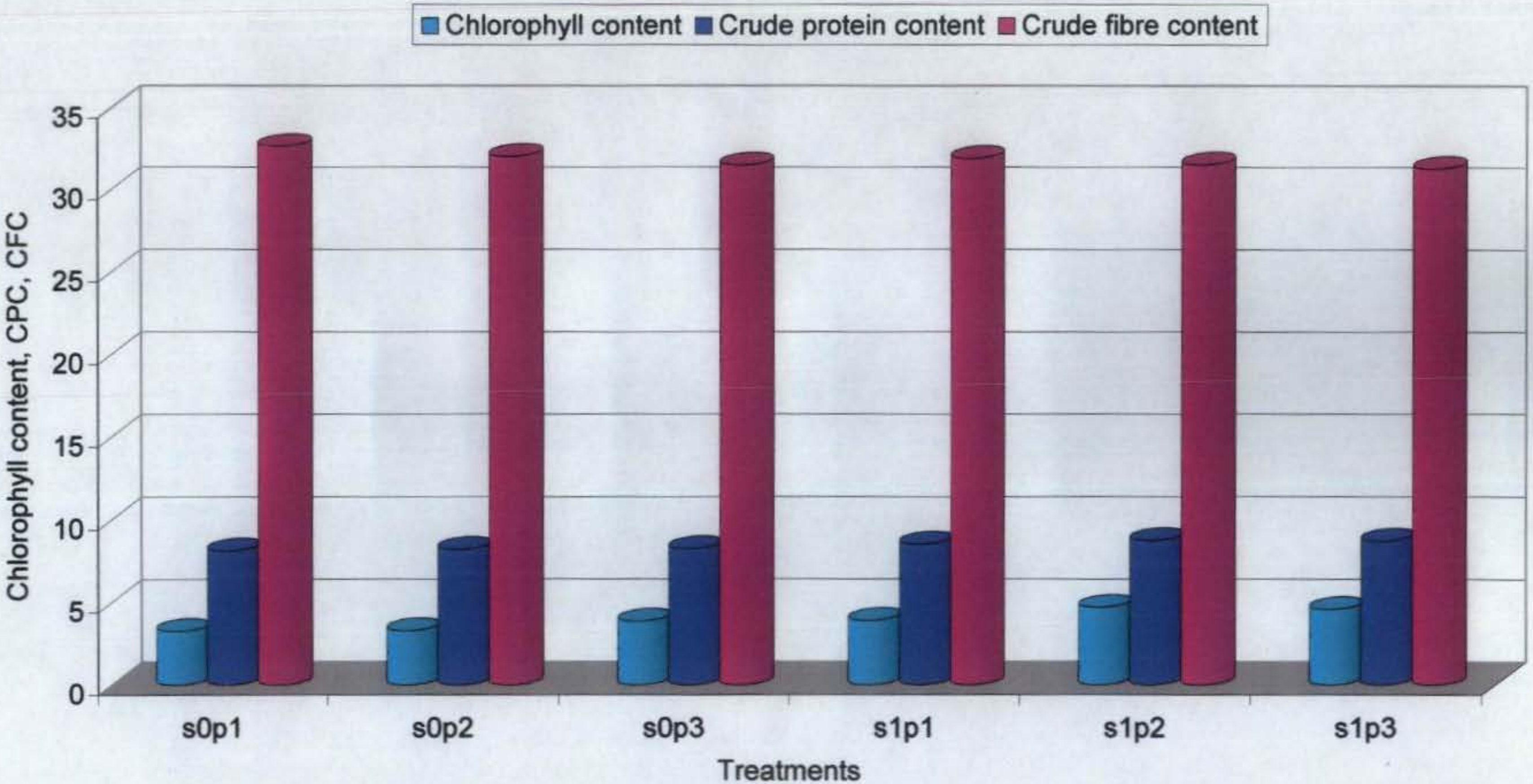


Fig. 15. Interaction effects of shade levels and phosphorus on chlorophyll content of plants (3rd cut) (mg g^{-1}), crude protein content (%) and crude fibre content (%) of guinea grass

N x P interaction was significant in all harvests. Under all levels of nitrogen, higher level of P_2O_5 (75 kg ha^{-1}) registered maximum chlorophyll content in all cuts (Fig. 16). While p_2 (50 kg P_2O_5 ha^{-1}) registered maximum chlorophyll content under n_3 (300 kg N ha^{-1}) in second cut and under n_2 (200 kg N ha^{-1}) in third, fourth and fifth cuts. The additive effects of individual nutrients might have resulted in the significant effects in the interactions. Similar finding was reported by Ajithkumar (1999) in ginger.

5.5 QUALITY ASPECTS

5.5.1 Crude Protein Content

Crude protein content was significantly influenced by shade levels, nitrogen and phosphorus application in guinea grass. Crude protein content increased significantly with increase in shade levels (Fig. 13). Crude protein content is much more responsive to shading than other quality characteristics. Plants adapted to shade have 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), Pillai (1986), Anita (2002) also observed an increase in crude protein content by shading in guinea grass, while the same trend was noticed by Baig *et al.* (2002) in *Cenchrus* genotypes and Misra *et al.* (2002) in *Panicum maximum, Pennisetum polystachyon, Setaria spahcelata* and *Brachiaria indica*.

Nitrogen levels significantly increased the crude protein content. Higher crude protein content was observed at highest dose of nitrogen (300 kg ha^{-1}) Protein content in forage crops is of prime importance since it is considered as the building block of any living system. Significant increase in crude protein content of the crop was noticed with increased level of N. The effect of N in influencing the protein content of plants is well known. Since nitrogen is the chief constituent of

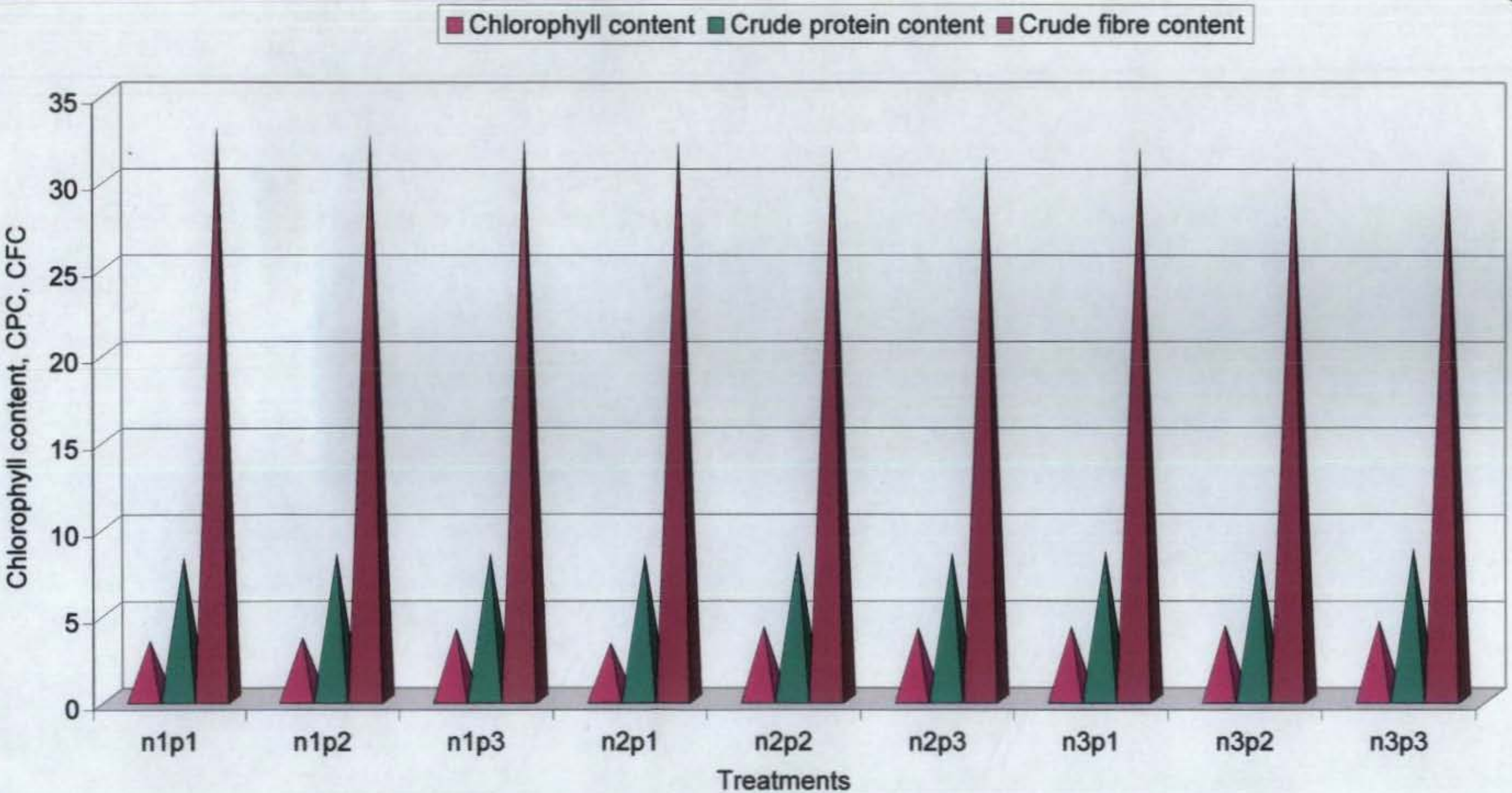


Fig. 16. Interaction effects of nitrogen and phosphorus on chlorophyll content of plant (3rd cut) mg g^{-1}, crude protein content (%) and crude fibre content (%) of guinea grass

protein, its application would naturally increase the protein content. Similar results were obtained by Jayakumar (1997) and Balbatti (1980) in hybrid napier, Pillai (1986) in guinea grass and setaria grass and Singh *et al.* (2002b) in *Iseilema laxum* where in 52.9 per cent increase in crude protein was obtained by increasing N application from 0 to 90 kg ha^{-1}.

Application of phosphorus also had significant influence on crude protein content. Higher levels of phosphorus (75 kg ha^{-1}) registered higher crude protein content of the plant. Phosphorus being one of the main constituents of protein might have favourably influenced the crude protein content of the grass in the present study, as reported by Dwivedi *et al.* (1980) in *Chrysopogon fulvus*, Ravikumar and Shankaranarayan (1980) in the natural grassland of *Sehima nervosum* (Rottl.) Stapf, Pillai (1986) in guinea grass and setaria grass and Singh *et al.* (2002b) in *Iseilema laxum*.

Significant S x N interaction was noticed with respect to crude protein content. Higher levels of nitrogen registered higher crude protein content under open and shaded situation (Fig. 14). Since nitrogen is the chief constituent of protein, its application would naturally increase the protein content. The crude protein content of grasses increased significantly with increase in nitrogen levels in the open as well as in shaded situation. However, the increase was more in partial shade than in open area. Nitrogen increase the protein yield of forage and no management practice other than the application of nitrogen appreciably influenced the protein content of grass (Capriel and Ashcroft, 1972). Similar result was reported by Pillai (1986) in guinea and setaria grass.

There was an increase in crude protein content with increase in phosphorus levels under open and shaded condition (Fig. 15). P being one of the main constituents of protein, might have favourably influenced the crude protein content of the grass in open as well as in 50 per cent shade as reported by Pillai (1986) in guinea grass and setaria grass.

Significant N x P interaction was observed. At 100 kg N ha^{-1} and 200 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} registered higher crude protein content while 75 kg P_2O_5 ha^{-1} registered higher crude protein content at 300 kg N ha^{-1} (Fig. 16). The role of nitrogen and phosphorus in increasing the protein content had already been discussed. The additive effect of the individual nutrients might have resulted in the significant effects of the interactions.

5.5.2 Crude Fibre Content

Shade levels significantly influenced the crude fibre content of the plant. Crude fibre content reduced significantly with increase in shade levels (Fig. 13). Lowest fibre content was noticed at 50 per cent shade level. Growing of forages in full sunlight causes changes in chemical composition at plant parts including that of cell walls. The increased utilization of assimilates for improvement of protein might have reduced the fibre content. Forage cell walls, composed mostly of polysaccharides and lignin limit forage consumption and digestibility (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*, Pillai (1986) in guinea grass and setaria grass and Anita (2002) in guinea grass.

The crude fibre content determines the digestibility of the forage and it is an important criterion for evaluation of any forage material. Crude fibre content registered a significant decrease with increase in nitrogen levels from 100 kg ha^{-1} to 300 kg ha^{-1}. This might be due to an indirect effect of nitrogen on carbohydrate metabolism. When nitrogen supplies are adequate, the conditions are favourable for growth, proteins are formed from the manufactured carbohydrates resulting in more succulent plant parts. If the nitrogen supply is inadequate, higher carbohydrates will be deposited in the cell walls, causing them to thicken (Black, 1968). Results in accordance to this were reported by Balbatti (1980) in hybrid napier, Pillai (1986) in guinea grass and setaria grass, Vineetha (1995) in gamba grass, Sonia (1999) in signal grass and Jayakumar (1997) in hybrid napier.

Application of phosphorus reduced the crude fibre content. Higher levels of phosphorus (75 kg ha^{-1}) resulted in lower crude fibre content. This is in accordance with the findings of Wilson *et al.* (1959) where increased levels of phosphorus reduced the content of crude fibre in clover-fescue mixture. An inverse relationship between crude protein content and crude fibre content was reported by Balbatti (1980) in hybrid napier. When protein content is higher and fibre content is lower, the fodder will be more digestible and would give more digestible energy. Any step to increase the protein content will naturally result in decreased content of crude fibre. Increased application of phosphorus resulted in increased nitrogen content thereby producing more vegetative growth and making it succulent in the present study. Increased application of phosphorus improved the quality of forages (Tisdale and Nelson, 1956). Similar findings were reported by Chandini (1980) in guinea grass, setaria grass and congosignal, Pillai (1986) in guinea and setaria grass and Vineetha (1995) in gamba grass.

S x N interactions was found to be significant. Under both open and 50 per cent shade, higher level of nitrogen (300 kg ha^{-1}) registered lower crude fibre content (Fig. 14). With higher content of nitrogen in the plant, the carbohydrates are utilized more for synthesis of protoplasm rather than for thickening of cell wall, resulting in reduced fibre content as reported by Tiwana *et al.* (1975) and Pillai (1986) in guinea and setaria grass.

Significant S x P interaction was noticed. Higher level of phosphorus (75 kg ha^{-1}) recorded lower crude fibre content under both open and 50 per cent shade (Fig. 15). The role of phosphorus in reducing fibre content had already been discussed. Similar observations also reported by Pillai (1986) in guinea and setaria grass.

In N x P interaction, there was a significant decrease in crude fibre content with higher levels of phosphorus (75 kg ha^{-1}) under all levels of nitrogen (Fig. 16). The additive effect of the individual nutrient might have resulted in the significant effects of the interactions as reported by Vineetha (1995) in gamba grass.

5.5.3 Total Protein Yield

The total protein yield was significantly higher at open followed by that at 50 per cent shade level. This may be due to the increased dry matter production in open compared to 50 per cent shade. The total protein yield was reduced by 23.4 per cent in 50 per cent shade compared to open. Similar results were reported by Buxton (2001) and Anitha (2002) in guinea grass.

Application of nitrogen had significant influence on total protein yield. Higher protein yield (1.4 t ha^{-1}) obtained at highest level of nitrogen (300 kg ha^{-1}) might be due to the higher dry fodder yield obtained at the said treatment. There was 25.7 per cent and 15 per cent increase in total protein yield with n_3 compared to n_1 and n_2. Nitrogen is essential for plant growth because it is a constituent of all proteins and hence the quantity of N supplied to the crop may influence the protein yield (Russel, 1973). The increased protein yield was mainly due to higher nitrogen content because N played an important role in the synthesis of protein.

Among the different phosphorus levels, p_3 (75 kg P_2O_5 ha^{-1}) was found to produce higher protein yield followed by p_2 and p_1. Increased dry fodder yield at p_3 level may be the cause of significantly higher total protein yield. There was 33.98 per cent increase in total protein yield with p_3 compared to p_1.

S x N interaction was found to be significant. Higher levels of nitrogen registered more total protein yield under open and 50 per cent shade. This might be due to higher dry fodder yield and crude protein content at higher levels of nitrogen.

Influence of N x P interaction on total protein yield was also in tune with that of the dry fodder yield. The additive effects of the individual nutrients might have resulted in the significant effect of the interactions.

5.6 NUTRIENT CONTENT AND UPTAKE

5.6.1 N Content and Uptake

Shade levels, nitrogen and phosphorus application had significant influence on nitrogen content and uptake by the plant (Fig. 17 and 18). A marked increase in nitrogen uptake with decrease in shade level was obtained. Highest N uptake was recorded at zero percent 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, Wilson and Wild (1991) in *Panicum maximum*, Anita (2002) in guinea grass and Misra *et al.* (2002) in *Panicum maximum, Pennisetum polystachyon*, *Cenchrus ciliaris* and *Setaria sphacelata.*

Among the nutrients, nitrogen occupies an important role in providing succulence, vegetative growth and palatability of fodder crops. A definite increasing trend in the content and uptake of nitrogen was noticed with the addition of nitrogen and was maximum when 300 kg N ha^{-1} was applied. The increase in the content and uptake of nitrogen would be attributed to the promotion of vegetative growth and increased protein content due to better availability of nitrogen. Increase in N content with increase in N levels was reported by Dwivedi and Kanodia

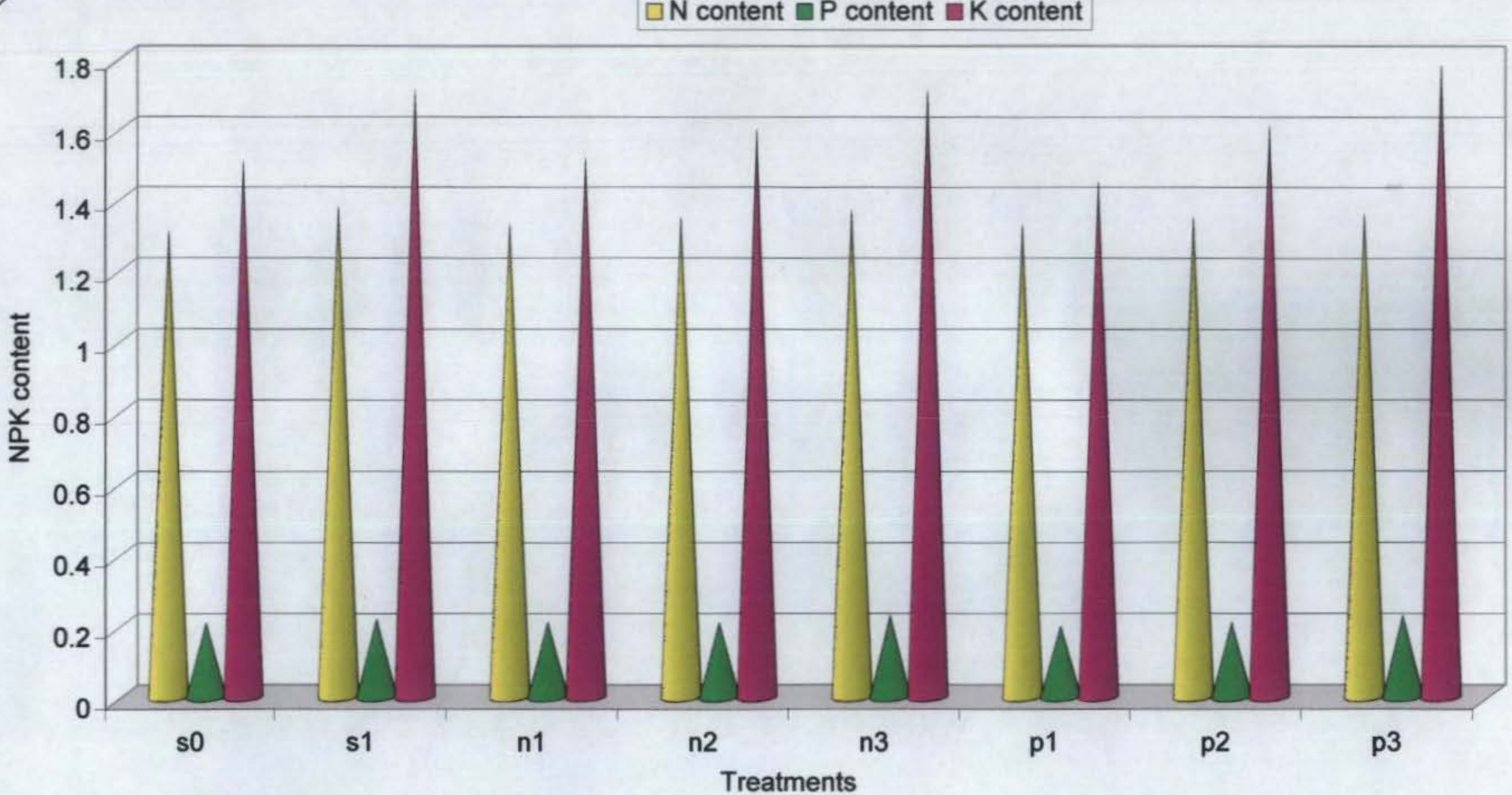


Fig. 17. Main effects of shade levels, nitrogen and phosphorus on NPK content of guinea grass, %

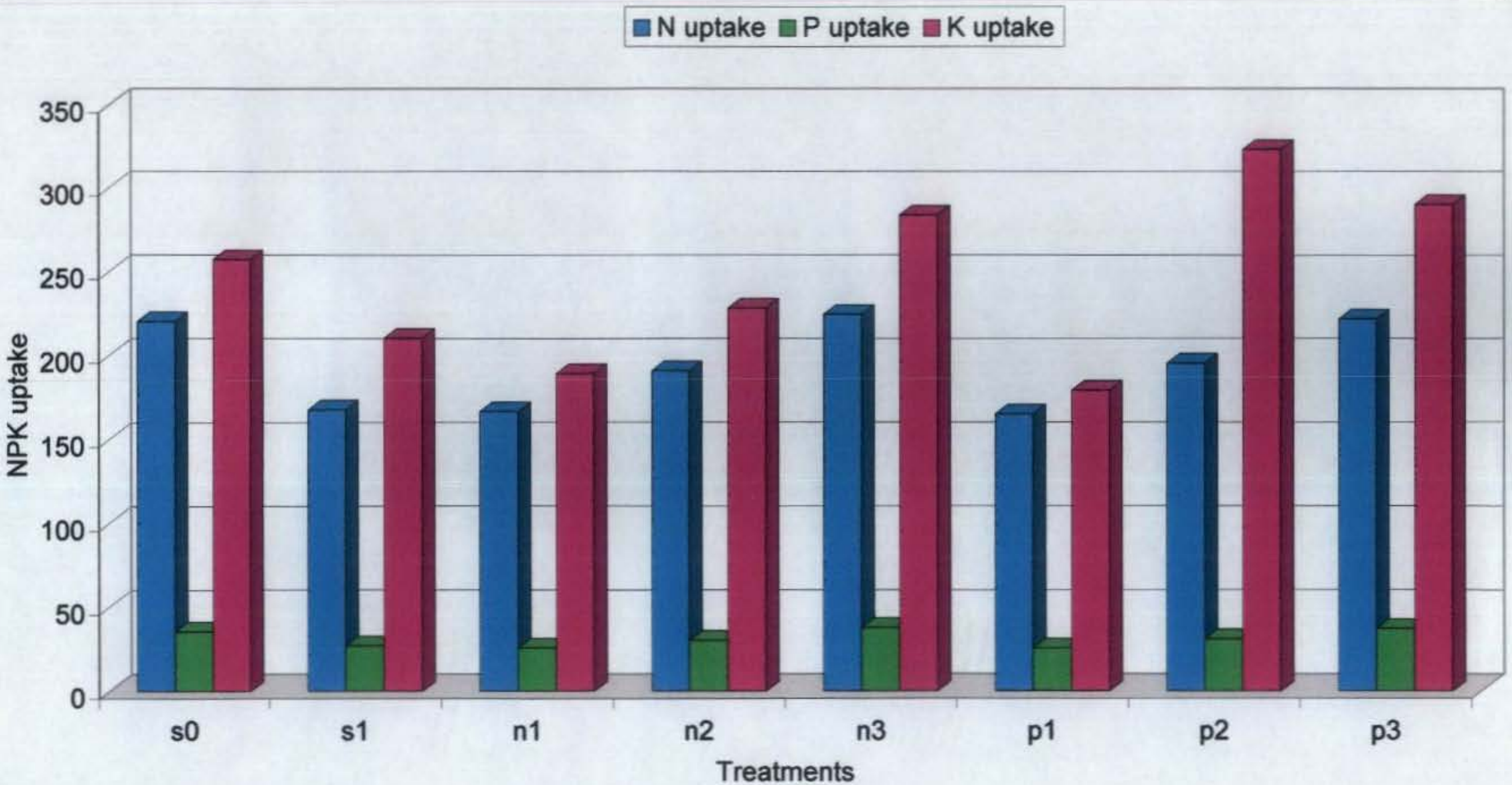


Fig. 18. Main effects of shade levels, nitrogen and phosphorus on the uptake of nitrogen , phosphrus and potassium by guinea grass, kg ha^{-1}

(1986) in setaria grass, Pillai (1986) in guinea and setaria grass, Jayakumar (1997) in hybrid napier and Vineetha (1995) in gamba grass.

Application of phosphorus also had significant effect on N content and uptake. Higher levels of phosphorus registered highest N content and uptake values. The improvement of N content with phosphorus fertilization could be attributed to the fact that added phosphorus increased the N content by balanced nutritional environment inside the plant, which favoured better crop yield. The dry matter yield and crude protein content were also higher due to phosphorus addition, which might be the reason for the higher uptake of N by grass. Higher uptake of nitrogen due to phosphorus application was noted in the case of *Chrysopogon fulvus* (spreng) (Dwivedi *et al.*, 1980) and by Pillai (1986) in guinea and setaria grass.

S x N interaction was found to be significant for N content and uptake. There was a significant increase in N content and uptake with higher levels of nitrogen under open and shaded situation (Fig. 19). Increase in nitrogen content with increase in nitrogen may be due to more absorption of nitrogen and higher leaf area index. Since N increases dry fodder yield, increasing N levels increased N uptake also. Similar finding also reported by Pillai (1986) in guinea and setaria grass.

Significant S x P interaction was found for N content only. Under open, 75 kg P_2O_5 ha^{-1} (p_3) recorded highest N content while under shaded situation, N content at 50 and 75 kg P_2O_5 ha^{-1} were found to be on par. The improvement in N content with phosphorus fertilization could be attributed to the fact that added phosphorus increased the content by balanced nutritional environment inside the plant, which favoured better crop yield.

N x P interaction was significant for total N uptake only. There was a progressive increase in N uptake with higher levels of nitrogen and phosphorus (Fig. 20). Sumner and Farina (1986) stated that N and P have mutually synergistic effects and this resulted in growth stimulation

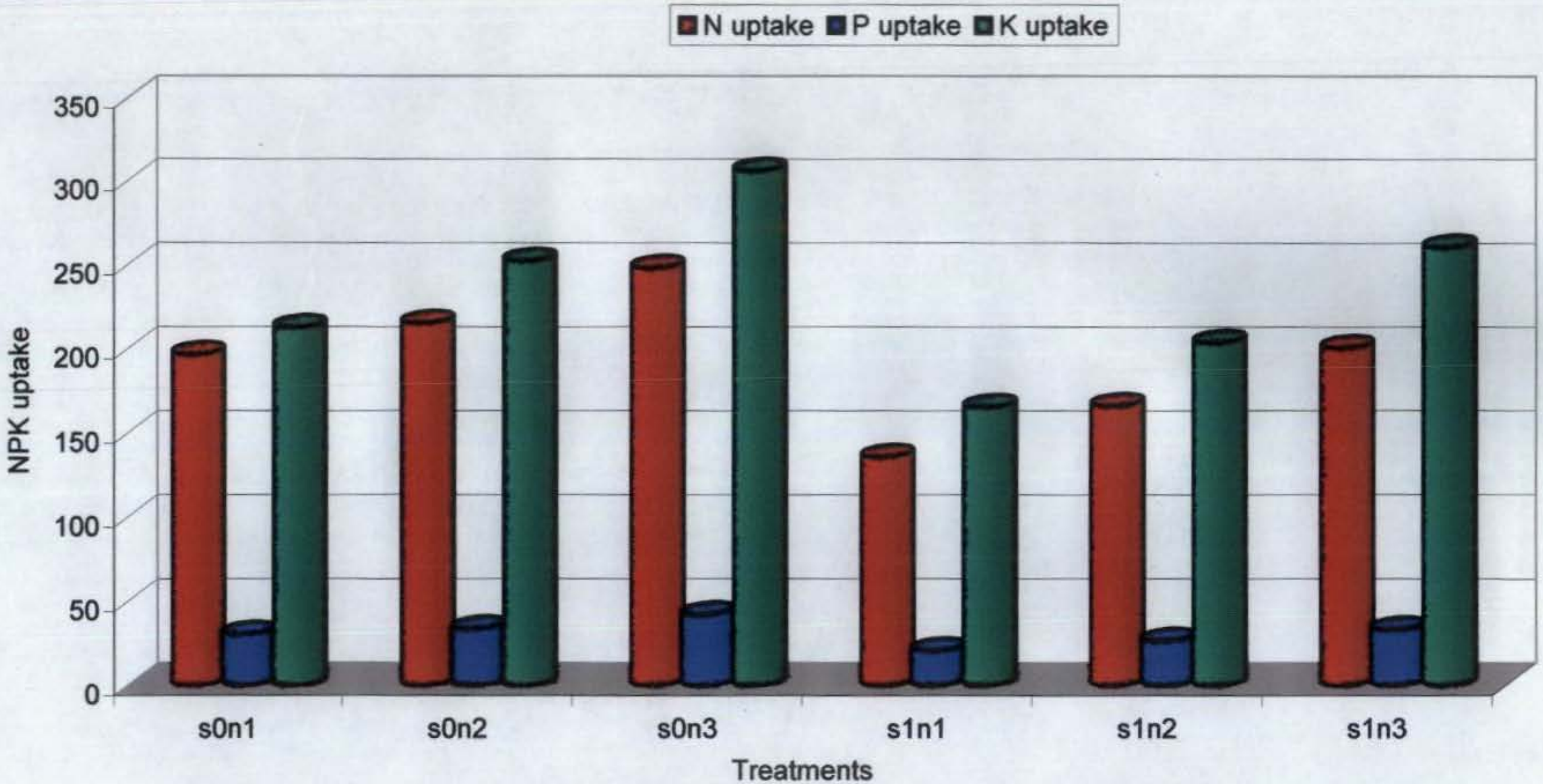


Fig. 19. Interaction effects of shade levels and nitrogen on the uptake of nitrogen, phosphorus and potassium by guinea grass, kg ha^{-1}

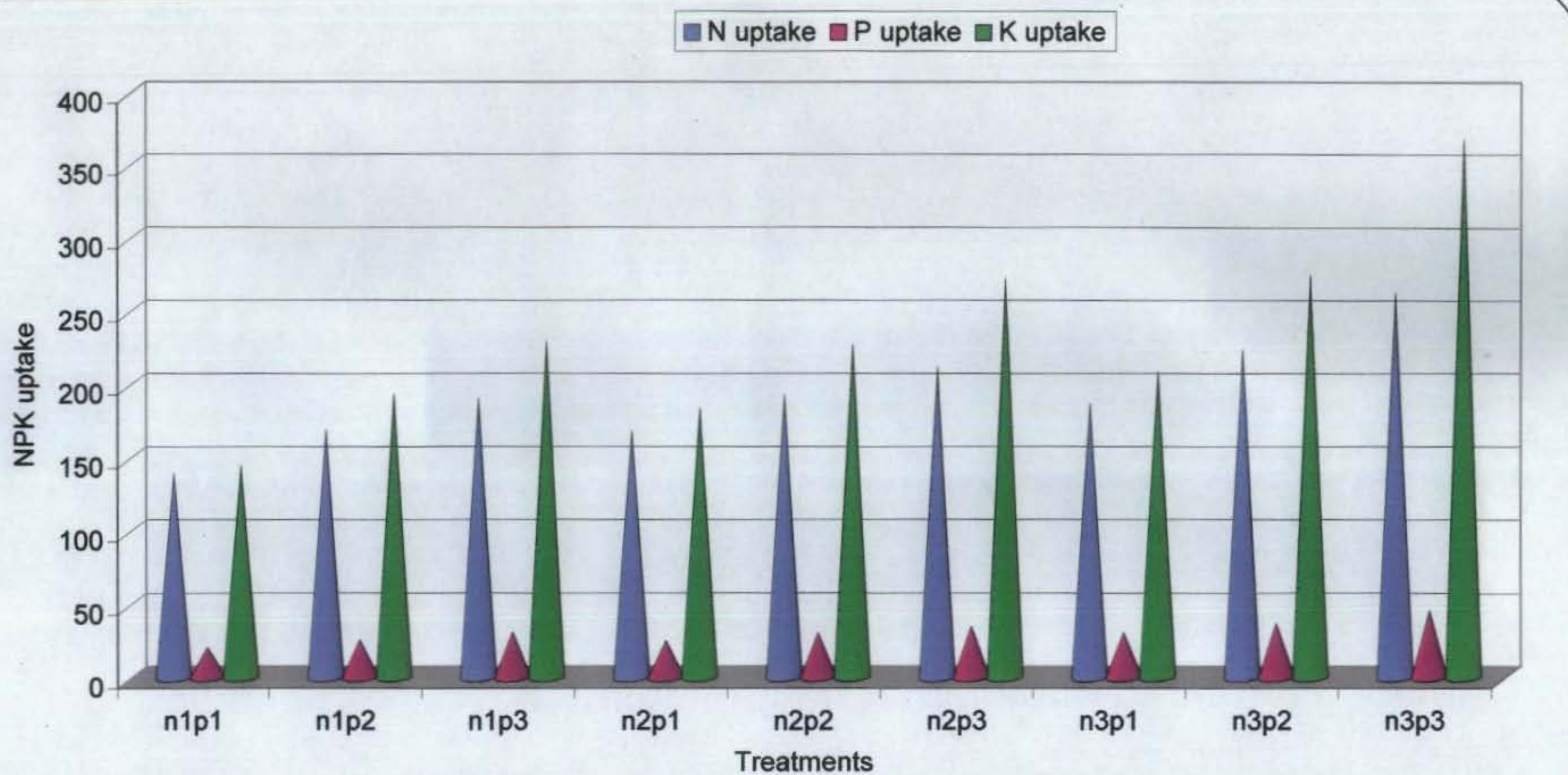


Fig. 20. Interaction effects of nitrogen and phosphorus on the uptake of nitrogen, phosphorus and potassium by guinea grass, kg ha^{-1}

and caused enhanced uptake of elements. In the present study also it is seen that N and P stimulate growth of the plants and hence this might have caused the increased uptake of nitrogen. Similar results were reported by Pillai (1986) in guinea and setaria grass and Vineetha (1995) in gamba grass.

5.6.2 P Content and Uptake

Shade levels had significant influence on P uptake of guinea grass only (Fig. 18). There was no significant influence of shade levels on P content as reported by Mayland and Grunes (1974). Total P uptake decreased with shade levels, which may be due to the increase in dry matter yield under open conditions. Similar results were also reported by Watson *et al.* (1984) in marshall rye grass, Pillai (1986) and Anita (2002) in guinea grass.

Application of nitrogen and phosphorus had significant influence on P content and uptake. N application was helpful in enhancing the content and uptake of P and the maximum was recorded when 300 kg N ha^{-1} was applied. Increased N content resulted in increased absorption of phosphorus, which in turn increased the phosphorus content and uptake as reported by Tisdale and Nelson (1975). Increased P uptake may be attributed to the increased content of P as a result of high growth rate of the plants due to higher availability of nutrients. Rathore and Vijayakumar (1978) obtained similar results in dinanath grass. They reported that higher dry matter production was due to high P uptake at the higher levels of N, which was in conformity with the results of Pillai (1986) in guinea and setaria grass and Vineetha (1995) in gamba grass.

P content in fodder was influenced by application of phosphorus. Increased supply of phosphorus might have increased the growth of crop roots, which further caused more phosphorus to be absorbed and translocated to the aerial portion. Thus content in shoot of p_3 recorded higher value than the treatments receiving lower supply. This is in accordance with the results obtained by Chandini (1980) in guinea grass, setaria grass and congosignal, Pillai (1986) in guinea and setaria grass, Krishnan (1993) in guinea grass and Vineetha (1995) in gamba grass.

The uptake of P increased with an increase in levels of P especially so with high doses. It was accompanied by an increase in P content of the fodder, showing that increased P uptake was a combined function of dry matter yield and phosphorus content (Rathore and Vijayakumar, 1978). Similar results were also reported by Pillai (1986) in guinea grass and setaria grass and Vineetha (1995) in gamba grass.

S x N interaction was significant for P uptake and uptake was higher at increasing levels of nitrogen both under shade and open (Fig. 19). This might be due to higher dry fodder yield obtained at higher levels of N.

Significant N x P interaction was found for P uptake only. There was progressive increase in P uptake with higher levels of nitrogen and phosphorus (Fig. 20). Sumner and Farina (1986) stated that N and P have mutually synergistic effects and this resulted in growth stimulation and caused enhanced uptake of elements. In the present study also it is seen that N and P stimulates growth of the plants and hence this might have caused the increased content and uptake of phosphorus. Similar finding also reported by Pillai (1986) in guinea and setaria grass.

5.6.3 K Content and Uptake

Shade levels had significant effect on K content only (Fig. 17). Uptake of potassium was found to be highest at zero per cent shade level but no significant difference was noticed. The potassium content was high in the shaded situation. Similar results were also reported by Myhr and Saebo (1969) and Mullakoya (1982) in guinea grass, Watson *et al.* (1984) in marshall rye grass, Pillai (1986) in guinea grass, Wilson *et al.* (1990) in *Paspalum notatum*, and Misra *et al.* (2002) in *Brachiaria brizantha, Pennisetum polystachyon, Brachiaria decumbens, Brachiaria bladhii* and *Panicum antidotale*.

Application of nitrogen and phosphorus had significant effect on K content and uptake. Significant and progressive increase in K content and uptake was observed due to higher levels of nitrogen. In this study, N applications might have helped to increase the K absorption of grass with increase in nitrogen dose. Lorsen (1966) obtained similar increase in K content in cocks foot and timothy grasses due to N application. Similar findings were also reported by Abraham *et al.* (1980) in dinanath grass, Pillai (1986) in guinea and setaria grass and Jayakumar (1997) in hybrid napier. Uptake of K was significantly increased due to N levels. Rathore and Vijayakumar (1978) reported that there was a consistent rise in the uptake of K due to N application as a result of increase in dry matter which is in accordance with Pillai (1986) in guinea and setaria grass and Vineetha (1995) in gamba grass.

Higher levels of phosphorus registered highest K content and uptake. Increase in P application resulted in increased dry matter production which might have increased K absorption from the soil thereby increasing the K content of grasses. Similar instances of increased K content of grasses due to P application were reported by Hendrikson (1960) and Pillai (1986) in guinea and setaria grass. The increased dry matter yield with higher K content with the application of P might have led to more uptakes of K, as reported by Pillai (1986) in guinea and setaria grass.

N x P interaction was found to be significant for K content and uptake. K content and uptake increased with increasing levels of nitrogen and phosphorus (Fig. 20). Adequate supply of phosphorus is required to utilize efficiently nitrogen as it helps in development of extensive root system for better use of soil moisture and nutrients (Bajpai and Gupta, 1979; Yadav *et al.* 1984). Sumner and Farina (1986) stated that N and P have mutually synergistic effects and this resulted in growth stimulation and caused enhanced uptake of elements. In the present study also it is seen that N and P stimulating growth of the plants and hence this might have caused the increased content and uptake of potassium. Similar results reported by Pillai (1986) in guinea and setaria grass and Vineetha (1995) in gamba grass.

5.7 NUTRIENT STATUS OF THE SOIL AFTER THE EXPERIMENT

5.7.1 Available Nitrogen Content

Shade levels had no significant influence on available nitrogen content of soil.

The different N levels significantly influenced the available nitrogen content of soil. Higher levels of N increased the available N content of soil. The results confirm the findings of Balbatti (1980) in a trial with hybrid napier, Vineetha (1995) in gamba grass, Jayakumar (1997) in hybrid napier and Sonia (1999) in signal grass.

Different levels of P significantly increased the nitrogen content of the soil. Similar results were obtained by Chandini (1980) in a trial with guinea and setaria grass and Vineetha (1995).in gamba grass.

5.7.2 Available Phosphorus Content

Shade levels had significant influence on available P content of soil. P status of soil was higher in 50 per cent shade than in open. Comparison of the data from the open and 50 per cent shade showed that a reasonably higher P residue is left in the soil in shaded situation than under open area. This might be due to the decreased uptake of P under shade and due to lesser mineralisation of P taking place in shade compared to open area as evidenced by the lower yield in shaded condition. Similar result was obtained by Pillai (1986) in a trial with guinea and setaria grass.

Higher levels of nitrogen significantly reduced P content of soil. This might be due to higher uptake of P with increasing N levels, which is indicated by higher yield with increasing N levels. Similar finding was reported by Pillai (1986) in a trial with guinea and setaria grass.

All levels of P resulted in significant increase in P content of soil. This confirms the results obtained by Kanwar (1978). He stated that phosphorus is a relatively immobile element and it is recognized that proportion of fertilizer P taken up by a single crop is often low and the P fertilizer have residual value. He has also reported that residual effect would be increased when the rate of application increased, due to increase in phosphate potential. Similar results also obtained by Pillai (1986) in a trial with guinea and setaria grass and Vineetha (1995) in gamba grass.

S x N, S x P, N x P interactions were significant. Pillai (1986) in a trial with guinea grass and setaria grass also reported a similar S x N and S x P interaction. Available P content of soil decreased with increase in nitrogen levels under open and shaded situation. P content of soil increased with increase in phosphorus levels under open and shaded situation as well as with different doses of nitrogen.

5.7.3 Available Potassium Content

There was a significant reduction of potassium content of soil with increased N application, which might be due to increased uptake for producing higher yield with higher N levels. The results are in conformity with the findings of Sonia (1999) in signal grass.

P application significantly increased the K content upto 50 kg P_2O_5 ha^{-1} and thereafter a significant reduction with 75 kg P_2O_5 ha^{-1}. Chandini (1980) also observed similar results in soils cropped with guinea grass, congosignal and setaria grass.

S x N, S x P and N x P interaction significantly influenced the potassium status of soil.

5.8 ECONOMICS

The results of the economic analysis indicated that the net income and benefit – cost ratio was highest when guinea grass was grown with 300 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1} (Fig. 21). Guinea grass can be

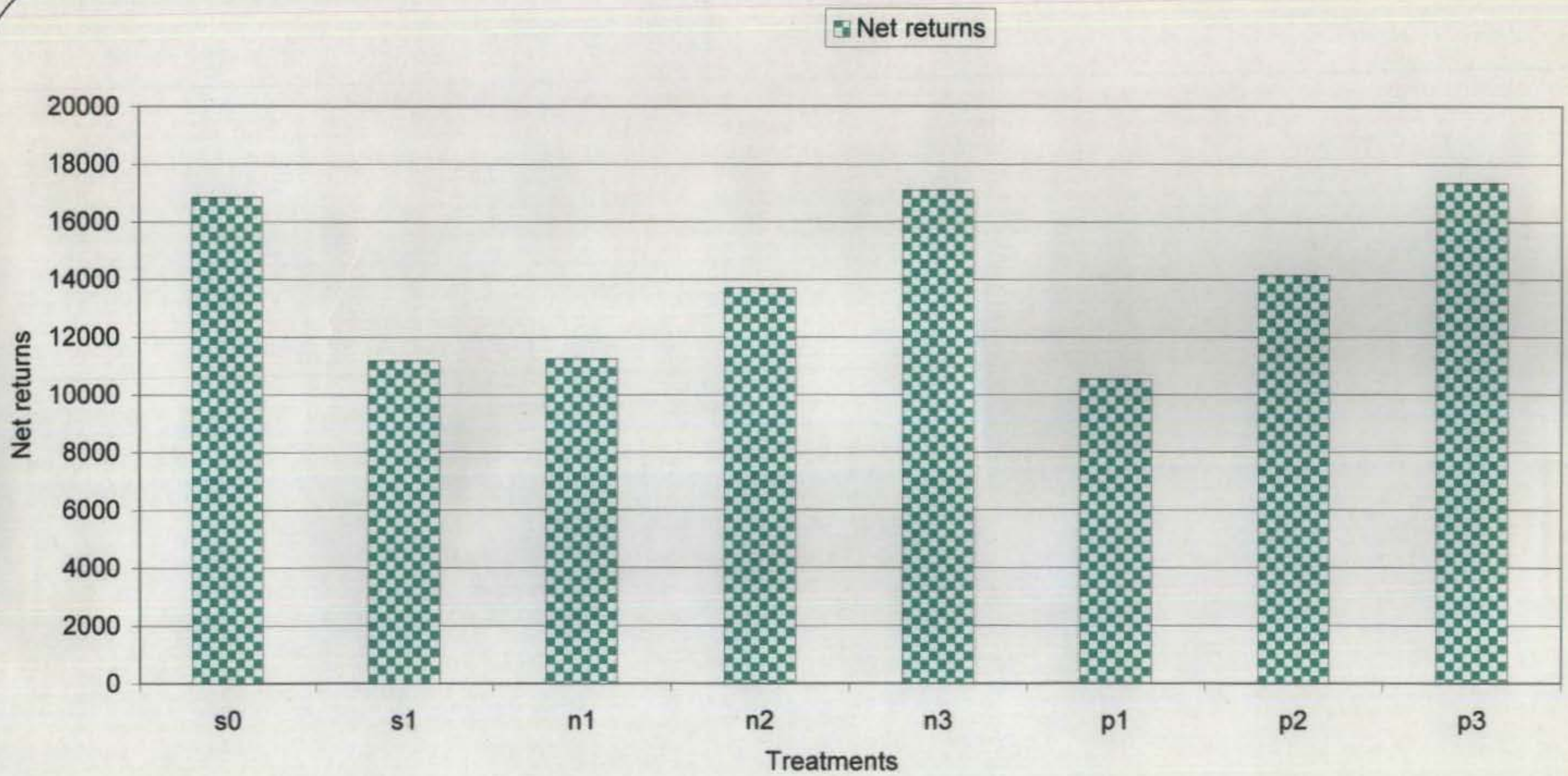


Fig. 21. Main effects of shade levels, nitrogen and phosphorus on net returns (Rs. ha^{-1})

economically cultivated in shade intensities upto 50 per cent shade level where the B:C ratio is 1.86 compared to 2.02 under open conditions. This is mainly due to the higher green fodder and dry fodder yields realized from the said treatments. Higher levels of nitrogen and phosphorus registered higher net returns and benefit – cost ratio.

SUMMARY

6. SUMMARY

An investigation was undertaken in the Instructional Farm, College of Agriculture, Vellayani to find out the nitrogen and phosphorus requirement for guinea grass (*Panicum maximum* J.) under zero and fifty per cent shade intensities. The experiment was laid out in split plot design with three replications. Combination of two levels of shade (0 and 50 per cent), three levels of nitrogen (100, 200 and 300 kg ha^{-1}) and three levels of phosphorus (25, 50 and 75 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. Application of nitrogen and phosphorus resulted in linear increase in the height of plant. Under open and 50 per cent shade, highest level of nitrogen (300 kg ha^{-1}) and phosphorus (75 kg ha^{-1}) registered more plant height. The highest level of nitrogen was found to record the highest plant height at all the three levels of phosphorus.
2. In general, tiller number, green fodder yield and dry fodder yield were significantly higher at open condition and a linear decrease in yield with shading to the tune of 27.90 per cent in green fodder and 27.90 per cent in dry fodder yield was observed in 50 per cent shade level compared to open. Application of nitrogen at the rate of 300 kg ha^{-1} and phosphorus @ 75 kg ha^{-1} resulted in maximum number of tillers, green fodder yield and dry fodder yield and the corresponding green fodder yield increase was 31.10 and 31.2 per cent and the corresponding dry fodder yield increase was 31.00 per cent and 31.20 per cent at 300 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1} respectively compared to their lowest levels.

3. The N levels tried, did not influence the green fodder yield in different shade intensities. Hence same level of nitrogen is sufficient to get equal yield under open and 50 per cent shade.
4. P application at different levels of p_1, p_2 and p_3 was found to influence the green fodder yield in open and 50 per cent shade significantly. Higher levels of P are required in 50 per cent shade compared to open to get equal fodder yield.
5. Interaction result indicate that highest levels of nitrogen (300 kg ha^{-1}) and phosphorus (75 kg ha^{-1}) produced more number of tillers in open and 50 per cent shade. Significantly higher number of tillers were produced by the treatment combination n_3p_3.
6. In open, n_3 treated plants produced highest number of tillers while in 50 per cent shade, nitrogen did not influence the tiller number.
7. When individual harvest are considered, the green and dry fodder yields were higher at the open condition in all the harvests.
8. Leaf : stem ratio was reduced significantly with increasing shade levels. Application of nitrogen and phosphorus also showed a linear increase in leaf : stem ratio. Under open and 50 per cent shade levels, 300 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1} registered highest leaf : stem ratio.
9. Leaf area index was significantly higher in open in all the harvests. Higher levels of nitrogen and phosphorus registered higher leaf area index. The treatment combinations s_0n_3, s_0p_3 and n_3p_3 recorded higher leaf area index.
10. CGR, RGR and NAR were significantly higher at open than at 50 per cent shade. Highest levels of nitrogen and phosphorus resulted in higher CGR, RGR and NAR.
11. Chlorophyll content increased significantly with increase in shade levels. Higher levels of nitrogen and phosphorus resulted in significantly higher chlorophyll content of the plant.

12. Shading improved the quality of fodder. Crude protein content of the plant enhanced with increase in shade levels. Higher levels of applied nitrogen and phosphorus increased the protein content at the fodder. The treatment combinations s_1n_3 and n_3p_3 produced higher crude protein content.
13. Crude fibre content reduced significantly with increase in shade levels. Highest level of nitrogen (300 kg ha^{-1}) and phosphorus (75 kg ha^{-1}) produced guinea grass with lower crude fibre content. The treatment combinations s_1n_3, s_1p_3 and n_3p_3 produced lower crude fibre consent.
14. Total protein yield increased significantly in open and it was reduced by 23.4 per cent in 50 per cent shade. Higher doses of nitrogen (300 kg ha^{-1}) and phosphorus (75 kg ha^{-1}) resulted in higher total protein yield to the tune of 25.7 and 25.4 percent respectively. The treatment combinations s_0n_3 and n_3p_3 recorded higher protein yield.
15. N and K_2O content of guinea grass increased significantly with increase in shade levels. Higher doses of nitrogen and phosphorus resulted in higher content of nutrients.
16. N and P_2O_5 uptake increased significantly with decrease in shade levels. Application of higher levels of nitrogen and phosphorus resulted in higher uptake of nutrients. The treatment combination s_0n_3 registered higher N uptake and P_2O_5 uptake while n_3p_3 registered higher N, P_2O_5 and K_2O.
17. Shade levels had no significant influence on available nitrogen content of the soil after the experiment. Application of nitrogen and phosphorus significantly increased the available nitrogen content of the soil.
18. There was a significant increase in phosphorus content of the soil with increase in shade levels and the highest doses of nitrogen

(300 kg ha^{-1}) and phosphorus (75 kg ha^{-1}) registered highest phosphorus content of the soil, after the experiment.

19. Application of nitrogen significantly reduced potassium status of the soil, after the experiment while application of phosphorus shown a parabolic type of response. The treatment combinations s_0n_1, s_0p_2 and n_1p_2 registered highest available potassium status of the soil, after the experiment.
20. 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 1.86 compared to 2.02 under open.

Future line of work

Being a shade tolerant crop, the suitability of different cultivars of guinea grass to varying shade intensities is to be evaluated. Nutrient requirement for optimum fodder production in different shade intensities are to be worked out with higher levels of nutrients since a linear trend was seen with the levels of N and P_2O_5 tried in the present investigation.

REFERENCES

7. REFERENCES

Abraham, C.T. 1978. Performance of dinanath grass (*Pennisetum pedicellatum* Trin.) as influenced by nitrogen and lime application. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 90 p.

Abraham, C.T., Sreedharan, C. and Pillai, G.R. 1980. Effect of nitrogen and lime on forage quality of dinanath grass. *Forage Res.* 6: 95-98

Acuna, P.G.H. and Wilman, D. 1993. Some effects of added phosphorous on perennial ryegrass – white clover swards. *Grass Forage Sci.* 48: 416-420

Agrawal, R.K. Sharma, K.C and Singh, K.K. 2002. Effect of split application of nitrogen on productivity and nutritional traits of perennial grasses. National Symposium on Grass land and fodder Research in the New Millenium. 30th October – 1st November, 2002. Indian Grassland and Fodder Research Institute, Jhansi. *Abstract*: 116-117

Ajithkumar, K. 1999. Production dynamics of ginger (*Zingiber officinale* R.) under varying levels of shade, nutrients and triazole. Ph. D thesis, Kerala Agricultural University, Thrissur, 266 p.

Andrade, J.B., Benintende, R.P., Ferrari, J.E. and Paulino, V.T. 1996. Effect of nitrogen and potassium fertilizers on yield and composition of forage of *Brachiaria ruziziensis*. *Pesquisa Agropecuaria Brasileira* 31:617-620 (Portuguese)

Anita, M.R. 2002. Shade response of guinea grass (*Panicum maximum* J.) under varying levels of potash. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 140 p.

Anu, S. 2001. Nutrient management of upland rice (*Oryza sativa* L.) varieties in coconut gardens. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 99 p.

A.O.A.C. 1975. *Official and Tentative Methods of Analysis*. Twelfth edition. Association of Official Agricultural Chemists, Washington, 218 p.

Archana, B. 2001. Integrated nutrient management for Coleus (*Solenostemon rotundifolius* (Poir) Morton). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 100 p.

Attridge, T.H. 1990. *Light and Plant Responses*. A division of Hodder and Stoughton Ltd., Great Britain, 101 p.

Awada, T., Perry, M.E.L. and Schacht, W.H. 2003. Photosynthetic and growth responses of the C_3 *Bromus inermis* and the C_4 *Andropogon gerardii* to tree canopy cover. *Canadian J. Pl. Sci.* 83: 533-540

Bahmani, I., Varlet-Grancher, C., Hazard, L., Matthew, C., Betin, M., Langlais, A., Lemaire, G. and Thom, E.R. 2000. Post flowering tillering in contrasting light environments of two New Zealand perennial rye grass cultivars with different perennation strategies. *Grass and Forage Sci.* 55: 367-371

Baig, M.J., Anand, A and Bhatt, R.K. 2002. Nutritional alteration in *Cenchrus* genotypes influenced by different light intensities. National Symposium on Grass land and fodder Research in the New Millenium. 30th October – 1st November, 2002. Indian Grassland and Fodder Research Institute, Jhansi. *Abstract*: 62-64

Bajpai, P.D. and Gupta, B.R. 1979. Effect of salinization, phosphorus fertilization and their interaction on the symbiosis between *Rhizobim trifolii* and berseem (*Trifolium alexandinum* L.). *J. Indian Soc. Soil Sci.* 27: 462-469

Balasko, J. A. 1977. Effect of N, P and K fertilization on yield and quality of tall fescue forage in winter. *Agron. J.* 69: 425-428

Balbatti, M.S. 1980. Effect of nitrogen level and low spacing on yield and quality of hybrid napier grown with and without a legume. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 84 p.

Belanger, G., Bregard, A. and Michaud, R. 2002. Phosphorus uptake and concentration of Timothy Genotypes under varying N applications. *Crop Sci.* 42: 2044-2048

Bhati, T.K. and Mathur, B.K. 1984. Effect of nitrogen, phosphorus and farmyard manure on forage and protein yields of *Cenchrus ciliaris* Linn. *Indian J. Agron.* 29: 80-86

Bhati, T.K. and Singh, M. 1982. Effect of nitrogen and phosphorus on forage yield and nutritive value of *Cenchrus ciliaris* Vahl. *Forage Res.* 8: 43-48

Bhatt, R.K and Sinha, N.C. 1990. Photosynthetic pigment a prerequisite for grass productivity. *Photosynthetica* 24: 147-150

Bhatt, R.K., Misra, L.P., Vandana and Tiwari, H.S. 2002. Growth and biomass production in tropical range grasses and legumes under light stress environment. *Indian J. Pl. Physiol.* 7: 349-353

Black, C.A. 1968. *Soil Plant Relationships*. Second Edition. John Wiley and Sons Inc, New York, 792 p.

Blair, R.M., Alcaniz, R. and Harrel, A. 1983. Shade intensity influences the nutrient quality and digestibility of southern deer browse leaves. *J. Range Mgmt* 36: 257-264

Blanche, S.A. 1999. The influence of light reduction upon the production, persistence and chemical composition of some forages. *J. Wildl. Mgmt* 63: 96-102

Bogdan, A.V. 1977. *Tropical Pasture and Fodder Plants (Grasses and Legumes*). Longman, London, 425 p.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agron. J.* 54: 464-465

Brejda, J.J., Brown, J.R., Wyman, G.W. and Schumache, W.K. 1994. Management of Switchgrass for forage and seed production. *J. Rangeland Mgmt* 47: 22-27

Buxton, D.R. and Fales, S.L. 1994. Plant environment and quality. *Forage Quality, Evaluation and Utilisation* (eds. Fahney, G.C. and Barnes, D.K.). Proceedings of the Symposium on Forage Quality, Evaluation and Utilisation, 1992. American Society of Agronomy, Madison, USA, pp.155-199

Buxton, R.D. 2001. *Growing Forages Under Variable Environmental Conditions.* Research Summaries No. 21, U. S. Dairy Forage Research Centre, Iowa State University, Ames, 204 p.

Caceres, O., Esperance, M. and Hernandez, N.C. 1986. Studies on hay making on three outstanding grasses. *Pastos Y Forajes* 9: 185-189

Cameron, A. G. and Ross, B. J. 1996. Fertilizer responses of established grass pastures in the Northern Territory. *Trop. Grassld* 30: 426–429

Cameron, D.M., Rance, S.J., Jones, R.M., Edwards, D.A. and Barnes, A. 1989. Project STAG: an experiment study in agroforestry. *Aust.J. agric. Res.* 40: 699-704

Capriel, M. and Ashcroft, G.L. 1972. Effect of irrigation, harvest interval and nitrogen on the yield and nutrient composition of napier grass. *Agron. J.* 64: 376-378

Carvalho, M.M., Freitas, V. de. P. and Xavier. D.F. 2002. Initial flowering, drymatter yield and nutritive value of tropical forage grasses under natural shading. *Pesquisa Agropecuaria Brasileira* 37: 717-722 (Portuguese)

Carvalho, M.M., Martins, C.E., Siqueira, C. and Savaiva, O.F. 1992. Growth of *Brachiaria species* with lime as top dressing and nitrogen rates. *J. Revista Brasileira de ciencia do solo* 6: 69–74 (Portuguese)

Chakraborty, T., Raj, D.K. and Sounda, G. 2002. Effect of fertilizers, rock phosphate and Azospirillum on growth and yield of finger millet (*Eleusine coracana* L. Gaertn). *Indian J. agric. Res.* 36: 192-195

Chandini, S. 1980. Fodder production potential of grass- legume mixtures. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 145 p.

Chandini, S., Pillai, G.R. and Sreedharan, C. 1985. Fodder production potential of grass legume mixtures as influenced by P levels. *Agric. Res. J. Kerala* 23: 196-199

Coblentz, W.K., Daniels, M.B., Gunsaulis, J.L., Turner, J.E., Scarbrough, D.A., Humphrey, J.B., Coffey, K.P., Moore, P.A. Jr., Teague, K.A. and Speight, J.D. 2004. Effect of nitrogen fertilization on phosphorus uptake in bermuda grass forage grown in high soil test phosphorus sites. *Professional Anim. Scientist* 20: 146-154

Costa, N.de L. 1989. Agronomic evaluation of forage grasses with three levels of phosphate fertilizes. *Comunicado Tenico- unidade de Execucao de Pesquisa de Ambito Estadual de Porto Velho No: 80.* 4 p. (French)

Davaria, R.L., Khanpara, V.D., Kaneria, B.B., Mathukia, R.K. and Asodaria, K.B. 2001. Effect of phosphorus and sulphur on growth, yield, quality and nutrient content of mustard (*Brassica juncea*). *Gujarat agric. Univ. Res. J.* 26: 77-79

Dayal, J.S. and Goswami, C.L. 2003. Effect of phosphorus application on growth, chlorophyll and proline under water deficit in cluster bean (*Cyamopsis tetragonoloba* L. Taub). *Indian J. Pl. Physiol.* 8: 150-154

Dias- Filho, M.B., Neto, M.S. and Serrao, E.A.S. 1989. Use of partially acidualated rock phosphate and simple phosphate in *Brachiaria brizantha* cv. Marandu establishment. *Pasturas Tropicales*11: 25-28

Dias-Filho, M.B. 2000. Growth and biomass allocation of the C_4 grasses *Brachiaria brizantha* and *B.humidicola* under shade. *Pesquisa Agropecuaria Brasileira* 35: 2335-2341 (Portuguese)

Dias-Filho, M.B. 2002. Photosynthetic light response of the C_4 grasses *Brachiaria brizantha* and *B. humidicola* under shade. *Scientia Agricola* 59: 65-68

Digvijay, S., Singh, V. and Joshi, Y.P. 2000. Effect of nitrogen fertilization and cutting intervals on yield and quality of napier bajra hybrid. *Range Mgmt Agroforesty.* 21: 128-34

Duggar, B.M.1903. The physiological effects of shading plants. *Proc. Soc. hort. Sci.* 19: 15-17

Dwivedi, G.K and Kanodia, K.C. 1986. Effect of nitrogen levels on different varieties of *Setaria sphacelata* (Schumach) stapf Et Ce, Hubb Ex M. B. Moss under rainfed conditions. *Forage Res.* 12: 21–25

Dwivedi, G.K., Kanodia, K.C. and Rai, P. 1980. Effect of nitrogen and phosphorus on quantity and quality of herbage of *Chrysopogon fulvus* (Spreng.). *Forage Res.* 6:181-186

Dwivedi, G.K., Tomer, P. S., Dixit, O.P and Singh, R.A. 1991. Effect of nitrogen and phosphorus levels of seed yield of *Pennisetum polystachyon* (L.) Schult. *Haryana J. Agron.* 7: 25–28

Enyi, B.A.C. 1973. The effect of time of planting and nitrogen application on growth, development and yield of lesser yam (*Dioscorea esculenta*). *Nigerian J. Sci.* 7: 93-103

Eriksen, F.I. and Whitney, A.S. 1981. Interaction of light intensity and nitrogen fertilizers on six forage grasses. *Agron. J.* 73: 427-433

Evans, J.R. and Seemann, J.R. 1996. Carbon dioxide diffusion inside leaves. *Pl. Physiol.* 110: 339-346

Ezenwa, J., Aribisala, O.A and Aken'ova, M.E. 1996. Dry matter yields of *Panicum* and *Brachiaria* with nitrogen fertilization of *Pueraria* in an oil palm plantation. *Trop. Grassld* 30: 414–417

Fernandes, F.M., Isepon, O.J. and Nascimento, V.M. 1985. Response of *Brachiaria decumbens* Stapf to levels of NPK application in soil originally covered with cerrado vegetation. *Cientifica* 13: 69–97

Fukai, S., Alcoy, A.B., Lamela, A.B. and Patterson, R.D. 1984. Effect of solar radiation on growth of Cassava (*Manihot esculenta* Crantz). *Fld. Crops Res.* 9: 347-360

Gaborcik, N. and Javorkova, A. 1990. Photosynthetic rate, leaf area index and drymatter production of a grassland ecosystem under different managements. *Pol'nohospodarstvo* 36: 20-24 (Czech)

Gardener, F.P., Pearce, B.B. and Mitchell, R.L. 1985. *Physiology of Crop Plants*. Iowa State University Press, Ames, Iowa, USA, 262 p.

Gauder, M.M., Chimmad, V.P., Janardhan, K.V. and Panchal, Y.C. 1988. Yield and growth performance of onion (*Allium cepa* L.). *Indian J. Pl. Physiol.* 31:76-83

Gelderman, R.H., Gerwing, J.R. and Twidwell, E. 2002. Point-injected phosphorus effects on established cool-season gram yield and phosphorus content. *Agron. J.* 94: 48-51

George, S. 1996. Agronomic evaluation of biofarming technique for forage production in coconut garden. Ph.D thesis, Kerala Agricultural University, Thrissur, 224 p.

Gomez, K.A. 1972. *Techniques for field experiments with rice*. International Rice Research Institute, Los Banos, 33 p.

Govindaswamy, M. and Manickam, T.S. 1988. Effect of nitrogen on the content of oxalic acid in Bajra – Napier hybrid grass BN 2. *Madras agric. J.* 75: 5–6

Gregory, G.F. 1917. Physiological conditions in cucumber houses. *Plant Physiology* (ed. Steward, F.L.). Academic Press, New York. pp.19-28

Gupta, R.P. and Dakshinamoorthi, C. 1980. *Procedures for Physical Analysis of Soil and Collection of Agro-meteorological Data*. Indian Agricultural Research Institute, New Delhi, 280 p.

Gupta, S.C., Gupta, D.K., Azad, B.S. and Soni, K.C. 1998. Effect of nitrogen and plant spacing on green fodder yield of *Setaria sphacelata*. *Forage Res.* 24:29-32

Hall, T.J. 1993. Response of *Stylosanthes hamata* cv. Verano and native pastures to fertilizers on two light textured soils in north-west Queensland. *Trop. Grassld* 27: 75 – 86

Hazra, C.R. and Tripathi, S.B. 1989. Soil properties and yield of sweet clover as influenced by phosphate application under agroforestry. *Forage Res.* 15:69-78

Hendrikson, A. 1960. Influence of fertilizer treatment on the mineral content of pastures. *Soils Fert.* 23: 363

Hernandez, M. and Cardenas, M. 1990. Studies on the effect of residual phosphorus fertilizer applied to guinea grass cv. Likoni. *Pastos y Forajes* 13: 165-170

Hiscox, J.D. and Israelstam, G.F. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian J. Bot.* 57: 1332-1334

Hong, K.Y. and Hsu, F.H. 1993. Effects of fertilizer application on forage yield and quality of dwarf napier grass. *J. Taiwan Livestock Res.* 26: 237-250

Illavska, I., Rataj, D., Gaborcik, N. and Gonda, L. 2001. The effect of mineral fertilizer application on some parameters of growth production process in temporary grassland. *Acta Fytotechnica et Zootechnica* 4: 5-9 (French)

Jackson, M.L. 1973. *Soil Chemical Analysis*. Second edition. Prentice Hall of India (Pvt.) Ltd., New Delhi, 498 p.

Jacob, R. 1999. Intensive fodder production under irrigated conditions in partial shade. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 128 p.

Jadhav, B.B. 1987. Effect of partial shading on the yield of rice. *Indian J. agric. Sci.* 57: 515-516

Jayakumar, G. 1997. Intensive fodder production through legume intercropping in hybrid napier. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 130 p.

Jiang, Y., Duncan, R.R. and Carrow, R.N. 2004. Assessment of low light tolerance of seashore Paspalum and Bermuda grass. *Crop Sci.* 44: 587-594

Joaquin, B.M., Hernandez, A., Perez, J., Herrera, J.G., Garcia, G. and Trejo, C. 2001a. Nitrogen fertilizer and harvest date effects on seed yield and quality of guinea grass (*Panicum maximum* Jacq.). *Pasturas Tropicales* 23: 2-8

Joaquin, B.M., Hernandez. A., Perez, J., Herrera, J.G., Garcia. G. and Trejo, C. 2001b. Effects of nitrogen fertilizers and harvest date on seed production in guinea grass (*Panicum maximum* Jacq.): yield components. *Pasturas Tropicales* 23: 10-15

Jung, H.B., Ito, T. and Maruo, T. 1994. Effects of shading and NO_3: NH_4 ratios in the nutrient solution on the growth and yield of pepper plants in nutrient film technique culture. *J. Japanese Soc. hort. Sci.* 63: 371-377

Kaligis, D.A. and Sumolong, C. 1991. Forage species for coconut plantation in North Sulawesi, *Proceedings of Workshop on Forages for Plantations Crops, Australian Centre for Industrial and Agricultural Research Proc.No.32, June 27-29, 1990* (eds. Shelton, H.M. and Stur, W.W.). Sanur Beach, Bali, Indonesia, pp.16-20

Kamaraj, S., Devarajan, L., Latha, M.R. and Indirani, R. 2002. Efficacy of levels and sources P on yield and nutrient uptake of rice var. TRY-1. *Madras agric. J.* 89: 321-323

Kanno, T., Macedo, M.C. and Bono, J.A. 1999. Growth responses of *Brachiaria decembens* cv. Basilisk and *Brachiaria brizantha* cv. Marandu to phosphorus supply. *Grassld Sci.* 45: 1-8

Kanwar, J.S. 1978. *Soil Fertility- Theory and Practice*. Indian Council of Agricultural Research, New Delhi, 533 p.

Kaushal, P., Malaviya, D.R. and Singh, K.K. 2000. Identification of shade tolerant genotypes and alterations in nutrient contents under shade in guinea grass. *Range Mgmt and Agroforestry* 21: 74-78

Kawata, Y. and Matsunaka, T. 1999. Differences among temperate grass species in growth response to nitrogen nutrition during the second growing period. *Grassld Sci.* 44: 368-373

Kephart, K.D. and Buxton, D.R. 1993. Cell wall digestibility affects forage value of woody twigs. *Crop Sci.* 33: 831-837

Kephart, K.D. and Buxton, D.R. 1996. *Non structural carbohydrate in cool and warm season perennial grasses adapted to shaded conditions*. Research Summaries No.16, U.S. Dairy Forage Research Centre, Iowa State University, Ames, 162 p.

Kephart, K.D., Buxton, D.R. and Taylor, S.E. 1992. The utilization of carbohydrate reserves in pasture plants after defoliation. *Crop. Sci.* 32: 1033-1038

Kinyanario, J.I., Trlica, M.J. and Njoka, T.J. 1995. Influence of tree shade on plant water stalin, gas exchange and water use efficiency of *Panicum maximum* J. and *Themeda triandra* Forsk in a Kenya Savanna. *Afr. J. Ecol.* 33: 114-123

Kothari, S. K. and Saraf, C.S. 1987. N-economy in fodder sorghum as affected by bacterial seed inoculation and P application in summer green gram. *Indian J. Agron.* 32: 117–120

Krishnan, K. 1993. Seed production potential of guinea grass (*Panicum maximum* Jacq.) cv. Riversdale under different management techniques. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 181 p.

Kulhari, R.K. and Katewa, S.S. 1998. Effect of nitrogen with different sources on the productivity and quality of natural grasslands of Udaipur Valley. *Forage Res.* 24: 91-92

Kumar, M. and Singh, M. 2002. Effect of nitrogen and phosphorus levels on growth and yield of maize (*Zea mays* L.) under rainfed condition of Nagaland. *Andhra agric. J.* 49: 203-206

Kumar, S.N. and Singh, S.P. 2001. Growth analysis of maize during long and short duration crop seasons: influence of nitrogen source and dose. *Indian J. agric. Res.* 35: 13-18

Lambers, H., Chaplin, F. and Pons, T.L. 1998. *Plant Physiological Ecology.* Springer-Verlag, New York, 540 p.

Laura, B., Roberts, L.B., Ferguson, T.V. and Wilson, L. 1986. Response of four sweet potato cultivars to levels of shade 2. Tuberisation. *Trop. Agric.* 63:265

Liu, Z.Q., Liu, Z.Y., Mad, P. and Zong, S.F. 1984. A study of relationship between chlorophyll content and photosynthetic rate in rice. *Acta Agronomica sinica* 10:57-62 (French)

Lorsen, E.R. 1966. Effect of nitrogen fertilization on yield and chemical composition of corn and certain grass spp. *Diss. Abstr.* 26: 6282

Maiti, S., Sahu, B.B., Pal, S. and Chatterjee, B.N. 1988. Effect of phosphate manuring on the intercropping of hybrid napier grass. *Environment Ecol.* 6: 422-427

Malik, C.P. and Srivastava, A.K. 1979. *Textbook of Plant Physiology.* Indian Reprint 1985. Kalyani Publishers, New Delhi, 785 p.

Mayland, H.F. and Grunes, D.L. 1974. Shade induced grass tetany prone chemical changes in *Agropyron desertorum* and *Elymus cinereus.* *J. Range Mgmt* 27: 198-201

Mckenzie, F.R. 1996. The influence of applied nitrogen on the vigour of *Lolium perenne* during the establishment year under subtropical conditions. *Trop. Grassld* 30: 345–349

Meerabai, M. Lakshmi, S., Saraswathy, P. and Pillai, G.R. 1992. Effect of nitrogen levels and cutting intervals on fodder production of Congosignal grass intercropped in coconut garden. *Forage Res.* 18: 88–92

Meerabai, M., Lakshmi, S. and Pillai, G.R. 1993. P and K nutrition of guinea and congo signal grasses grown in coconut gardens. *J. trop. Agric.* 31: 181-183

Misra, L.P., Bhatt, R.K., Tiwari, H.S. and Vandana. 2002. Effect of light stress on nutrient content and productivity of tropical grasses and legumes under shade environment. National Symposium on Grass land and fodder Research in the New Millenium. 30th October – 1st November, 2002. Indian Grassland and Fodder Research Institute, Jhansi. *Abstract*: 174-176

Morelli, G. and Ruberti, I. 2000. Shade avoidance response. Driving auxin along lateral routes. *Pl. Physiol.* 122: 621-626

Mori, T., Nakashizaka, T., Sumizono, T. and Yap, S.K. 1990. Growth and photosynthesis responses to temperature in several Malaysian tree species. *J. trop. Forests Sci.* 3: 44-57

Mullakoya, P. 1982. Shade tolerance of guinea grass cv. Mackuenii under different levels of potassium. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 109 p.

Munda, G.L., Pal, M. and Pandey, S.L. 1984. Effect of nitrogen and phosphorus on drymatter accumulation and nutrient uptake pattern in hybrid pearl millet. *Indian J. Agron* 29: 185-198

Myhr, K. and Saebo, S. 1969. The effect of shade on growth, development and chemical composition in some grass species. *Forsk. Fors. Landbr.* 20: 297-315 (Swedish)

Nandal, D.P.S. and Singh, R.R. 2001. Productivity of different cropping sequences in *Dalbergia sisso*. Roxb. based agro siviculture system. *Crop Sci.* 41: 96-102

Nayar, T.V.R. 1986. Production potential for Cassava (*Manihot esculenta* Crantz) intercropped in coconut garden. Ph. D thesis, Kerala Agricultural University, Thrissur, 197 p.

Nehra, D.S., Tomar, P.S., Singh, S.M. and Pahiya, S.S. 1981. Effect of nitrogen levels, weed control and seed rate on yield and quality of fodder maize. *Forage Res.* 7: 195-200

Okoli, D.U.U. and Owasu, J.K. 1975. Growth analysis and photosynthetic rate of cocoa seedlings in relation to varying shade and nutrient regumes. *Ghana J. agric. Sci.* 8: 50-57

Oommen, M. 1989. Cultural, manurial and water requirements for sweet potato (*Ipomoea batatus* (L.) Lam). Ph.D. thesis, Kerala Agricultural University, Thrissur, 253 p.

Pamo, E.T. 1991. Response of *Brachiaria ruziziensis* Germain and Evrard to nitrogen fertilizer and different cutting frequencies at Adamaoua Cameroon. *Revue d'Elevage' et de Medicine Veterinarie des Pays Tropicaux*. 44: 373-380 (French)

Panse, V.G. and Sukhatme, P.V. 1967. *Statistical Method for Agricultural Workers*. Third Edition, Indian Council of Agricultural Research, New Delhi, 381 p.

Parihar, S.S and Agarwal. P. 2002. Effect of nitrogen on seed yielding components and seed quality of spear grass (*Heteropogon contortus*). National Symposium on Grass land and fodder Research in the New Millenium. 30th October – 1st November, 2002. Indian Grassland and Fodder Research Institute, Jhansi. *Abstract*: 91-92

Paulino, V.T. and Malavotta, E. 1989. Effect of phosphogypsum, phosphorus and lime on *Andropogon gayanus* Kunth. *Proceedings of the XVI International Grassland Congress. October 4-11, 1989*, Nice, France, pp. 64-81

Paulino, V.T., Malavotta, E. and Pigato, A.M. 1989. Effects of gypsum, phosphorus and lime on *Andropogon gayanus*. *Revista de Agricultura*. 64: 55-90 (Portuguese)

Paynter, R.M. and Dampney, P.M.R. 1996. The effect of rate and timing of phosphate fertilizer on the yield and P uptake of grass grown for silage at moderate to high levels of soil phosphorus. *Grass Forage Sci.* 46: 131-137

Peake, D.C.I., Myers, R.J.K. and Henzell, E.F. 1990. Sown pasture production in relation to nitrogen fertilizer and rainfall in Southern Queensland. *Trop. Grassld* 24: 291-298

Pearson, C.J. and Ison, R.L. 1987. *Agronomy of Grassland Systems*. Cambridge University Press, Cambridge, 286 p.

Pieterse, P.A. and Rethman, N.F.G. 1995. Level of nitrogen fertilization and drymatter yield of *Digitaria eriantha* cv. Irene in the Transvaal middle veld. *Afr. J. Range Forage Sci.* 12: 87–88

Pieterse, P.A., Rethman, N.F.G. and Bosch, J.V. 1997. Production. water use efficiency and quality of four cultivars of *Panicum maximum* at different levels of nitrogen fertilization. *Trop. Grassld* 31: 117-123

Pillai, G.R. 1986. Production potential of two fodder grasses under different management practices. Ph.D thesis, Kerala Agricultural University, Thrissur, 180 p.

Prakash, K.S., Mani, A. and Zidgali, T.A. 1994. Effect of nitrogen, phosphorus and potassium fertilization on herbage yield and quality of plant parasitic nematode populations in an irrigated Rhodes grass (*Chloris gayana*) pasture in Oman. *Trop. Grassld* 28: 164–169

Purushotham, S., Siddaraju, R. and Narayanaswamy, G.V. 2001. Effect of cutting and nitrogen management in promising varieties of guinea grass for fodder-cum-seed purposes. *Karnataka J. agric. Sci.* 14:295-298

Purushotham, S., Umesha. K. and Manjunatha, M. 1995. Agronomic practices for fodder-cum-seed purpose in anjan grass (*Cenchrus ciliaris*). *Indian J. Agron.* 40: 689-692

Pushpakumari, R. and Sasidhar, V.K. 1992. Influence of shade on growth attributes of minor tuber crops. *J. Root Crops* 18: 64-67

Rai, P. 1989. Effect of fertilizers and legumes on the productivity of *Cenchrus ciliaris* in the Bundelkhand region of Uttar Pradesh, India. *Trop. Grassld* 23: 189–191

Rai, P. 1991. Effect of nitrogen on yield and quality of *Cenchrus ciliaris* x *Cenchrus setigerus* hybrid. *Indian J. Agron.* 36: 243–246

Rai, P. and Shankaranarayan, K.A. 1981. Effect of nitrogen and phosphorus on seed yield of Pusa giant anjan (*Cenchrus ciliaris* Linn). *Forage Res.* 7: 181–186

Ramamurthy, V. 2002a. Response of napier bajra hybrids to integrated nitrogen management. *Indian J. Agron.* 47: 455-459

Ramamurthy, V. 2002b. Effect of nitrogen and Azospirillum inoculation on growth and green forage yield of *Pennisetum* trispecific hybrid. *Indian J. Agron.* 47: 566-570

Ramamurthy, V. and Vinodshankar. 1998. Response of *Pennisetum* trispecific hybrid to N and harvesting dates. *Indian J. Agron.* 43: 533-536

Ramanujam, T. and Jose, J.S. 1984. Influence of light intensity on chlorophyll distribution and anatomical characters of cassava leaves. *Turrialba* 34: 467-471

Ramus, D.A.H. 1995. *Forage growth and its relationship to grazing management.* Research Summaries No.21, University of South Western Louisiana, Lafeyelt, 96 p.

Rani, V.G.S. 2001. Evaluation and Nutritional Management of fodder crops in summer rice fellows. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 136 p.

Rathore, D.N. and Vijayakumar. 1978. Nutrient uptake and concentration in Dinanath grass and Sorghum grown at different levels of nitrogen and phosphorus. *Indian J. agric. Sci.* 48: 546-550

Ravikumar and Shankaranarayan, K.A. 1980. Response of fertilizers in the natural grassland of *Sehima nervosum* (Rottl.) Stapf. *Forage Res.* 6: 15-20

Ravikumar, Dabadghao, P.M., Shankaranarayan, K.A. and Rai, P. 1980. Effect of different levels of nitrogen and phosphorus on the forage potential of *Cenchrus setigerus* Vahl. *Indian J. agric. Sci.* 50: 488–491

Reddy, G.M. 1990. Effect of fertilization and legume associates on the yield and quality of hybrid *Pennisetum.* Ph.D thesis, University of Agricultural Sciences, Bangalore, 90 p.

Reid, R.L. and Jung, G.A. 1974. Effects of elements other than nitrogen on nutritive value of forages. *Forage Fertilization* (ed. May, D.A). Crop Science Society of America and Soil Science Society of America, Madison WI, pp. 395-435

Reynolds, S.G. 1988. *Pastures and cattle under coconuts.* FAO plant production and protection paper No.91. FAO of United Nations, Rome, 126 p.

Roberts-Nkrumah, L.B., Wilson, L.A. and Ferguson, T.V. 1986. Response of four sweet potato cultivars to levels of shade and tuberisation. *Trop. Agric.* 63: 265

Rocha, G.P., Evangelista, A.R., Lina, J.A. de and Rosa, B. 2002. Nitrogen doses on grasses of the Cynodon enus. *Ciencia Anim. Brasileira* 3: 1-9 (Portuguese)

Russel, E.W. 1973. *Soil Conditions and Plant Growth.* Eighth edition, Longman Group Ltd., London, 635 p.

Sangakkara, U.R. 1988. Relationship between nitrogen fertilizer, defoliation frequency and seed productivity of *Panicum maximum* Jacq. *Seed Res.* 16: 206–210

Sato, A. and Dalmacio, R.V. 1991. Maize production under an intercropping system with fast growing tree species, a case study in Philippines. *Japan agric. Res. Quarterly* 24: 319-326

Schreiner, H.G. 1987. Tolerance of four forage grasses to different levels of shading. *Boletim de Pesquisa Florestal* 15: 61-72 (Portuguese)

Shankaranarayan, K.A., Hassan, N. and Kathsu, S. 1987. Agroforestry in the arid zones of India. *Agroforestry Systems* 5: 69-88

Shanmugasundaram, V.S. 1985. Studies on the association of perennial grass (NB-21) legume (Lucerne) mixtures on the forage yield and quality. *Madras agric. J.* 73: 61-66

Sharma, K.K., Khanna, P. and Gulati, A. 1996. The growth and yield of wheat and paddy as influenced by *Dalbergia sissoo* Roxb. boundary plantation. *Indian Forester* 22: 1114-1126

Shelton, H.M., Humphreys, L.R. and Batello, C. 1987. Pasture in the plantations of Asia and Pacific:Performance and Prospect. *Trop. Grassld* 21: 16-19

Shivay, Y.S., Singh, R.P. and Pandey, C.S. 2002. Physiological analysis of growth in maize (*Zea mays* L.) as influenced by cropping systems and nitrogen levels. *Indian J. Pl. Physiol.* 7: 126-130

Simpson, J.E., Adair, C.R., Kohler,G.D., Dawson,E.N., Debald,H.A., Kester, E.B. and Klick, J.T. 1965. *Quality evaluation of foreign and domestic rices.* Technical Bulletin No.1331 Series, United States Department of Agriculture, Washington, D.C., 250 p.

Singer, J.W. 2002. Species and Nitrogen effect on growth rate, tiller density and botanical composition in grasshay production. *Crop Sci.* 42: 208-214

Singh, C.V., Singh, R.V., Variar, M. and Chauhan, V.S. 1992. Agroeconomic assessment of production technology of upland rice. *Indian J. agric. Sci.* 62: 187-190

Singh, D., Singh, V. and Joshi, Y.P. 2002a. Herbage yield and yield attributes of Napier Bajra hybrid at different cuts as affected by cutting intervals and varying levels of nitrogen. *Forage Res.* 27: 267-271

Singh, I., Chouhan, G.S and Choudhary, L.S. 1993. Response of Sorghum (*Sorghum bicolor*) to nitrogen and phosphate under western Rajasthan condition. *Indian J. Agron.* 38: 305-306

Singh, K.A. 1984. Response of forage green panic and veranostylo intercropping to fertilization. *Indian J. Agron.* 29: 277-281

Singh, K.A. 1999. Response of promising forage grasses to nitrogen. *Indian J. Agron.* 44: 419-423

Singh, M.M., Singh, S.P. and Singh, A.K. 2001. Response of guinea grass varieties to nitrogen and spacing under saline sodic soil. *Range Mgmt Agroforestry* 22: 212-215

Singh, R., Kumar, N. and Rana, N.S. 2000. Response of rainfed guinea grass (*Panicum maximum*) to biofertilizers inoculation and nitrogen. *Indian J. Agron.* 45: 205-209

Singh, U.N., Singh, U.K and Ratan, N. 2002b. Effect of fertilizers on forage production potential and quality of Iseilema grassland community in Bundelkhand Region. National Symposium on Grass land and fodder Research in the New Millenium. 30th October – 1st November, 2002. Indian Grassland and Fodder Research Institute, Jhansi. *Abstract*: 101

Singh, V. 1987. Promising intercropping systems for increasing forage production. *Indian Fmg.* 37 (5): 31

Smith, I.E., Savage, M.I. and Mills, P. 1984. Shading effects on green house tomatoes and cucumbers. *Acta Hort.* 148: 491-500

Solanki, R.M. and Patel, R.G. 1998. Influence of irrigation, sowing methods and phosphorus on quality of alfalfa. *Forage Res.* 24: 77-81

Sonia, V.K. 1999. Forage and Seed production of signal grass (*Brachiaria decumbens* Stapf.) under different management practices. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 110 p.

Soratto, R.P., Lima, E.do V., Silva, T.R.B. da, Boaro, C.S.F. and Cataneo, A.C. 2004. Nitrogen fertilization of fall *Panicum* cultivars (*Panicum dichotomiflorum* Michx.): biochemical and agronomical aspects. *Scientia Agricola* 61: 82-87

Sreelathakumary, I. 2000. Genetic analysis of shade tolerance in chilli (*Capsicum* spp.). Ph.D thesis. Kerala Agricultural University. Thrissur, 153 p.

Stur, W.W. 1991. Screening forage species for shade tolerance-A preliminary report. *Proceedings of Workshop on Forages for Plantation Crops, Australian Centre for Industrial and Agricultural Research Proc. No. 32, June 27-29, 1990* (eds. Shelton, H.M. and Stur, W.W.), Sanur Beach, Bali, Indonesia, pp.78-81

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* 29: 259-260

Sudhakar, K., Prasad, R. and Nair, T.V.R. 1987. Effect of levels and time of nitrogen application on nitrate reductase activity, yield and nitrogen uptake by direct seeded rice. *Fert. News* 32: 41-43

Suja, G. 2001. Resource management for intercropping white yam (*Dioscorea rotundata* Poir) in coconut garden. Ph. D thesis, Kerala Agricultural University, Thrissur, 195 p.

Sumner, M.E. and Farina, M.P.W. 1986. Phosphorus interaction with other nutrients and lime in field cropping systems. *Adv. Soil Sci.* 5: 201-236

Sunilkumar, B. 2000. Suitability of upland rice cultivars (*Oryza sativa* L.) for shaded situations. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 114 p.

Thakral, S.K., Singh, B.P. and Faroda, A.S. 1997. Effect of soil moisture and fertility management on LAI, LAD and CGR of *Brassica* species in Aridisols. *Annals agric. Res.* 18: 115-117

Thakuria, K. 2002. Effect of nitrogen and cutting management on *Setaria sphacelata* cv. Kazangula under rainfed conditions. *Forage Res.* 27: 303-305

Thomas, J. 1978. Comparative performance of guinea grass and hybrid napier under varying levels of nitrogen and cutting intervals. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 66 p.

Tisdale, S. and Nelson, W. 1956. *Soil Fertility and Fertilizers.* Second edition. Macmillan Publishing Co. Inc., New York, 694 p.

Tisdale, S.L. and Nelson, W.L. 1975. *Soil Fertility and Fertilizers*. Third edition. Macmillan Publishing Co. Inc., New York, 694 p.

Tisdale, S.L., Nelson, W.L. and Beaton, J.D. 1985. *Soil Fertility and Fertilizers*. Fourth edition. Macmillan Publishing Company. Inc., New York 735 p.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. 1995. *Soil Fertility and Fertilizers.* Fifth edition, Prentice Hall of India (Pvt.) Ltd., New Delhi, 735 p.

Tiwana, M.S., Bains, D.S. and Gill, S.S. 1975. Effect of various levels of nitrogen and phosphorus under different spacings on fodder of napier – bajra hybrid. *J. Res. Punjab agric. Univ.* 12: 345-350

Tiwari, G., Dwivedi, S.K., Shrivastava, S.K., Tiwari, J.P. and Agarwal. V.K. 2001. Effect of plant population density and phosphorus nutrition on physiological determinants of yield in linseed (*Linum usitatissimum* L.). *Crop Res. (Hisar).* 21: 57-59

Tiwari, H.S., Bhatt, R.K., Vandana and Misra, L.P. 2002. Variation in chlorophyll and energy content under different light intensity in tropical range grasses and legumes. National Symposium on Grass land and fodder Research in the New Millenium. 30th October – 1st November, 2002. Indian Grassland and Fodder Research Institute, Jhansi. *Abstract*: 168-170

Tomer, P.S., Mehta, G.S., Gill, P.S. and Bishnoi, C.K. 1974. Effect of levels of phosphorus and molybdenum on growth, yield and quality of berseem. *J. Res. Haryana agric. Univ. (Hisar)* 4: 271-276

Tripathi, S.N. and Singh, R.A. 1991. Effect of nitrogen fertilization on forage yield and quality of dinanath grass (*Pennisetum pedicellatum*) varieties. *Indian J. Agron.* 36: 567-570

Tudsri, S. and Sornprasiti, P. 1988. Response of four tropical pasture grasses to N application. *Kasetsart. J. Natural Sci.* 22:37-44

Turner, A.D. and Wein, H.C. 1994. Photosynthesis, dark respiration and bud sugar concentrations in pepper cultivars differing in susceptibility to stress-induced bud abscission. *Ann. Bot.* 73: 623-628

Valenzuela, H.R. 1990. Shade tolerance and photosynthesis of cocoyams (*Xanthosoma sagithfolium*). *Sci. Engg.* 52: 173

Viji, M.M. 1995. Molecular, physiological and biochemical aspects of lowlight stress tolerance in rice (*Oryza sativa* L.). Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, 186 p.

Vineetha, L.J. 1995. Seed production of gamba grass (*Andropogon gayanus* Kunth.) under varying levels of nitrogen, phosphorus and potassium. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 137 p.

Wadi, A., Ishii, Y. and Idota, S. 2003. Effects of the level of fertilizer input on drymatter productivity of napier grass and king grass. *Grassld Sci.* 48: 490-503

Watson, D.J. 1958. The dependence of net assimilation rate on leaf area index. *Ann. Bot.* 22: 37-54

Watson, H., Charles, H., William, E.K. and Henry, A.P. 1984. Shade tolerance of grass and legume germplasm for use in the Southern Forest Range. *J. Range Mgmt* 37: 229-232

Watson, S.E. and Whiteman, P.C. 1981. Animal production from naturalized and sown pastures at three stocking rates under coconut in the Solomon islands. *J. agric. Sci.* 97: 669-676

Williams, R.F. 1946. The phenology of plant growth with special reference to the concept of net assimilation rate. *Ann. Bot.* 10: 41-72

Wilson, J.R. and Wild, D.W.M. 1991. Improvement of nitrogen nutrition and grass growth under shading. *Proceedings of Workshop on Forages for Plantation Crops, Australian Centre for Industrial and Agricultural Research Proc. No. 32, June 27-29, 1990* (eds. Shelton, H.M. and Stur, W.W.) Sanur beach, Bali, Indonesia, pp. 12-16

Wilson, J.R., Hill, K., Cameron, D.M. and Shelton, H.M. 1990. The growth of *Paspalum notatum* under the shade of a *Eucalyptus grandis* plantation canopy or in full sun. *Trop. Grassld* 24: 24-28

Wilson, M.L., Chang, C.W. and Watson, C.E. 1959. Effect of fertilization on irrigated pastures. *Soils Fert.* 23: 115-117

Wong, C.C. 1991. Shade tolerance of tropical forages : A review. *Proceedings of Workshop on Forages for Plantation Crops, Australian Centre for Industrial and Agricultural Research Proc. No.32, June 27-29, 1990* (eds. Shelton, H.M. and Stur, W.W.). Sanur Beach, Bali, Indonesia, pp.64-69

Wong, C.C. and Wilson, J.R. 1980. Effects of shading on growth and nitrogen content of green panic and siratro in pure and mixed sward defoliated at two frequencies. *Aust. J. agric. Res.* 31: 269-285

Yadav, P.K. and Sharma, R.S. 1989. Effect of different fertility levels and cutting management on the yield of dinanath grass (*Pennisetum pedicellatum* Trin.) *Indian J. Agron.* 31: 102–103

Yadav, R.P., Yadav, D.V. and Khanna, S.S. 1984. Improved nodulation and nitrogen fixation in berseem with the appication of cobalt and phosphorus. *Indian J. agric. Sci.* 54: 506-508

Yeh, M.T. 1988. Response of hybrid napier grass lines 7001 and 7007 to levels of fertilizers. *J. Taiwan Livestock Res.* 21: 23–25

Yinghua, C. and Jianzhen, J. 1998. The effects of light intensity on photosynthetic characteristics, growth and development in pepper (*Capsicum annuum*). *Acta agri. Shanghai* 14: 46-50 (French)

APPENDICES

APPENDIX – I

Weather parameters during the cropping period (April 30th 2003 to March 10th 2004) – weekly averages

Standard weeks	Temperature °C		Relative humidity		Rainfall (mm)	Evaporation (mm)	Sunshine hours	Wind speed (km h^{-1})
	Maximum	Minimum	7.22 am	2.22 pm				
18 (April 30 – May 6)	32.2	24.4	93.9	71.9	157.4	2.5	36.5	4.6
19 (May 7 – May 13)	32.8	25.6	86.6	70.4	3.9	3.4	34.4	7.4
20 (May 14 – May 20)	32.4	25.5	87.6	68.6	4.0	3.5	45.8	10.6
21 (May 21 – May 27)	32.5	25.8	86.4	69.9	2.6	4.5	70.5	10.3
22 (May 28 – June 3)	33.1	25.9	83.7	67.1	1.4	4.5	65.6	10.3
23 (June 4 – June 10)	33.0	25.4	85.6	68.0	6.8	4.6	68.3	10.2
24 (June 22 – June 17)	31.4	24.3	90.6	68.0	44.6	3.6	39.0	9.1
25 (June 18 – June 24)	30.2	23.5	93.0	75.3	129.8	3.1	15.9	8.6
26 (June 25 – July 1)	30.8	23.8	89.6	69.9	31.6	3.6	40.4	9.1
27 (July 2 – July 8)	30.1	23.2	87.7	71.7	28.7	2.7	30.0	8.3
28 (July 9 – July 15)	30.6	23.7	89.9	64.3	21.4	3.8	34.0	10.6
29 (July 16 – July 22)	30.3	23.7	90.7	73.3	43.2	3.3	47.4	10.0
30 (July 23 – July 29)	30.8	24.3	92.3	73.6	14.1	3.0	36.0	9.1
31 (July 30 – Aug. 5)	31.0	24.3	91.1	76.0	23.1	3.8	39.1	7.7
32 (Aug. 6 – Aug. 12)	30.9	24.5	90.6	70.7	11.0	3.8	49.4	9.7
33 (Aug. 13 – Aug. 19)	31.6	24.4	85.4	68.9	1.4	4.4	10.2	8.9

APPENDIX I (Continued...)

Standard weeks	Temperature °C		Relative humidity		Rainfall (mm)	Evaporation (mm)	Sunshine hours	Wind speed (km h^{-1})
	Maximum	Minimum	7.22 am	2.22 pm				
34 (Aug 20 – Aug 26)	30.4	24.5	91.3	74.1	44.5	3.5	34.4	8.6
35 (Aug 27 – Sept 2)	30.1	23.4	91.3	71.1	23.1	4.0	49.6	9.4
36 (Sept 3 – Sept 9)	30.8	23.7	90.2	69.7	4.6	4.2	68.2	10.6
37 (Sept 10 – Sept 16)	31.3	23.6	87.1	67.1	3.1	4.7	66.2	11.1
38 (Sept 17 – Sept 23)	31.8	24.3	83.6	66.4	0	5.2	68.1	10.9
39 (Sept 24 – Sept 30)	32.2	24.3	80.3	63.3	0	5.2	60.9	11.1
40 (Oct 1 – Oct 7)	29.9	23.8	93.6	79.6	222.8	2.9	17.7	5.7
41 (Oct 8 – Oct 14)	30.6	23.5	92.1	72.0	19.2	3.6	58.6	9.1
42 (Oct 15 – Oct 21)	30.5	24.0	93.2	73.6	72.8	3.5	39.9	6.9
43 (Oct 22 – Oct 28)	30.2	23.0	93.9	75.7	201.1	2.1	45.7	6.3
44 (Oct 29 – Nov 4)	30.6	23.0	91.7	74.6	24.0	2.5	37.8	3.4
45 (Nov 5 – Nov 11)	30.0	22.9	93.9	74.6	119.7	2.9	23.1	4.0
46 Nov 12 – Nov 18)	30.9	23.5	93.7	69.9	23.2	2.3	30.9	5.1
47 (Nov 19 – Nov 25)	30.9	23.4	93.6	67.9	1.7	2.6	42.4	5.4
48 (Nov 26 – Dec 2)	30.7	23.5	94.0	68.7	0.8	2.3	33.1	5.1

APPENDIX I (Continued...)

Standard weeks	Temperature °C		Relative humidity		Rainfall (mm)	Evaporation (mm)	Sunshine hours	Wind speed (km h^{-1})
	Maximum	Minimum	7.22 am	2.22 pm				
49 (Dec 3 – Dec 9)	31.3	21.3	92.6	59.6	0	2.9	53.5	5.4
50 (Dec 10 – Dec 16)	31.0	20.7	95.1	57.4	0	3.1	57.6	6.9
51 (Dec 17 - Dec 23)	31.1	22.1	92.0	60.6	0	3.3	55.6	6.3
52 (Dec 24 – Dec 31)	31.4	22.1	95.0	62.3	0	3.6	74.2	9.1
1 (Jan 1 - Jan 7)	31.7	22.3	94.0	61.0	0	3.6	57.4	6.0
2 (Jan 8 – Jan 14)	31.5	20.9	93.3	56.7	0	3.3	66.3	8.0
3 (Jan 15 – Jan 21)	30.8	20.5	95.6	59.4	0	3.2	66.0	8.6
4 (Jan 22 - Jan 28)	31.8	22.3	94.1	60.1	0	4.1	62.3	8.6
5 (Jan 29 – Feb 4)	32.0	22.9	95.3	57.9	7.2	4.0	66.5	9.7
6 (Feb 5 – Feb 11)	32.0	22.9	93.6	61.1	0	4.1	67.2	9.1
7 (Feb 12 – Feb 18)	32.3	21.5	94.3	53.0	0	4.2	58.8	7.4
8 (Feb 19 – Feb 25)	32.1	21.3	93.1	55.6	0	4.4	70.1	8.0
9 (Feb 26 - Mar 3)	32.5	22.8	94.6	59.7	0	4.4	65.8	9.1
10 (Mar 4 –Mar 10)	33.1	22.6	93.3	58.6	0	4.8	68.4	9.4

APPENDIX II (a)

Interaction effects of shade, nitrogen and phosphorus levels on plant height of guinea grass, cm

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
$s_0n_1p_1$	129.30	59.27	128.07	59.00	51.27
$s_0n_1p_2$	136.37	66.47	133.07	67.20	55.53
$s_0n_1p_3$	136.97	81.60	139.47	72.40	64.20
$s_0n_2p_1$	137.93	75.43	130.80	72.67	53.13
$s_0n_2p_2$	138.83	84.87	133.87	77.87	67.13
$s_0n_2p_3$	148.33	93.07	135.47	99.53	79.77
$s_0n_3p_1$	131.50	82.57	132.93	77.60	61.90
$s_0n_3p_2$	135.77	96.07	143.00	100.20	80.70
$s_0n_3p_3$	142.40	103.23	147.13	108.33	93.47
$s_1n_1p_1$	135.43	96.93	138.13	96.00	103.20
$s_1n_1p_2$	155.87	103.47	141.87	123.37	118.87
$s_1n_1p_3$	170.60	121.07	146.00	129.93	125.13
$s_1n_2p_1$	142.83	104.13	142.30	119.13	112.73
$s_1n_2p_2$	146.57	106.40	147.50	121.33	120.67
$s_1n_2p_3$	161.80	115.07	150.00	128.33	128.60
$s_1n_3p_1$	141.87	95.40	146.87	116.53	115.87
$s_1n_3p_2$	150.47	103.40	151.83	126.33	129.90
$s_1n_3p_3$	167.30	110.43	157.03	133.67	134.60
$F_{4, 34}$	10.79**	0.14^{ns}	0.31^{ns}	1.28^{ns}	0.76^{ns}
SE	1.054	4.477	2.954	7.126	5.232
CD	3.025	-	-	-	-

** Significant at 1 per cent level   ns – not significant

APPENDIX II (b)

Interaction effects of shade, nitrogen and phosphorus levels on number of tillers of guinea grass

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
$s_0n_1p_1$	11.67	10.67	17.47	14.80	21.13
$s_0n_1p_2$	12.67	14.40	18.60	18.33	24.13
$s_0n_1p_3$	12.27	14.80	21.47	23.80	28.27
$s_0n_2p_1$	11.00	11.07	13.73	14.07	18.47
$s_0n_2p_2$	12.80	11.47	18.47	17.67	25.93
$s_0n_2p_3$	12.80	16.07	20.80	20.47	29.73
$s_0n_3p_1$	10.53	12.73	16.93	17.27	25.53
$s_0n_3p_2$	14.20	16.13	21.93	18.07	29.67
$s_0n_3p_3$	14.27	17.40	28.07	22.47	35.07
$s_1n_1p_1$	5.73	7.53	8.20	7.47	9.00
$s_1n_1p_2$	7.60	7.93	10.07	10.27	9.67
$s_1n_1p_3$	8.13	10.27	10.53	11.20	14.60
$s_1n_2p_1$	6.07	7.00	7.60	9.73	8.53
$s_1n_2p_2$	7.33	8.07	8.87	10.47	12.40
$s_1n_2p_3$	8.80	9.27	9.87	14.27	13.60
$s_1n_3p_1$	7.00	7.27	6.47	9.67	8.80
$s_1n_3p_2$	8.40	9.27	7.73	12.87	12.47
$s_1n_3p_3$	9.00	11.07	13.67	13.80	16.07
$F_{4, 34}$	0.53^{ns}	0.55^{ns}	0.51^{ns}	1.94^{ns}	0.14^{ns}
SE	0.981	1.375	1.292	0.940	2.635
CD	-	-	-	-	-

ns – not significant

APPENDIX II (c)

Interaction effects of shade, nitrogen and phosphorus levels on Leaf: Stem Ratio of guinea grass

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
$s_0n_1p_1$	1.29	2.13	2.71	1.89	1.77
$s_0n_1p_2$	1.31	2.22	2.76	1.90	1.80
$s_0n_1p_3$	1.32	2.32	2.79	1.94	1.85
$s_0n_2p_1$	1.31	2.15	2.73	1.92	1.79
$s_0n_2p_2$	1.34	2.24	2.79	1.95	1.87
$s_0n_2p_3$	1.36	2.32	2.83	1.99	1.91
$s_0n_3p_1$	1.34	2.17	2.76	1.96	1.86
$s_0n_3p_2$	1.37	1.95	2.81	2.04	1.91
$s_0n_3p_3$	1.39	2.01	2.84	2.09	1.98
$s_1n_1p_1$	0.66	1.70	1.72	1.16	1.06
$s_1n_1p_2$	0.75	1.73	1.74	1.20	1.10
$s_1n_1p_3$	0.77	1.78	1.80	1.24	1.14
$s_1n_2p_1$	0.68	1.73	1.75	1.20	1.09
$s_1n_2p_2$	0.76	1.76	1.78	1.24	1.16
$s_1n_2p_3$	0.79	1.79	1.82	1.28	1.19
$s_1n_3p_1$	0.68	1.73	1.79	1.23	1.12
$s_1n_3p_2$	0.77	1.78	1.83	1.29	1.18
$s_1n_3p_3$	0.79	1.82	1.85	1.35	1.24
$F_{4, 34}$	0.25^{ns}	0.56^{ns}	0.15^{ns}	0.14^{ns}	0.02^{ns}
SE	0.013	0.109	0.023	0.024	0.024
CD	-	-	-	-	-

ns – not significant

APPENDIX II (d)

Interaction effects of shade, nitrogen and phosphorus levels on Leaf Area Index of guinea grass

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
$s_0n_1p_1$	4.22	4.14	4.04	4.11	4.22
$s_0n_1p_2$	4.41	4.18	4.28	4.15	4.28
$s_0n_1p_3$	4.63	4.34	4.29	4.16	4.32
$s_0n_2p_1$	4.63	4.56	4.41	4.16	4.42
$s_0n_2p_2$	4.62	4.63	4.37	4.16	4.49
$s_0n_2p_3$	4.69	4.72	4.51	4.18	4.50
$s_0n_3p_1$	4.72	4.86	4.62	4.32	4.58
$s_0n_3p_2$	4.82	5.03	4.75	4.37	4.63
$s_0n_3p_3$	4.98	5.13	4.82	4.44	4.79
$s_1n_1p_1$	3.61	3.84	3.45	4.01	3.58
$s_1n_1p_2$	3.63	4.01	3.73	3.86	3.69
$s_1n_1p_3$	3.73	3.94	4.05	3.90	3.75
$s_1n_2p_1$	3.87	4.13	3.64	4.10	4.03
$s_1n_2p_2$	4.21	4.16	4.01	4.13	4.09
$s_1n_2p_3$	4.32	4.23	4.34	4.15	4.15
$s_1n_3p_1$	4.35	4.32	4.32	4.20	4.14
$s_1n_3p_2$	4.33	4.34	4.41	4.22	4.18
$s_1n_3p_3$	4.58	4.67	4.44	4.28	4.22
$F_{4,34}$	136.84**	52.24**	15.36**	0.67^{ns}	0.85^{ns}
SE	0.012	0.011	0.034	0.052	0.043
CD	0.033	0.032	0.096	–	–

** Significant at 1 per cent level   ns – not significant

APPENDIX II (e)

Interaction effects of shade, nitrogen and phosphorus levels on CGR (g m^{-2} day^{-1}), RGR (mg $g^{-1}day^{-1}$) and NAR (g $m^{-2}day^{-1}$) of guinea grass

Interaction effects of factors	CGR	RGR	NAR
$s_0n_1p_1$	2.25	5.57	0.11
$s_0n_1p_2$	2.55	8.00	0.21
$s_0n_1p_3$	2.59	8.84	0.29
$s_0n_2p_1$	2.28	12.00	0.49
$s_0n_2p_2$	2.58	12.39	0.50
$s_0n_2p_3$	2.63	23.51	0.52
$s_0n_3p_1$	2.77	10.52	0.53
$s_0n_3p_2$	3.18	23.71	0.53
$s_0n_3p_3$	3.21	24.07	0.60
$s_1n_1p_1$	1.88	3.99	0.09
$s_1n_1p_2$	1.91	6.31	0.10
$s_1n_1p_3$	2.01	4.46	0.16
$s_1n_2p_1$	1.94	4.45	0.42
$s_1n_2p_2$	1.97	5.67	0.46
$s_1n_2p_3$	2.12	7.25	0.51
$s_1n_3p_1$	2.49	10.46	0.53
$s_1n_3p_2$	2.57	11.44	0.53
$s_1n_3p_3$	2.53	15.36	0.58
$F_{4, 34}$	5.61**	329.33**	16.97**
SE	0.019	0.165	0.01
CD	0.054	0.473	0.02

** Significant at 1 per cent level

APPENDIX II (f)

Interaction effects of shade, nitrogen and phosphorus levels on chlorophyll content (mg g^{-1} of plant) of guinea grass

Interaction effects of factors	I cut	II cut	III cut	IV cut	V cut
$s_0n_1p_1$	1.46	1.31	2.61	1.22	3.40
$s_0n_1p_2$	1.99	1.99	2.66	1.72	3.17
$s_0n_1p_3$	2.65	2.75	3.73	3.77	3.03
$s_0n_2p_1$	1.67	1.38	3.13	1.43	3.35
$s_0n_2p_2$	1.77	1.35	3.52	1.57	3.83
$s_0n_2p_3$	2.63	2.52	3.88	1.86	2.25
$s_0n_3p_1$	2.49	2.25	4.02	1.57	3.78
$s_0n_3p_2$	2.54	3.04	3.63	2.55	3.60
$s_0n_3p_3$	4.25	1.64	3.93	3.35	4.10
$s_1n_1p_1$	2.55	3.34	4.11	2.33	4.71
$s_1n_1p_2$	2.62	3.34	4.41	2.41	4.02
$s_1n_1p_3$	3.42	3.63	4.38	2.64	4.75
$s_1n_2p_1$	1.31	4.01	3.31	2.66	2.55
$s_1n_2p_2$	2.14	3.12	4.82	4.13	4.60
$s_1n_2p_3$	3.22	2.33	4.32	2.79	3.78
$s_1n_3p_1$	2.34	3.46	4.29	4.22	3.69
$s_1n_3p_2$	3.03	4.58	4.83	3.45	4.63
$s_1n_3p_3$	3.06	3.72	5.04	3.04	5.03
$F_{4, 34}$	707.58**	1085.96**	205.82**	595.74**	319.76**
SE	0.017	0.020	0.022	0.025	0.025
CD	0.050	0.058	0.064	0.071	0.071

** Significant at 1 per cent level

APPENDIX II (g)

Interaction effects of shade, nitrogen and phosphorus levels on crude protein content (%), crude fibre content (%) and total protein yield ($t\ ha^{-1}$) of guinea grass

Interaction effects of factors	CPC	CFC	Total protein yield
$s_0n_1p_1$	8.06	33.44	1.04
$s_0n_1p_2$	8.19	32.85	1.26
$s_0n_1p_3$	8.17	32.36	1.39
$s_0n_2p_1$	8.08	32.45	1.20
$s_0n_2p_2$	8.19	32.22	1.35
$s_0n_2p_3$	8.15	31.17	1.46
$s_0n_3p_1$	8.17	32.21	1.30
$s_0n_3p_2$	8.21	31.04	1.55
$s_0n_3p_3$	8.38	31.01	1.79
$s_1n_1p_1$	8.25	32.47	0.70
$s_1n_1p_2$	8.56	32.31	0.86
$s_1n_1p_3$	8.52	32.12	0.97
$s_1n_2p_1$	8.48	31.83	0.90
$s_1n_2p_2$	8.75	31.48	1.06
$s_1n_2p_3$	8.65	31.52	1.15
$s_1n_3p_1$	8.81	31.45	1.05
$s_1n_3p_2$	8.88	30.83	1.24
$s_1n_3p_3$	8.94	30.26	1.50
$F_{4, 34}$	1.05^{ns}	324.21**	0.38^{ns}
SE	0.046	0.016	0.024
CD	-	0.047	-

** Significant at 1 per cent level ns – not significant

APPENDIX II (h)

Interaction effects of shade, nitrogen and phosphorus levels on NPK content (%) of guinea grass

Interaction effects of factors	N content	P content	K content
$s_0n_1p_1$	1.29	0.19	1.26
$s_0n_1p_2$	1.30	0.20	1.41
$s_0n_1p_3$	1.31	0.22	1.50
$s_0n_2p_1$	1.30	0.19	1.35
$s_0n_2p_2$	1.31	0.21	1.51
$s_0n_2p_3$	1.33	0.22	1.69
$s_0n_3p_1$	1.31	0.21	1.42
$s_0n_3p_2$	1.33	0.22	1.62
$s_0n_3p_3$	1.34	0.23	1.81
$s_1n_1p_1$	1.32	0.20	1.49
$s_1n_1p_2$	1.37	0.21	1.68
$s_1n_1p_3$	1.38	0.22	1.76
$s_1n_2p_1$	1.36	0.21	1.57
$s_1n_2p_2$	1.39	0.22	1.67
$s_1n_2p_3$	1.39	0.23	1.81
$s_1n_3p_1$	1.40	0.22	1.61
$s_1n_3p_2$	1.42	0.23	1.75
$s_1n_3p_3$	1.43	0.25	2.08
$F_{4, 34}$	2.39^{ns}	1.62^{ns}	1.18^{ns}
SE	0.005	0.003	0.039
CD	-	-	-

ns – not significant

APPENDIX II (i)

Interaction effects of shade, nitrogen and phosphorus levels on total NPK uptake of guinea grass (kg ha^{-1})

Interaction effects of factors	N uptake	P uptake	K uptake
$s_0n_1p_1$	167	24	163
$s_0n_1p_2$	201	31	219
$s_0n_1p_3$	224	37	258
$s_0n_2p_1$	192	29	201
$s_0n_2p_2$	217	34	252
$s_0n_2p_3$	239	39	305
$s_0n_3p_1$	208	36	226
$s_0n_3p_2$	250	41	306
$s_0n_3p_3$	287	50	388
$s_1n_1p_1$	113	17	127
$s_1n_1p_2$	138	21	161
$s_1n_1p_3$	158	25	202
$s_1n_2p_1$	144	22	168
$s_1n_2p_2$	169	27	203
$s_1n_2p_3$	186	31	241
$s_1n_3p_1$	166	26	191
$s_1n_3p_2$	198	33	245
$s_1n_3p_3$	239	42	349
$F_{4, 34}$	0.44^{ns}	2.71*	0.43^{ns}
SE	3.572	0.752	10.760
CD	-	2.159	-

* Significant at 5 per cent level ns – not significant

APPENDIX II (j)

Interaction effects of shade, nitrogen and phosphorus levels on on available N, P and K status of soil after the experiment (kg ha^{-1})

Interaction effects of factors	Available N	Available P_2O_5	Available K_2O
$s_0n_1p_1$	202.40	21.58	78.95
$s_0n_1p_2$	203.73	24.87	92.25
$s_0n_1p_3$	204.12	31.70	55.94
$s_0n_2p_1$	203.81	34.65	52.19
$s_0n_2p_2$	203.71	24.74	47.52
$s_0n_2p_3$	204.76	31.63	47.52
$s_0n_3p_1$	205.34	21.22	47.82
$s_0n_3p_2$	204.46	22.30	54.49
$s_0n_3p_3$	205.58	27.10	37.87
$s_1n_1p_1$	204.60	30.33	44.09
$s_1n_1p_2$	202.62	34.14	50.02
$s_1n_1p_3$	204.69	35.85	49.70
$s_1n_2p_1$	201.36	28.34	51.11
$s_1n_2p_2$	203.74	24.03	48.45
$s_1n_2p_3$	204.47	25.42	46.63
$s_1n_3p_1$	203.61	24.84	41.87
$s_1n_3p_2$	204.82	26.65	58.27
$s_1n_3p_3$	205.83	32.14	58.67
$F_{4, 34}$	2.19^{ns}	1.98^{ns}	8.22**
SE	0.786	1.127	2.633
CD	-	-	7.560

** Significant at 1 per cent level ns – not significant

APPENDIX II (k)

Interaction effects of shade, nitrogen and phosphorus levels on net returns (Rs. ha^{-1}) and Benefit: Cost Ratio of guinea grass

Interaction effects of factors	Net returns (Rs. ha^{-1})	BCR
$s_0n_1p_1$	10726	1.72
$s_0n_1p_2$	15255	1.99
$s_0n_1p_3$	17978	2.13
$s_0n_2p_1$	13471	1.85
$s_0n_2p_2$	16446	2.00
$s_0n_2p_3$	18829	2.10
$s_0n_3p_1$	14541	1.85
$s_0n_3p_2$	19876	2.13
$s_0n_3p_3$	24467	2.35
$s_1n_1p_1$	5321	1.46
$s_1n_1p_2$	7859	1.65
$s_1n_1p_3$	10327	1.84
$s_1n_2p_1$	8746	1.70
$s_1n_2p_2$	11355	1.88
$s_1n_2p_3$	13298	2.00
$s_1n_3p_1$	10381	1.78
$s_1n_3p_2$	14117	2.03
$s_1n_3p_3$	19205	2.37
$F_{4, 34}$	0.40^{ns}	0.57^{ns}
SE	567.555	3.036
CD	-	-

ns – not significant

NUTRIENT MANAGEMENT OF GUINEA GRASS (*Panicum maximum* J.) UNDER OPEN AND SHADED CONDITIONS

LEKSHMI, P.

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

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2004

Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM-695 522

ABSTRACT

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala state to find out the nitrogen and phosphorus requirement for guinea grass (*Panicum maximum* J.) under zero and 50 per cent shade levels.

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

Two levels of shade (0 and 50 per cent), three levels of nitrogen (100, 200 and 300 kg ha^{-1}) and three levels of phosphorus (25, 50 and 75 kg ha^{-1}) were combined to form eighteen treatment combinations. The experiment was laid out in split plot design with three replications.

Results of the experiment revealed that lower levels of shade as well as higher levels of nitrogen and phosphorus had significant positive influence on improving the fodder production potential of guinea grass. The lower levels of shade and higher doses of nitrogen and phosphorus were found to increase significantly the growth parameters namely number of tillers and leaf : stem ratio and physiological parameters like leaf area index, CGR, RGR and NAR.

Lower levels of shade and higher doses of nitrogen and phosphorus registered maximum green fodder yield in all the five harvests. Total green fodder yield was also highest at open and at higher levels of nitrogen and phosphorus. Similar results were obtained in the case of dry fodder yield also.

Quality parameters of the forage significantly improved as shade progresses. Higher levels of nitrogen and phosphorus registered higher crude protein and chlorophyll contents and lower crude fibre content.

The nutrient content of plant showed a significant increase with increasing levels of shade while the nutrient uptake showed a significant increase with lower levels of shade. Application of nitrogen and phosphorus significantly increased the content and uptake of nitrogen, phosphorus and potassium.

There was a significant increase in available phosphorus and a decrease in available potassium content of the soil with increase in shade levels. Application of nitrogen significantly increased the nitrogen content of the soil while reduced phosphorus and potassium content of the soil after the experiment. Phosphorus levels also significantly increased the nitrogen and phosphorus content but potassium content of the soil after the experiment showed a parabolic type of response.

Lower levels of shade with higher dose of nitrogen and phosphorus registered highest net returns and benefit cost ratio. But economic yield was obtained in shade intensity upto 50 per cent.