ENHANCING THE NITROGEN USE EFFICIENCY IN BHINDI WITH NITRIFICATION INHIBITORS

By

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THESIS
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Dedicated

to

my beloved Husband

DECLARATION

I hereby declare that this thesis entitled "**Enhancing the nitrogen use efficiency in bhindi with nitrification inhibitors**" 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,
19-3-1994.

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CERTIFICATE

Certified that this thesis entitled "**Enhancing the nitrogen use efficiency in bhindi with nitrification inhibitors**" is a record of research work done independently by **Mrs. BINDU S. KURUP** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

m	Metre
t	Tonnes
q	Quintals
g	Gram
N	Nitrogen
^{o}C	Degree celsius
nm	Nanometre
mg	Milligram
kg	Kilogram
cm	Centimetre
ha	Hectare
Rs	Rupees
DAS	Days after sowing
DMP	Dry matter production
CGR	Crop growth rate
NAR	Net assimilation rate
RGR	Relative growth rate
LAI	Leaf area index
NBU	Neem cake blended urea
MBU	Mahuacake blended urea

INTRODUCTION

INTRODUCTION

Vegetables play a vital role in the health and nutrition of people throughout the world. It also provides employment and income thereby contributing to higher living standards.

Okra or lady's finger commonly known as bhindi (Abelmoschus esculentus (L) Moench) in India is one of the most important fruit vegetables, because of its pleasant taste and its wider availability due to its greater adaptability to our climate. It is an important summer and rainy season vegetable and grown popularly throughout India on commercial scale.

In Kerala, vegetables cover an area of 1.62 lakh hectares producing 1.62 lakh tonnes per year (Anon, 1989), of which about 6312 tonnes of vegetables valued at Rs. 12 crores have been exported to foreign countries. Among the different vegetables exported to Arabian countries bhindi occupies an important position constituting 60 per cent of the total export (Sulekha and Mohanakumaran, 1992).

Bhindi requires proper and timely manuring to provide regular fruiting and subsequent pickings. Under most conditions, the use of fertilizers affords the quickest method of achieving the objective of high yield. But fertilizer is one of the costliest inputs in agricultural production. It is estimated that 50 to 60 per cent of the cost incurred in crop production goes to fertilizer alone which accounts for 35 per cent of the increased food production (Shivananda et al., 1987). Of the three primary plant nutrients nitrogen has made the real impact in Indian agriculture and today it constitutes two third of the chemical fertilizer consumed in the country.

Most important source of nitrogen for bhindi has been found to be urea (Kirti Singh and Singh, 1965). Losses from urea fertilized soils are potentially more serious than those from soil receiving other nitrogenous fertilizers. Urea when applied to soil undergoes several transformations, resulting in various losses like leaching, volatilization and denitrification, of which denitrification constitutes about 95 per cent of the total loss.

Vegetables removed only 43 per cent of the fertilizer nitrogen applied to soil (Maynard and Lorenz, 1979) and the rest is lost through the above mentioned processes. But the current soaring price of nitrogen fertilizers and inadequate availability, warrent the most judicious and efficient use of nitrogen. The basic concept of judicious application point towards enhancing the fertilizer use efficiency by minimizing the various losses (Parr, 1967). Nitrogen use efficiency and nitrogen economy can be increased by using nitrification inhibitors like nitrapyrin, AM etc. which cause toxicity to ammonium oxidising bacteria like Nitrosomonas and Nitrobacter and thereby retard nitrification (Goring, 1962, Janert et al., 1968).

However, the exhorbitant cost and availability of these materials prohibit their large scale use in the field. Under such conditions, several indigenous materials like oilcakes have been tried and are found to be efficient nitrification inhibitors.

Oilcake is the residue left after the extraction of oil from oil bearing seeds. There are edible and non edible possibilities of using the indigenous nitrification inhibitors in vegetables, the present trial was conducted in bhindi. The objectives of the study are

1. to study the influence of different levels of nitrogen on the growth and productivity of bhindi.

2. to assess the use efficiency of applied nitrogen by blending urea with oilcakes.

3. to work out the economics of different sources of nitrogen

REVIEW OF LITERATURE

REVIEW OF LITERATURE

An experiment was conducted in the College of Agriculture with four levels of nitrogen and two indigenous nitrification inhibitors viz., neem cake and mahua cake for enhancing the nitrogen use efficiency in bhindi. The available literature relating to the above topic is reviewed hereunder.

2.1 Effect of nitrogen

2.1.1 Effect of nitrogen on growth characters

2.1.1.1 Height of plant

Application of nitrogen stimulates the plant growth resulting in an increase in the plant height of bhindi. There was a progressive increase in the height of plants by increasing the level of nitrogen in the soil as reported by Chauhan and Gupta (1973), Verma *et al*. (1973), Sharma and Rajendra Prasad (1979), Pandey and Singh (1979), Pandey *et* *al*. (1980), Hooda *et al*. (1980), Jana and Das (1986), Sharma *et al*. (1987), Balasubramoni (1988), Khan and Jaiswal (1988), Arora *et al*. (1991), Saimbi *et al*. (1991), Elizabeth and Rajan (1992), Sajitharani (1993).

Chhonkar and Singh (1963) while studying the inorganic nutrition of okra in sand culture found that increase in nitrogen concentration upto 210 ppm stimulated the height of plants but further increase retarded the same.

Konhar *et al*. (1974) observed that although there was an increase in plant height with successive doses of nitrogen upto 80 kg ha^{-1}, this increase was only apparent. Hence nitrogen application beyond 20 kg ha^{-1} failed to increase the height of the plant remarkably. Singh (1979) could not obtain significant differences in plant height with varying levels of nitrogen tried from 75 to 150 kg N ha^{-1}.

2.1.1.2 Number of leaves per plant

With the increasing levels of nitrogen an increase in the leaf number in okra was reported by Chhonkar and Singh (1963), Chandrasekharan (1965), Singh and Singh (1965), Chauhan and Gupta (1973), Verma *et al*. (1973), Sharma and Rajendra Prasad (1979), Pandey and Singh (1979).

Verma *et al*. (1970) observed no effect on the number of leaves in bhindi by increasing fertilizer nitrogen from 90-120 kg ha^{-1} and he suggested that this may probably be due to limited amount of plant capacity beyond a certain optimum. Konhar *et al*. (1974) found no significant difference in the number of leaves of bhindi by increasing the nitrogen dose beyond 20 kg N ha^{-1}.

2.1.1.3 Number of branches per plant

Increase in the levels of nitrogen brought an increase in the number of branches per plant in bhindi as reported by Chandrasekharan (1965), Chauhan and Gupta (1973), Hooda *et al*. (1980), Hooda *et al*. (1981).

According to Sharma *et al*. (1987) branching in okra was more a varietal trait and there was very little influence by agronomic practices eventhough nitrogen fertilization increased the number of branches.

2.1.1.4 Root length

Maharana and Das (1973) opined that higher doses of nitrogen were detrimental for root growth in cowpea. They obtained significant increase in the length of the root by applying 10 kg N ha^{-1} whereas 50 kg N ha^{-1} increased the number of lateral roots.

Konhar *et al*. (1974) reported that increasing levels of nitrogen increased the length of the root of bhindi and maximum length was obtained with 80 kg N ha^{-1}. But, Balasubramoni (1988), obtained maximum length and width of root by supplying 30 kg N ha^{-1}.

2.1.1.5 Dry matter production (DMP)

Chauhan and Gupta (1973) reported that dry matter production of bhindi plants increased with increasing levels of nitrogen. Maximum was obtained with the highest dose of 67.5 Kg N ha^{-1}. Subramonian (1980) also obtained the same result upto 60 kg N ha^{-1}, though the statistical significance was observed only upto 30 kg N ha^{-1}. Balasubramoni (1988) got maximum DMP with the application of 30 kg N ha^{-1} in bhindi. Sajitharani (1993) while studying the standardisation of fertilizer schedule for export oriented production of bhindi found that there was a progressive increase in DMP due to nutrient application at all growth stages. DMP increased significantly from 50 kg N ha^{-1} to 330 kg N ha^{-1} and maximum with 330 kg N ha^{-1}.

Chougule and Mahajan (1979) found that dry matter content of chilli was significantly increased by the application of nitrogen upto 200 kg ha^{-1}. Wankhade and Morey (1984) reported that in chilli nitrogen produced significantly higher DMP upto 100 kg N ha^{-1}. Saji John (1989) found that the DMP in chilli increased with increasing levels of nitrogen upto 125 kg N ha^{-1}. But Medhi <u>et al</u>. (1990) obtained maximum DMP in chilli with 80 Kg N ha^{-1} . Jeyaraman and Balasubramanian (1991) found that 125 kg N ha^{-1}. significantly influenced the DMP over the lower levels of 75 and 100 kgNha^{-1} in chilli. Ramakrishna Praseeda and Sulladmath (1979) reported that there was a significant increase in the dry weight of tomato plants with the application of nitrogen upto 345 kg N ha^{-1}. Subbiah and Raniperumal (1986) obtained maximum dry matter in tomato with 120 kg N ha^{-1}.

2.1.2 Effect of nitrogen on growth analytical parameters

2.1.2.1 Leaf area index (LAI)

Increased leaf area index with increasing levels of nitrogen in bhindi had been reported by several workers. Konhar *et al*. (1974) obtained maximum leaf area with 80 kg N ha^{-1} which was more than double in comparison to no fertilised plants. Subramonian (1980) reported that increasing levels of nitrogen significantly increased the leaf area index both at 30th and 60th day after sowing. Sajitharani (1993) found that there was a general increase in the leaf area index of the crop with increasing levels of nitrogen, recording the maximum LAI of 0.94 with 330 kg N ha^{-1}.

In other vegetables also leaf area index was found to be influenced by nitrogen levels. In brinjal, KirtiSingh and Sandhu (1970) found that leaf area index increased with the higher doses of nitrogen, irrespective of method of application. The largest leaves were obtained in the plots fertilized with 75 kg N ha^{-1}. Wankhade and Morey (1984) obtained significant increase in leaf area index on chilli due to the application of nitrogen upto 100 kg N ha^{-1}. According to Ramakrishna Praseeda and Sulladmath (1979) increasing levels of nitrogen increased the leaf area index and leaf area duration in tomato upto 203 kg N ha^{-1}. In amaranthus, Ramachandra and Thimmaraju (1983) got significant increase in leaf area index with nitrogen at all stages of growth upto 200 kg N ha^{-1} but Rajan (1991) obtained maximum leaf area index with 125 kg N ha^{-1}.

2.1.2.2 Relative growth rate, Net assimilation rate, Crop growth rate

It was seen that net assimilation rate (NAR) relative growth rate (RGR) and crop growth rate (CGR) were found to be influenced by nitrogen.

Ramakrishna Praseeda (1976) found a decrease in net assimilation rate with nitrogen levels in tomato. Maximum was recorded by 115 kg N ha^{-1} at ten weeks after planting than 203 kg N ha^{-1}.

Ramana Gowda (1981) reported that nitrogen application favourably influenced the physiological parameters like NAR, RGR and CGR in fodder cowpea. The highest level of nitrogen recorded the maximum NAR, CGR and RGR. Ramachandra and Thimmaraju (1983) reported that NAR increased with increasing levels of nitrogen in amaranthus. The maximum being recorded at the time of harvest with 200 kg Nha^{-1}. Nitrogen application also resulted in higher CGR compared to no nitrogen application. Ramakrishnan Nayar (1986) found that in cassava, during the later growth phase (180-240 days) nitrogen upto 150 kg N ha^{-1} significantly increased CGR than lower levels. But higher levels of nitrogen had depressing effect on NAR at all the phases of growth. Sajitharani (1993) showed that nitrogen levels significantly influenced the CGR of bhindi. CGR increased with increasing levels of nitrogen in bhindi.

In general, the growth characters like height of plants, number of leaves and branches, length and spread of root, DMP, LAI, RGR, NAR and CGR were found to increase with increasing levels of nitrogen in bhindi.

2.1.3 Effect of nitrogen on days to 50 per cent flowering yield attributes and yeild

2.1.3.1 Days to 50 per cent flowering

Delayed flowering was reported in bhindi with increasing levels of nitrogen by Thompson and Kelly (1957), Yawalker (1969) and Kamalanathan et al. (1970). Shrestha (1983) in a study to find out the effect of spacing and nitrogen fertilization in bhindi variety Pusa savani found that nitrogen fertilised plants took four to six days more for flowering when compared with control receiving no nitrogen. Balasubramoni (1988) also obtained the same result in bhindi. Sajitharani (1993) opined that nutrient application significantly influenced the days taken for 50 per cent flowering and reported a delay in flowering due to increased levels of fertilizer.

Chandrasekharan (1965) and Chauhan and Gupta (1973) reported that nitrogen had not shown any difference in earliness of flowering of bhindi.

Arvind Gupta and Gill (1988) reported that number of days taken for opening of first flower decreased with increase in nitrogen application.

2.1.3.2 Number of flowers per plant

Chauhan and Gupta (1973) reported that higher dose of nitrogen ie, 67.5 kg N ha^{-1} gave maximum number of flowers per plant. Sharma and Rajendra Prasad (1979) opined that nitrogen application significantly increased the number of flowers per plant. Subramonian (1980) reported that application of nitrogen resulted in significantly higher number of flowers upto the highest level of 60 kg ha^{-1}. Arora et al. (1991) got maximum number of flowers with 120 kg N ha^{-1}. Sajitharani (1993) reported that the number of flowers produced per plant increased with increasing levels of nutrients upto 330 kg N ha^{-1}.

Chandrasekharan (1965) in an experiment found that nitrogen at 100 kg ha^{-1} had only a slight effect in increasing the number of flowers, beyond which a decline was noticed and the result was not statstically significant also. Randhawa and Pannun (1969) in an experiment in bhindi with three levels of nitrogen viz., 34, 68 and 102 kg ha^{-1} found that the number of flowers per plant was maximum when 68 kg N ha^{-1} was applied.

2.1.3.3 Number of fruits per plant

Singh and Singh (1965) reported that the number of fruits per plant increased with increasing levels of nitrogen upto 90 kg N ha^{-1}. Verma et al. (1970) also got the same result. Chauhan and Gupta (1973) opined that higher doses of nitrogen gave maximum number of fruits per plant. It is apparent that as the level of nitrogen application was increased from 22.5 to 67.5 kg ha^{-1} there was an increase in the number of pods.

Similar increase in the number of pods per plant with increasing levels of nitrogen had been reported by several workers viz., Balasubramoni (1988) upto 30 kg ha^{-1}, Shrestha (1983) upto 60 kg ha^{-1}, Elizabeth and Rajan (1992) upto 75 kg ha^{-1}, Mishra and Pandey (1987) and Arvind Gupta and Gill (1988) upto 80 kg ha^{-1}, Arora et al. (1991) and Saimbi et al. (1991) upto 90 kg ha^{-1}, Pandey and Singh (1979), Gupta and Rao (1979), Majanbu et al. (1985) and

Manphool Singh *et al*. (1993) upto 100 kg ha^{-1}, Pandey *et al*. (1980) and Hooda *et al*. (1981) upto 120 kg ha^{-1}, Jana and Das (1986) and Khan and Jaiswal (1988) upto 150 kg ha^{-1} and Sajitharani (1993) upto 330 kg ha^{-1}.

Chandrasekharan (1965) reported that nitrogen levels could not exert any significant influence on the number of fruits per plant. Gupta and Rao (1979) found that in bhindi application of nitrogen above 100 kg N ha^{-1} did not increase the number of fruits per plant significantly.

2.1.3.4 Setting percentage

In bhindi, Chandrasekharan (1965) reported higher setting percentage with 100 kg N ha^{-1} over 125 kg N ha^{-1}.

Chauhan and Gupta (1973) reported that setting percentage was unaffected by increasing levels of nitrogen. Among the doses they tried viz.22.5, 45 and 67.5 kg N ha^{-1} the lowest dose of nitrogen 22.5 kg ha^{-1} gave maximum percentage of flowers to set fruit.

Subramonian (1980) studied the effect of nitrogen at different levels (0, 30, 60 kg ha^{-1}) on the setting percentage and observed that increasing levels of nitrogen tended to reduce the fruit set. Among the doses he tried, 60 kg N ha^{-1} recorded the lowest setting percentage where as the setting percentage at 0 and 30 kg N ha^{-1} were on a par.

Arvind Gupta and Gill (1988) and Sajitharani (1993) obtained no significant influence on the fruit set in bhindi by nutrient application.

2.1.3.5 Height of the first fruit bearing node

Arvind Gupta and Gill (1988) reported that the height of the first fruit bearing node in bhindi was found to increase with increasing levels of nitrogen from 0 kg to 80 kg ha^{-1}. Similar result was obtained by Balasubramoni (1988) also in bhindi.

2.1.3.6 Length of the fruit

Singh and Singh (1965) found that all the nitrogen levels tried viz., 0, 30, 60, 90, 120 kg ha^{-1} increased the length of the fruit. The maximum increase in length being 17.6 cm resulted from 120 kg N ha^{-1} which was 2.5 cm more than the control. Verma et al. (1970) also obtained the same result. Sharma and Rajendra Prasad (1979) obtained significant increase in pod length due to nitrogen application upto 66 kg N ha^{-1}. Hooda et al. (1980) observed maximum length of fruit with the highest dose of nitrogen of 120 kg ha^{-1}. Jana and Das (1986) reported that the length of fruit was markedly influenced by the different doses of fertilizer application and maximum length of fruit was obtained with the highest dose of nitrogen of 150 kg ha^{-1},

Sharma et al. (1987) opined that nitrogen fertilization in general increased the fruit length. Balasubramoni (1988) also reported that in bhindi nitrogen application showed significant increase in fruit length with increasing levels of nitrogen Arora et al. (1991) found that maximum fruit length was produced in plots where nitrogen was applied @ 90 kg ha^{-1}. Manphool Singh et al. (1993) reported that nitrogen application in general, positively influenced the fruit length.

Hooda *et al.* (1981) found that 120 kg N ha^{-1} had the longest pods but it was statistically at par with 80 kg N ha^{-1}. Lenka *et al.* (1989) in a study in bhindi with four levels of nitrogen (0, 50, 75 and 100 kg ha^{-1}) found that all levels were on a par with respect to length of bhindi fruits.

Pandey *et al.* (1980) opined that the application of nitrogen did not show any significant effect on the length of fruits. Sajitharani (1993) reported that the levels of nutrients had no effect on the length of fruit.

Contrary to the above reports, reduction in the length of the fruit was also observed in bhindi by Chandrasekharan (1965). He observed that when nitrogen was increased from 75 to 125 kg ha^{-1}, the length of the fruit was reduced by 0.42 cm. Pandey and Singh (1979) in a study with 0, 50, 100, 150 kg N ha^{-1}, found that 100 kg N ha^{-1} produced the maximum length of fruit than 150 kg N ha^{-1}. Singh (1979) reported that when nitrogen dose was increased from 75 to 150 kg N ha^{-1} there was adverse effect on pod length.

2.1.3.7 Girth of the fruit

Singh and Singh (1965) observed an increase in diameter of fruit with different levels of nutrient. Verma et al. (1970) found that the fruit diameter increased to a maximum of 2.31 cm at 90 kg N ha^{-1} as compared with 1.84 cm for zero level of nitrogen. Majanbu et al. (1985) reported that nitrogen application significantly increased the pod diameter. Similar findings were reported by Sharma et al. (1987) and Balasubramoni (1988).

Gupta and Rao (1979) in an experiment with bhindi observed no significant difference in the size of the fruit with 100 and 150 kg N ha^{-1}. Jana and Das (1986) recorded no marked difference in the diameter of fruits with increasing levels of nitrogen. Sajitharani (1993) reported that the levels of nitrogen had no effect on the girth of the fruit.

On the other hand, Singh (1979) observed an adverse effect on the pod diameter when nitrogen dose was increased from 75 to 150 kg ha^{-1}

2.1.3.8 Total fruit yield

In all the studies, bhindi has shown good response to application of nitrogen (Singh, 1978). Optimum levels of nitrogen for getting maximum yield in bhindi varied from place to place as reported by several workers.

Experiments carried out at Coimbatore, Kamalanathan et al. (1970) and in Agra Sharma (1970) have shown that optimum level of nitrogen was 90 kg ha^{-1} to get maximum yield in bhindi. However, Verma et al. (1973) found significant response upto 150 kg N ha^{-1} in Agra.

Verma et al. (1970) obtained highest pod yield with 90 kg N ha^{-1} at Udaipur (Rajasthan). While working at Hisar, Saimb and Padda (1970) obtained highest pod yield with 134 kg N ha^{-1}. Sharma and Shukla (1973) however, calculated 116.7 kg ha^{-1} as economic dose of nitrogen for Bangalore region. Singh (1978) at Varanasi found 75 kg N ha^{-1} as optimum dose of nitrogen for bhindi. Experiments carried out at Ludhiana (Kumar, 1983) have shown that optimum level of nitrogen was 90 kg ha^{-1}. In Bihar, Mishra and Pandey (1987), Tomar and Rathore (1987) in Gujarat found 75 kg N ha^{-1} as optimum dose for bhindi. In Himachal Pradesh, the optimum level of nitrogen was worked out to be 60 kg ha^{-1} (Rastogi et al. 1987). Khan and Jaiswal (1988) at Faizabad found significant response of bhindi upto 150 kg N ha^{-1}. Pandey and Manocha (1989) however, worked out 136 kg N ha^{-1} as the economic dose of nitrogen for Harayana. Experiment carried out at Jalandhar, (Saimbi et al., 1991) have shown that optimum level of nitrogen was 90 kg ha^{-1}. In Kerala , Anon (1993) found optimum dose of nitrogen for getting higher yield was 50 kg ha^{-1} while for reclaimed soils of Kuttanad, Elizabeth and Rajan (1992) obtained maximum yield with 75 kg N ha^{-1} .

Several other workers have reported that the yield of bhindi fruits was significantly increased by nitrogen fertilisation. It was notworthy that every increase in the level of application of nitrogen correspondingly increased the yield of bhindi fruits as reported by Singh and Singh (1965), Bid et al. (1971), Chauhan and Gupta (1973), Mani and Ramanathan (1980), Hooda et al. (1980), Jana and Das (1986), Arora et al. (1991), Saimbi et al. (1991), Sajitharani (1993).

However, Chandrasekharan (1965) found that none of the nitrogen levels tried (75, 100, 125 kg ha^{-1}) were significant eventhough there was an increasing trend with the increase in the level of nitrogen. Konhar et al. (1974) also observed nonsignificant difference among higher levels of nitrogen on fruit yield. He reported that the application of nitrogen beyond 20 kg ha^{-1} was not beneficial.

Ahmad and Tulloch - Reid (1968) found that increase in the rates from 112 kg N ha^{-1} to 336 kg N ha^{-1} resulted in a decrease in yield by 16.8 metric tons ha^{-1}. Anon (1983) reported that maximum yield obtained at 162.5 kg N ha^{-1} was on par with 237.5 kg N ha^{-1}. Sharma et al. (1987) observed that there was a decline in fruit yield when the nitrogen level was increased beyond 120 kg ha^{-1}.

In general, application of nitrogen increased the yield attributes and total yield of bhindi.

2.1.4 Effect of nitrogen on chemical aspects

2.1.4.1 Effect of nitrogen on chlorophyll content of leaves

Synthesis of chlorophyll was accelerated with the greater nitrogen supply. With every increase in the level of nitrogen added there was a corresponding increase in the chlorophyll content of leaves as reported by several workers in bhindi [Chhonkar and Singh (1963), Chauhan and Gupta (1973), Verma et al. (1973), Balasubramoni (1988), Arora et al. (1991)], in tomato (Bhatnagar and Pandita, 1979), in amaranthus (Subbiah and Ramanathan, 1982) and in chilli (Nazeer Ahmed and Tanaki, 1991).

2.1.4.2 Effect of nitrogen on quality

2.1.4.2.1 Effect of nitrogen on crude protein

Thampan (1963) observed maximum protein content in bhindi with 75 kg N ha^{-1}. Subramonian (1980) found that application of nitrogen at the highest level of 60 kg ha^{-1} increased the protein content of fruits. He also reported that nitrogen at 0 and 30 kg ha^{-1} were on a par as far as protein content was concerned. Sajitharani (1993) reported that application of nitrogen exerted significant influence on the fruit protein content of bhindi. A maximum of 16.21 per cent was recorded with the highest dose of 330 kg N ha^{-1}.

Chandrasekharan (1965) found that nitrogen at 75 kg ha^{-1} and 100 kg ha^{-1} increased the crude protein content while 125 kg ha^{-1} reduced the crude protein in bhindi.

In amaranthus, Subbiah and Ramanathan (1982) observed an increase in crude protein content with added nitrogen. Among the nitrogen levels viz. 0, 20, 40, 60, 80 kg ha^{-1}, the higher levels of nitrogen (N_{60} and N_{80}) recorded higher crude protein content than the lower levels (N_{20} and N_{40}). They found 60 kg N ha^{-1} as the optimum dose for amaranthus for obtaining higher crude protein content whereas, Singh et al. (1986) opined that with every increase in the level of nitrogen there was a corresponding increase in the crude protein content of amaranthus. Rajan (1991) obtained a maximum crude protein content of 27.5 per cent with the highest dose of 125 kg Nha^{-1} in amaranthus.

2.1.4.2.2 Effect of nitrogen on ascorbic acid content of fruits

Asorbic acid content of fruits increased with increasing levels of nitrogen as reported by Balasubramoni (1988) upto 30 kg ha^{-1}, Irene Vethamoni (1988) upto 55 kg ha^{-1} and Sajitharani (1993) upto 330 kg ha^{-1}.

In other vegetables also ascorbic acid content of fruits increased with increasing levels of nitrogen. In tomato, Sharma and Mann (1971) and Ramakrishna Praseeda (1976) observed that plants which received higher doses of nitrogen had appreciably more ascorbic acid. In amaranthus, Ramachandra and Thimmaraju (1982) found that application of nitrogen significantly increased the ascorbic acid content and maximum was recorded with the highest dose of 200 kg N ha^{-1}. In chilli, Saji John (1989) found that application of 100 and 125 kg N ha^{-1} significantly increased the fruit ascrobic acid content compared with nitrogen at 75 kg ha^{-1} and the effects due to 100 and 125 kg ha^{-1} were on a par. Dod _et al_. (1992) observed increase in ascrobic acid content of fruits of chilli with every increase in nitrogen levels.

On the contrary, Sinha (1975) reported reduced ascorbic acid content of fresh chilli fruits with increase in nitrogen levels. Subbiah and Ramanathan (1982) observed a higher ascorbic acid content in amaranthus with the lowest dose of nitrogen tried ie. 20 kg N ha^{-1}. Singh _et al_. (1986) found that the nitrogen application significantly decreased the ascorbic acid content of amaranthus. They obtained a minimum ascorbic acid content of 52.29 mg 100 g^{-1} with the highest dose of 60 kg N ha^{-1} and a maximum of 76.96 mg 100 g^{-1} with 20 kg N ha^{-1}. This might be probably due to the interaction of nitrogen in the hormonal metabolism of the plant system especially the auxins.

2.1.4.3 Effect of nitrogen on crude fibre

Mani and Ramanathan (1980) reported that crude fibre content of bhindi fruit was significantly decreased by nitrogen fertilization. Application of 80 kg N ha^{-1} recorded least crude fibre content of 12.91 per cent as against 14.2 per cent with zero level of nitrogen. Application of 55 kg N ha^{-1} decreased the crude fibre content of fruits as reported by Irene Vethamoni (1988). Balasubramoni (1988) reported least crude fibre content in bhindi fruits with 30 kg N ha^{-1}. Sajitharani (1993) found that application of nitrogen exerted significant influence on crude fibre content of bhindi fruits from first to fourth day after harvest. Maximum crude fibre content of 13.91 per cent was obtained from plots fertilized with 50 kg N ha^{-1} and a minimum of 7.36 per cent from 330 kg N ha^{-1}.

In amaranthus, Ramachandra and Thimmaraju (1983) and Singh et al. (1985) opined that the crude fibre content decreased inversely with increase in the levels of nitrogen. The plots which received no nitrogen recorded maximum crude fibre content. Rajan (1991) also observed a decreasing trend in fibre content in amaranthus with increasing levels of nitrogen from 50 to 125 kg N ha^{-1}.

2.1.4.4 Effect of nitrogen on uptake of nutrients

Leela et al. (1975) observed that application of fertilizers at the rate of 125 kg N ha^{-1} produced the highest content of nitrogen in bhindi leaf. Balasubramoni (1988) found that application of 30 kg N ha^{-1} increased the uptake of nitrogen, phosphorus and potassium content of plants than the lower levels. Irene Vethamoni (1988) also observed significant increase in the nutrient uptake of crop by the application of various levels of nitrogen. Sajitharani (1993) reported that there was a progressive increase in the uptake of nitrogen, phosphorus and potasssium by plants and fruits of bhindi due to different nitrogen levels and the difference was found to be significant.

In other vegetable crops also, several workers have reported increased nitrogen, phosphorus and potassium uptake with increasing levels of nitrogen. In turnip green, Brantley (1961) opined that total nitrogen value of the plant increases with increase in the levels of nitrogen. Anand and Muthukrishnan (1974) found significant increase in leaf nitrogen of tomato with increasing levels of nitrogen. In tomato, Ramakrishna Praseeda (1976), Ramachandra and Thimmaraju (1982) and Subbiah and Raniperumal (1986) observed significantly higher values for nitrogen, phosphorus and potassium contents with different levels of nitrogen. The maximum being recorded with the highest dose of nitrogen.

Saimbi and Padda (1970) found that in bhindi application of nitrogen increased the nitrogen content but decreased the phosphorus content. Asif and Greig (1972) also agreed with the above findings. Subramonian (1980) reported that in bhindi, when the nutrients were applied in combination, the uptake of nitrogen, phosphorus and potassium were generally high and the highest uptake was not always with the highest level of nutrients.

2.1.4.5 Effect of nitrogen an available nutrient content of soil

The available nutrient status of soil increased with increasing levels of nitrogen and the maximum being recorded with the highest dose tried as reported by Balasubramoni (1988) upto 30 kg N ha^{-1}, Irene Vethamoni (1988) upto 55 kg N ha^{-1} and Sajitharani (1993) upto 330 kg N ha^{-1} in bhindi.

In other vegetable crops also a similar trend was observed. In tomato, Anand and Muthukrishnan (1974) observed a significant increase in the available nutrient status of soil with increasing nitrogen levels. Rajan (1991) in amaranthus found an increasing trend in available nitrogen, phosphorus and potassium status of soil with increasing levels of nitrogen from 50 to 125 kg ha^{-1}.

In general, quality aspects uptake of nutrients and available nutrient status of soil were favaourably influenced by nitrogen levels.

2.2 Use of nitrification inhibitors

The nitrogenous fertilizers when applied to soil undergo several transformations such as ammonification, nitrification and denitrification depending upon the soil conditions. During the process of such transformations loss of nitrogen occurs due to leaching, volatilization of ammonia or denitrification. Denitrification is the major loss causing the liberation of nitrous oxide and elemental nitrogen to the atmosphere. These losses can be minimised to a certain extent by the controlled release of fertilizer nitrogen by using nitrification inhibitors. Literature available on nitrification inhibitors in increasing the nitrogen use efficiency are reviewed here.

In recent years, a large number of chemicals including nitrapyrin (N - serve), AM (2amino-4 chloro - 6 methyl pyrimidine), dicyandiamide (DCD), thiourea, ST (2-sulfanilamido thiazole) have been tested for their nitrification retarding properties under laboratory as well as field conditions.

N-serve inhibited nitrification of ammonium and amide fertilizers at rates varying from 0.2 to 2 per cent of nitrogen. Retardation of nitrification by N-Serve is brought about mainly due to toxicity to ammonium oxidising autotrophs of genus Nitrosomonas as reported by Goring (1962).

Increased yields of irrigated sugarbeet, sweetcorn, cotton and spinach were obtained when anhydrous ammonia, urea or ammonium sulphate was treated with N-Serve as observed by Swezey and Turner (1962). They concluded that these results were due to the inhibition of nitrification and subsequent reduction in leaching losses of nitrates.

N-Serve was also found to be toxic to autotrophs of *Nitrobacter* sp, but possessed a low order toxicity to organisms or enzymes converting urea to ammonia, and to organisms converting nitrite to nitrate as reported by Shattuck and Alexander (1963). Workers at IRRI, Anon (1967) showed that soil samples receiving N-Serve contained upto 40 ppm more extractable ammonium than the soil samples treated with ammonium sulphate alone. Using N^{15}, Carter *et al*. (1967) showed that the greatest advantage of adding N-Serve to retard nitrification was to hold the nitrogen in the root zone for longer periods of time.

AM when applied at 5-6 kg ha^{-1} and mixed with fertilizers, effectively retarded the nitrification of urea and leaching of nitrogen (Anon, 1969). Rajale and Prasad (1970) observed that when urea was treated with AM at 5ppm, only 74 per cent of ammonium was nitrified within 20 days. At higher concentrations AM was still more effective. Even at the end of 40 days of incubation, the nitrification rate of urea treated with AM at 10 ppm of soil was 76 per cent as against 100 per cent in the case of urea.

Soubies et al. (1962) reported that the application of dicyandiamide at the rate of 5.5 - 24 per cent of nitrogen retarded nitrification. He also observed that in winter the nitrification was stopped for five months by dicyandiamide and it also reduced the leaching losses of nitrogen by 67 per cent

Mc Beath (1962) reported that thiourea retarded nitrification by lengthening the lag period prior to exponential growth of Nitromonas although it did not kill the organisms. Even at low concentration allyl thiourea was found to inhibit nitrification.

2, Sulfanilamido thiazole when applied at 1-10 ppm on soil basis retarded nitrification of urea. Increased yield of barley and spinach were obtained by using ST.

Several other chemicals were also found to possess nitrification inhibition property as reported by several workers. Golden et al. (1984) found that addition of potassium chloride effectively suppressed nitrification and this was found to be due to the presence of chloride ions rather than potassium ions. Touchton et al. (1985) reported that ethlene dibromide was an effective nitrification inhibitor for several weeks after application, since ammonium nitrogen persisted in the soil.

Goos et al. (1986) observed that the ammonium thiosulphate, a sulphur fertilizer found to possess some ability to inhibit nitrification.

Freney et al. (1992) studied the effectiveness of wax coated calcium carbide as a nitrification inhibitor and showed that it provide a slow release of acetylene to inhibit nitrification and denitrification in soil. The inhibitor limited ammonium oxidation and prevented nitrogen loss by denitrification for 75 days.

Due to cost considerations, it was difficult to use these synthetic chemicals in agricultural practice, so some materials of indigenous origin have also been tried by several workers.

In India, non edible oil cakes have been used since time immemorial in admixtures with manures with advantages. One of the beneficial effects of these cakes can be attributed to their nitrification inhibition property.

Chandra and Shrikhande (1955) reported that neemcake containing 7.1 per cent nitrogen mineralized only 61 per cent nitrogen while castor cake containing 4.6 per cent nitrogen mineralized to an extent of 71 per cent. They attributed the lower nitrification rate in neemcake to the presence of bitter substances in it. They also observed that nitrification inhibitors was more when oil content in cake was more than 14 per cent.

Patil (1972) reported that neem oil was effective in decreasing nitrification rate with increase in the level from 1.5 to 12 per cent. The total bitter fractions from 12 per cent neem oil was most responsible for inhibition followed by sulphur containing odourescent compounds, while pre-refined oil fractions did not show any effect.

Sahrawat et al. (1974) conducted detailed study to find the efficacy of extracts of seed, bark and leaves of Karanja tree and observed that the components of the alcohol extracts of seeds were effective upto 60 days.

Mishra et al. (1975) found that neem seed cake delayed nitrification for six weeks. It checked the conversion of ammonium to nitrite presumably by its selective effects on the ammonium oxidising bacteria. Khandelwal et al. (1977) reported that a commercial neem extractive applied at 1 and 2 ppm of nitrogen inhibited the population of Nitrosomonas sp for four weeks and that of Nitrobacter sp for one week.

Sahrawat and Mukherjee (1977) established that karanjin was the major cystalline principle of karanj cake. It compared well with N-Serve. Studies showed that its furan ring was essential for showing the inhibitory effect.

Biddappa and Sarkunan (1981) showed that neem cake and coal tar coatings of urea conserved the ammoniacal nitrogen and retarded nitrification. Neem cake blended urea, coaltar coated urea, and application of neem cake in the moist soil were equally effective in checking the nitrification upto 20 days. Application of neem cake inhibited the formation of nitrate in the soil. The inhibitory effect lasted even upto 70 days in the case of laterite soil.

Rajkumar and Sekhon (1981) found that neem cake was more effective in inhibiting nitrification of urea in alkali soils than AM. Selvaseelan (1981) reported that neem and mahua cakes were efficient only for a limited period of 10 to 25 days. The nitrification inhibition was more pronounced in red sandy loam and black soils than laterite and alluvial soils.

Rajendra Prasad and Subbiah (1982) observed that urea treated with acetone extract of neem seed gave as good efficiency as AM treated urea, IBDU or sulphur coated urea.

Sahrawat (1982) compared the effect of alcohol extracts of karanj and neem seeds to that of karanjin. Application of seed extracts at a rate corresponding to 30 per cent of the nitrogen rate was comparable to karanjin applied at five and ten percent concentration. The extracts were effective for a period of upto 45 days, while karanjin was effective upto 60 days. The different patterns of nitrification inhibition observed with karanj and neem seed extracts suggested an advantage in using a mixture of the two.

Sathianathan (1982) found in cassava that neem and mahua cake treatments were efficient in retaining more nitrogen in the ammoniacal form under field condition also. Thus, these oil cakes reduced leaching losses and extended the period of availability of nitrogen to the crop from applied nitrogen. Narrowing the ratio of urea to oil cakes have enhanced the efficiency of inhibition of all the oil cake treatments except that of urea-maroti blend.

Yadav and Shrivastava (1987) found that the low nitrification rate of neem cake coated urea and karanj cake blended urea was due to the presence of active principles viz. lipid associates, nimbin, nimbidin and karanjin in the cakes. Extracts of neem oil and neem cake inhibited the growth of Nitrosomonas and Nitrobacter. Lipid associates of karanj cake applied @ 20 ppm reduced the number of Nitrosomonas and Nitrobacter for 8 weeks.

Muneshwar Singh and Singh (1989) observed that neem cake blended urea reduced the leaching loss of nitrate nitrogen over urea alone in Maize. Nearly, 9-38 per cent reduction in the leaching loss of nitrate nitrogen was observed at different rates of nitrogen application. Neem cake was more effective in reducing the leaching losses at higher rates of nitrogen application.

Singh et al. (1991) showed that neem cake treated urea resulted in lower nitrate nitrogen. This is due to the lower population of nitrifying bacteria as a result of retarded nitrification by the neem cake. Nitrification inhibition activity of neem cake was upto a period of three weeks.

Vyas et al. (1991) showed that there was a gradual increase in nitrate nitrogen levels upto a period of one month in soils treated with neem extract coated urea, whereas the period was 7-15 days with uncoated urea. In laterite soils the percentage of nitrification inhibition due to neem extract coated urea was 46.2 after 30 days, whereas for black soils it was 39.7 per cent. Maximum inhibition of 78.9 - 86.9 per cent was at seven days after incubation.

2.3 Effect of oil cakes

2.3.1 Effect of oil cakes on growth characters

Singh and Sitaramaiah (1963) while studying the use of organic amendments in bhindi found that among the oil cakes, castor oil cake treated plants recorded the maximum plant height. Dev and Tilak (1976) reported that application of linseed cake and mustard cake beyond 2.5 tons ha^{-1} to the soil reduced the number of nodules present in the root of soyabean. Sharma and Sinha (1979) reported that five per cent neem cake blended urea @ 150 kg N ha^{-1} increased the dry matter content of wheat.

Jain and Hasan (1986) in a field experiment found that the oil cakes increased the chlorophyll content of leaves and neem cake recorded the maximum chlorophyll content of oats leaves. Apurba Sarkar (1987) while studying the different nitrogen sources for jute found that neem coated urea was better than other sources tried viz. urea, ammonium sulphate and wax coated urea in producing maximum plant height, basal diameter and dry matter yield.

Muniram et al. (1987) reported that neem coated urea increased the plant height significantly over prilled urea at all the growth stages of Japenese mint. They also found that neem coated urea was superior to lac coated urea and prilled urea in increasing the leaf area index, relative growth rate and crop growth rate. Neem coated urea have shown higher rate of dry matter accumulation from the very beginning of crop growth to the final harvest. Singh et al. (1988) observed in maize that leaf area index in neem coated urea was higher when a larger quantity of nitrogen was applied as basal or applied as basal and 30 DAS.

Vinod (1988) tried neem coated urea, urea super granules and rubber coated urea as slow release nitrogen sources for cassava and found that during initial stages neem coated urea recorded maximum plant height which was on a par with urea super granules, while during later stages urea super granules recorded maximum plant height but it was on a par with neem coated urea. He also observed that the different sources of nitrogen were not influential in producing significant variations in the number of leaves. During initial stages neem cake coated urea was the best source in producing maximum leaf area index while at later stages urea super granules produced the maximum leaf area index but it was on a par with neem cake coated urea. Neem coated urea was superior to prilled urea and rubber cake coated urea in producing maximum dry matter while inferior to urea super granules. In all the biometric observations recorded, rubber cake coated urea was found to be the most inferior source.

Shivaprakash (1991) while studying the effect of concentrated non edible oil cakes on the growth and yield of mulberry plants found that mahua oil cake when applied in two split doses increased the number of shoots per plant and root length whereas neem oil cake increased the plant height, number of leaves per plant and leaf area index when compared to other oil cakes. Pongamia oil cake applied plants recorded maximum dry matter content and chlorophyll content of leaves. Vyas et al. (1991) reported that in maize, nimin (the neem extract) produced the maximum dry matter yield which was also superior to three split applications of uncoated urea.

Som et al. (1992) observed the influence of organic manures on growth and yield of brinjal. The different oil cakes tried were karanj, mahua, mustard and neem cake. The highest plant height of 70.77 cm, was recorded in the treatment receiving neem cake @ 50 q ha^{-1} followed by mustard cake at its higher dose. Mahua cake registered the lowest height. All the high doses of oil cakes (50 q ha^{-1}) except mahua cake were significantly superior to the lower doses in producing maximum number of primary branches per plant. Wali and Totawat (1992) reported that in maize the application of urea granules coated with neem cake @ 120 kg N ha^{-1} gave significantly higher values of plant height, number of leaves per plant and leaf area index.

In general, oil cakes like neem cake, mahua cake, caster cake, pongam cake, karanj cake etc. increased the various growth characters like height of the plant, DMP, LAI, CGR, RGR of various upland crops like bhindi, brinjal cassava, maize, jute etc.

2.3.2 <u>Effect of oilcakes on yield attributes and yield</u>

In this section the available literature on the effect of oil cakes on yield attributes and yield of upland crops are reviewed. Since the works on this aspect on vegetable crops are meagre, research work on similar aspect done qn other upland crops like cereals, millets, fodder, sugarcane, Japanese mint, tobacco, betelvine and mulberry are also cited here.

Jiro Asano (1984) reported that the crops of egg plant, cabbage, tomato, radish and lettuce harvested from the rape seed cake applied plot produced higher yield than the crop from inorganic fertilizer alone treated plot.

Shanmugavelu (1987) observed that application of mahua cake, caster cake and neem cake at 500 kg N ha^{-1} one day prior to transplanting of tomato cv. Marutham increased the fruit yield by 31.7, 27.8 and 9.0 per cent respectively over control. Anon (1990) reported that application of neemcake @ one ton ha^{-1} before planting gave maximum yield in ginger.

In the review of soil and fertilizer management for vegetables in Bengladesh, Islam and Haque (1992) mentioned the application of oil cakes as an organic manure during land preparation to brinjal, chillies and bhindi, for getting higher yield.

Som et al (1992) while studying the influence of organic manures on growth and yield of brinjal found that maximum fruit length and diameter were recorded by mahua cake and neemcake applied @ 50 q ha^{-1} respectively. Mahua cake recorded highest number of fruits of 11.68 per plant. Neem cake @ 50 q ha^{-1} produced the maximum fruit weight of 125.38 g, highest per plant yield of 1.43 kg and highest fruit yield of 22.56 tons ha^{-1}.

In cassava Sathianathan (1982) obtained maximum tuber yield with neem cake blended urea and Vinod (1988) reported that neem coated urea and urea super granules were on a par in producing maximum number of tubers per plant, length of tuber, tuber yield, top yield and utilisation index.

In maize, Ketkar (1976) found that neem cake blended urea provided 16.3 per cent higher grain yield over non blended urea. At equivalent fertilizer dose, blended urea recorded higher yield than non blended. Rajendra Prasad (1979) also obtained the same result and showed that there was 23 per cent increase in yield due to 26 kg neem cake with 60 kg N ha^{-1} and 12 per cent due to 52 kg neem cake with 120 kg N ha^{-1}.

Muneshwar Singh and Singh (1989) also found a significant increase in grain and straw yield of maize with neem cake blended urea over prilled urea. Vyas et al. (1991) reported that nimin the neem extract coated urea increased the grain yields compared to those obtained in case of uncoated urea for maize ranging from 4.3 to 71.6 per cent depending upon the crop, soil and other environmental conditions.

Wali and Totawat (1992) found that the application of neem coated urea @ 120 kg N ha^{-1} gave significantly higher values for number of cobs per plant and 1000 grain weight. He also observed that there was an increase of 90 and 15.4 per cent in grain and straw yield of maize respectively with neem cake coated urea @ 120 kg N ha^{-1} over uncoated urea.

In maize, Singh et al. (1988) showed that grain yield from neem coated urea applied plants was 9.6 and 19.4 per cent lower than untreated urea. Delayed application of neem coated urea beyond 30 DAS resulted in 21 per cent lower grain yield than urea in three equal splits,

In Sorghum, Anon (1972) reported that neem cake coated urea faired better than untreated urea at 100 kg

N ha^{-1}. Ketkar (1976) opined that neem coated urea was more useful for a kharif crop like jowar in heavy rainfall years as compared to normal rainfall years for getting maximum yield. Venkata Rao and Badiger (1977) showed that neem coated urea performed better than ordinary urea applied in two splits at 100 kg N ha^{-1} in respect of grain yield of jowar.

Results of pooled data for three years revealed that in sorghum 100 kg N ha^{-1} through neem coated urea produced the highest yield and it was superior to same dose of nitrogen applied through mud ball and urea super granules. It was observed that 80 kg N ha^{-1} applied as neem extract coated urea as single basal dose gave significantly superior yield (29.9 q ha^{-1}) over control (17.14 q ha^{-1}). Application of 75 kg N ha^{-1} through neem cake coated urea and mahua cake coated urea increased the grain yield of sorghum CSH-9 by 8.7 and 5.5 per cent respectively over single application of urea (Anon, 1989).

Das et al. (1992) observed that urea performed better than neem coated urea in sorghum.

In pearl millet, Yadav et al. (1989) observed a lower yield with neem coated urea than the split application of urea even though it was superior to untreated urea in both grain and stover yield.

In ragi, Muthuswamy et al. (1975) found that the grain and straw yield were significantly higher in mahua cake extract treated urea and was superior to sulpha thiazole, crotonilidine di urea, neem cake extract and neem oil blended urea. Subbiah et al. (1979) opined that there was a trend of increase in the yield of finger millet when the urea was blended with neem seed crush, the increase being 5.3 per cent over untreated urea at 90 kg N ha^{-1}. Neem seed crush blended urea increased the straw yield also.

In cotton, Sivaraj and Iruthayaraj (1980), Jain et al. (1982) and Jain (1984) observed that blending urea with neem cake pushed up the boll number, yield per plant and seed cotton yield much higher than uncoated urea.

Dalip Singh and Virk (1987) also obtained increased boll number and yield per plant due to neem coated urea and they also showed that highest seed cotton yield of 2534 kg ha^{-1} was obtained with the application of neem cake coated urea at 60 kg N ha^{-1} at sowing which was 673 and 250 kg ha^{-1}

more than the unfertilized and uncoated urea plots respectively.

Tandon (1989) reported that for cotton 60 kg N given through neem coated urea was considered equivalent to 80 kg N as untreated urea. They also recommended that whenever neem cake treated urea was used, the optimum dose of nitrogen should be 75 per cent of untreated urea. This implied a 25 per cent higher efficiency by treating urea with neem cake.

On the contrary, Sheshadri and Prasad (1979) obtained 5.7 per cent reduced yield of cotton with neem coated urea over urea alone at 60 kg N ha^{-1}.

Yadav (1984) found that neem coated urea increased the total herbage yield from four harvests of Java citronella by 30 per cent over urea, whereas the increase in yield by neem cake mixed urea over urea was 18.7 per cent. Rao et al. (1985) showed that at 100 and 200 kg Nha^{-1} , urea and neem cake coated urea produced similar herb age yields of Java citrorella but at 300 and 400 kg N ha^{-1} the neem coated urea produced the highest yields.

Ketkar (1976) observed that coating of neem cake over urea did not exert any significant influence on the green fodder yield of fodder crops.

In sugarcane, Ketkar (1976) and Rajendra Prasad (1979) found that neem cake application along with urea increased the cane yields than urea alone.

In IARI, Parashar et al. (1980) reported that neem cake coated urea @ 150 kg N ha^{-1} increased the sugarcane yield to an extent of 20.9 per cent over 150 kg N ha^{-1} of urea alone. At Pusa, Singh et al. (1987) observed 10.2 per cent increase in the cane yield with neem coated urea @ 84 kg N ha^{-1} over uncoated urea.

In mulberry, Anon (1968) reported that among the four organic manures tried viz. groundnut cake, castor cake, neem cake and farm yard manure, ground nut cake stood first followed in order by neem cake, farm yard manure and castor cake in producing maximum yield from the total of four harvests. Shiva prakash (1991) obtained maximum leaf yield of mulberry with neem oil cake treated plants than mahua oil cake and pongam oil cake treated plants.

Kadam et al. (1993) found out the effect of organic and inorganic sources on the yield of betel vine. Among the various sources tried viz. neem cake, Karanj cake, neem cake plus urea and urea alone, application of nitrogen through neem cake produced significant response in increasing the yield. The highest net monetary returns were also received from the treatment of application of 200 kg N ha^{-1} through neem cake ie, Rs.34,400 per year.

2.3.3 Effect of oil cakes on quality aspects

Ketkar (1976) found that blending urea (300 or 400 kg N ha^{-1}) with neem cake have given slightly more sucrose than urea in sugarcane.

Jiro Asano (1984) reported that crops of egg plant, cabbage, tomato, radish and lettuce harvested from the rape seed cake applied plot produced slightly higher vitamin C content after storage than the crops from inorganic fertilizer alone treated plot.

Sathianathan (1982) showed that in cassava neem coated urea produced the maximum crude protein content than the other treatments.

Among the oil cakes tried viz, neem cake, mahua cake, castor cake and pongamia cake in mulberry Shivaprakash (1991) observed that neem oil cake produced the maximum crude fibre content of 13.61 per cent whereas mahua cake registered the least crude fibre content.

Improvement in the juice quality with respect to higher brix and purity was recorded from neem extract (nimin) coated urea applied sugarcane plants as reported by Vyas et al. (1991).

Abusaleha (1992) recommended equal quantity or more of organic form of nitrogen for getting good quality of okra fruits. He observed that application of organic form of nitrogen combined with inorganic form has lowered the crude fibre content but increased the crude protein content of okra fruits.

2.3.4 Effect of oil cakes on uptake of nutrients

Venkata Rao and Badiger (1977) working with CSH-1 variety of jowar found that urea treated with neem cake at 20 per cent by weight applied in one dose appeared to be on a par or better than ordinary urea applied in two splits at 100 kg N ha^{-1} in respect of uptake of nitrogen.

Sheshadri and Prasad (1979) showed that neem coated urea increased the nitrogen uptake by cotton to an extent of 7.4 per cent over uncoated urea.

In cassava, Sathianathan (1982) tried different sources of nitrogen like urea-neem, urea-mahua, urea-marotti, urea-rubber and urea on increasing the nitrogen use efficiency and found that at three months after planting the sources had no influence on the nitrogen content of various parts of plants whereas at six months after planting urea. Neem and urea-mahua blends were significantly superior to all other treatments in increasing the nitrogen content of stem. Neem cake blended urea recorded maximum value of nitrogen and uptake by plants and tubers.

Yadav (1984) observed that the nitrogen uptake of Java citronella was improved by 22.5 per cent due to neem coated urea and 14.3 per cent due to neem mixed urea over prilled urea. Neem cake coated urea gave maximum nitrogen uptake at all levels of nitrogen application for bread wheat (Bijay Singh et al., 1985).

Prasad et al. (1986) obtained maximum nitrogen uptake in wheat with non edible oil cakes viz., neem, karanj, mahua, undi and ratan jyoti than inorganic fertilizers. In pearl millet, Yadav et al. (1989) got maximum nitrogen uptake with neem cake coated urea than split application of urea Mishra et al. (1991) reported that the total nitrogen uptake of wheat was increased with neem coated urea than urea alone. Shiva Prakash (1991) found that in mulbery split application of mahua and castor oil cake increased the nitrogen content of mulberry leaves than neem oil cake and pongamia oil cake.

Vyas et al. (1991) opined that neem extract (nimin) coated urea was superior to three split application of uncoated urea in increasing the nitrogen uptake in maize. Ahmed and Baroova (1992) obtained maximum nitrogen uptake in wheat with the application of neem coated urea @ 120 kg N ha^{-1}.

Bhatia et al. (1985) reported that in wheat the nitrogen uptake was considerably decreased by mixing urea uptake at all levels of nitrogen application for bread wheat (Bijay Singh et al., 1985).

Prasad et al. (1986) obtained maximum nitrogen uptake in wheat with non edible oil cakes viz., neem, karanj, mahua, undi and ratan jyoti than inorganic fertilizers. In pearl millet, Yadav et al. (1989) got maximum nitrogen uptake with neem cake coated urea than split application of urea Mishra et al. (1991) reported that the total nitrogen uptake of wheat was increased with neem coated urea than urea alone. Shiva Prakash (1991) found that in mulbery split application of mahua and castor oil cake increased the nitrogen content of mulberry leaves than neem oil cake and pongamia oil cake.

Vyas et al. (1991) opined that neem extract (nimin) coated urea was superior to three split application of uncoated urea in increasing the nitrogen uptake in maize. Ahmed and Baroova (1992) obtained maximum nitrogen uptake in wheat with the application of neem coated urea @ 120 kg N ha^{-1}.

Bhatia et al. (1985) reported that in wheat the nitrogen uptake was considerably decreased by mixing urea attributes and yield, quality aspects and uptake of nutrients of several upland crops like vegetables, cereals, millets, fibre crops, sugarcane, oil seed crops, mulberry etc. eventhough there are rare evidences of negative influence of urea blended with oil cakes on some of the crops.

MATERIALS AND METHODS

MATERIALS AND METHODS

An experiment was conducted at College of Agriculture, Vellayani to increase the nitrogen use efficiency in bhindi using indigenous nitrification inhibitors. The details of the materials used and methods adopted for the study are presented in this chapter.

3.1 Experimental site

The experiment was conducted at the Instructional Farm attached to the college of Agriculture, Vellayani situated at 8.5^{o}N latitude and 76.9^{o}E longitude and at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experimental area was oxisol having a pH of 5.0, medium in available nitrogen and potassium and high in available phosphorus. The physico-chemical properties of the experimental site are presented in Table 1.

Table 1.a. Mechanical analysis of the soil of the experimental site

Sl.No	Parameter	Content in soil (%)	Methods used
1	2	3	4
1.	Coarse Sand	36.35	Bouyoucos -
2.	Fine sand	15.00	Hydrometer method (1962)
3.	Silt	17.50	
4.	Clay	30.00	
5.	Textural class	Sandy clay loam	

Table 1.b. Chemical properties of the soil of the experimental site

Sl.No.	Parameter	Content	Rating	Method used
1.	Available N	250.88 kg ha^{-1}	Medium	Alkaline Potassium Permanganate method (Subbiah and Asija,1956)
2.	Available P_2O_5	51.29 kg ha^{-1}	High	Bray Colorimetric method (Jackson, 1973)
3.	Available K_2O	120.96 kg ha^{-1}	Medium	Ammonium acetate method (Jackson, 1973)
4.	pH	5.0	Acidic	pH meter with glass electrode (Jackson, 1973)

3.1.3 Cropping history of the field

The experimental area was previously cropped with vegetables and was lying fallow three months before the experiment.

3.1.4 Season

The experiment was conducted during the summer season of 1993 (29th January to 27th April)

3.1.5 Weather Conditions

The weekly averages of temperature, evaporation, relative humidity and the weekly totals of rainfall during the cropping period collected from the meteorological observatory at the College of Agriculture, Vellayani are presented in figure - 1 and Appendix - I

In general, weather conditions were favourable for the satisfactory growth of the crop.

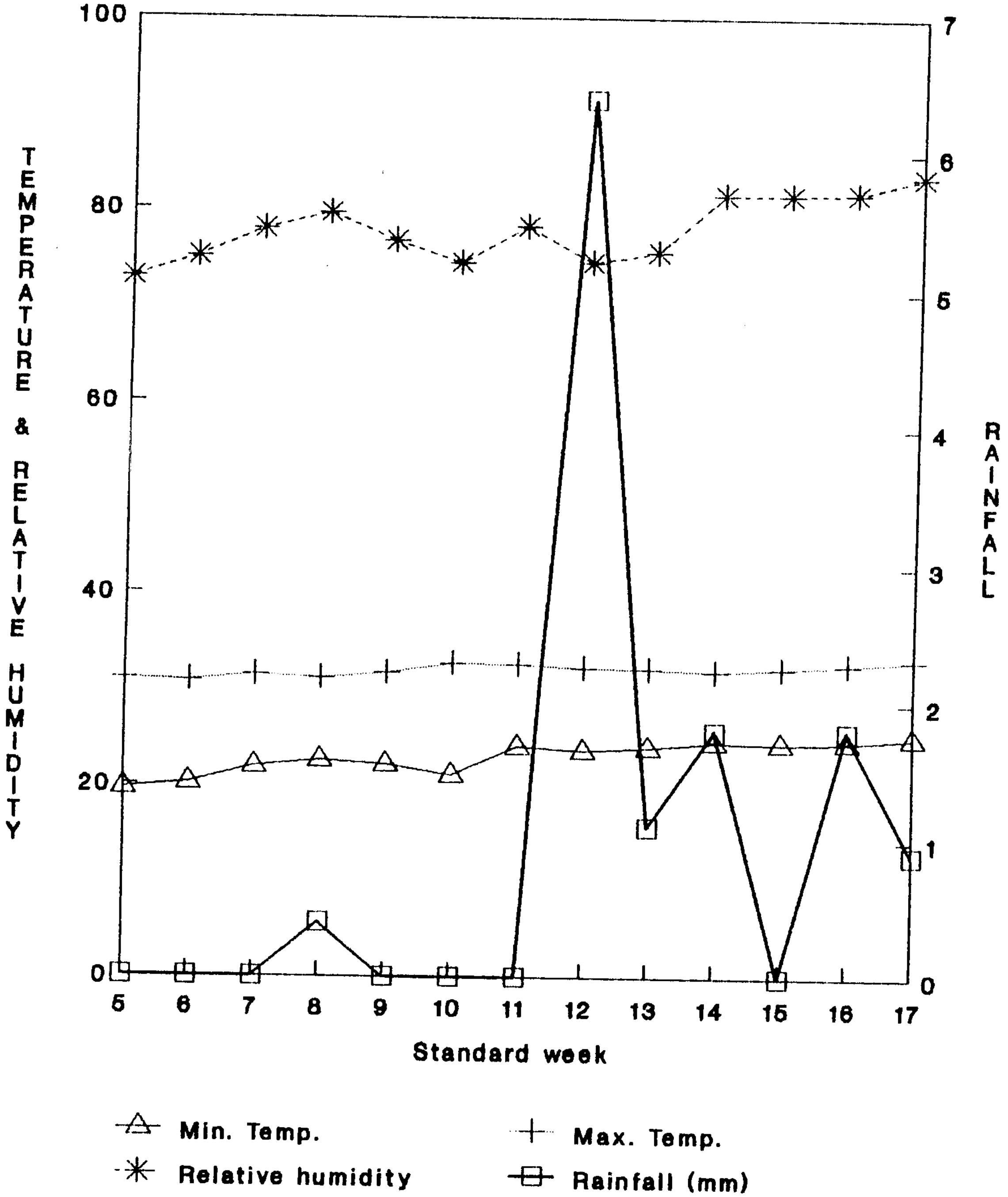


Fig. 1. Weather conditions during cropping period

3.1.6 Cultivar used

The cultivar of bhindi used for this study was Kiran (selection AE-1). This variety was evolved at the College of Agriculture, Vellayani by single plant selection from locally popular variety 'Kilichundan'. The variety flowers in 35 days and the first harvest can be done in 45 days. Reported yield of the variety is 11.2 t/ha. It is tolerant to fruit and shoot borer and yellow vein mosaic. This variety is recommended for the southern district of Kerala in red loam, clay loam and laterite soils.

3.1.7. Source of seed material

Seeds of variety Kiran obtained from the Instructional Farm, College of Agriculture, Vellayani was used for the experiment.

3.1.8. Manures and fertilizers

Farm yard manure (0.4%; 0.3%, 0.2% N : P_2O_5 : K_2O) Urea (46% N) Mussoorie phos (20% P_2O_5) and muriate of potash (60% K_2O) were used as sources of organic manure, nitrogen, phosphorus and potassium respectively. Neem cake (4.86 %: 0.86% : 1.02% N: P_2O_5: K_2O) and Mahua Cake (2.2% : 0.76% 1.34% N : P_2O_5 : K_2O) were used as sources of nitrification inhibitors.

3.2 Methods

3.2.1 Design and layout

The field experiment was laid out as a factorial experiment in randomised block design The layout of the experiment is given in figure - 2. The details of the layout are given below.

Number of treatment combinations	: 12
Number of replications	: 3
Total number of plots	: 36
Gross plot size	: 3.6m x 3.15 m
Net plot size	: 2.4 m x 2.25 m
Spacing	: 60 cm x 45 cm
Number of plants in gross plot area	: 42
Number of plants in net plot area	: 20

N

F_1N_3	F_3N_3	F_4N_2	F_2N_2	
F_3N_2	F_4N_3	F_1N_1	F_2N_3	R I
F_1N_2	F_2N_1	F_4N_1	F_3N_1	
F_3N_3	F_1N_2	F_3N_1	F_4N_3	
F_4N_1	F_2N_3	F_3N_2	F_2N_1	R II
F_1N_1	F_2N_2	F_1N_3	F_4N_2	
F_2N_2	F_2N_3	F_3N_1	F_1N_1	
F_3N_3	F_2N_1	F_1N_2	F_4N_1	R III
F_4N_2	F_3N_2	F_1N_3	F_4N_3	

Treatments

Nitrogen levels

F_1 = 50 kg N ha^{-1}

F_2 = 100 kg N ha^{-1}

F_3 = 200 kg N ha^{-1}

F_4 = 300 kg N ha^{-1}

Nitrification inhibitors

N_1 = Urea as control

N_2 = Neem cake blended urea

N_3 = Mahua cake blended urea

Plot size – 3.6 m x 3.15 m

Fig. 2. LAYOUT PLAN

One row was left as border all around the plots. Five plants in each plot were randomly selected to facilitate periodical observations

3.2.2 Treatments

The treatments comprised of four different combinations of nitrogen with two nitrification inhibitors and urea as control. Phosphorus and potassium were applied as per package of practices recommendation, to all the treatment combinations.

A. Nitrification Inhibitors

N1 : Urea alone (U)

N2 : Neem Cake blended urea (NBU)

N3 : Mahua Cake blended urea (MBU)

B. Nitrogen levels

F1 : 50 kg N ha^{-1}

F2 : 100 kg N ha^{-1}

F3 : 200 kg N ha^{-1}

F4 : 300 Kg N ha^{-1}

3.2.3 Treatment combination

T_1 - F_1N_1	T_5 - F_1N_2	T_9 - F_1 N_3
T_2 - F_2N_1	T_6 - F_2N_2	T_{10} - F_2 N_3
T_3 - F_3N_1	T_7 - F_3N_2	T_{11} - F_3 N_3
T_4 - F_4N_1	T_8 - F_4N_2	T_{12} - F_4 N_3

3.2.4 Field Culture

3.2.4.1 Land preparation

The experimental plot was dug twice, stubbles were removed, clods were broken and levelled. The field was then laid out into blocks and plots as per the experimental design. 36 plots of 3.6 m x 3.15 m size were taken and 42 pits were taken at a spacing of 60 cm x 45 cm in each plot Each pit was half filled with a mixture of top soil dried and powdered cowdung before sowing of seeds.

3.2.4.2 Fertilizer application

A uniform dose of cattle manure @ 12t ha $^{-1}$ was applied to each pit. Urea was applied to all plots as per the treatments. Blending urea with neemcake and mahua cake as specified in the treatments was done before application. Mussoorie phos @ 42g and muriate of potash @ 58 g were applied to all pits. Fertilizers were applied in two split doses viz; at the time of sowing and 30 DAS.

3.2.4.2.1 Blending of fertilizers

As per the treatment the required quantity of urea was taken in separate plastic bags. Then oil cake according to the treatment was mixed with urea in the ratio of 1:5. After 24 hours it was applied to the plots.

3.2.4.3 Seeds and sowing

Two seeds per pit were dibbled at a depth of 3-5 cm. After one week, gap filling was done and thinning was conducted after two weeks retaining one plant in each pit.

3.2.4.4 After cultivation

The crop was irrigated daily and weeding was done as and when required. Top dressing was done one month after sowing along with the inter cultural operations.

3.2.4.5 Plant protection

Prophylactic spraying with Rogor was done against fruit borer and petiole maggot during the crop growth.

3.2.4.6 Harvesting

The crop was harvested on alternate days from 45th day onwards after sowing. Altogether 24 harvests were obtained over the entire cropping period. Maturity of fruits for harvest was judged by visual observation.

3.3 Observations recorded

3.3.1 Growth characters

Five plants were selected after eliminating the border rows and all the biometric observations were recorded from these plants at 15 days interval. Random samples were taken from the net plot area for destructive sampling, for dry weight observations.

3.3.1.1 Height of plants

From the observational plants the height was measured from the base to the terminal bud and the average was worked out and expressed in cm.

3.3.1.2 Number of leaves

Total number of fully opened green leaves were counted from the observational plants and the mean was worked out.

3.3.1.3 Number of branches

Total number of branches per plant were counted from the observational plants and their mean was worked out.

3.3.1.4 Root length

Plants were uprooted and the root system was separated. After cleaning, the entire length of the tap root was measured by using a thread and scale and the mean was worked out and expressed in cm.

3.3.1.5 Root spread

The lateral roots of the root system was spread over a plain paper. The length of the longest lateral root on both sides of the taproot was measured using a thread and scale and their average was found out.

3.3.1.6 Dry matter production

Plants left for destructive sampling were cut close to the ground at 15 days interval. These plants were chopped and dried in shade and after that they were oven dried at 70 $\pm$ 5^{o}C till a constant weight was obtained. The final dry weight was averaged and expressed in kg ha^{-1}.

3.3.2 <u>Computed parameters</u>

3.3.2.1 Leaf area index (LAI)

Leaf area index was worked out at every 15 days interval. Area of all leaves produced per plant was recorded using LI - 3100 leaf area meter and LAI was worked out using the formula suggested by William (1946).

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

3.3.2.2 Relative growth rate (RGR)

The rate of increase in dry weight per unit dry weight per unit time expressed as mg day^{-1} was calculated by the following formula suggested by Blackman (1919).

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

where, W1 and W2 are dry matter of the plant produced at time t1 and t2 respectively

3.3.2.3 Net assimilation rate (NAR)

The rate of increase in dry weight per unit leaf area per unit time was worked out by the following formula of William (1946) This was expressed in mg cm^{-2} day^{-1}.

$$NAR = \frac{(W2-W1)\ (Log_e L_2 - log_e L_1)}{(t_2-t_1)\ \ (L_2 - L_1)}$$

where, W1 and W2 are dry weight of the plant produced at time t_1 and t_2 respectively. L_1 and L_2 are the leaf area of the plant at time t1 and t_2 respectively.

3.3.2.4 Crop growth rate (CGR)

It is the rate of increase in dry weight per unit area per unit time. Crop growth rate between stages were worked out by using the following formula as explained by Hunt (1978) and expressed in $m^{-2}g$ day $^{-1}$.

$$CGR = \frac{W_2-W_1}{t_2-t_1} \times \frac{1}{p}$$

where, W1 and W2 are the dry weight produced by the plant at time t_1 and t_2 respectively and P is the ground area.

3.3.3 Yield attributes and yield

3.3.3.1 Days to 50 percent flowering

Total number of plants flowered were counted daily in each plot and the date on which 50 percent of the plants flowered was taken as the date of 50 per cent flowering.

3.3.3.2 Number of flowers formed per plant.

Total number of flowers formed were counted from the five observational plants and the average was worked out to get the number of flowers formed per plant.

3.3.3.3 Number of flowers shed

The total number of flowers shed from the five selected plants were counted and the mean was worked out.

3.3.3.4 Number of fruits per plant

Total number of fruits collected from the five observational plants were counted and the average was worked out.

3.3.3.5 Setting percentage

From the total number of flowers formed and number of fruits per plant, setting percentage was calculated for the five observational plants and their mean was worked out.

3.3.3.6 Height of the first bearing node

The height of the node in which the first fruit formed was measured from the ground level in all the five observational plants and their mean was worked out.

3.3.3.7 Length of the fruit

The length of the fruits obtained from the five observational plants were measured during first two harvests middle two harvest and final two harvests and the average was worked out.

3.3.3.8 Girth of the fruit.

The same fruits used for measuring the length were used for finding out the girth of the fruit also.

Measurement was effected by winding a thread around the the individual fruits. The mean values were worked out and expressed in cm.

3.3.3.9 Fruit yield per plant

The weight of the fruits obtained from the five selected plants were recorded at each harvest and the total weight of the fruits from the 34 harvests was calculated and expressed as fruit yield per plant.

3.3.3.10 Total fruit yield

Total weight of the fruits from the net plot area was calculated at the end of the cropping season and the yield in quintal per hectare was worked out.

3.4 Chemical analysis

3.4.1 Chlorophyll content of leaves

The leaf samples were homogeniosed in 85 percent acetone and centrifuged to get the clear extract. The absorbance of the extracts were measured at wavelength of 645 and 663 nm in Spectronic 20 spectrophotometer. The amounts of total chlorophyll was calculated using the formula of Starnes and Hadley (1965) and expressed in mg g^{-1}.

$$\text{Total Chlorophyll} = \frac{(20.2 \times A_{645} + 8.02 \times A_{663})V}{a \times 1000 \times w}$$

where,

a - length of path light in the cell (usually 1 cm)

V - volume of extract in millilitre

W - fresh weight of the sample in gram

A_{645} and A_{663} are the absorbance reading at 645 and 663 nanometer.

3.4.2 Quality aspects

3.4.2.1 Protein content of fruits

The nitrogen content in the fruit was multiplied by the factor 6.25 to obtain the crude protein of fruits and the values were expressed as percentage (Simpson et al., 1965).

3.4.2.2 Ascorbic acid content of fruits

The ascorbic acid content of fruits was estimated by titrimetric method (Paul Gyorgy and Pearson, 1967).

3.4.3 Plant analysis

The plant samples were analysed for nitrogen at every 15 days interval, phosphorus and potassium at the final harvest. The plant was separated into root, stem, leaves and fruits. These were chopped and dried separately in air oven at 70 ± 5C till constant weights were obtained. Samples were ground to pass through a 0.4 mm mesh in a Willey mill. The required quantity of samples were then weighed out accurately in a physical balance and analysed.

3.4.3.1 Total nitrogen content

Total nitrogen content was estimated by modified microkjeldahl method as given by Jackson (1973) and the values were expressed as percentages.

3.4.3.2 Uptake of nitrogen

This was calculated by multiplying the nitrogen content of the root, stem, leaves or the fruits as the case may be with the total dry weight of the root, stem, leaves or fruits. The uptake values were expressed in Kg ha^{-1}.

3.4.3.3 Total phosphorus content

Phosphorus content was analysed colorimetrically (Jackson, 1973) after wet digestion of the sample using 2:1 mixture of nitric acid and perchloric acid and developing colour by Vanadomolybdo phosphoric yellow colour method and read in a Klett Summerson photo electric colour meter.

3.4.3.4 Uptake of phosphorus

This was calculated by multiplying the phosphorus content and dry weight of the root, stem, leaves and fruits as the case may be. The values were expressed in Kg ha^{-1}.

3.4.3.5 Total potash content

Total potash content in plants was estimated by the flame photo metric method in a Perkin Elmer 3030 Atomic Absorption spectrophotometer after wet digestion of the sample using diacid mixture.

3.4.3.6 Uptake of potash

This was calculated by multiplying the dry weights and potash content of the root, stem, leaves or fruits as the case may be. The uptake values were expressed in kg ha^{-1}.

3.4.4 <u>Soil analysis</u>

Soil samples were taken from the experimental area before the experiment and at every 15 days interval for available nitrogen analysis and the air dried samples were analysed for available nitrogen by the Alkaline potassium permanganate method (Subbiah and Asija, 1956). Initial and final soil samples were analysed for available phosphorus by Bray colourimetric method (Jackson, 1973) and available potash by the ammonium acetate method (Jackso 973).

3.5 Economics of cultivation

The economics of cultivation of the experiment was worked out as per the formula given below

$$\text{Net return (Rs ha}^{-1}\text{)} = \text{Gross income} - \text{Cost of cultivation}$$

$$\text{Benefit Cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.6 Statistical analysis

The data relating to each character in the experiment was analysed using the analysis of variance technique as applied to randomised block design described by Cochran and Cox (1965). Whenever the effects were significant, critical differences were calculated for comparing the means. Correlation studies were also carried out between yield and characters like growth, yield attributes and nitrogen status of soil.

RESULTS

RESULTS

An experiment was conducted in the Instructional Farm, College of Agriculture, Vellayani during the summer season of 1993, to increase the nitrogen use efficiency in bhindi using indigenous nitrification inhibitors like neem cake and mahua cake. The results obtained from the study are statistically analysed and presented here.

4.1 Growth characters

4.1.1 Height of the plant

The results on mean height of plants recorded at 30 DAS, 45 DAS, 60 DAS and 75 DAS are presented in Table 2.

The effect of nitrogen levels on the height of plant was significant only at 30 DAS. At this stage F_1 (50 kg N ha^{-1}) recorded the maximum plant height of 24.82 cm which was on a par with F_2 (100 kg N ha^{-1}) and significantly superior to F[illegible] (200 kg N ha^{-1}). Increase in nitrogen level did not exert any significant influence on the height of the

Table 2. Height of plant in cm as affected by nitrogen levels and nitrification inhibitors

Treatments	Height of plant (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels				
F_1	24.82	61.83	79.64	123.60
F_2	23.73	61.09	84.42	122.56
F_3	16.19	50.16	71.02	115.78
F_4	17.00	55.36	74.67	114.11
$F_{3, 22}$	7.48**	1.88^{NS}	0.94^{NS}	0.42^{NS}
SE	1.635	3.982	6.035	7.041
CD(0.05)	4.795	-	-	-
Nitrification inhibitors				
N_1	20.58	57.07	73.65	110.42
N_2	20.07	53.34	76.17	121.92
N_3	20.67	60.92	82.50	124.25
$F_{2, 22}$	0.05^{NS}	1.21^{NS}	0.76^{NS}	1.48^{NS}
SE	1.415	3.449	5.226	6.098
CD (0.05)	-	-	-	-

** Significant at 0.01 level

NS Non significant

plant beyond 30 DAS. With increasing age, there was an increase in the plant height and the highest was recorded at 75 DAS.

Nitrification inhibitors had no significant influence on the height of plant at any of the growth stages. It was seen that mahua cake applied plants recorded a maximum height of 124.25 cm at 75 DAS.

The interaction F x N was found to be non significant.

4.1.2 <u>Number of leaves</u>

The data on the number of leaves per plant are presented in Table 3.

Nitrogen levels showed significant influence on the number of leaves per plant only at the initial growth stage of the plant (30 DAS). At this stage F_2 and F_3 recorded maximum number of leaves of 6.67 which was on a par with F_4 but significantly superior to F_1. During later growth stages, the number of leaves increased with increasing levels of

Table 3. Number of leaves as affected by nitrogen levels and nitrification inhibitors

Treatments	Number of leaves			
	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels				
F_1	5.44	16.33	18.33	15.89
F_2	6.67	17.33	18.89	17.56
F_3	6.67	16.00	18.89	19.78
F_4	5.67	17.56	19.00	19.89
$F_{3,\ 22}$	3.51*	0.59^{NS}	0.05^{NS}	0.68^{NS}
SE	0.345	0.977	1.355	2.331
CD(0.05)	1.012	-	-	-
Nitrification inhibitors				
N_1	6.00	16.58	17.92	16.67
N_2	6.58	17.00	19.92	21.5
N_3	5.75	16.88	19.00	16.67
$F_{2,\ 22}$	2.04^{NS}	0.06^{NS}	0.43^{NS}	1.91^{NS}
SE	0.299	0.846	1.174	2.018
CD (0.05)	-	-	-	-

* significant at 0.05 level

NS Non significant

nitrogen and the maximum of 19.89 being recorded by F_4 at the final harvest, eventhough the effects were not significant.

Nitrification inhibitors did not show any significant influence on the number of leaves at various growth stages. Maximum number of leaves was produced by neem cake blended urea. It was also seen that with aging the number of leaves went on increasing for N_2, whereas a reduction in leaf number was recorded by urea and mahua cake blended urea from 60 to 75 DAS.

The interaction F x N was found to be non significant.

4.1.3 Number of branches per plant

Number of branches recorded at 45, 60 and 75 DAS are presented in Table 4.

Nitrogen levels exerted significant influence on the number of branches only at 60 and 75 DAS. At 60 DAS F_3 produced the highest number of branches which was on par with F_4 but significantly superior to F_1 and F_2. At 75 DAS, F_4

Table 4. Number of branches affected by nitrogen levels and nitrification inhibitors

Treatments	Number of branches		
	45 DAS	60 DAS	75 DAS
Nitrogen levels			
F_1	1.56	1.67	1.89
F_2	1.56	1.67	1.78
F_3	1.89	2.44	2.44
F_4	2.00	2.22	3.11
$F_{3,\ 22}$	0.93^{NS}	5.02^{**}	9.31^{**}
SE	0.237	0.176	0.200
CD(0.05)	-	0.517	0.587
Nitrification inhibitors			
N_1	1.58	1.83	2.00
N_2	1.92	2.17	2.50
N_3	1.75	2.00	2.42
$F_{2,\ 22}$	0.66^{NS}	1.89^{NS}	2.38^{NS}
SE	0.205	0.153	0.173
CD (0.05)	-	-	-

** Significant at 0.01 level

NS Non Significant

recorded the maximum number and significantly superior to F_1, F_2 and F_3.

The effect of nitrification inhibitors and F x N interaction were not significant. However, at all growth stages, number of branches was more for N_2.

4.1.4 <u>Length of the taproot</u>

The data on the length of the taproot recorded at 30, 45, 60 and 75 DAS are given in Table 5.

Nitrogen levels had significant influence on the length of the tap root at 30 and 60 DAS while the effect was not significant at 45 and 75 DAS. At 30 and 60 DAS, F_2 was significantly superior to all other treatments but was on par with F_1. At all the growth stages, root length was maximum for F_2 and minimum for F_4.

Nitrification inhibitors did not show any significant influence on the length of roots. However, neem cake treated plots recorded highest root length at all the growth stages.

Table 5. Length of the tap root in cm as affected by nitrogen levels and nitrification inhibitors

Treatments	Length of the tap root (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels				
F_1	9.78	13.61	16.68	24.63
F_2	12.78	16.39	20.17	25.27
F_3	7.94	11.22	14.86	23.92
F_4	8.89	12.72	12.33	22.40
$F_{3,\ 22}$	3.82*	1.46NS	3.61*	0.59NS
SE	1.071	1.796	1.734	1.604
CD(0.05)	3.141	–	5.086	–
Nitrification inhibitors				
N_1	9.08	11.88	17.94	25.18
N_2	10.67	16.25	19.69	26.11
N_3	9.79	12.33	15.40	22.88
$F_{2,\ 22}$	0.73NS	2.39NS	1.29NS	0.69NS
SE	0.927	1.555	1.501	1.389
CD (0.05)	–	–	–	–

NS - Non significant

* Significant at 0.05 level

The root length also increased with the age of the plant recording the maximum at 75 DAS.

The interaction of F x N was non significant.

4.1.5 Root spread

The data on the root spread of the plant recorded at 30, 45, 60 and 75 DAS are given in Table 6.

In general, there was no appreciable variation in the spread of roots due to various levels of nitrogen. However, there was an increase in the spread with increasing levels of nitrogen which varied from 27.11 cm for F_1 to 31.03 cm for F_4 at the final harvest.

Nitrification inhibitors exerted significant influence on the root spread at 60 and 75 DAS while their effect at 30 and 45 DAS were non significant. Neem cake blended urea recorded the maximum root spread at all growth stages while N_1 and N_3 were on par with each other.

Table 6. Root spread in cm as affected by nitrogen levels and nitrification inhibitors

Treatments	Root spread (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels				
F_1	11.56	18.22	26.33	27.11
F_2	12.22	18.50	26.39	29.33
F_3	13.61	18.61	26.89	30.72
F_4	16.17	19.06	28.22	31.01
$F_{3,\ 22}$	2.21^{NS}	0.08^{NS}	0.32^{NS}	1.34^{NS}
SE	1.373	1.207	1.565	1.544
CD(0.05)	-	-	-	-
Nitrification inhibitors				
N_1	12.33	17.63	24.21	27.50
N_2	14.79	19.08	30.75	32.44
N_3	13.04	19.08	25.92	28.71
$F_{2,\ 22}$	1.13^{NS}	0.65^{NS}	6.27^{**}	3.71^{*}
SE	1.189	1.045	1.355	1.377
CD (0.05)	-	-	3.975	3.923

* - Significant at 0.05 level

** - Significant at 0.01 level

NS - Non significant

4.1.6 Dry matter production (DMP)

The effect of nitrogen levels and nitrification inhibitors on the dry matter production of the plants are presented in Table 7 and 7a.

In general, nitrogen levels did not exert any significant influence on dry matter production at any of the growth stages. However, an increase in the dry matter production was observed with every increase in the nitrogen level at almost all growth stages and it varied from 3432.78 kg ha^{-1} for F_1 to 4250.18 kg ha^{-1} for F_4 at harvest.

The effect of nitrification inhibitors on the DMP was non significant. It was seen that at all the growth stages, NBU produced the highest dry matter and urea the lowest.

The interaction effect was significant only at 60 DAS. At this stage, NBU at 300 kg ha^{-1} recorded the highest DMP of 4768.55 kg ha^{-1} followed by NBU at 200 kg ha^{-1} (3926.10 kg ha^{-1}). The least was recorded by NBU at 50 kg ha^{-1} followed by urea at 300 kg ha^{-1}. In the absence of

Table 7. Dry matter production in Kg ha^{-1} as influenced by nitrogen levels and nitrification inhibitors

Treatments	Dry matter production (Kg ha^{-1})			
	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels				
F_1	237.55	1129.76	2132.10	3432.78
F_2	417.27	1190.55	2710.65	4058.72
F_3	297.06	1213.72	3121.56	4071.19
F_4	298.46	1742.08	3221.86	4250.18
$F_{3, 22}$	1.97^{NS}	2.06^{NS}	2.27^{NS}	1.15^{NS}
SE	5.628	198.257	312.599	333.978
CD(0.05)	-	-	-	-
Nitrification inhibitors				
N_1	242.95	1071.07	2544.55	3563.50
N_2	374.53	1530.84	3157.35	4313.96
N_3	320.27	1355.17	2687.73	3982.11
$F_{2, 22}$	2.03^{NS}	1.83^{NS}	1.40^{NS}	1.69^{NS}
SE	46.443	171.695	270.719	289.231
CD (0.05)	-	-	-	-

NS - Non Significant

Table 7a. Combined effect of nitrogen levels and nitrification inhibitors on the dry matter production at 60 DAS in kg ha^{-1}

Treatments	F_1	F_2	Nitrogen levels F_3	F_4	Mean
Nitrification inhibitors					
N_1	3195.93	3214.33	2207.09	1560.85	2544.55
N_2	1382.33	2552.42	3926.10	4768.55	3157.35
N_3	1818.05	2365.20	3231.49	3336.18	2687.73
Mean	2132.10	2710.65	3121.56	3221.86	
FxN					
SE	541.437				
CD (0.05)	1588.079				

nitrification inhibitor, urea at 100 kg ha^{-1} recorded the highest DMP, whereas with nitrification inhibitors the highest fertilizer level (F_4) produced the highest DMP. At higher levels of nitrogen (F_3 and F_4) Oil cake blending was found advantageous in producing more drymatter, while with lower levels oilcake blending cause substantial reduction in DMP.

4.2 Computed parameters

4.2.1 Leaf Area Index (LAI)

The effect of nitrogen levels and nitrification inhibitors and their interaction on LAI of the plant are presented in Tables 8 and 8a.

Leaf area index was significantly influenced by nitrogen application at 60 and 75 DAS. At 60 DAS, LAI value of 1.61 was observed at F_4 level, which was significantly superior to F_1 but was on apar with F_2 and F_3. At harvest, maximum LAI of 1.65 was produced by F_4 which was on a par with F_3 but significantly superior to F_1 and F_2. There was an increase in the LAI with increasing age of crop till 60 DAS for F_1 and F_2 and till final harvest for F_3 and F_4.

Table 8 Leaf area index as affected by nitrogen levels and nitrification inhibitors

Treatments	LAI			
	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels				
F_1	0.25	0.72	0.83	0.77
F_2	0.32	0.94	1.21	1.04
F_3	0.27	0.65	1.58	1.62
F_4	0.22	0.86	1.61	1.65
$F_{3, 22}$	1.19^{NS}	1.16^{NS}	7.13^{**}	6.23^{**}
SE	3.638	0.175	0.137	0.166
CD(0.05)	-	-	0.401	0.489
Nitrification inhibitors				
N_1	0.262	0.60	1.13	1.10
N_2	0.289	1.02	1.58	1.66
N_3	0.244	0.75	1.21	1.28
$F_{2, 22}$	0.52^{NS}	3.87^{*}	3.98^{*}	3.09^{NS}
SE	3.151	0.108	0.119	0.144
CD (0.05)	-	0.317	0.348	-

** Significant at 0.01 level

NS Non Significant

Table 8a. Combined effect of nitrogen levels and nitrification inhibtors on the leaf area index

a. at 60 DAS

Treatments	Nitrogen levels				
	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	0.730	1.283	1.723	0.813	1.137
N_2	1.383	1.357	1.010	2.570	1.580
N_3	0.390	0.997	2.017	1.450	1.213
Mean	0.834	1.212	1.583	1.611	
FxN					
SE	0.237				
CD (0.05)	0.696				

b. at 75 DAS

Treatments	Nitrogen levels				
	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	0.723	0.363	0.5	1.923	1.100
N_2	0.557	1.837	2.440	1.797	1.658
N_3	1.030	0.920	1.920	1.242	1.278
Mean	0.770	1.040	1.620	1.650	
FxN					
SE	0.289				
CD (0.05)	0.846				

Nitrification inhibitors exerted significant influence on the LAI only at 45 and 60 DAS. At 45 DAS, neem cake blended urea was significantly superior to urea. But at 60 DAS N_2 was significantly superior to N_1 and N_3 while N_1 and N_3 were on a par. At 30 and 75 DAS, there was not significant effect.

Significant interaction between nitrogen levels and nitrification inhibitors was observed on LAI at 60 and 75 DAS. At 60 DAS, in the absence of nitrification inhibitors application of nitrogen significantly influenced LAI and maximum LAI was obtained at F_3 level (1.723) which was on a par with F_2 (1.283). With neem cake, nitrogen application at F_4 level recorded the maximum LAI of 2.57 which was significantly superior to other three levels. With mahua cake, F_3 level recorded the maximum LAI of 2.017 which was on a par with F_4 but significantly superior to F_1 and F_2.

At F_1 level, N_2 was on a par with N_1 but significantly superior to N_3. At F_2 and F_4 levels, maximum LAI was obtained at N_2 whereas at F_3 level, N_3 was significantly superior to N_2 but was a par with N_1. Maximum LAI was recorded for F_4N_2.

At 75 DAS, maximum LAI was recorded by F_3N_2 followed by F_4N_1 and F_3N_3. With urea alone F_4 produced the maximum LAI. But in the presence of nitrification inhibitors F_3 level recorded the maximum LAI whereas at F_1 level and F_4 level, N_3 and N_1 recorded the highest LAI respectively.

4.2.2 <u>Relative growth rate (RGR)</u>

Relative growth rate recorded between 30 and 45 DAS, 45 and 60 DAS and 60 and 75 DAS are presented in Table 9, 9a and 9b.

Nitrogen levels significantly influenced the RGR of various growth stages. During all the stages of growth F_4 recorded the highest value which was significantly superior to F_1, F_2 and F_3 and each higher level of nitrogen was significantly superior to the next lower level of nitrogen. The lowest level of nitrogen (F_1) was significantly inferior to all other levels of nitrogen and recorded the least value for RGR. As the crop went on aging, the RGR decreased.

Nitrification inhibitors also showed significant influence on the relative growth rate at all stages of

Table 9 Relative growth rate in mg g^{-1} day^{-1} as influenced by nitrogen levels and nitrification inhibitors

Treatments	Relative growth rate		
	Between 30 and 45 DAS	Between 45 and 60 DAS	Between 60 and 75 DAS
Nitrogen levels			
F_1	72.39	21.40	15.83
F_2	90.69	39.44	28.72
F_3	100.42	63.05	36.33
F_4	114.43	82.55	50.68
$F_{3, 22}$	995.14**	1587.21**	239.68**
SE	0.559	0.672	0.941
CD (0.05)	1.641	1.970	2.759
Nitrification inhibitors			
N_1	87.66	39.32	18.97
N_2	101.88	64.22	42.96
N_3	93.91	51.29	36.74
$F_{2, 22}$	216.19**	458.47**	233.35**
SE	0.484	0.582	0.815
CD (0.05)	1.421	1.706	2.390

** Significant a .01 level

Table 9a. Combined effect of nitrogen levels and nitrification inhibitors on the relative growth rate in mg g^{-1} day^{-1}

a. between 30 and 45 days

Treatments	F_1	F_2	Nitrogen levels F_3	F_4	Mean
Nitrification inhibitors					
N_1	54.00	86.64	95.33	114.67	87.66
N_2	81.07	96.76	108.66	121.03	101.88
N_3	82.11	88.67	97.26	107.58	93.91
Mean	72.39	90.69	100.42	114.43	
FxN					
SE	0.969				
CD (0.05)	2.843				

a. between 30 and 45 days

Treatments	F_1	F_2	Nitrogen levels F_3	F_4	Mean
Nitrification inhibitors					
N_1	15.78	20.91	49.4	71.17	39.32
N_2	27.79	57.67	72.58	98.85	64.22
N_3	20.64	39.74	67.18	77.63	51.29
Mean	21.40	39.44	63.05	82.55	
FxN					
SE	1.164				
CD (0.05)	3.413				

Table 9b. Combined effect of nitrogen levels and nitrification inhibitors on the relative growth rate (mg g^{-1} day^{-1}) between 60 and 75 days

Treatments	Nitrogen levels F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	9.19	14.34	22.33	30.02	18.97
N_2	20.16	38.49	46.43	66.75	42.96
N_3	18.14	33.32	40.23	55.26	36.74
Mean	15.83	28.72	36.33	50.68	
FxN					
SE	1.629				
CD (0.05)	4.780				

growth. NBU was significantly superior to MBU and urea and MBU inturn was significantly superior to urea.

The FxN interaction was significant at all stages. For almost all nitrogen levels, NBU recorded the highest RGR followed by MBU and the least by urea alone. At all stages of growth maximum RGR was recorded by NBU at 300 kg N ha^{-1} and the minimum by F_1N_1. RGR went on increasing as the nitrogen levels increased with all the three sources recording the maximum at F_4 levels. The value ranged from 54 mg g^{-1} day^{-1} to 121.03 mg g^{-1} at initial growth stage and 9.19 mg g^{-1} day^{-1} to 66.75 mg g^{-1} day^{-1} at later growth stage.

4.2.3 Net assimilation rate (NAR)

The data on the NAR recorded between 30 and 45 DAS, between 45 and 60 DAS and between 60 and 75 DAS are given in Table 10.

Nitrogen levels exerted significant influence on the NAR during various growth stages. It was observed that NAR increased with every successive dose of nitrogen at all

Table 10. Effect of nitrogen levels and nitrification inhibitors on the net assimilation rate in mg cm^{-2} day^{-1}

Treatments	Net assimilation rate		
	Between 30 and 45 DAS	Between 45 and 60 DAS	Between 60 and 75 DAS
Nitrogen levels			
F_1	0.44	0.85	0.94
F_2	0.55	0.96	1.04
F_3	0.83	1.28	1.38
F_4	1.08	1.52	1.63
$F_{3, 22}$	65.06**	49.87**	49.69**
SE	0.035	0.043	0.045
CD (0.05)	0.104	0.125	0.131
Nitrification inhibitors			
N_1	0.58	1.10	1.18
N_2	0.84	1.20	1.30
N_3	0.76	1.16	1.26
$F_{2, 22}$	19.69**	1.82^{NS}	2.50^{NS}
SE	0.030	0.037	0.038
CD (0.05)	0.090	-	-

** Significant at 0.01 level

NS Not significant

growth stages and F_4 recorded the maximum value. It was significantly superior to all the other levels of nitrogen. F_1 recorded the lowest NAR at all stages. NAR went on increasing upto the final stage of the crop and the highest value of 1.63 was recorded at the last phase (between 60 and 75 DAS) by F_4.

The effect of inhibitors on NAR was significant only between 30 and 45 days. At this stage, NBU was on a par with MBU but significantly superior to urea. During other stages, eventhough the effects were not significant NBU recorded the highest value.

The effect of F x N interaction was not significant.

4.2.4 Crop growth rate (CGR)

The effect of nitrogen levels and nitrification inhibitors on the CGR recorded between 30 and 45 DAS, between 45 and 60 DAS and between 60 and 75 DAS are presented in Table 11.

Table 11. Crop growth in mg^{-2} day^{-1} as influenced by nitrogen levels and nitrification inhibitors

Treatments	Crop growth rate		
	Between 30 and 45 DAS	Between 45 and 60 DAS	Between 60 and 75 DAS
Nitrogen levels			
F_1	0.39	0.49	0.48
F_2	0.57	1.04	0.84
F_3	0.82	1.39	0.94
F_4	0.96	1.51	1.09
$F_{3,\ 22}$	22.27**	60.63**	157.67**
SE	0.054	0.059	0.021
CD (0.05)	0.158	0.172	0.061
Nitrification inhibitors			
N_1	0.63	1.06	0.74
N_2	0.73	1.14	0.94
N_3	0.69	1.13	0.83
$F_{2,\ 22}$	1.15^{NS}	0.73^{NS}	28.88**
SE	0.047	0.051	0.018
CD (0.05)	-	-	0.053

** Significant at 0.01 level

NS Not significant

CGR of plant was found to increase with incremental dose of nitrogen upto F_4. Between 30 and 45 DAS and between 45 and 60 DAS, F_4 recorded the maximum value which was on a par with F_3 but significantly superior to F_1 and F_2. But at final stage, F_4 was significantly superior to all the other levels of nitrogen and at this stage, all the treatments showed a general decline.

CGR was found to be significantly influenced by nitrification inhibitors only at the later stages of growth (between 60 and 75 DAS). At this stage, NBU recorded the highest value of 0.94 m^{-2} day^{-1} which was significantly superior to MBU and urea and MBU inturn was significantly superior to urea. For all other stages, the effect was non significant, however, NBU recorded the highest value.

F x N interaction was non significant.

4.3 Yield attributes and yield

4.3.1 Time of 50 per cent flowering

The mean number of days taken for 50 per cent flowering are given in Table 12.

Table 12. Effect of nitrogen levels and nitrification inhibitors on the time of 50 per cent flowering, number of flowers per plant, percentage of fruit set, number of fruits formed per plant

Treatments	Time of 50 per cent flowering	Number of flowers per plant	Number of fruits per plant	Percentage of fruit set
Nitrogen levels				
F_1	37.67	33.61	21.00	48.79
F_2	38.33	36.99	22.07	52.33
F_3	44.67	38.78	20.07	36.67
F_4	46.44	39.97	19.43	30.20
$F_{3,\ 22}$	19.90**	11.81**	78.55**	53.59**
SE	0.993	0.026	0.042	0.045
CD(0.05)	2.912	0.075	0.120	0.131
Nitrification inhibitors				
N_1	40.50	34.95	17.19	39.60
N_2	41.50	37.85	22.69	44.59
N_3	43.33	39.22	22.06	41.79
$F_{2,\ 22}$	2.79NS	97.23**	71.47**	41.87**
SE	0.860	0.022	0.035	0.039
CD (0.05)	-	0.064	0.104	0.113

** - Significant at 0.01 level

NS - Non Significant

The influence of different levels of nitrogen on the number of days taken for 50 per cent flowering was significant. Days taken for 50 per cent flowering were significantly delayed by increasing levels of nitrogen. Plants supplied with the highest level of nitrogen (F_4) took about 46 days which was on a par with F_3 which took 44 days for 50 per cent flowering, whereas the lowest levels of nitrogen F_1 and F_2 took only 37 and 38 days respectively.

The effect of nitrification inhibitors and F x N interaction were non significant. However, it was seen that the flowering duration was delayed by 2-3 days when oil cakes were applied along with urea.

4.3.2 Number of flowers per plant

The mean number of flowers per plant recorded are shown in Table 12 and 12a.

The total number of flowers per plant was significantly influenced by the different nitrogen levels. The number of flowers per plant increased with each successive dose of nitrogen and F_4 produced the maximum

Table 12a. Combined effect of nitrogen levels and nitrification inhibitors on the number of flowers per plant

Treatments	Nitrogen levels				
	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	30.62	34.83	36.14	38.21	34.95
N_2	33.73	37.68	39.66	40.33	37.85
N_3	36.48	38.47	40.54	41.37	39.22
Mean	33.61	36.99	38.78	39.97	

F x N	
SE	0.044
CD(0.05)	0.129

number of flowers of about 40 per plant which was significantly superior to all other lower levels of nitrogen, Flower production was very low for F_1 (34 numbers).

It is evident from the table that nitrification inhibitors significantly influenced the number of flowers per plant. In general, oil cake applied plants produced more number of flowers when compared with plants that received urea alone. Mahua cake blended urea (N_3) was significantly superior to neem cake blended urea (N_2) and urea alone (N_1). Neem cake was also found to be superior to urea alone.

The interaction effect between nitrification inhibitors and nitrogen levels was also significant. With all the three sources the number of flowers produced per plant increased significantly, as the level of nitrogen was increased and the maximum was produced by mahua cake blended urea at 300 kg N ha^{-1} followed by mahua cake blended urea at 200 kg N ha^{-1} and neem cake blended urea at 300 kg N ha^{-1}. The number of flowers per plant was lowest for urea at 50 kg N ha^{-1} followed by urea at 100 kg N ha^{-1}. The number ranged from 30.68 to 38.21 for urea alone and 33.73 to 40.33 for neem cake blended urea and 36.48 to 41.37 for mahua cake

Table 12b Combined effect of nitrogen levels and nitrification inhibitors on the number of fruits per plant

Treatments	Nitrogen levels				
	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	16.75	18.82	17.15	16.04	17.19
N_2	22.71	24.87	21.73	21.43	22.69
N_3	23.55	22.53	21.33	20.82	22.06
Mean	21.00	22.07	20.07	19.43	

F x N

SE	0.071
CD(0.05)	0.208

blended urea. Even at 300 kg N ha^{-1}, urea alone could produce only 38.21 number of flowers whereas with oil cake blending even with lower doses of nitrogen an increase in the number of flowers was observed.

4.3.3 Number of fruits per plant

The effect of nitrogen levels and nitrification inhibitors and their interaction effects on the number of fruits per plant are presented in Table 12 and 12b.

On a perusal of the data it was observed that the number of fruits per plant was significantly influenced by nitrogen levels. Maximum number of fruits per plant was obtained by F_2 level (22.07) followed by F_1, F_3 and F_4 in the decreasing order. Each value exhibited significant superiority over the respective other level and F_4 recorded the lowest fruit number of 19.43.

A significant increase in the number of fruits per plant was observed with nitrification inhibitors. neem cake blended urea was significantly superior to mahua cake blended urea and urea. Maximum number of fruits per plant were observed at N_2 (22.69).

The interaction between nitrogen and nitrification inhibitors also influenced the number of fruits per plant. At all levels of nitrogen, addition of nitrification inhibitors increased the number of fruits per plant significantly. Without oil cake blending the number of fruits per plant got drastically reduced registering on an average of 17.19 number per plant. With mahua cake blended urea, the number of fruits per plant showed decreasing trend with increasing levels of nitrogen. But with neem cake blended urea and urea alone, the fruit number increased upto 100 kg N ha^{-1} and then declined. Maximum number of fruits per plant was observed at F_2 N_2 followed by F_1N_3 and the lowest fruit number was registered by F_4 N_1 followed by F_1N_1.

4.3.4 <u>Setting percentage</u>

The influence of various treatments on setting per cent are given in Table 12 and 12c.

Nitrogen levels and nitrification inhibitors had significant influence on the setting percentage. Setting percentage was significantly higher in F_2 (52.33) than F_1, F_3 and F_4. Increasing levels of nitrogen markedly reduced the setting percentage beyond 100 kg N ha^{-1}. The highest level of nitrogen (F_4) was significantly inferior to all the lower levels of nitrogen and recorded the least setting percentage of 30.2.

Neem cake blended urea recorded the maximum setting percentage of 44.59 which was significantly superior to mahua cake blended urea and urea alone which inturn were significantly different.

Interaction FxN had significant influence on setting percentage. At all levels of nitrogen except at F_1, N_2 increased the setting percentage significantly when compared to N_1 and N_3. The setting percentage went on increasing upto 100 kg N ha^{-1} with urea alone and neem cake blended urea, beyond which a sharp decline was observed. But with mahua cake blended urea, with every increase in nitrogen level, the setting percentage decreased substantially. In the absence of nitrification inhibitors F_2 recorded the highest setting percentage of 48.34. With neem cake blended urea also F_2 recorded the maximum percentage of 57.29 whereas for mahua cake blended urea F_1 recorded the highest value of

Table 12c Combined effect of nitrogen levels and nitrification inhibitors on the percentage of fruit set

Treatments	Nitrogen levels				
	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	42.65	48.34	35.10	32.31	39.60
N_2	49.37	57.29	40.58	31.13	44.59
N_3	54.34	51.35	34.33	27.16	41.79
Mean	48.79	52.33	36.67	30.20	

F x N

SE	0.077
CD(0.05)	0.227

54.34. The least setting percentage of 27.16 was for F_4N_3 followed by F_4N_2.

4.3.5 <u>Height of the first bearing node</u>

The data on the height of the first bearing node are presented in Table 13.

It is evident from the table that neither the nitrogen levels nor the nitrification inhibitors did influence the height of the first fruit bearing node significantly. However, it was seen that the height of the first bearing node increased with increasing level of nitrogen and maximum of 16.9 cm being recorded by F_4.

Among the oil cakes, mahua cake recorded the maximum height of 16.87 cm whereas neem cake recorded the least of 14.57 cm.

Interaction FxN was not significant.

Table 13 Effect of nitrogen levels and nitrification inhibitors on the height of the first bearing node from the ground level in cm

Treatments	Height of the first bearing node from the ground level (cm)
Nitrogen levels	
F_1	14.40
F_2	14.62
F_3	15.86
F_4	16.90
$F_{3,\ 22}$	1.18^{NS}
SE	1.076
CD(0.05)	-
Nitrification inhibitors	
N_1	14.90
N_2	14.57
N_3	16.87
$F_{2,\ 22}$	1.79^{NS}
SE	0.934
CD (0.05)	-

NS Non Significant

4.3.6 Length of the fruit

The data on the mean length of the fruit are presented in Table 14 and 14a.

Nitrogen levels exerted significant influence on the length of the fruit only at the final harvest. At the final harvest, F_2 was significantly superior to F_1, F_3 and F_4 in producing the maximum length of fruit. During the initial and middle harvests, eventhough the effects were not significant, it was observed that F_2 produced the maximum fruit length and F_1 the minimum.

Nitrification inhibitors significantly influenced the length of the fruit during the first and the final harvests. At these stages NBU was significantly superior to MBU and urea alone. NBU produced longer fruits in all the other harvests also, eventhough the effects were not significant.

The interaction FxN had significant influence only at the final harvest. As the levels of nitrogen increased, there was a decrease in the length of fruit in case of MBU

Table 14 Length of the fruit in cm as influenced by nitrogen levels and nitrification inhibitors

Treatments	Length of the fruit (cm)					
	First two harvests		Middle two harvests		Final two harvests	
	1	2	1	2	1	2
Nitrogen levels						
F_1	17.89	15.26	16.59	17.44	11.78	10.95
F_2	19.79	17.47	17.85	19.48	15.62	13.12
F_3	19.15	17.06	16.82	19.20	14.87	11.61
F_4	18.42	16.75	16.77	18.49	13.78	11.16
$F_{3, 22}$	2.43^{NS}	1.47^{NS}	0.57^{NS}	2.93^{NS}	6.23^{**}	9.24^{**}
SE	0.532	0.791	0.756	0.532	0.213	0.327
CD(0.05)	-	-	-	-	0.625	0.956
Nitrification inhibitors						
N_1	18.15	15.73	16.66	18.04	12.61	10.32
N_2	19.99	17.20	17.25	18.98	15.29	13.89
N_3	18.30	16.97	17.13	18.95	14.15	10.91
$F_{2, 22}$	4.85^{*}	1.31^{NS}	0.23^{NS}	1.34^{NS}	70.81^{**}	45.19^{**}
SE	0.461	0.690	0.653	0.464	0.186	0.287
CD (0.05)	1.362	-	-	-	0.531	0.823

* - Sgnificant at 0.05 level NS - Non Significant

** - Significant at 0.01 level

Table 14a. Combined effect of nitrogen levels and nitrification inhibitors on the length of the fruit of final two harvests in cm

a. First harvest

Treatments	Nitrogen levels F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	9.91	15.57	13.53	11.43	12.61
N_2	13.53	15.59	15.54	16.47	15.29
N_3	11.9	15.70	15.54	13.44	14.15
Mean	11.78	15.62	14.87	13.78	
FxN					
SE	0.367				
CD (0.05)	1.076				

b. Second harvest

Treatments	Nitrogen levels F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	10.67	11.16	11.67	7.36	10.32
N_2	12.72	13.53	13.67	15.67	13.89
N_3	9.45	14.22	9.51	10.45	10.91
Mean	10.95	13.12	11.61	11.16	
FxN					
SE	0.559				
CD (0.05)	1.640				

and urea alone, whereas it increased for NBU. Urea and MBU recorded maximum fruit length at F_2 level. NBU produced the maximum fruit length at F_4 level. Maximum fruit length was recorded by F_4 N_2.

In general, the fruits become shorter at the final harvest stage when compared with the early harvested fruits.

4.3.7 Girth of the fruit

The data on the mean girth of the fruit recorded at initial, middle and final harvests are presented in Table 15.

It is clear from the table that nitrogen levels exerted significant influence on the girth of the fruit during the middle and the last harvest. During the middle harvest, F_2 recorded the maximum girth of 6.74 cm which was on a par with F_3 and F_4 but significantly superior to F_1 and F_3 in turn was superior to F_1 and F_4. While F_1 was significantly inferior.

There was a significant increase in the fruit girth due to oilcake application only at the final harvests. At

Table 15 Girth of the fruit in cm as influenced by nitrogen levels and nitrification inhibitors

Treatments	Girth of the fruit (cm)					
	First two harvests		Middle two harvests		Final two harvests	
	1	2	1	2	1	2
Nitrogen levels						
F_1	6.69	5.69	6.10	6.23	4.61	4.87
F_2	6.94	6.14	6.60	6.74	5.43	5.65
F_3	6.76	5.98	6.42	6.73	4.72	5.31
F_4	6.73	5.77	6.36	6.42	4.65	4.99
$F_{3, 22}$	1.01^{NS}	1.94^{NS}	0.62^{NS}	3.83^{*}	2.44^{NS}	19.17^{**}
SE	0.112	0.154	0.263	0.129	0.248	0.079
CD(0.05)	-	-	-	0.381	-	0.234
Nitrification inhibitors						
N_1	6.71	5.75	6.11	6.45	4.53	4.98
N_2	6.88	6.00	6.50	6.63	5.29	5.33
N_3	6.75	5.94	6.50	6.51	4.73	5.32
$F_{2, 22}$	0.97^{NS}	1.07^{NS}	1.01^{NS}	0.71^{NS}	3.45^{*}	8.24^{*}
SE	0.092	0.130	0.229	0.113	0.210	0.068
CD (0.05)	-	-	-	-	0.631	0.201

* - Sgnificant at 0.05 level

NS - Non Significant

** - Significant at 0.01 level

this stage, NBU was significantly superior to urea but was on a par with MBU. During other harvests, eventhough there was no significant difference on the fruit girth due to oilcake application, NBU recorded the highest value.

In general, the girth of the fruit decreased as the number of harvests increased irrespective of nitrogen levels and nitrification inhibitors.

The interaction F x N effect was not significant.

4.3.8 Fruit yield per plant

The data on the fruit yield per plant are presented in Table 16.

Nitrogen levels significantly influenced the fruit yield per plant. F_2 recorded the highest fruit yield of 2.02 kg per plant which was on a par with F_1 and F_3 but significantly superior to F_4. The highest nitrogen level (F_4) recorded the lowest yield of 1.62 kg per plant.

Table 16 Fruit yield per plant (Kg $plant^{-1}$) and total fruit yield (q ha^{-1}) as affected by nitrogen levels and nitrification inhibitors

Treatments	Fruit yield per plant (Kg $plant^{-1}$)	Total fruit yield (q ha^{-1})
Nitrogen levels		
F_1	1.98	89.28
F_2	2.02	95.97
F_3	1.86	75.87
F_4	1.62	65.05
$F_{3,\ 22}$	5.73**	3.26*
SE	0.074	4.220
CD(0.05)	0.218	12.378
Nitrification inhibitors		
N_1	1.86	77.93
N_2	1.90	87.21
N_3	1.85	79.50
$F_{2,\ 22}$	0.18^{NS}	0.56^{NS}
SE	0.064	3.655
CD (0.05)	-	-

* - Significant at 0.05 level

** - Significant at 0.01 level

NS - Non Significant

The effect of nitrification inhibitors and F x N interaction was non significant. However, NBU was found to produce the highest fruit yield of 1.90 kg per plant.

4.3.9 Total fruit yield

Total fruit yield was significantly influenced by the different nitrogen levels. 100 kg N ha^{-1} (F_2) recorded the highest fruit yield of 95.97 q ha^{-1} which was on a par with F_1 but significantly superior to F_3 and F_4. The highest dose of nitrogen (F_4) recorded the lowest yield of fruits of 65.06 q ha^{-1}, which was on a par with F_3.

Nitrification inhibitors showed no significant influence on the total fruit yield. However, the highest fruit yield of 87.21 q ha^{-1} was obtained with NBU and the lowest with urea alone (77.93 q ha^{-1}).

The effect due to F x N interaction was not significant.

4.4 Analytical aspects

4.4.1 Chlorophyll content of leaves

The data on the chlorophyll content of leaves are given in Table 17.

There was no significant influence on the chlorophyll content of leaves due to the application of various doses of nitrogen. However, it was seen that with every increase in the nitrogen level there was an increase in the chlorophyll content of leaves, the highest being recorded by F_4 (2.04 mg g^{-1}).

Similarly nitrification and FxN interaction were not significant. However, urea alone recorded the highest chlorophyll content of 1.93 mg g^{-1}.

4.4.2 Quality Aspects

4.4.2.1 Crude protein content of fruits

The effects of nitrogen and nitrification and their interaction effects on the crude protein content of the fruit are presented in Tables 18 and 18a.

Table 17 Chlorophyll content of leaves in mgg^{-1} as influenced by nitrogen levels and nitrification inhibitors.

Treatments	Chlorophyll content of leaves (mgg^{-1})
Nitrogen levels	
F_1	1.75
F_2	1.78
F_3	1.78
F_4	2.04
$F_{3, 22}$	0.83^{NS}
SE	0.154
CD(0.05)	-
Nitrification inhibitors	
N_1	1.93
N_2	1.82
N_3	1.77
$F_{2, 22}$	0.97^{NS}
SE	0.132
CD (0.05)	-

NS - Non Significant

Table 18 Effect of nitrogen levels and nitrification inhibitors on the crude protein content of fruits in per cent and ascorbic acid content (mg $100g^{-1}$ fresh weight of fruit)

Treatments	Crude protein Content (%)	Ascorbic acid content (mg $100g^{-1}$ fresh weight of fruits)
Nitrogen levels		
F_1	15.63	19.16
F_2	16.72	21.15
F_3	17.87	23.29
F_4	18.85	24.34
$F_{3,\ 22}$	197.25**	351.31**
SE	0.009	0.112
CD(0.05)	0.002	0.325
Nitrification inhibitors		
N_1	15.96	22.40
N_2	18.64	24.01
N_3	17.20	22.56
$F_{2,\ 22}$	242.24**	88.30**
SE	0.008	9.434
CD (0.05)	0.025	0.285

** Significant at 0.01 level

Addition of nitrogen increased the protein content of fruit significantly. Maximum value was recorded at F_4 level (18.85%) which was significantly superior to other three levels. Each higher level was significantly superior to the next lower level and F_1 recorded the lowest protein content of 15.63 per cent which was significantly inferior to all higher levels.

Application of nitrification inhibitors recorded higher content of protein than urea alone and the maximum being recorded by neem cake blended urea (18.64%) which was significantly superior to N_1 and N_3 and N_3 inturn was significantly superior to N_1.

The interaction was significant. At all levels of nitrogen neem cake blended urea recorded significantly higher values for protein content of fruits. With and without nitrification inhibitors F_4 recorded the highest value for protein content of fruits.

Maximum protein content was recorded by F_4N_2 followed by F_4N_3 whereas the least by F_1N_1 followed by F_2N_1.

Table 18a Combined effect of nitrogen levels and nitrification inhibitors on the crude protein content of fruits in percent

Treatments	Nitrogen levels F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	14.70	15.20	16.80	17.15	15.96
N_2	16.75	18.65	18.90	20.25	18.64
N_3	15.45	16.30	17.90	19.15	17.20
Mean	15.63	16.72	17.87	18.85	
FxN					
SE	0.017				
CD (0.05)	0.050				

4.4.2.2 Ascorbic acid content of fruits

Table 18 and 18 b gives the mean value of ascorbic acid content of fruits.

On a perusal of the data it was observed that the ascorbic acid content of fruits was significantly influenced by nitrogen levels. The highest dose of nitrogen (F_4) recorded the highest ascorbic acid content and was significantly superior to other three levels of nitrogen and each higher level of nitrogen was inturn significantly superior to the next lower level. F_1 recorded the lowest ascorbic acid content of fruits and was significantly inferior to all the other three levels of nitrogen.

Nitrification inhibitors significantly influenced the ascorbic acid content of fruits. NBU recorded significantly higher value of ascorbic acid content of fruits than MBU and urea alone, while N_1 and N_3 inturn were on par.

The effect of interaction was significant. At all nitrogen levels, NBU recorded significantly superior values than MBU and urea alone. MBU inturn was significantly

Table 18b Combined effect of nitrogen levels and nitrification inhibitors on the ascorbic acid content of fruits

Treatments	Nitrogen levels				
	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	17.11	18.65	20.87	21.35	22.40
N_2	20.75	23.02	25.55	26.73	24.01
N_3	19.63	21.76	23.45	24.94	22.56
Mean	19.16	21.15	23.29	24.34	

F x N	
SE	0.189
CD (0.05)	0.554

superior to urea alone. In the absence and presence of nitrification inhibitors, 300 kg N ha^{-1} recorded the highest value and the least by 50 kg N ha^{-1}. There was significant difference among the treatments. Maximum ascorbic acid content of fruits was recorded by F_4 N_2 followed by F_3N_2 and the minimum by F_1N_1 followed by F_2N_1.

4.4.3 <u>Nutrient uptake</u>

4.4.3.1 Uptake of nitrogen by plants

The data on the uptake of nitrogen by plants recorded at 30, 45, 60 and 75 DAS are presented in Table 19, 19a and 19b.

Application of nitrogen in varying levels significantly influenced the total uptake of nitrogen by plants at all stages of growth. At 30 DAS, F_4 recorded the highest uptake of 24.88 kg ha^{-1} which was on par with F_3 but significantly superior to F_1 and F_2. F_3 and F_2 were inturn on a par. F_1 was inferior to all higher levels of nitrogen. During other growth periods, F_4 recorded the highest uptake which was significantly superior to F_1, F_2 and F_3. Each

Table 19 Effect of nitrogen levels and nitrification inhibitors on the total uptake of nitrogen by plants in kg ha^{-1}

Treatments	Uptake of nitrogen			
	at 30 DAS	at 45 DAS	at 60 DAS	at 75 DAS
Nitrogen levels				
F_1	12.58	33.13	42.01	30.34
F_2	18.39	37.46	45.60	35.18
F_3	22.30	44.38	49.44	39.59
F_4	24.88	51.27	55.52	42.86
$F_{3, 22}$	707.73**	1861.29**	1968.38**	1753.21**
SE	1.348	0.030	0.063	0.049
CD (0.05)	3.921	0.097	0.134	0.141
Nitrification inhibitors				
N_1	14.62	32.58	38.55	31.16
N_2	24.74	49.98	57.35	42.86
N_3	21.39	42.14	48.54	36.97
$F_{2, 22}$	1816.31**	2735.71**	2972.81**	2522.17**
SE	1.154	0.033	0.072	0.054
CD (0.05)	3.462	0.191	0.240	0.120

** Significant at 0.01 level

Table 19a Combined effect of nitrogen levels and nitrification inhibitors on the uptake of nitrogen by plant

a. at 45 DAS

Treatments	Nitrogen levels F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	24.34	27.38	34.44	44.15	32.58
N_2	42.53	46.65	52.65	58.09	49.98
N_3	32.52	38.36	46.05	51.59	42.14
Mean	33.13	37.46	44.38	51.27	
FxN					
SE	0.068				
CD (0.05)	0.086				

b. at 60 DAS

Treatments	Nitrogen levels F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	31.98	34.36	39.08	48.78	38.55
N_2	52.19	56.45	59.37	61.36	57.35
N_3	41.86	45.98	49.88	56.44	48.54
Mean	42.01	45.60	49.44	55.52	
FxN					
SE	0.009				
CD (0.05)	0.035				

Table 19b. Combined effect of nitrogen levels and nitrification inhibitors on the uptake of nitrogen by plant at 75 DAS

Treatments	Nitrogen levels F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	25.44	29.99	33.68	35.54	31.16
N_2	34.61	40.39	45.72	50.69	42.86
N_3	30.96	35.15	39.38	42.36	36.97
Mean	30.34	35.18	39.59	42.86	
FxN					
SE	0.006				
CD (0.05)	0.024				

higher level inturn was significantly superior to the next lower level of nitrogen.

Nitrification inhibitors also exerted significant influence on the uptake of nitrogen by plants. At 30 DAS, NBU was on a par with MBU but significantly superior to urea alone. During other stages of growth, NBU was significantly superior to MBU and urea alone and MBU inturn was significantly superior to urea alone.

In general, the nitrogen uptake increased with aging of crop upto 60 DAS, beyond which a drastic reduction was noticed.

F x N interaction was significant at 45, 60 and 75 DAS. During these periods F_4N_2 recorded the highest value followed by F_3N_2 and the least by F_1N_1 followed by F_2N_1 without and nitrification inhibitors, F_4 recorded the highest uptake. Among the nitrification inhibitors. NBU followed by MBU recorded the highest uptake.

4.4.3.2 Uptake of phosphorus by plant

Tables 20 and 20a give the total uptake of phosphorus by plant at 75 DAS.

Nitrogen levels significantly influenced the total phosphorus uptake by plant. F_4 was significantly superior to F_1, F_2 and F_3 in recording the highest value of 16.78 kg ha^{-1}. Each higher level of nitrogen was inturn significantly superior to the next lower level in recording the phosphorus uptake. F_1 was the most inferior treatment.

Nitrification inhibitors also exerted positive influence on the total phosphorus uptake by plants. NBU was significantly superior to MBU and urea alone and MBU inturn was significantly superior to urea alone.

The interaction effect was also significant without nitrification inhibitors the highest levels of nitrogen (F_4) recorded the highest value of 14.13 kg ha^{-1}. In the presence of nitrification inhibitors also F_4 recorded the maximum value. Among the nitrification inhibitors NBU recorded significantly higher value followed by MBU. F_4N_2 recorded the highest uptake of 18.92 kg ha^{-1} followed by F_3N_3 (17.83

Table 20. Effect of nitrogen levels and nitrification inhibitors on the total uptake of phosphorus and potassium by the plant in kg ha^{-1} at 75 DAS

Treatments	Uptake of Phosphorus	Uptake of Potassium
Nitrogen levels		
F_1	14.46	37.86
F_2	15.69	40.96
F_3	16.20	44.88
F_4	16.78	45.26
$F_{3,\ 22}$	960.02**	7.25**
SE	0.029	0.602
CD (0.05)	0.093	1.862
Nitrification inhibitors		
N_1	13.75	37.67
N_2	17.28	46.38
N_3	16.33	42.66
$F_{2,\ 22}$	3989.56**	9.76**
SE	0.028	0.521
CD (0.05)	0.081	1.493

** - Significant at 0.01 level

Table 20a Combined effect of nitrogen levels and nitrification inhibitors on the total uptake of phosphorus by plant in kg ha^{-1} at 75 DAS

Treatments	Nitrogen levels F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	13.09	13.81	13.92	14.13	13.74
N_2	15.39	16.99	17.83	18.92	17.28
N_3	14.91	16.26	16.78	17.29	16.31
Mean	14.46	15.69	16.18	16.78	
FxN					
SE	0.039				
CD (0.05)	0.115				

kg ha^{-1}) and the least by F_1N_1 (13.09 kg ha^{-1}) followed by F_2N_1 (13.81 kg ha^{-1}).

4.4.3.3 Uptake of potassium by plant

Effect of nitrogen levels and nitrification inhibitors on the total uptake of potassium by plants is presented in Table 20.

Nitrogen levels and nitrification inhibitors influenced the total potassium uptake significantly. Among the nitrogen levels F_2 recorded the highest uptake of 45.26 kg ha^{-1} which was on par with F_4 (44.88 kg ha^{-1}) but significantly superior to F_1 and F_2.

In case of nitrification inhibitors NBU recorded significantly higher values for potassium uptake (46.38 kg ha^{-1}) than MBU and urea alone while MBU inturn was significantly superior to urea alone.

The effect of F x N interaction was non significant.

4.4.3.4 Uptake of nitrogen by fruits

The data on the uptake of nitrogen by fruits are presented in Table 21.

Table 21 Uptake of nitrogen, phosphorus and potassium content by fruits influenced by nitrogen levels and nitrification inhibitors in kg ha^{-1}

Treatments	Uptake of nitrogen	Uptake of phosphorus	Uptake of potassium
Nitrogen levels			
F_1	33.39	3.07	26.59
F_2	37.32	3.28	33.55
F_3	41.41	3.59	28.92
F_4	43.81	3.91	24.02
$F_{3, 22}$	26.41**	176.36**	52.54**
SE	0.891	0.027	0.558
CD(0.05)	2.622	0.081	1.638
Nitrification inhibitors			
N_1	32.57	3.08	26.69
N_2	45.25	3.88	29.91
N_3	39.13	3.44	28.20
$F_{2, 22}$	67.29**	280.86**	11.05**
SE	0.777	0.024	0.483
CD (0.05)	2.276	0.070	0.419

** Significant at 0.01 level

There was a progressive increase in the uptake of nitrogen by fruits due to different levels of nitrogen. The higher levels of nitrogen were significantly superior to the lower levels. F_3 and F_4 were on a par.

Nitrification inhibitors significantly influenced the nitrogen uptake by fruit. NBU was significantly superior to urea and MBU and MBU was inturn significantly superior to urea.

F x N interaction was not significant.

4.4.3.5 Uptake of phosphorus by fruits

The data on the phosphorus uptake by fruits are presented in Table 21 and 21a.

Uptake of phosphorus was significantly influenced by the application of nitrogen in varying levels. Phosphorus uptake increased with successive increase in levels of nitrogen. F_4 was significantly superior to F_1, F_2 and F_3. Each higher level of nitrogen was significantly superior to the next lower level of nitrogen.

Table 21a. Combined effect of nitrogen levels and nitrification inhibitors on the uptake of phosphorus by fruit in kg ha^{-1}

Treatments	F_1	F_2	F_3	F_4	Mean
			Nitrogen levels		
Nitrification inhibitors					
N_1	2.67	2.93	3.12	3.59	3.08
N_2	3.59	3.85	3.96	4.12	3.88
N_3	2.96	3.05	3.71	4.02	3.44
Mean	3.07	3.28	3.59	3.91	
FxN					
SE	0.048				
CD (0.05)	0.141				

Nitrification inhibitors also significantly influenced the phosphorus uptake. NBU was significantly superior to urea and MBU.

The effect of interaction was significant. Maximum phosphorus uptake was obtained by F_4N_2 followed by F_4N_3 and the minimum by F_1N_1 followed by F_2N_1. At all nitrogen levels NBU recorded the highest uptake followed by MBU. With and without nitrification inhibitors the highest nitrogen level (F_4) recorded the highest uptake of phosphorus. The uptake value of fruits ranged from 2.67 kg ha^{-1} to 4.12 kg ha^{-1}.

4.4.3.6 Uptake of potassium by fruits

The effect of nitrogen levels and nitrification inhibitors on the potassium uptake are given in Table 21.

Nitrogen levels exerted significant influence on the potassium uptake by fruits. F_2 recorded the highest uptake of 33.55 kg ha^{-1} of potassium and was significantly superior to other three levels of nitrogen. The highest dose of nitrogen (F_4) recorded the least uptake of potassium and was significantly inferior to the other three levels.

Nitrification inhibitors significantly influenced the potassium uptake by fruits. NBU recorded the highest value of 29.91 kg ha^{-1} of potassium and was significantly superior to MBU and urea. Urea inturn was significantly superior to MBU.

F x N interaction was not significant.

4.4.4 Available nutrient status of soil.

4.4.4.1 Available nitrogen

Tables 22, 22a and 22b give the data on the mean content of available nitrogen in soil at 30, 45, 60 and 75 DAS. Available nitrogen status of the soil was significantly influenced by nitrogen levels. As the levels of nitrogen increased, the available nitrogen status also increased. At all stages, F_4 recorded the maximum value and was significantly superior to the next lower level. The lowest level of nitrogen (F_1) recorded the lowest value at all

Table 22 Available nitrogen status of soil in Kg ha^{-1} as influenced by nitrogen levels and nitrification inhibitors

Treatments	Available nitrogen status of soil ($Kgha^{-1}$)			
	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels				
F_1	308.96	382.39	353.67	319.91
F_2	325.24	412.63	386.60	345.14
F_3	353.60	462.84	430.68	376.45
F_4	371.02	516.02	466.56	395.78
$F_{3,\ 22}$	62.68**	675.69**	1072.63**	5183.99**
SE	3.518	2.256	1.511	0.466
CD(0.05)	10.320	6.612	4.432	1.367
Nitrification inhibitors				
N_1	251.78	309.76	275.10	254.19
N_2	400.88	551.03	514.75	437.86
N_3	366.44	469.62	438.29	385.90
$F_{2,\ 22}$	656.32**	3945.76**	8751.66**	55031.34**
SE	3.047	1.954	1.308	0.404
CD (0.05)	8.937	5.731	3.837	1.184

** Significant at 0.01 level

stages and was significantly inferior to all higher levels of nitrogen.

Nitrification inhibitors also exerted significant influence on the nitrogen status of soil. NBU recorded higher values at all stages of the experiment which was significantly superior to MBU and urea. NBU was inturn significantly superior to urea.

Maximum available nitrogen in soil was observed at 45 DAS. Towards the end of the experiment a drastic reduction was noted.

The effect of FxN interaction was significant at 45, 60 and 75 DAS. There was a significant difference among treatments the maximum being recorded by F_4N_2 followed by F_3N_2 and the minimum by F_1N_1 followed by F_2N_1. For all nitrogen levels, NBU recorded the highest value followed by MBU. In the absence and presence of nitrification inhibitors maximum available nitrogen in soil was recorded by the higher levels of nitrogen (F_4 and F_3) and the minimum by F_1 followed by F_2.

Table 22a Combined effect of nitrogen levels and nitrification inhibitors on the available nitrogen status of soil in Kg ha^{-1}

a. at 45 DAS

Treatments	Nitrogen levels				
	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	280.71	301.44	318.76	338.12	309.76
N_2	472.82	502.85	563.63	664.81	551.03
N_3	393.65	433.59	506.11	545.12	469.62
Mean	382.39	412.63	462.84	516.02	
F x N					
SE	3.908				
CD (0.05)	11.462				

b. at 60 DAS

Treatments	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	244.12	264.07	285.95	306.28	275.10
N_2	437.49	499.61	534.41	587.48	514.75
N_3	379.41	396.12	471.68	505.93	438.29
Mean	353.67	386.60	430.68	466.56	
F x N					
SE	2.616				
CD (0.05)	7.675				

Table 22b Combined effect of nitrogen levels and nitrification inhibitors on the available nitrogen status of soil in Kg ha^{-1} at 75 DAS

Treatments	Nitrogen levels				
	F_1	F_2	F_3	F_4	Mean
Nitrification inhibitors					
N_1	225.23	244.86	263.64	283.06	254.19
N_2	395.43	432.95	451.98	471.09	437.86
N_3	339.06	357.61	413.75	433.19	385.90
Mean	319.91	345.14	376.45	395.78	

F x N

SE	0.807
CD (0.05)	2.367

4.4.4.2 Available phosphorus

The data on available phosphorus content of the soil after the experiment are given in Table 23.

Nitrogen application significantly influenced the available phosphorus status of soil. F_4 recorded the higher value of 57.14 kg ha^{-1} which was on a par with F_3 and significantly superior to F_1 and F_2. F_1 and F_2 were on a par. F_1 obtained the least phosphorus status of 56.22 kg ha^{-1}.

Nitrification inhibitors showed significant influence on the phosphorus status of soil and the highest value was observed with NBU which was significantly superior to urea and MBU. N_3 was inturn significantly superior to N_1.

F x N interaction was not significant.

4.4.4.3 Available potassium

The data on the available potassium content of the soil after the experiment are presented in Table 23.

Table 23 Effect of nitrogen levels and nitrification inhibitors on the available phosphorus and potassium status of soil in Kg ha^{-1}

Treatments	Available phosphorus status of soil (Kg ha^{-1})	Available potassium status of soil (Kg ha^{-1})
Nitrogen levels		
F_1	56.22	221.19
F_2	56.52	221.39
F_3	56.89	221.59
F_4	57.14	221.86
$F_{3, 22}$	15.88**	2.93NS
SE	0.101	0.149
CD(0.05)	0.296	0.436
Nitrification inhibitors		
N_1	56.15	220.95
N_2	57.26	222.00
N_3	56.67	221.58
$F_{2, 22}$	39.27**	15.71**
SE	8.089	0.129
CD (0.05)	0.259	0.377

** - Significant at 0.01 level

NS - Non Significant

There was no significant effect on the available potassium status of soil due to the application of varying levels of nitrogen. However F_4 recorded the maximum value of 221.86 kg ha^{-1}.

Nitrification inhibitors significantly influenced the potassium status of soil. N_2 recorded the highest value of 222 kg ha^{-1} which was significantly superior to N_1 and N_3. N_3 was inturn significantly superior to N_1.

The interaction F x N effect was not significant.

4.5 Economics of cultivation

4.5.1 Net profit

The data on net profit are shown in Table 24 and 24a.

Nitrogen levels significantly influenced the net profit. F_2 recorded the highest net profit of Rs. 16017.50 which was significantly superior to all other treatments. F_4

Table 24. Economicsof cultivation

Treatments	Total cost of prouction Y (Rs.)	Fruit yield (kg)	Value X (Rs.)	Net profit X-Y (Rs.)	Benefit cost ratio $\frac{X}{Y}$ (Rs.)
Nitrogen levels					
F_1	21948.99	8927.92	35711.68	13762.69	1.63
F_2	22372.10	9597.39	38389.60	16017.50	1.72
F_3	23218.38	7586.93	30347.73	7129.35	1.31
F_4	23624.94	6505.22	26020.87	2395.93	1.10
$F_{3, 22}$				1993.19**	27.68**
SE				143.415	0.055
CD (0.05)				420.648	0.163
Nitrification inhibitors					
N_1	22524.19	7793.46	31173.83	8649.64	1.38
N_2	23089.41	8719.79	34879.14	11789.73	1.51
N_3	22759.71	7949.86	31799.44	9039.73	1.39
$F_{2, 22}$				209.05**	2.39^{NS}
SE				124.201	0.048
CD (0.05)				364.292	-

Table 24a. Combined effect of nitrogen levels and nitrification inhibitors on the net profit (Rs.)

Treatments	Nitrogen levels				
	F1	F2	F3	F4	Mean
Nitrification inhibitors					
N_1	10966.40	13978.07	5991.69	3662.42	8649.64
N_2	13261.08	20127.79	11602.77	2167.30	11789.73
N_3	17060.60	13946.63	3793.61	1358.08	9039.73
Mean	13762.69	16017.50	7129.36	2395.93	
FxN					
SE	248.40				
CD (0.05)	728.58				

was significantly inferior to all the lower levels of nitrogen and recorded the lowest net profit of Rs. 2395.93.

Nitrification inhibitors also significantly influenced the net profit from bhindi. Application of neem cake blended urea gave the maximum net profit of Rs.11789.73 which was significantly superior to N_1 and N_3. Mahua cake blended urea and urea were on a par.

FxN interaction was significant. Maximum net profit of Rs.20127.79 was recorded by neem cake blended urea at 100 kg N ha^{-1} and the minimum value of Rs. 1358.08 was obtained for mahua cake blended urea at 300 kg N ha^{-1}. With the lowest dose of nitrogen, MBU produced maximum profit and this went on decreasing with increasing levels of nitrogen. But with NBU the profit went on increasing upto 100 kg N ha^{-1}.

4.5.2 Benefit cost ratio

The data on benefit cost ratio are presented in Table 27.

As in the case of net profit, benefit cost ratio also was maximum for F_2 which was significantly superior to all the other three treatments. F_4 recorded the least value of 1.10 which was significantly inferior to all the other lower levels of nitrogen.

Oil cakes also exerted profound influence on the benefit cost ratio. Application of neem cake blended urea increased the benefit cost ratio to 1.51 and the effects due to mahua cake blended urea and urea alone were almost similar.

The interaction F x N effect was not significant.

Correlation studies

Simple correlation studies were undertaken with a view to elucidate the relationship of each of the various growth and yield attributing characters and yield. Correlation coefficients of yield with these characters were calculated. The results showed that all the correlation coefficients were statistically significant.

Values of simple correlation coefficients

Sl. No.	Character correlated	Correlation coefficient
1.	Yield x height of plant at 30 DAS	0.6195**
2.	Yield x height of plant at 45 DAS	0.4851**
3.	Yield x height of plant at 60 DAS	0.6204**
4.	Yield x height of plant at 75 DAS	0.4486**
5.	Yield x LAI at 30 DAS	0.3312*
6.	Yield x LAI at 45 DAS	0.3345*
7.	Yield x LAI at 60 DAS	0.3916*
8.	Yield x LAI at 75 DAS	0.3684*
9.	Yield x DMP at 30 DAS	0.3312*
10.	Yield x DMP at 30 DAS	0.3534*
11.	Yield x DMP at 45 DAS	0.3657*
12.	Yield x DMP at 60 DAS	0.3489*
13.	Yield x length of fruit of initial harvest	0.4531**
14.	Yield x length of fruit of middle harvest	0.4732*
15.	Yield x length of fruit of final harvest	0.4933**
16.	Yield x girth of fruit of initial harvest	0.3847**
17.	Yield x girth of fruit of middle harvest	0.4671**
18.	Yield x percentage of fruit set	0.5562**
19.	Yield x number of fruits per plant	0.4671**
20.	Yield x per plant yield	0.5323**
21.	Yield x Available nitrogen at 30 DAS	0.4231*
22.	Yield x Available nitrogen at 45 DAS	0.4110*
23.	Yield x Available nitrogen at 60 DAS	0.7094**
24.	Yield x Available nitrogen at 75 DAS	0.5254**
25.	Net assimilation rate between 30 and 45 DAS	0.3343*
26.	Net assimilation rate between 45 and 60 DAS	0.3614*
27.	Net assimilation rate between 60 and 75 DAS	0.3523*

DISCUSSION

DISCUSSION

An experiment was conducted to find out the effect of different levels of nitrogen and nitrification inhibitors on the growth, yield, quality and nutrient uptake by bhindi. The results obtained from this study are briefly discussed in this chapter.

5.1 Growth characters

The results of mean height of the plant are shown in Table 2. It was observed that there was no appreciable variation in the height of plants with increasing levels of nitrogen. The variation observed by the higher levels of nitrogen beyond 100 kg N ha^{-1} was not significant and the maximum plant height was 123 cm. Such a performance by the crop may be due to the inherent nature of the plants which cannot grow beyond a certain height even after receiving additional quantity of nitrogen. Similar observations has been reported by Sajitharani (1993) in bhindi variety Kiran where she observed that by the application of nitrogen beyond 220 kg ha^{-1} had no significant difference and she has also reported that the maximum plant height attained by this variety was 106 cm with 330 kg ha^{-1}. Konhar et al. (1974) opined that nitrogen application beyond 20 kg ha^{-1} failed to increase the height of the plant remarkably. Likewise, Singh (1979) could not obtain any significant differences in plant height with varying levels of nitrogen tried from 75 to 150 kg N ha^{-1}. Plant height was not influenced by the nitrification inhibitors at any of the growth stages. But it was clear that oilcakes blended urea produced more plant height than urea alone. Similar increase in plant height of bhindi due to oilcake application was reported by Singh and Sitaramaiah (1963).

The number of leaves increased with increasing levels of nitrogen and significant difference was observed only at the early stage (Table 3). The highest level of nitrogen recorded the maximum number of leaves of about 20 at the harvest stage. The increase may be due to the property of nitrogen fertilizer to enhance the vegetative growth. Similar increase in leaf number in bhindi with increasing levels of nitrogen was reported by Chhonkar and Singh (1963), Chandrasekharan (1965), Pandey and Singh (1979). After 60 DAS there was a decrease in the leaf number with lower levels of nitrogen. This might be due to the defoliation and lesser leaf production due to low quantity of nitrogen. Russel (1973) had reported that as the amount of nitrogen increased, the leaf longevity also increased. Oilcakes blended urea produced more leaves than unblended urea though the effects were non significant. The alkaloids like nimbin, nimbidin, saponin and the sulphur compounds present in the oilcakes might have inhibited the nitrification process, thereby providing a continuous supply of nitrogen which might have more efficiently been utilized by the crop when urea was blended with oilcakes. Sathianathan (1982) also reported positive influence of oilcakes on the leaf number of cassava. Similar observation was also obtained in maize (Wali and Totawat, 1992). With the aging of the plant the leaf production was found to be decreased with MBU and urea alone, whereas with NBU there was a definite increase in the leaf production and the increased leaf production due to NBU till the final growth phase may be due to the retention of more nitrogen in the absorbable form in the plant rhizophere. Mahua cake was not as efficient in nitrification inhibition as NBU which may be due to its lower oil content of 12 per cent, in comparison with neem cake which contain 17.75 per cent of oil (Ketkar, 1976).

Branching was increased significantly with increasing levels of nitrogen (Table 4). Maximum number of branches of 3.11 per plant was produced by the application of 300 kg N ha^{-1} which was the highest level. The increase in the number of branches may be due to the higher nitrogen content in the tissue which helps in the assimilation of protoplasm resulting in greater cell division and formation of more tissues which leads to the vigour of the plant. The results are in conformity with the findings of Chandrasekharan (1965), Chauhan and Gupta (1973), Hooda et al. (1980). Eventhough the effect of nitrification inhibitors were not significant, NBU recorded the highest number of branches per plant. This may be due to the increased and continued supply of nitrogen rendered by oilcakes over urea alone.

Nitrogen levels significantly influenced the length of the tap root at 30 and 60 DAS only (Table 5). F_2 (100 Kg N ha^{-1}) recorded the longest taproot. At harvest 100 kg N ha^{-1} gave 25.27 cm long roots which was 2.87 cm more than that obtained at 300 kg N ha^{-1}. Due to leaching, nitrogen might have got accumulated more in the lower layers of soil which might have inhibited the root growth downwards. Maharana and Das (1973) opined that higher doses of nitrogen were detrimental for root growth in cowpea. Non significant difference was observed in case of nitrification inhibitors. However, neem cake blended urea recorded the longest root. This is in agreement with the findings of Shivaprakash (1991) who obtained maximum root length in mulberry with mahua oil cake.

Root spread was not influenced by nitrogen levels (Table 6). However, F_4 (300 Kg N ha^{-1}) recorded the maximum root spread at all stages of growth. But nitrification inhibitors significantly influenced the root spread only at 60 and 75 DAS. During these stages oilcakes blended urea recorded significantly higher value for root spread than urea. Due to inhibition of nitrification, oilcakes provide constant and sufficient quantity of nitrogen for the growth of the lateral roots.

The levels of nitrogen and nitrification inhibitors positively influenced the DMP at all the stages of plant growth (Table 7 and 7a and Fig. 3). In general, there was a progressive increase in DMP due to nitrogen application at

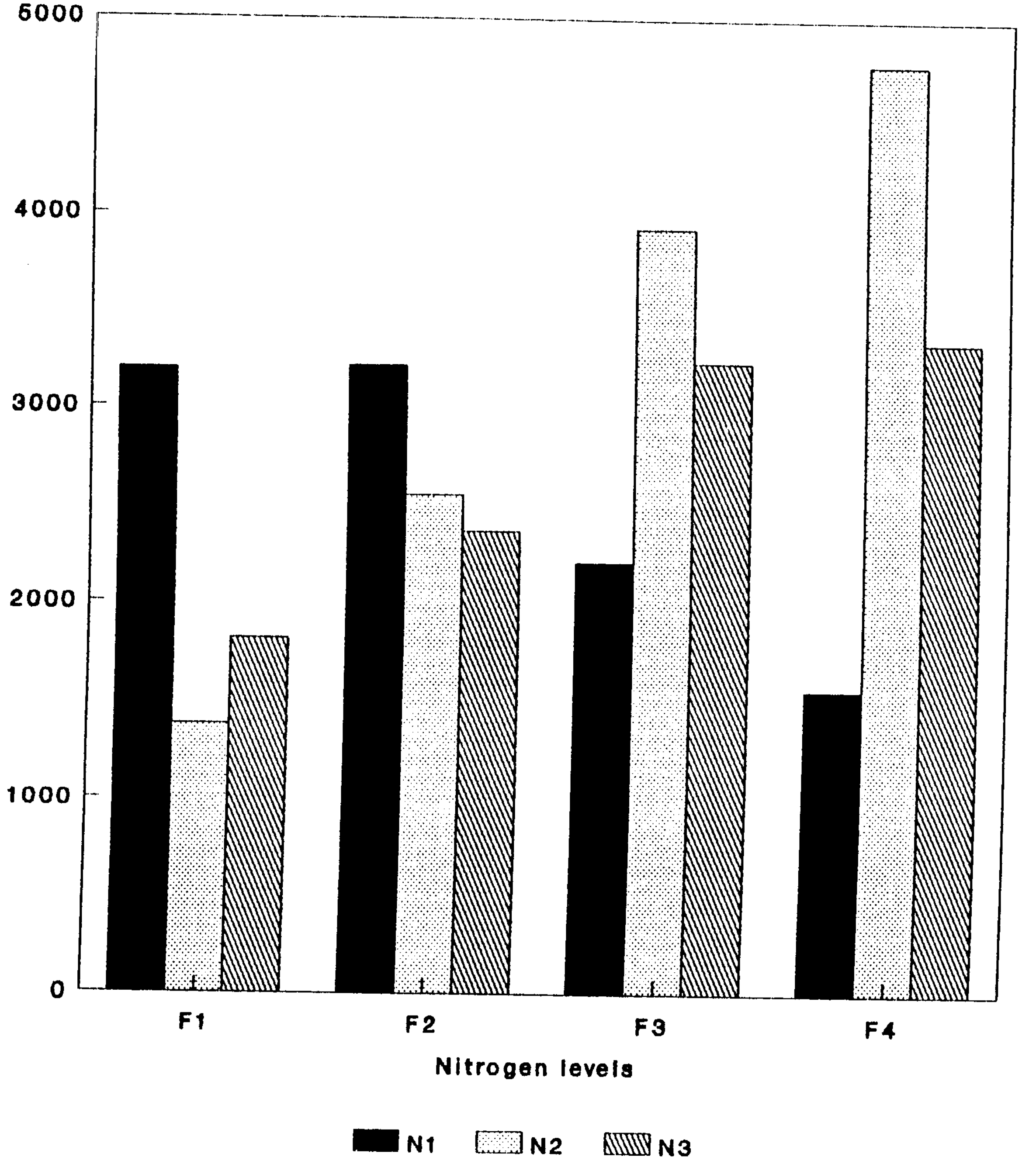


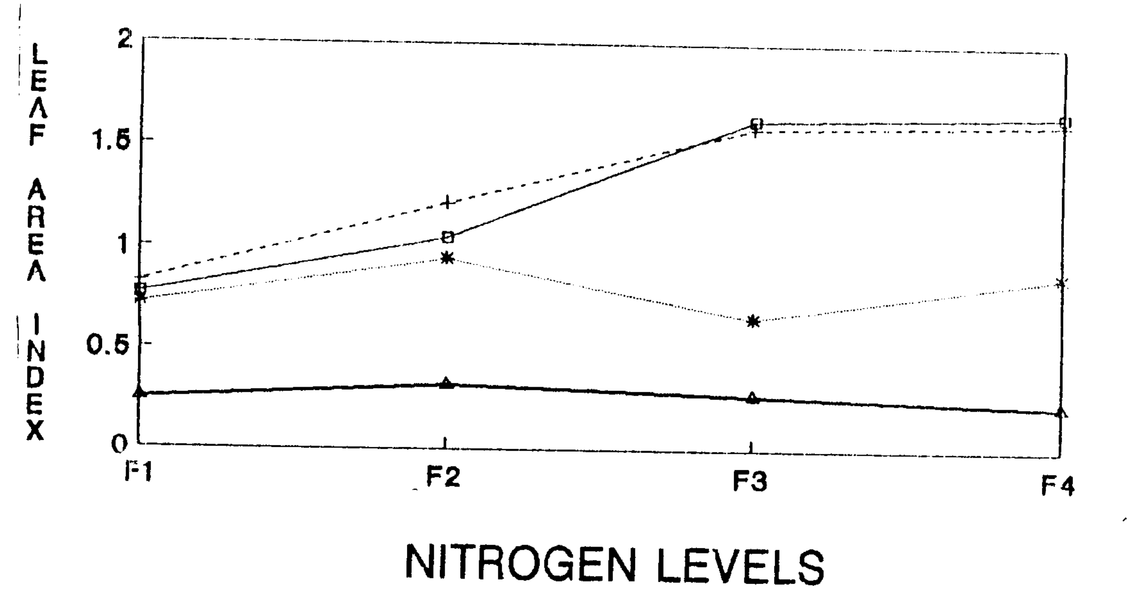
Fig. 3. DMP as affected by nitrogen levels and nitrification inhibitors at 60 DAS

almost all the growth stages. At harvest, the highest nitrogen level (300 kg ha^{-1}) recorded the highest DMP of 4250.18 kg ha^{-1} and the lowest DMP of 3432.78 kg ha^{-1} by the lowest nitrogen level (50 kg ha^{-1}). The percentage increase in DMP with F_2, F_3 and F_3 was 18,19 and 24 respectively over F_1 at harvest. The increased leaf number and branches have contributed to the increased DMP at higher nitrogen levels. The spectacular role played by nitrogen in increasing the vegetative growth in plants and DMP had been revealed since long (Black, 1973 and Russel, 1973). Similar results were also reported by Chauhan and Gupta (1973) and Sajitharani (1993).

Nitrification inhibitors also increased the DMP over urea alone at all the stages of growth. NBU was found to be better than MBU and urea alone. At harvest, NBU and MBU recorded 21 and 18 per cent increase respectively in DMP over urea alone. Oilcake provide a steady supply of nitrogen which might have supported the plant growth resulting in increased plant height, number of leaves and branches and finally the DMP. The results are in conformity with the findings of Sathianathan (1982) in cassava, Apurba Sarkar (1987) in jute and Muniram et al. (1987) in Japanese mint.

The combined effect of nitrogen and nitrification inhibitors significantly influenced the DMP at 60 DAS. At this stage, the highest value was recorded by NBU at 300 kg N ha^{-1} (4768.55 kg ha^{-1}) and the least by NBU at 50 kg N ha^{-1} (1382.33 kg ha^{-1}). Neem cake inhibited the nitrification and released nitrogen slowly and continously thus providing sufficient quantity of nitrogen to bring about maximum DMP.

Results on LAI (Table 8 and 8a and Fig. 4) clearly signifies the influence of nitrogen levels at different growth stages of bhindi. At the later growth phase the effect was significant and the highest dose recorded the maximum LAI of 1.65 at harvest. As the crop growth advanced there was a general increase in the LAI of the crop till harvest for F_3 and F_4 and upto 60 DAS for F_1 and F_2. The reduced LAI for F_1 and F_2 may be due to lesser leaf number per plant at harvest. The increased leaf number and leaf area have contributed to increased LAI for F_3 and F_4. According to Russel (1973) as the level of nitrogen supply increased, the extra protein produced allows the plant leaves to grow larger and hence to have a larger surface available for



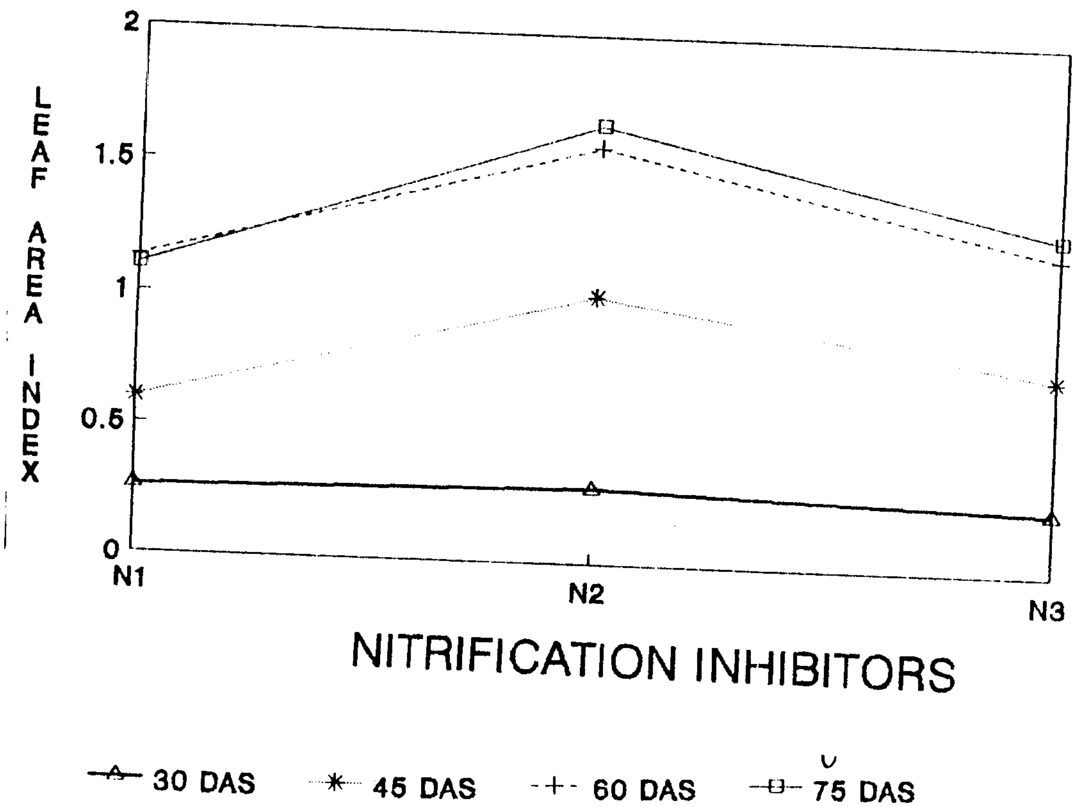


Fig. 4 LAI at different growth stages as affected by nitrogen levels and nitrification inhibitors

photosynthesis He also reported that leaf area available for photosynthesis is roughly proportional to the amount of nitrogen supplied. Similar results have been reported by Konhar et al. (1974) and Sajitharani (1993).

Nitrification inhibitors significantly influenced the LAI only at 45 and 60 DAS. It was observed that oilcakes blended urea increased the LAI over urea alone. This might be due to the increased leaf number and leaf area for oilcakes blended urea. The results are in conformity with the findings of Muniram et al. (1987) in Japanese mint, Singh et al. (1988) in maize, Shiva prakash (1991) in mulberry and Wali and Totawat (1992) in maize.

The interaction was significant only at 60 and 75 DAS. At 60 DAS, NBU at 300 kg N ha^{-1} and at 75 DAS NBU at 200 kg N ha^{-1} recorded the highest value of LAI. This might be due to increased leaf number and leaf area due to neem cake blended urea application.

It is evident from the data (Table 9,9a and 9b) that the RGR of bhindi plants was significantly influenced by nitrogen levels and the highest being recorded by 300 kg N ha^{-1} at all growth stages. This is mainly because of the increased DMP at higher levels. After 45 DAS, there was a decline in RGR. The rate of decline in the RGR between stages was also found to be significantly influenced by the nitrogen levels. The lowest dose of nitrogen (50 kg ha^{-1}) recorded the highest percentage of decline (78) whereas 300 kg N ha^{-1} recorded only 55 per cent decline at harvest. As the crop advanced to its senescence stage, a reduction in metabolic activities might have occurred resulting in reduced rate of increase in dry weight which have contributed towards the decline of RGR at later stages. Similar results had been observed by Ramana Gowda (1981) in fodder cowpea.

Oilcakes blended urea also significantly influenced the RGR at all stages of growth over urea alone (Table 9,9a and 9b). During the initial periods of growth, NBU and MBU recorded 16 and 7 per cent increase in RGR over urea. NBU, MBU and urea alone recorded 58, 61 and 78 per cent decline respectively at harvest. The increased RGR due to oil cake blending may be due to increased dry weight of the plant at all stages of growth. The results are in conformity with the findings of Muniram _et_ _al_. (1987) in Japanese mint. The combined effect of nitrogen levels and nitrification inhibitors also influenced the RGR at all stages of growth. NBU at 300 kg N ha^{-1} recorded the maximum RGR and the minimum by urea at 50 kg N ha^{-1} during all growth stages. About 124 per cent increase in RGR was noted due to NBU at 300 Kg N ha^{-1} over 50 kg N ha^{-1} of urea alone during initial growth period. The increased RGR due to oilcake blends at higher levels of nitrogen may be due to their positive effect on the dry weight of the plant.

NAR was significantly influenced by nitrogen levels throughout the growth period of crop (Table 10). With increasing age, the NAR increased with increasing levels of nitrogen and the maximum being recorded by 300 Kg N ha^{-1} at all growth stages. This may be due to the continuous growth put forth by the plant and that might have resulted in more photosynthetic area. Similar results were reported by Ramachandra and Thimmaraju (1983) in amaranthus. Nitrification inhibitors exerted significant influence on the NAR only between 30 and 45 DAS. Oilcake blended urea recorded higher values than urea alone. During initial periods NBU recorded 44 per cent and MBU 31 per cent increase in NAR over urea. This may be due to the increased dry weight and leaf area of the plant observed with oilcakes blended urea treatments.

The mean data on the crop growth rate are presented in Table-11. It is evident from the data that the CGR of bhindi plants in this study was significantly influenced by nitrogen levels and the highest being recorded by F_4 (300 Kg N ha^{-1}). Similar increase in CGR with increasing nitrogen levels was reported by Sajitharani (1993). Watson (1952) is of the opinion that CGR is directly influenced by LAI rather than NAR and hence the increased CGR noticed may be due to the increased LAI recorded at this stage. From the data it is evident that the general growth rate of the plant was declining at the reproductive phase. This may be due to the reduced metabolic activities as the crop advanced to senescence resulting in the reduced rate of increase in DMP at later growth periods.

Nitrification inhibitors showed significant influence on the CGR only between 60 and 75 days. At this stage, NBU and MBU recorded 27 and 12 per cent increase in CGR over urea alone. Oilcakes are efficient nitrification inhibitors which reduce the leaching loss of nitrogen and provided a constant supply of nitrogen throughout the growth period resulting in an increased DMP which might have contributed to an increase in CGR. The results are in conformity with the findings of Muniram et al. (1987) in Japanese mint.

5.2 Yield attributes, yield and quality

Nitrogen levels significantly influenced the time taken for 50 per cent flowering (Table 12). Delay in flowering was observed due to increased levels of nitrogen. 300 kg N ha^{-1} took about 46 days while the lowest dose of nitrogen (50 kg ha^{-1}) took only 38 days for attaining 50 per cent flowering. This may be due to the balancing of C/N ratio. High levels of nitrogen are expected to shift the C/N ratio towards more vegetative growth rather than the development of reproductive organs. Increasing the nitrogen supply increases the vegetative growth and delays the maturity, (Tisdale and Nelson, 1985). The results are in conformity with the findings of Sajitharani (1993).

Nitrification inhibitors did not exert any significant influence on the time of 50 per cent flowering. However, neem cake and mahua cake took about 42 days and 43 days respectively.

Levels of nitrogen significantly increased the number of flowers produced per plant (Table 12 and 12a). The number of flowers per plant increased with increasing levels of nitrogen and it varied from 34 (50 kg N ha^{-1}) to 40 (300 kg N ha^{-1}). The higher availability of nitrogen might have enabled the plants to produce more number of flower buds. Increase in the number of flowers per plant with increasing levels of nitrogen have been reported by Chauhan and Gupta (1973), Arora et al. (1991) and Sajitharani (1993). Oilcakes blending with urea also significantly influenced the number of flowers per plant. They recorded about 12 per cent increase in flowers over urea alone. This may be due to the increased availability of nitrogen as a result of inhibition of nitrification. The combined effect of nitrogen levels and nitrification inhibitors on the number of flowers per plant was significant. MBU at 300 kg N ha^{-1} recorded the highest number of flowers (41) and the least by urea at 50 kg N ha^{-1} (31). Oilcakes might have inhibited the nitrification and thereby provided nitrogen slowly and steadily in sufficient quantities to produce maximum number of flowers.

Number of fruits per plant significantly influenced by varying levels of nitrogen (Table 12 and 12b). Maximum number of fruits per plant (22) was recorded by 100 kg N ha^{-1} which was 14 per cent more than the number of fruits (19) produced per plant at the highest level of nitrogen (300 kg ha^{-1}). This may be due to the nutrient imbalance occured due to higher amount of nitrogen which have upset the normal metabolic activities. Moreover the setting percentage was higher with 100 kg N ha^{-1}. A similar increase in the number of fruits per plant with increased levels of nitrogen have been reported by Pandey <u>et al</u>. (1980), Hooda <u>et al</u>. (1981), Manphool Singh <u>et al</u>. (1993) and Sajitharani (1993). Nitrification inhibitors significantly influenced the number of fruits per plant. Oilcakes recorded about 32 per cent increase in the number of fruits per plant over urea alone. This may be due to the increased number of flowers per plant and highest setting percentage recorded with oilcakes. The results are in agreement with the findings of Som <u>et al</u>. (1992) in brinjal. The interaction effect was also significant. NBU at 100 kg N ha^{-1} recorded the highest fruit number and the least by urea at 50 kg N ha^{-1}. This may be due to the highest setting percentage obtained for this treatment.

An appraisal of the table 12 and 12c revealed that nitrogen levels significantly influenced the percentage of fruit set. Maximum setting percentage of 52 was obtained for 100 kg N ha^{-1} and the least (30 per cent) by 300 kg N ha^{-1}. This may be due to the increased flower drop at higher levels which might be due to the limited capacity of the plants to utilise greater amount of nitrogen beyond a certain optimum. Higher levels of nitrogen mostly promoted the vegetative growth. Similar results have been reported by Chandrasekharan (1965) and Subramanian (1980). The setting percentage was significantly influenced by nitrification inhibitors. Oil cakes recorded about 41-45 percentage of setting which was higher than urea alone. This may be due to the increased number of flowers and fruit formed with these treatments. The interaction was also significant. NBU at 100 kg N ha^{-1} recorded the highest setting percentage (57) whereas 50 kg N ha^{-1} recorded the least (43). Blending urea with oilcakes might have resulted in the conservation of more of ammonical nitrogen thereby providing sufficient quantities of nitrogen to achieve maximum setting percentage.

Neither the nitrogen levels nor the nitrification inhibitors did influence the height of the first bearing node significantly (Table 13). However, 300 kg N ha^{-1} recorded the maximum height of 16.90 cm which was 2.5 cm more than that at 50 kg N ha^{-1}. Mahua cake recorded the maximum height of 16.87 cm which was 1.87 cm more than that obtained with urea alone.

Levels of nitrogen significantly influenced the length of fruit only at final harvest (Table 14 and 14a and Fig. 5). 100 kg N ha^{-1} recorded the maximum length and 50 kg N ha^{-1} obtained the smallest fruit at final harvest. Highest level of nitrogen also showed a reduction in length of the fruit. This might be due to the limited capacity of the plants to utilize greater amount of nitrogen beyond a certain optimum. The results are in conformity with the findings of Verma et al. (1970), Manphool Sing et al. (1993). Nitrification inhibitors also exerted significant influence on the length of fruit only at the initial and final harvests. This might be due to increased availability of nitrogen in sufficient quantities at critical stages of crop growth. The results are in agreement with the findings of Vinod (1988) in cassava. Combined effect of nitrogen levels

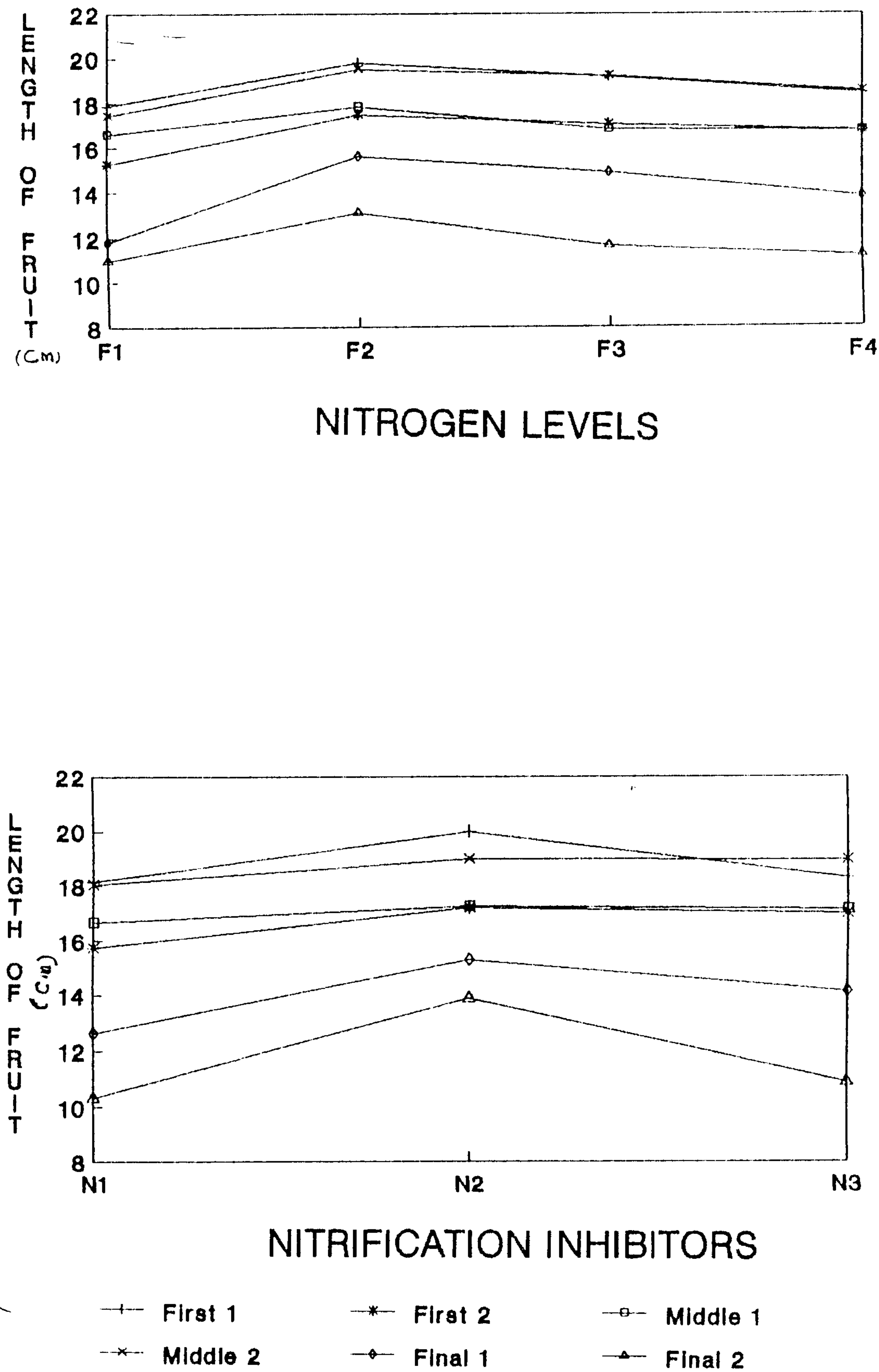
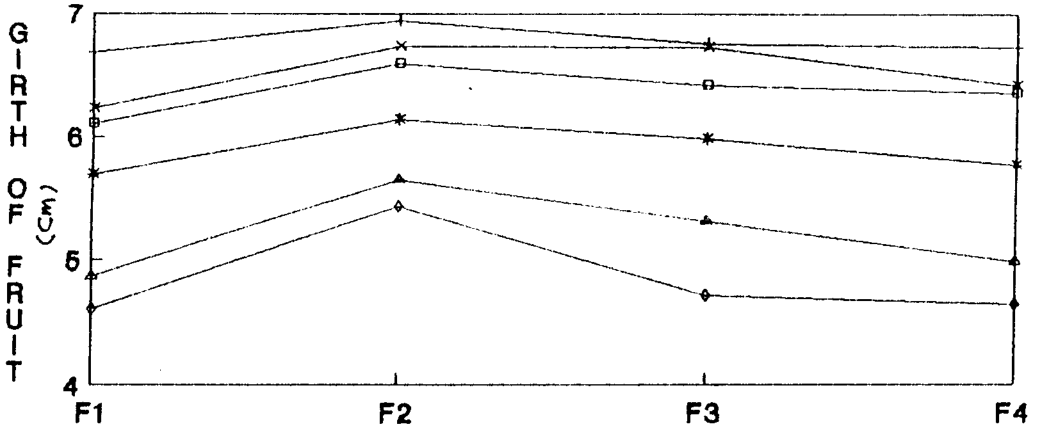


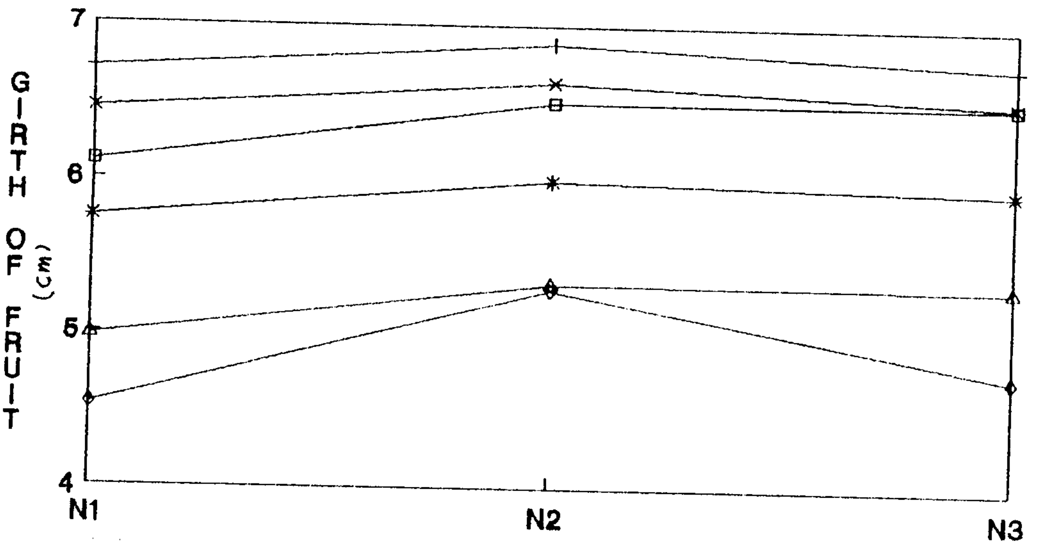
Fig. 5. Length of fruit as affected by nitrogen levels and nitrification inhibitors

and nitrification inhibitors on the length of fruit was significant at final harvest, maximum being recorded by NBU at 300 kg N ha^{-1} and the minimum by urea at 50 kg N ha^{-1} (for first harvest) and urea at 300 kg N ha^{-1} (for second harvest). Neem cake being an efficient nitrification inhibitor checked the leaching loss of nitrogen and thereby supplying nitrogen only in sufficient quantity for meeting the requirement and this might have resulted in producing longer fruits.

Nitrogen levels significantly influenced the girth of the fruit at middle and final harvest (Table 15 and Fig. 6). During these stages, 100 kg N ha^{-1} recorded the maximum girth and the minimum by 50 kg N ha^{-1}. Higher levels of nitrogen reduced the girth due to the ineffectiveness of these levels to produce maximum girth of fruit. The results are in line with the findings of Sharma et al. (1987). Nitrification inhibitors also significantly influenced the girth of fruit at final harvest. Oilcakes recorded maximum girth of fruit over urea alone. This might be due to continued and steady supply of nitrogen in sufficient quantities to produce maximum girth of fruit.



NITROGEN LEVELS



NITRIFICATION INHIBITORS

First 1 — First 2 — Middle 1
Middle 2 — Final 1 — Final 2

Fig. 6. Girth of fruit as affected by nitrogen levels and nitrification inhibitors

The per plant yield of fruit was significantly influenced by nitrogen levels (Table 16). 100 kg N ha^{-1} recorded the highest per plant yield of 2.02 kg. This might be due to the increased number of fruits per plant, length and girth of fruit obtained at 100 kg N ha^{-1}. There was no significant difference between 50 kg N ha^{-1} and 200 kg N ha^{-1} whereas 300 kg N ha^{-1} produced the least fruit yield of 1.62 kg per plant. Nitrification inhibitors didnot influence the per plant yield. However, neem cake blended urea recorded the highest yield of 1.90 kg per plant.

Application of nitrogen significantly influenced the fruit yield (Table 16 and Fig. 7). 100 kg N ha^{-1} recorded the highest fruit yield of 95.97 q ha^{-1} which was 48 per cent more than that obtained at the highest level of nitrogen (300 kg ha^{-1}). The fruit yield obtained at 200 and 300 kg N ha^{-1} were not significantly different. This increase in yield may be due to the increase in the number of fruits per plant, maximum length and girth of fruit and maximum fruit yield per plant. Thus it appears that at the optimum levels of nitrogen, more number of bigger sized fruits have been produced resulting ultimately in greater yield. The yield of a crop is a very complex competitive

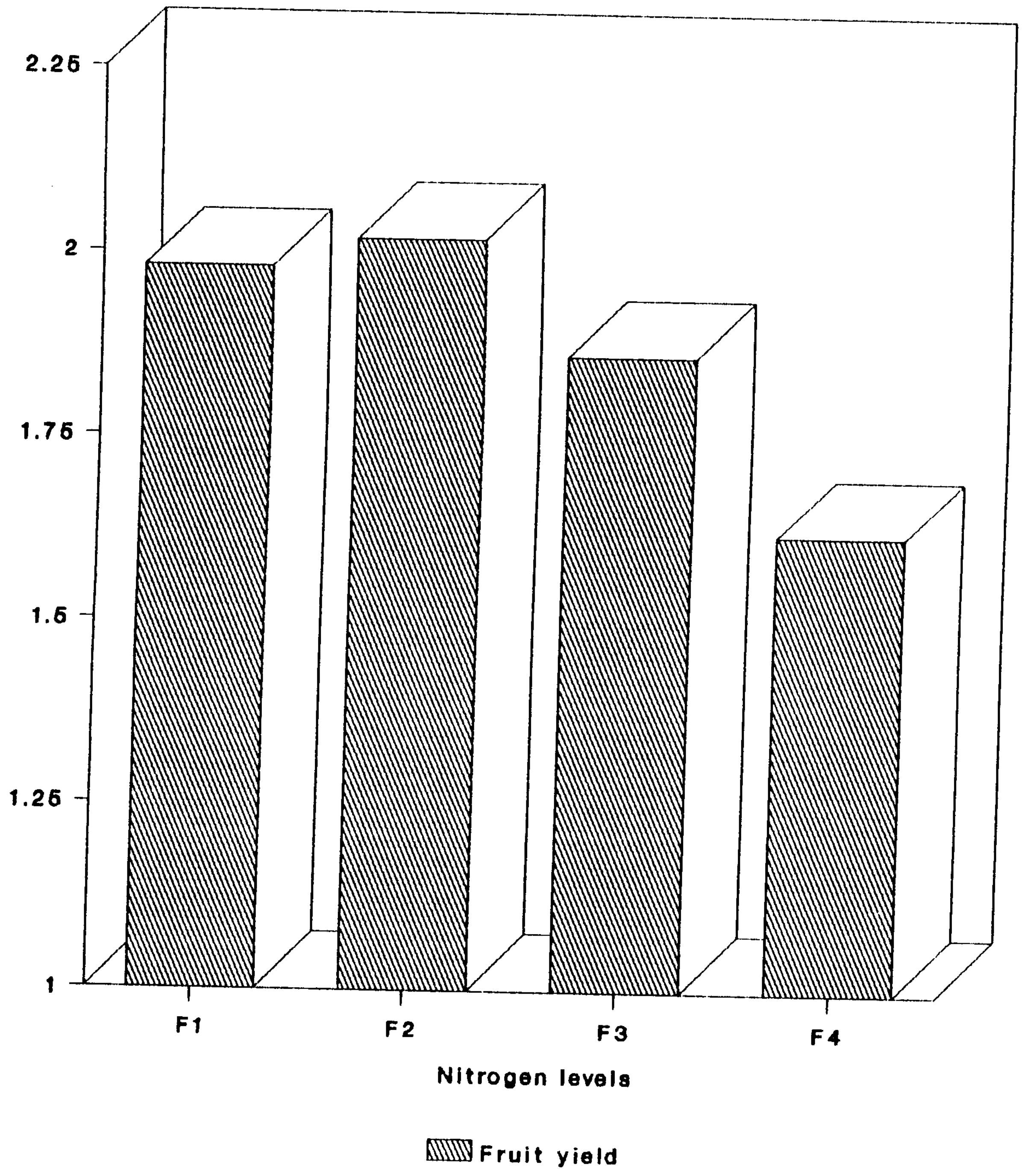


Fig. 7. Fruit yield of bhindi as affected by nitrogen levels (q ha^{-1})

character resulting from different factors, the more important being the yield per plant and number of plants per unit area (Tanaka et al., 1964). The yield is also controlled by other factors like uptake of nutrients, genetic potential and environmental conditions of the plant. Parr (1967) recorded that when larger amount of nitrate is absorbed by plants, it is not properly reduced to ammonium due to inefficient nitrate reductase enzyme system. This excessive nitrate accumulation often limits the yield. Similar results have been reported by Saimbi et al. (1991), Elizabeth and Rajan (1992) and Sajitharani (1993). Nitrification inhibitors didnot influence the fruit yield over urea alone. However, neem cake recorded the highest yield of 87.21 q ha^{-1} over urea alone. Similar results have been reported by Som et al. (1992) in brinjal, Ahmed and Baroova (1992) and Singh et al. (1992) in wheat.

From the figure 8 it is seen that maximum fruit yield was obtained during the second period of six harvests in the case of nitrogen levels and nitrification inhibitors. A positive correlation was found between yield and various characters like height of plant,

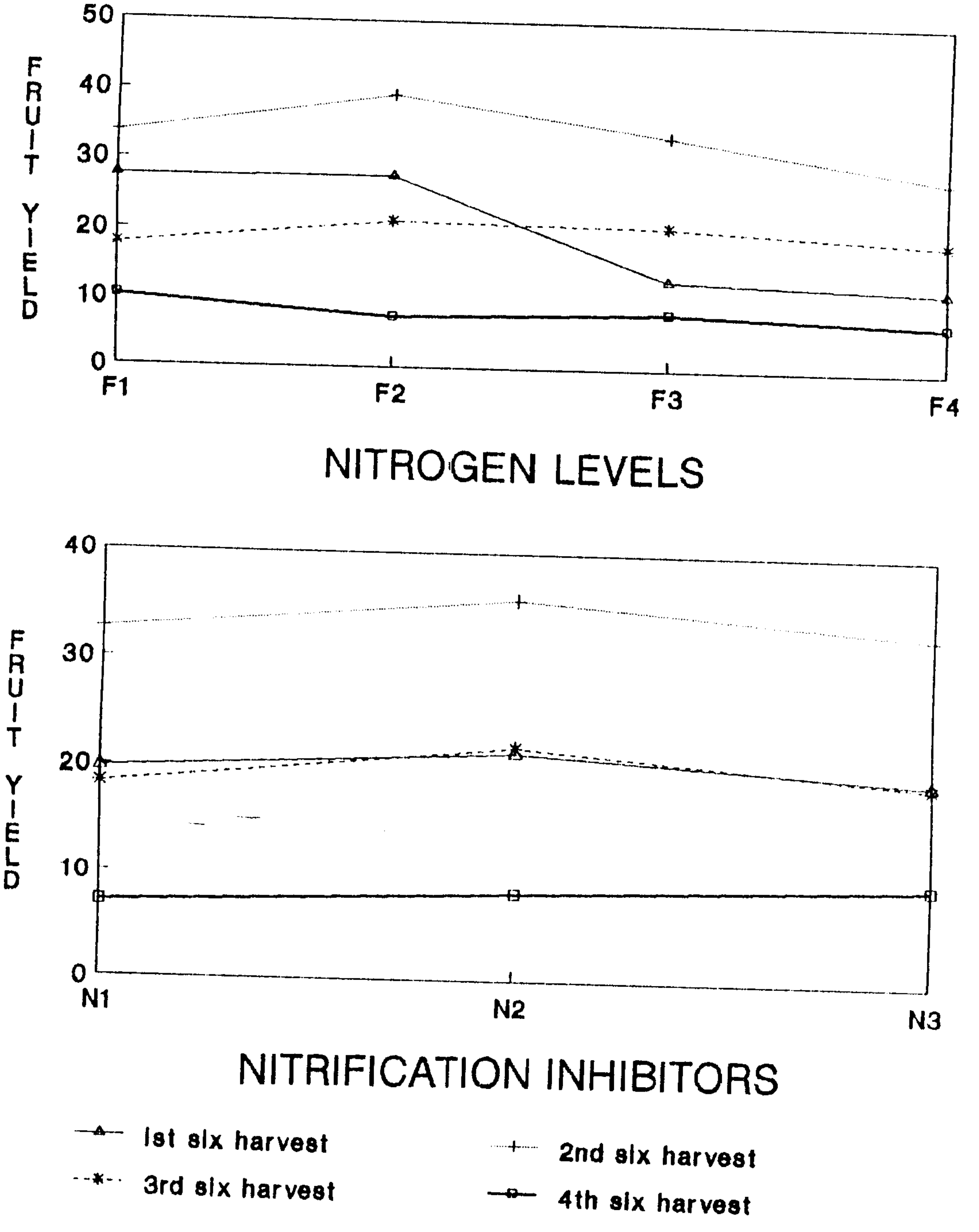
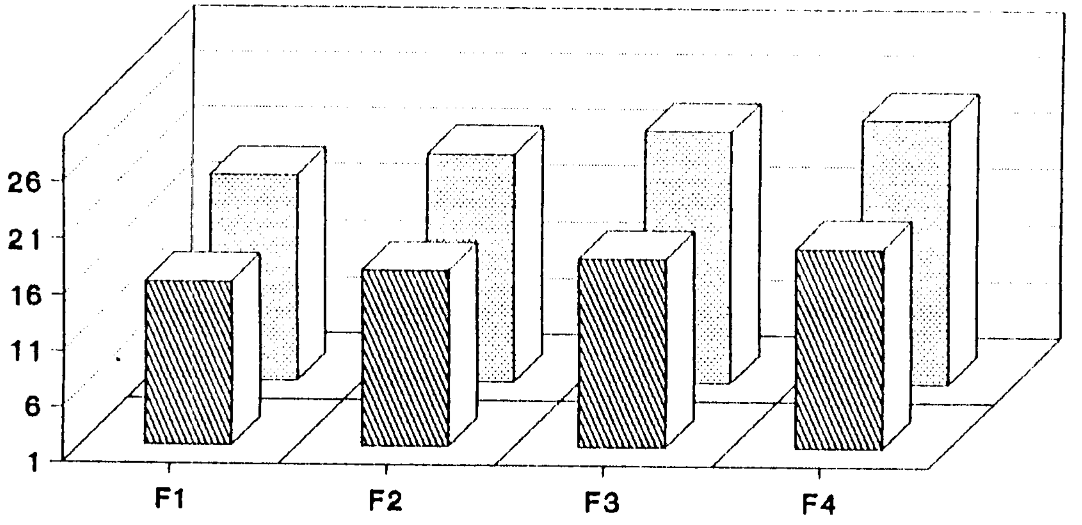


Fig. 8. Fruit yield of different periods of harvest (qha) as affected by Nitrogen levels & nitrification inhibitors

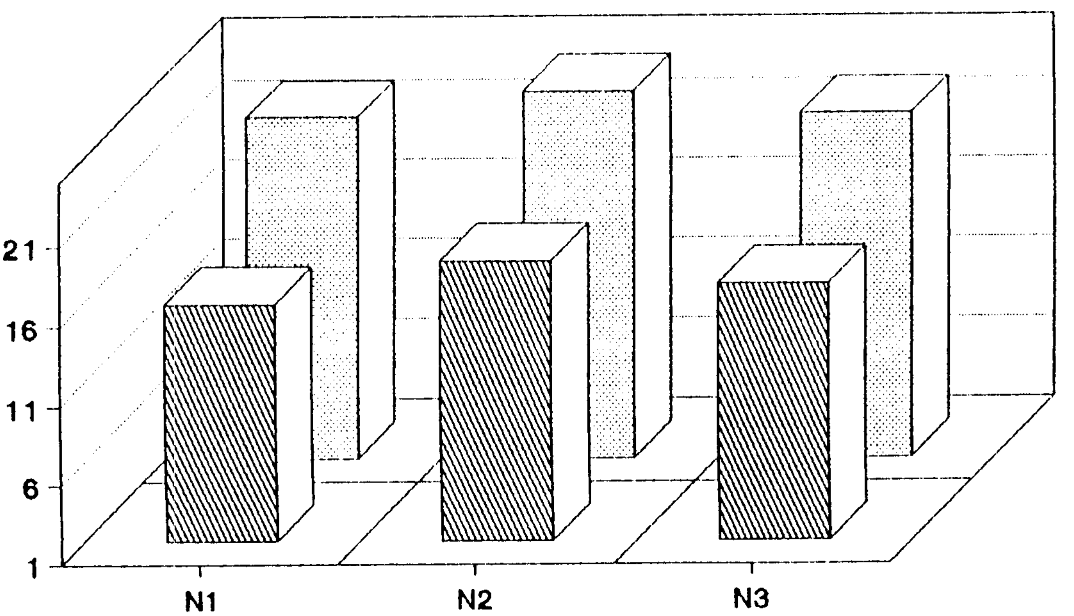
LAI, DMP, length and girth of fruit, percentage of fruit set, number of fruits per plant, per plant yield, availability of nitrogen and NAR.

Chlorophyll content of leaves was not influenced by nitrogen levels and nitrification inhibitors (Table 17). 300 kg N ha^{-1} recorded the highest chlorophyll content of 2.04 mg g^{-1} and the lowest of 1.75 mg g^{-1} by 50 kg N ha^{-1}. Urea recorded higher chlorophyll content of 1.93 mg g^{-1} over oil cakes.

Crude protein content was significantly influenced by nitrogen levels (Table 18 and 18a and Fig. 9). 300 kg N ha^{-1} recorded 18.85 per cent of crude protein which was 21 per cent more than that obtained at 50 kg N ha^{-1}. This might be due to the enhanced absorption of the added nitrogen and direct utilization of nitrogen in the protein synthesis. The results are in agreement with the findings of Sajitharani (1993). Oilcakes also recorded significant influence on the crude protein content. They recorded about 17 per cent increase over urea alone. This might be due to the increased availability of nitrogen throughout the growth period of crop. Similar increase in crude protein content by



NITROGEN LEVELS



NITRIFICATION INHIBITORS

Crude protein(%) Ascorbic acid (mg/100g)

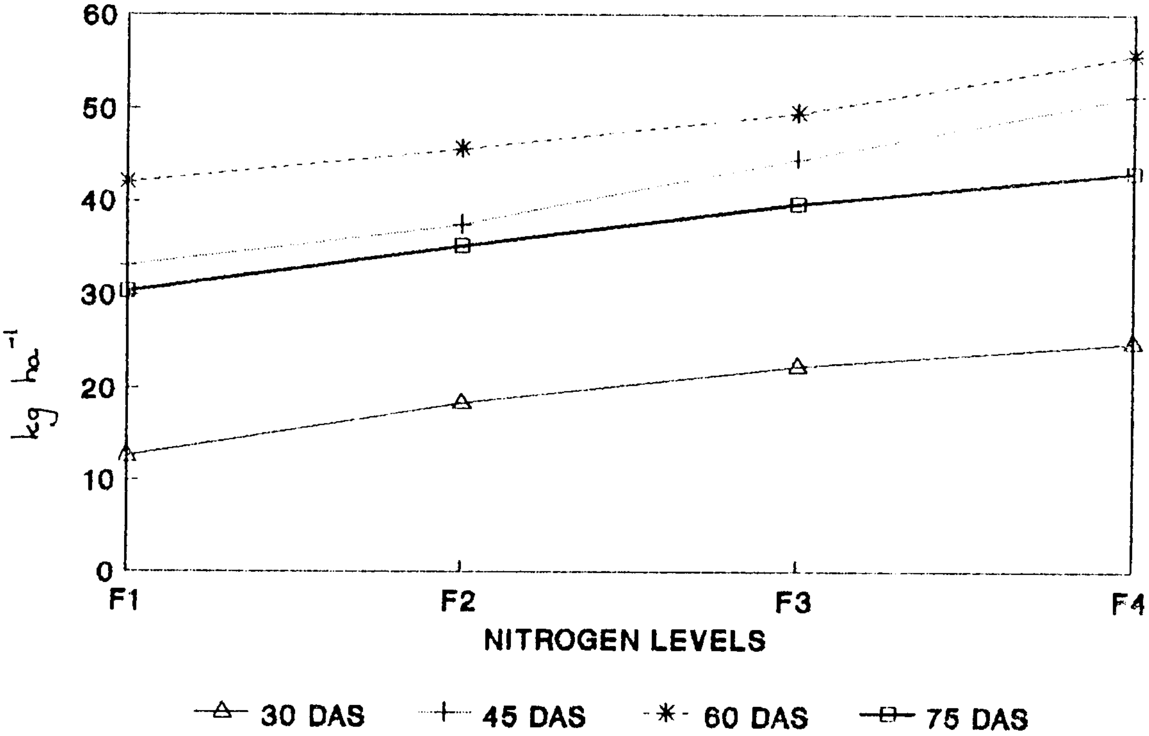
Fig. 9. Content of protein & ascorbic acid of fresh fruit affected by Nitrogen levels and Nitrification inhibitors

oil cakes have been observed by Sathianathan (1982) in cassava and Abusaleha (1992) in bhindi. The interaction was found to be significant. Maximum crude protein content was recorded by NBU at 300 kg N ha^{-1} and minimum by urea at 50 kg N ha^{-1}. Oilcakes inhibited nitrification and provided sufficient quantity of nitrogen throughout the growth period of crop.

Nitrogen levels significantly influenced the ascorbic acid content of fruits (Table 18 and 18b and Fig. 9). It increased with increasing levels of nitrogen, maximum being recorded by 300 kg N ha^{-1} and the minimum by 50 kg N ha^{-1}. 300 kg N ha^{-1} recorded 27 per cent increase over 50 kg N ha^{-1}. The increase in ascorbic acid content may be attributed to increased leaf area and chlorophyll and their influence on the assimilation. Similar results have been observed by Sajitharani (1993). Oilcakes also recorded significant influence on the ascorbic acid content which was 7 per cent more than that of urea alone. This can be explained by the slow dissolution and mineralisation of nitrogen thereby causing a steady and longer availability from these sources. The combined effect of nitrogen levels and nitrification inhibitors was also significant, maximum being recorded by NBU at 300 kg N ha^{-1} and the minimum by urea at 50 kg N ha^{-1}. Oil cakes blended urea inhibited nitrification due to the presence of alkaloids, bitter odoriferous compounds and sulphur compounds which provided a steady and continuous supply of nitrogen in required quantities which inturn might have enhanced the ascorbic acid content.

5.3 Uptake of nutrients

Uptake of nitrogen by plants are given in table 19, 19a and 19b and Fig. 10. It is seen that levels of nitrogen resulted in a marked increase in the nitrogen uptake by plant at all stages of growth. The rate of increase in nitrogen uptake between the stages and between nitrogen levels was significant. 300 kg ha^{-1} recorded 98, 55, 32 and 41 per cent increase in the nitrogen uptake over 50 kg N ha^{-1} at 30, 45, 60 and 75 DAS respectively, thus recording the highest uptake of nitrogen throughout the growth period of crop. A stimulated growth under higher levels of nitrogen application might have resulted in better proliferation of root system and increased intake efficiency of plants. According to Tanaka <u>et al</u>. (1964) the nutrient availability is controlled



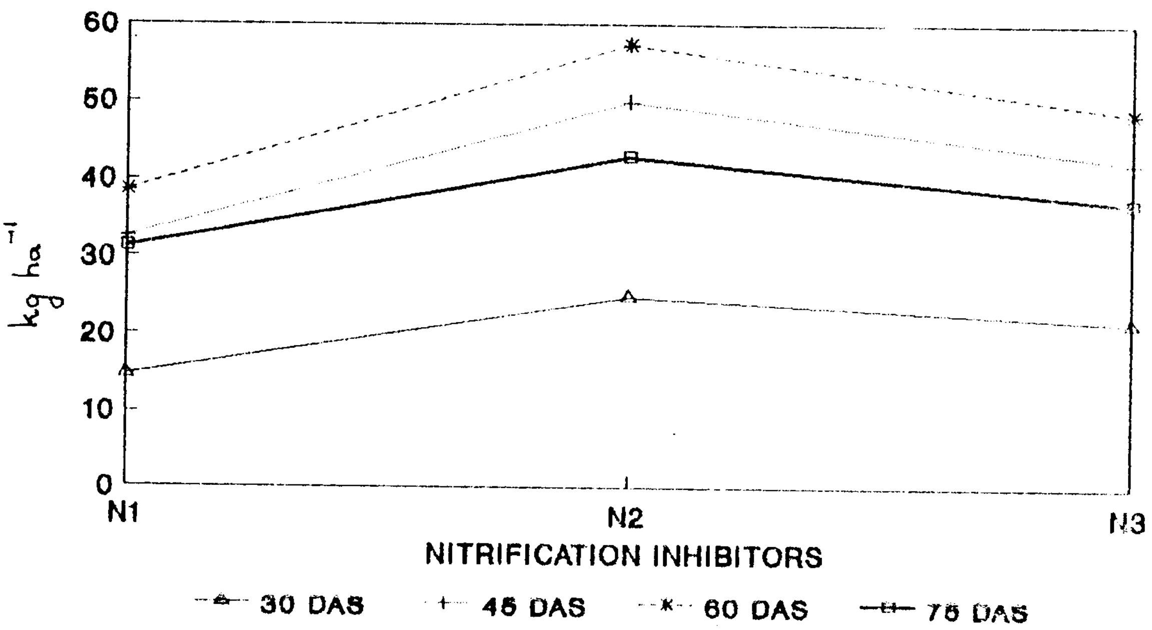


Fig. 10. Uptake of nitrogen by plants as affected by nitrogen levels and nitrification inhibitors

by factors like nutrient availability on soil, nutrient absorption power of roots and rate of increase in dry matter. Similar increase in the nitrogen uptake by bhindi was also reported by Sajitharani (1993). It was also seen that beyond 60 DAS, there was a drastic reduction in nitrogen uptake by plants. About 23 to 28 per cent reduction in the uptake was noted as the levels of nitrogen increased from 50 to 300 kg N ha^{-1}. This reduction may be due to the translocation of nitrogen from the vegetative parts to the fruits during later periods of growth. Oelseligle and McCollum (1975) have also observed a similar trend in cassava, which may be either due to the increase in structural material or due to the less vigorous nutrient absorption with respect to DMP. Sathianathan (1982) also obtained the same result in cassava.

Nitrification inhibitors also showed significant influence on the nitrogen uptake by plants for all stages. Oilcakes blended urea recorded higher value than urea alone. Due to the presence of certain alkaloids, oilcakes inhibited the population of Nitrosomonas sp and Nitrobacter sp. thereby reducing the nitrification. Thus they behaved as a slow releasing nitrogenous fertilizer, and checked the leaching and volatilization losses of nitrogen resulting in an even availability of nitrate nitrogen throughout the crop growth period commensurate with plant needs (Sahrawat and Parmar, 1975). Among the oilcakes, neem cake blended urea recorded the highest nitrogen uptake over mahua cake. This is mainly because of the bitter odoriferous substance namely nimbidin and high amount of sulphur present in neem cake which are responsible for reducing the nitrification more effectively than mahua cake. At harvest, NBU and MBU recorded 38 and 19 per cent increase in nitrogen uptake over urea alone. This might be due to the increased DMP for NBU and MBU over urea. The results are in conformity with the findings of Sathianathan (1982) in cassava, Prasad et al (1986) and Ahmed and Baroova (1992) in wheat.

The interaction between nitrogen levels and nitrification inhibitors on the nitrogen uptake was also significant for all stages of crop. Through out the entire growth period, neemcake blended urea at 300 kg N ha^{-1} recorded the maximum value and the minimum uptake by urea at 50 kg N ha^{-1}. Due to oilcake blending, nitrification was reduced and thereby releasing the nitrogen in sufficient quantity for the crop thr ghout its growth period whereas in the case of urea the nitrogen might have been lost through leaching and run off due to irrigation and thereby resulting in reduced nitrogen content in plant parts.

Nitrogen levels significantly influenced the uptake of phosphorus by plants (Table 20 and 20a). The highest dose of nitrogen (300 kg ha^{-1}) recorded the highest value of phosphorus uptake. Higher levels of nitrogen might have influenced the phosphorus uptake through appreciable growth of aerial parts of the plant. Similar results were observed by Balasubramoni (1988) and Sajitharani (1993) in bhindi.

Oilcakes also exerted significant influence on the phosphorus uptake by plants. NBU and MBU recorded 26 and 19 per cent increase in phosphorus uptake by plants over urea alone. This may be due to the increased available phosphorus in soil and also due to increased phosphorus content and dry weight of plants. The higher nutrient yields are attributable to the proliferated root system and increased biomass production by a balanced nutritional environment in the soil which is also reflected through higher available nutrient status of the soil (Mahajan et al., 1985). Similar results have been obtained by Shivaprakash (1991) in mulberry.

The interaction due to nitrogen levels and nitrification inhibitors on the phosphorus uptake by plants was also significant. Maximum uptake was recorded by neem cake blended urea at 300 kg N ha^{-1} followed by NBU at 200 kg N ha^{-1} and the minimum by urea at 50 kg N ha^{-1} followed by urea at 100 kg N ha^{-1}. Oilcakes blending resulted in a slow dissolution and mineralisation of nitrogen thereby causing a steady and longer availability of nitrogen from these sources and thus providing sufficient nitrogen for getting good plant growth,finally resulting in maximum phosphorus uptake.

Uptake of potassium by plants was significantly influenced by nitrogen levels (Table 20). 300 kg N ha^{-1} (F2) recorded the highest uptake of 45.26 kg ha^{-1} which was on a par with 200 kg N ha^{-1} (44.88 kg ha^{-1}). 50 kg N ha^{-1} recorded the least uptake of 37.86 kg ha^{-1}. Higher nitrogen levels stimulated the vegetative growth of plants, thus increased the DMP which might have enhanced the potassium uptake. The results are in conformity with the findings of Sajitharani (1993) in bhindi.

Nitrification inhibitors also exerted significant influence on the potassium uptake by plants. NBU and MBU recorded 23 and 13 per cent increase in potassium uptake over urea alone. Oilcakes might have provided sufficient quantity of nitrogen throughout the growth period resulting in an increased bio-mass production which might have contributed towards the increased potassium uptake. The results are in agreement with the findings of Sathianathan (1982) in cassava and Shivaprakash (1991) in mulberry.

Nitrogen levels significantly influenced the nitrogen, phosphorus and potassium uptake by fruits (Table 21 and Fig. 11). The highest level of nitrogen (300 kg ha^{-1}) recorded the highest value for nitrogen uptake (43.81 kg ha^{-1}) and phosphorus uptake(3.91 kg ha^{-1}) which was 31 and 27 per cent more than the lower levels of nitrogen (50 kg ha^{-1}). This may be due to the increased nitrogen and phosphorus content of fruits. Hundred kg N ha^{-1} gave the highest potassium uptake by fruits. Sajitharani(1993) also observed increased nitrogen and phosphorus uptake by fruits of bhindi due to higher levels of nitrogen.

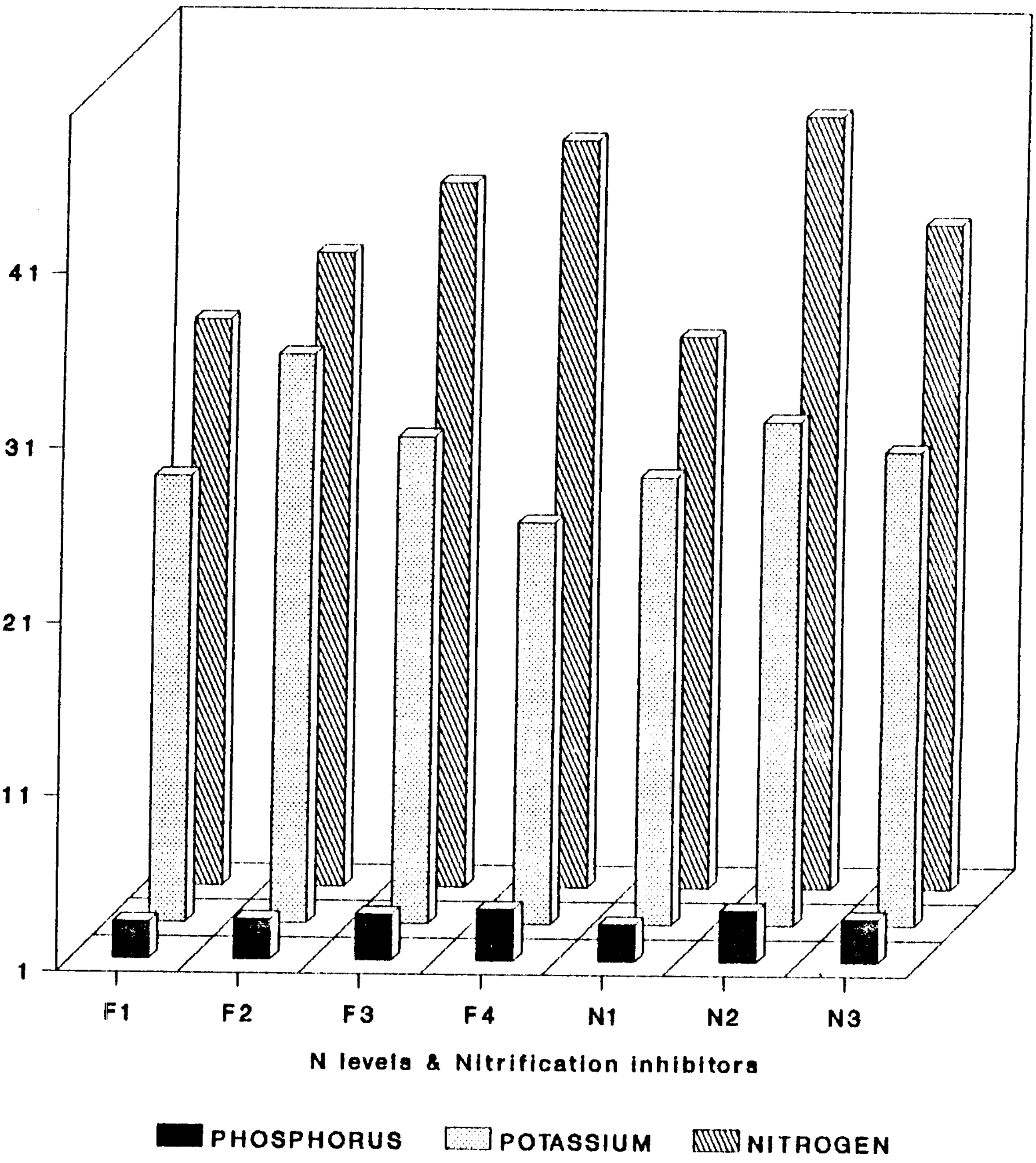


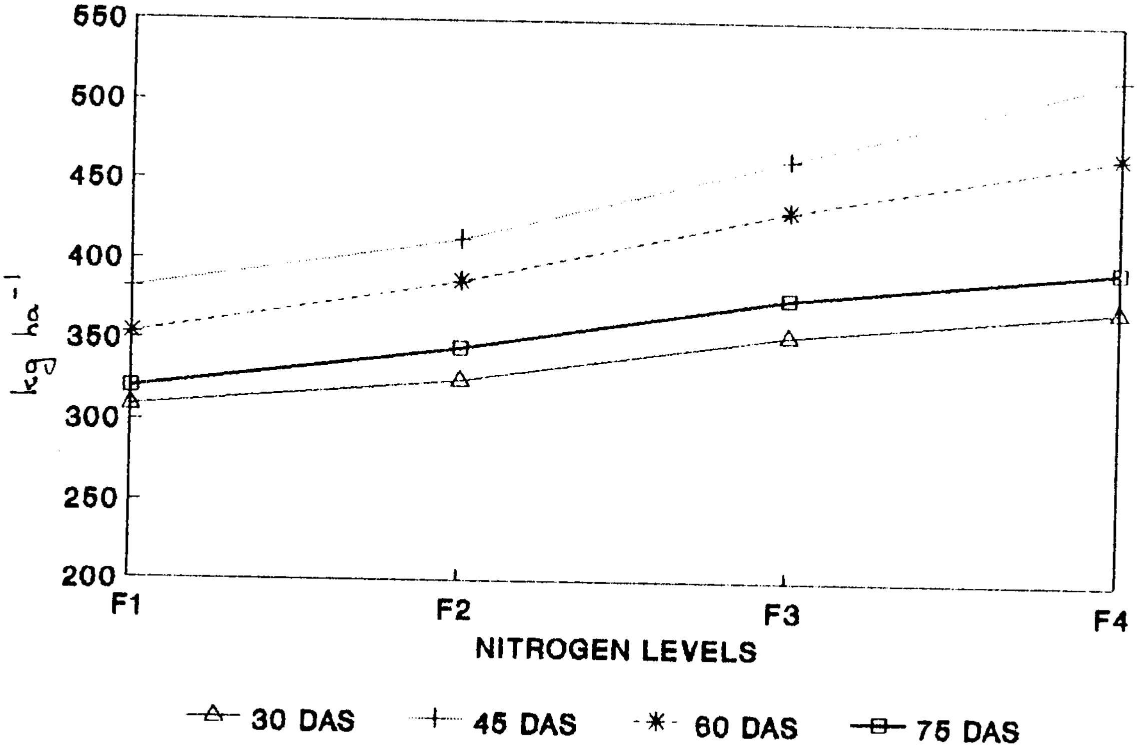
Fig. 11. Uptake of N, P and K (kg ha^{-1}) by fruits as influenced by Nitrogen levels and nitrification inhibitors

Nitrification inhibitors also significantly influenced the nitrogen, phosphorus and potassium uptake by fruits. NBU and MBU recorded significantly superior values for the uptake over urea alone which was 39 and 20,26 and 12 and 12 and 6 per cent more than urea in case of nitrogen, phosphorus and potassium uptake respectively. Due to the presence of certain alkaloids, oilcakes inhibited nitrification resulting in a steady and continuous supply of nitrogen throughout the crop growth period which might have contributed to increased fruit yield and thereby resulting in an increased nitrogen, phosphorus and potassium uptake.

The interaction between nitrogen levels and nitrification inhibitors significantly influenced the phosphorus uptake by fruits (Table 21a). NBU at 300 kg N ha^{-1} recorded the highest value of 4.12 kg ha^{-1} followed by MBU at 300 kg N ha^{-1} (4.02 kg ha^{-1}) and the least by urea at 50 kg N ha^{-1} (2.67 kg ha^{-1}) followed by urea at 100 kg N ha^{-1} (2.93 kg ha^{-1}). This may be due to the increased phosphorus content and increased fruit yield with NBU.

5.4. Available nutrient status of soil

Available nitrogen status of soil was significantly influenced by nitrogen levels (Table 22, 22a and 22b and Fig. 12). At all stages of observation the highest level of nitrogen (300 kg ha^{-1}) recorded the maximum available nitrogen in soil. There was significant difference among the nitrogen levels. 300 kg N ha^{-1} recorded about 20 to 39 per cent increase in the available nitrogen status over 50 kg N ha^{-1} at different stages of the experiment. This is mainly because of the increased dose of nitrogen applied to the soil. Sajitharani (1993) also obtained increased available nitrogen in soil due to the application of higher rates of nitrogen. Beyond 45 DAS, a general decline in the available nitrogen was noticed. The reduction was drastic for 300 kg N ha^{-1} (23 per cent) and the least for 50 kg N ha^{-1} (16 per cent). This might be due to the loss of greater amount of nitrogen at higher levels. Muthuswamy et al. (1977) is of the opinion that when urea is applied to soil it undergoes several transformations and is converted to ammonia and nitrate and to a lesser extent nitrite forms of nitrogen. These forms of nitrogen are subjected to various losses and



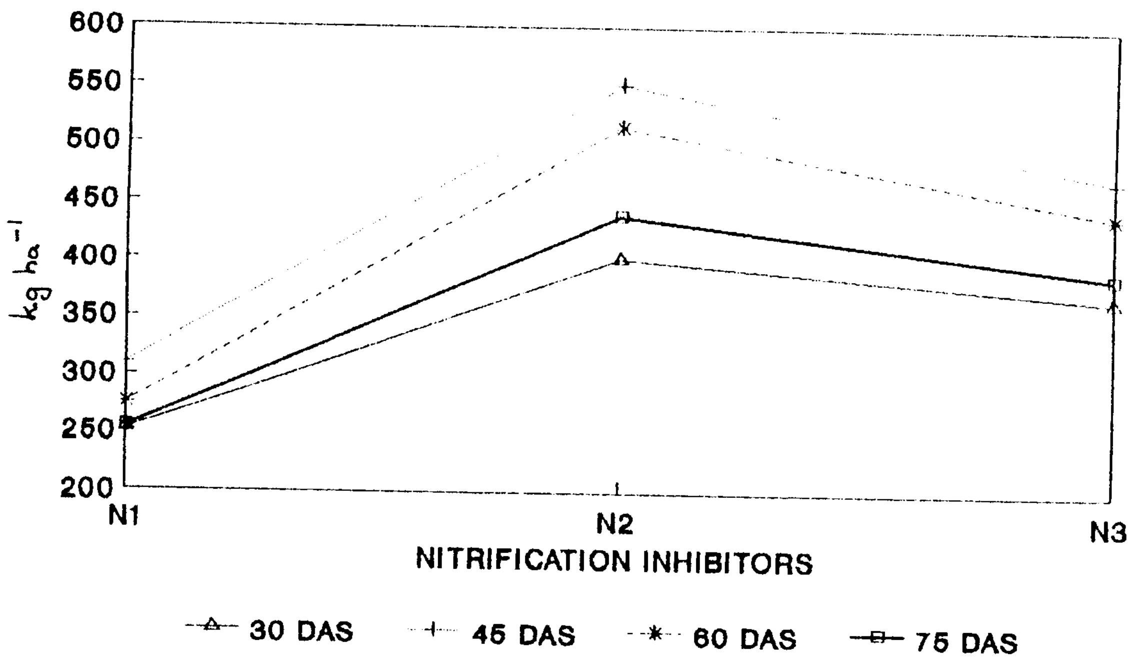


Fig. 12. Available nitrogen status of soil as affected by nitrogen levels and nitrification inhibitors

these losses assume serious proportions when larger quantities of nitrogen are applied.

Nitrification inhibitors also exerted significant influence on the available nitrogen status of soil at all the stages of experiment. Neem cake blended urea recorded about 59 to 87 per cent and mahua cake blended urea about 45 to 59 per cent increase in available nitrogen status of soil over urea alone at different stages of the experiment. This might be due to the fact that oilcakes act as efficient nitrification inhibitors thereby conserving more of ammoniacal nitrogen resulting in the minimisation of losses of nitrogen through leaching, denitrification and volatilization. Achaya (1992) suggested that this property of oilcakes may be due to the presence of certain alkaloids like nimbin, nimbidin and epinimbin in neem cake and saponin in mahua cake. These alkaloids are toxic to nitrifying bacteria like Nitrosomonas sp and Nitrobacter sp thereby inhibiting nitrification to a great extent. Eventhough a decline in available nitrogen was noticed beyond 45 DAS,oilcakes still recorded the highest value even after the experiment. This might be due to the inhibition of nitrification for about one month by oilcakes. Khandewal et al. (1977) have found that urea coated with neem extract inhibited the Nitrosomonas sp for one week only, whereas uncoated urea was completely mineralized in the soil within one week of incubation because of increased population of these microorganisms.

The effect of interaction due to nitrogen levels and nitrification inhibitors was also significant at 45, 60 and 75 DAS. During these stages, NBU at 300 kg N ha^{-1} followed by NBU at 200 kg N ha^{-1} recorded the highest value and the lowest by urea at 50 kg N ha^{-1} followed by urea at 100 kg N ha^{-1}. This is because by blending urea with oilcakes the efficiency of utilization of nitrogen contained in urea was increased probably by retarding the nitrification and releasing the nitrogen slowly in smaller quantities throughout the crop growth period.

Nitrogen levels significantly influenced the available phosphorus status of soil (Table 23). 300 kg N ha^{-1} recorded the highest available phosphorus of 57.14 Kg ha^{-1} in soil which was only 1.6 per cent more than 50 Kg N ha^{-1}. Even though nitrogen levels did not influence the available potassium status of soil the highest level of nitrogen (300 kg ha^{-1}) recorded the highest available potassium of 221.86 kg ha^{-1}.

Nitrification inhibitors significantly influenced the available phosphorus and potassium status of soil. NBU and MBU recorded higher values for available phosphorus and potassium than urea alone. By blending urea with oilcakes the organic acids present in the oilcakes solubilised more of native phosphate and potassic fertilizers which might have contributed to increased availability of phosphorus and potassium in soil.

5.5 Economics of cultivation

The data on the economics of cultivation are presented in Table 24 and 24a and Fig. 13. The results indicated that the net profit and benefit-cost ratio were significantly influenced by nitrogen levels. Hundred Kg N ha^{-1} recorded the highest profit of Rs. 16017.50 and the lowest by 300 kg N ha^{-1} (Rs. 2395.93). This might be due to the increased fruit yield at 100 kg N ha^{-1} and higher cost of cultivation at 300 kg N ha^{-1}. Thus the optimum was worked out as 142 kg N ha^{-1}.

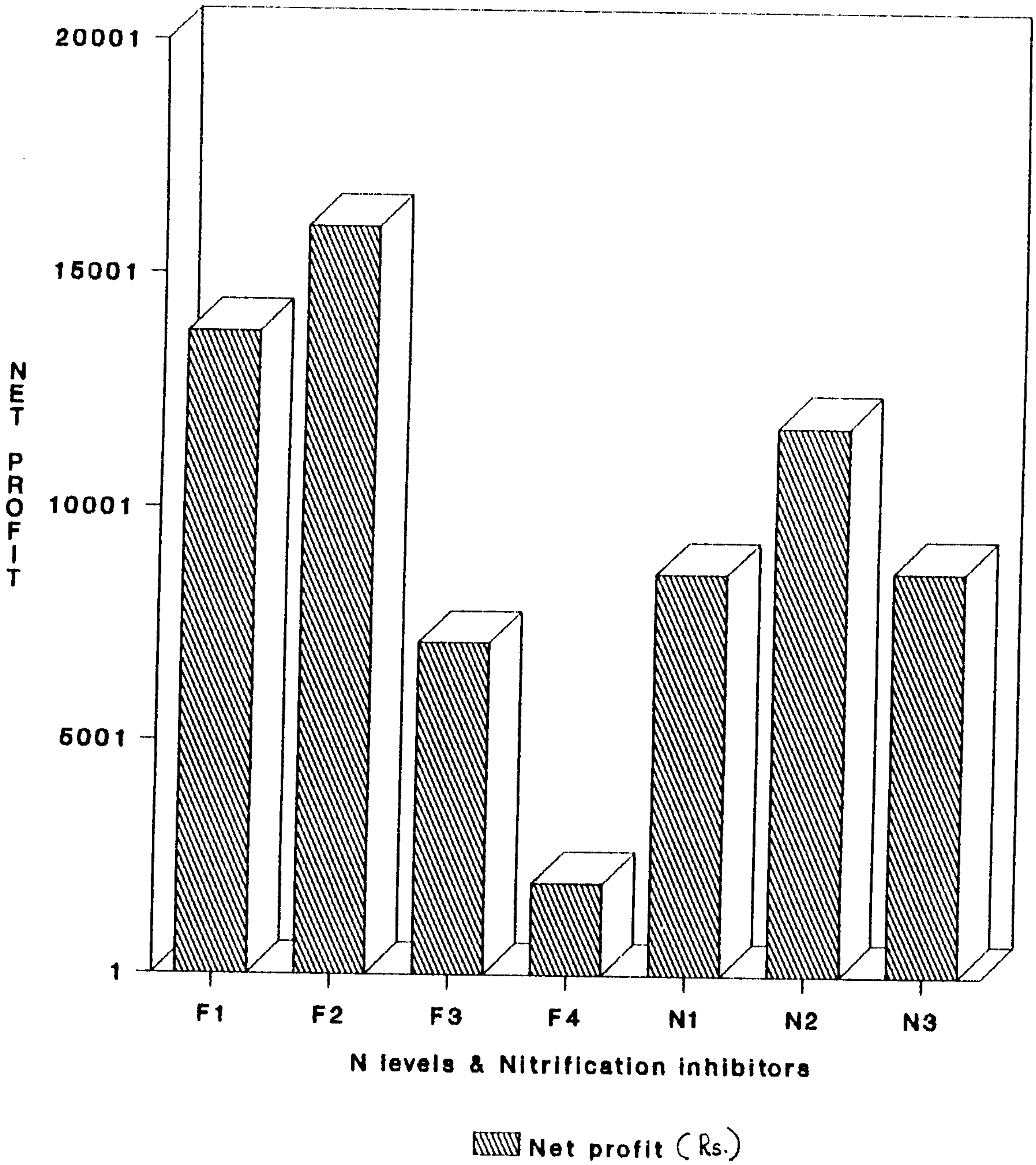


Fig. 13. Net profit as affected by nitrogen levels and nitrification inhibitors

It is seen from the table that benefit cost ratio was maximum for F_2 (100 kg N ha^{-1}) and the lowest for F_4 (300 kg N ha^{-1}). The reason was the increased fruit yield at 100 kg N ha^{-1}.

Nitrification inhibitors significantly influenced the net profit only. NBU recorded the highest net profit of Rs. 11789.73 and the lowest by urea (Rs 8649.64). This might be due to the increased fruit yield obtained for neem cake blended urea.

The effect of interaction between nitrogen level and nitrification inhibitors was significant for net profit only. NBU at 100 kg N ha^{-1} recorded the highest net profit of Rs. 20127.79 followed by MBU at 50 kg N ha^{-1} and the least net profit was recorded by MBU at 300 kg N ha^{-1}. This is mainly because of increased fruit yields at lower levels of nitrogen upto 100 kg N ha^{-1} and increased cost of cultivation coupled with less fruit yield at higher levels of nitrogen.

It is also observed that at all levels of nitrogen upto 200 kg N ha^{-1} NBU surpassed the other two sources in the net profit. The superiority of neem cake blended urea treatment may also be due to the contribution of nitrogen from the neemcake itself.

Thus, it may be concluded from the results of the experiment that application of nitrogen at 100 kg N ha^{-1} as neem cake blended urea was the most economical dose for getting maximum profit in bhindi.

SUMMARY

SUMMARY

A field experiment was conducted at the Instructional Farm of the College of Agriculture, Vellayani during the summer season of 1993, to study the effect of nitrification inhibitors to enhance the nitrogen use efficiency in bhindi and also their effect on the growth, yield, quality and nutrient uptake of bhindi variety, Kiran. The soil of the experimental field was oxisol, Vellayani series with acidic in reaction, medium in available nitrogen and potassium and high in available phosphorus. The treatments were four levels of nitrogen viz., 50 kg ha^{-1}, 100 kg ha^{-1}, 200 kg ha^{-1} and 300 kg ha^{-1} along with nitrification inhibitors viz., neem cake, mahua cake and urea alone. The experiment was laid out as a 3 x 4 factorial experiment in RBD, in three replications. The result of the experiment are summarised below:

1. Nitrogen levels significantly influenced the height of plant only at 30 DAS. Nitrification inhibitors did not affect the height the plant at any of the growth stages.

2. Number of leaves was significantly influenced by the nitrogen levels only at 30 DAS but it was not influenced by nitrification inhibitors.

3. Nitrogen levels significantly increased the number of branches per plant only at 60 and 75 DAS where as nitrification inhibitors didnot influence the number of branches per plant.

4. Length of the tap root was positively influenced by nitrogen levels. 100 kg N ha^{-1} recorded the longest tap root. Nitrification inhibitors did not influence the length of tap root at any of the growth stages.

5. Root spread was not influenced by nitrogen levels significantly while nitrification inhibitors significantly influenced the root spread only at 60 and 75 DAS.

6. The dry matter production of plant at all growth stages increased progressively with increase in the level of nitrogen and also with nitrification inhibitors. The

interaction was significant at 60 DAS. NBU at 300 kg N ha^{-1} recorded the highest DMP at this stage.

7. Nitrogen levels significantly increased the LAI of the plants at 60 and 75 DAS. Whereas LAI was significantly increased by nitrification inhibitors at 45 and 60 DAS only.

8. Relative growth rate was maximum with the highest levels of nitrogen (F_4) and NBU recorded the maximum relative growth rate.

9. Net assimilation rate was significantly influenced by nitrogen levels and the maximum being recorded by 300 kg N ha^{-1}. NBU significantly increased the net assimilation rate over MBU and urea alone.

10. Crop growth rate was maximum with the highest nitrogen level and NBU recorded the highest crop growth rate.

11. Increased levels of nitrogen significantly delayed the time taken for 50 per cent flowering whereas nitrification inhibitors didnot influence the time taken for 50 per cent flowering.

12. Mean number of flowers per plant significantly increased with increasing levels of nitrogen and nitrification inhibitors.

13. Nitrogen levels and nitrification inhibitors significantly influenced the mean number of fruits produced per plant

14. Setting percentage was significantly influenced by nitrogen levels and nitrification inhibitors

15. Neither the nitrogen levels nor the nitrification inhibitors did influence the height of the first fruit bearing node from the ground level.

16. Length of the fruit was significantly influenced by nitrogen levels and nitrification inhibitors only at final harvests.

17. Nitrogen levels significantly influenced the girth of the fruit of middle and last harvest only whereas nitrification inhibitors significantly influenced the girth of the fruit at final harvests only.

18. Nitrogen levels significantly increased the fruit yield per plant whereas nitrification inhibitors could not affect the per plant yield.

19. Fruit yield was significantly influenced by nitrogen levels and the maximum being recorded by F_2. Nitrification inhibitors didnot influence the fruit yield of bhindi.

20. Neither the nitrogen levels nor the nitrification inhibitors did influence the chlorophyll content of leaves.

21. Crude protein content of fruits was significantly increased with increasing levels of nitrogen and the maximum was recorded by F_4. Nitrification inhibitors also significantly increased the protein content of fruits.

22. Nitrogen levels and nitrification inhibitors significantly increased the ascorbic acid content of fruits.

23. Total uptake of nitrogen by plants significantly increased with increasing levels of nitrogen and nitrification inhibitors.

24. Total uptake of phosphorus by plant significantly increased with increasing levels of nitrogen and nitrification inhibitors.

25. Potassium uptake by plants was significantly influenced by nitrogen levels and nitrification inhibitors.

26. Uptake of nitrogen, phosphorus and potassium by fruits was significantly influenced by the levels of nitrogen and nitrification inhibitors. Maximum being recorded by 300 kg N ha^{-1} and neem cake blended urea.

27. Available nitrogen status of soil was significantly influenced by nitrogen levels and nitrification inhibitors during the entire crop growth period.

28. Available phosphorus status of soil significantly increased with increasing levels of nitrogen and nitrification inhibitors whereas available potassium status was influenced by nitrification inhibitors only.

29. Net profit and benefit cost ratio were maximum for F_2 (100 kg N ha^{-1}) levels of nitrogen and neem cake blended urea.

Future line of work

1. Residual effect of the oilcakes should be studied by raising a succeeding crop.

2. Different proportions of oilcakes with urea should be tried inorder to find out the optimum ratio of cakes to urea.

3. The experiment can also be tried with other vegetable crops and perennial crops.

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* Originals not seen

APPENDIX

Appendix - I

Weather data during the cropping period

Standard week	Period From	Period To	Rainfall mm	Maximum temperature ^{o}C	Minimum temperature ^{o}C	Relative humidity %
5	29.1.93	4.2.93	0	30.9	19.6	72.9
6	5.2.93	11.2.93	0	30.8	20.2	75.05
7	12.2.93	18.2.93	0	31.4	21.9	77.95
8	19.2.93	25.2.93	0.4	31.1	22.6	79.6
9	26.2.93	4.3.93	0	31.7	22.2	76.75
10	5.3.93	11.3.93	0	32.7	21.1	74.5
11	12.3.93	18.3.93	0	32.6	24.1	78.25
12	19.3.93	25.3.93	6.4	32.3	23.7	74.55
13	26.3.93	1.4.93	1.1	32.2	24.0	75.65
14	2.4.93	8.4.93	1.8	31.9	24.6	81.55
15	9.4.93	15.4.93	0	32.3	24.4	81.6
16	16.4.93	22.4.93	1.8	32.7	24.6	81.7
17	23.4.93	29.4.93	0.9	33.2	25.1	83.47

ENHANCING THE NITROGEN USE EFFICIENCY IN BHINDI WITH NITRIFICATION INHIBITORS

By

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ABSTRACT OF THE THESIS
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ABSTRACT

An experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani inorder to find out the effect of nitrification inhibitors in enhancing the nitrogen use efficiency in bhindi. The treatments consisted of four levels of nitrogen viz., 50 kg ha^{-1}, 100 kg ha^{-1}, 200 kg ha^{-1} and 300 kg ha^{-1} and three nitrification inhibitors viz., urea, neem cake and mahua cake. Phosphorus and potassium were applied as per package of practices recommendation.

The results revealed that nitrogen levels significantly influenced most of the growth and yield contributing characters, yield of bhindi, uptake of nutrients and available nutrient status of soil. Biometric observations like number of leaves, branches, root spread, DMP, LAI, RGR, NAR and CGR increased with increasing levels of nitrogen and the maximum was produced by the highest levels of nitrogen (300 kg ha^{-1}). F_1 produced the maximum height and F_2 the longest tap root. Time of 50 per cent flowering and number of flowers per plant was maximum with the highest levels of nitrogen (F_4). Wheareas other yield

contributing characters like number of fruits per plant, percentage of fruit set, length and girth of fruit, fruit yield per plant and total yield of bhindi was maximum with F_2 (100 kg N ha^{-1}). Quality aspects like crude protein and ascorbic acid content of fruits, uptake of nutrients by plant and fruit was also maximum with the highest levels of nitrogen (F_4). However, the height of the first bearing node and chlorophyll content of leaves remain unchanged with increasing levels of nitrogen. The optimum level of nitrogen to get maximum fruit yield and net profit was worked out as 142 kg N ha^{-1}.

Nitrification inhibitors caused significant variation in some of the characters like root spread, LAI RGR, NAR, CGR, number of flowers and fruits per plant, percentage of fruit set, length and girth of fruit, crude protein content and ascorbic acid content of fruit, uptake of nutrients by plant and fruit and available nutrient status of soil. In all these cases neem cake blended urea recorded the highest value followed by mahua cake blended urea.

From the economic point of view, the maximum net profit of Rs. 11787.74 was obtained for neem cake blended urea and among nitrogen levels, 100 kg N ha^{-1} recorded the highest net profit of Rs. 16017.50. Thus neem cake blended urea at 100 kg N ha^{-1} can be suggested as the best economic dose of nitrogen for getting maximum yield and net profit.