NUTRITIONAL REQUIREMENT FOR HORSEGRAM
(*Dolichos biflorus* Roxb.)

BY

KUMARI SWADIJA. O

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DECLARATION

I hereby declare that this thesis entitled "Nutritional requirement for horsegram (*Dolichos biflorus* Roxb.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Kumari Swadija O

(KUMARI SWADIJA.O)

Vellayani,

26th March, 1984.

CERTIFICATE

Certified that this thesis, entitled "Nutritional requirement for horsegram (Dolichos biflorus Roxb.)" is a record of research work done independently by Smt. KUMARI SWADIJA.O 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.

(P. CHANDRASEKHARAN)

Chairman
Advisory Committee
Associate Professor of Agronomy

Vellayani,
26th March, 1984.

APPROVED BY:

CHAIRMAN:

SHRI.P. CHANDRASEKHARAN

MEMBERS:

1. DR.V.MURALEEDHARAN NAIR

2. SHRI N.PURUSHOTHAMAN NAIR

3. SHRI M. ABDUL HAMEED

16/4/84

Ex. Examiner

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Introduction

INTRODUCTION

Pulses have a unique position in Indian agriculture owing to their high nutritive value and soil enriching properties. The importance of pulse crop in our new and intensive cropping system, as a crop to fit in the rotation and filling the nitches in our cropping gaps, is ever increasing. As catch crops, they form the linchpin of our crop rotations. Pulses are indispensable in the overall economy of the country. Pulses occupy a predominent place in our diet, firstly because they supply the cheapest source of proteins and secondly because of the vegetarian habits of the people.

Traditionally our farmers have grown pulses not as principal but as bonus crops. Scared by pests and diseases, deterred by low yields and lured by the remunerative cereal crops, our farmers have relegated pulses to marginal lands. The area under pulses was fluctuating between 20-22 million hectares in the last two decades and pulse production is stagnant around 11-12 million tonnes, the average yield being 500 kg per hectare (Singh, 1980). Stagnation in pulse production on one hand and increase in population on the other has posed serious problem for protein availability. This not only results in malnutrition but also exerts undue pressure on the consumption of cereals.

The per capita availability of pulses has progressively declined from 68.5 grams in the Second Plan period to 43.9 grams in the Fifth Plan period as against the minimum per capita requirement of 80 grams per day and the optimum requirement of 104 grams per day (Jeswani and Saini, 1981). If the pulses are to be made available even at the rate of 60 grams per capita per day our requirement of pulses by the end of the present century would be about 24 million tonnes. In fact, this includes the requirement for animal feed and losses which occur during processing. To reach this end, adoption of improved varieties and proper production technology can play a pivotal role.

The nutritive quality of pulse crops is considerably affected by the macro and micronutrients resulting in profound changes in the metabolic processes of the plants. Application of fertiliser elements like nitrogen, phosphorus and potassium may improve the quantity and quality of protein in pulses. The influence of nitrogen, phosphorus and potassium application in increasing the protein contents in legumes have been reported by many workers in the recent past.

The ever increasing crisis for energy is a threat to our agriculture which is becoming increasingly dependent on chemical fertilizer. Excess of chemical fertilizer too results in pollution problem. Hence biological nitrogen fixation has been the mainstay for nitrogen nutrition of crops at least in developing countries like India where cost of fertilizers has gone up steeply. Out of the total biological nitrogen fixed per year, more than 75 per cent (about 40×10^6 tonnes per year) is contributed by pulse-Rhizobium association (Kush and Mishra, 1981). Thus every plant of pulses in itself is a mini fertilizer factory and has maintained Indian soils in good health.

The legume crop can meet a majority of its nitrogen requirement through symbiotic nitrogen fixation. Hence it is generally believed that these crops do not respond to nitrogen application. However, starter doze of nitrogen through fertiliser along with inoculation is recommended to initiate better root growth and nodulation.

Besides inoculation, phosphorus has its own say on nodulation which in turn reflects on grain yield. Application of phosphorus to pulses with rhizobial inoculation improves yield, quality of grain and fixation of atmospheric nitrogen resulting in restoration of soil fertility (Singh et al., 1976). Potassium application is also necessary to meet the balanced requirement of NPK by the crops. Thus it is evident that a suitable fertilizer management programme has to be evolved to achieve a sustained high yield of short duration pulses.

Horsegram, a short duration pulse crop, is cultivated over an area of 20.5 lakh hectares with an estimated production of 7.1 lakh tonnes of grain the country (Sreeramulu, 1981). The average yield of the crop is 350 kg per hectare. The grain of horsegram contains 22 per cent protein and is used as human food and also as a concentrated feed for cattle. It is invariably grown as a rainfed crop in areas of low rainfall and mostly on poor or lateritic soils. When the farmer is unable to sow any crop due to want of timely rains, he grows horsegram. It is also grown as an inter and mixed crop and as a green manure crop.

In Kerala, horsegram is grown over an area of about 5000 hectares during the rabi season in uplands, with an average yield of about 400 kg per hectare (Anon, 1980). There is great scope for increasing the yield of grain and fodder of this "poor man's pulse" by adopting a suitable fertilizer management programme. So a detailed investigation has been taken up with the following objectives.

1. To study the growth, development and yield of horsegram as affected by different levels of nitrogen, phosphorus and potassium.

2. To assess the quality of grains as influenced by various levels of nutrients.

3. To find out a suitable combination of N, P and K for maximum yield under upland conditions.

4. To work out the economics of fertilizer application of horsegram.

Review of Literature

REVIEW OF LITERATURE

An investigation was conducted at the College of Agriculture, Vellayani during October-December, 1983 to find out the effect of nitrogen, phosphorus and potassium on growth, yield and quality of horsegram (Dolichos biflorus Roxb.). Published works on the influence of these nutrients on horsegram are rare. However, the research conducted in India and abroad on the influence of these nutrients on the growth, yield, quality and nutrient uptake of this crop and other legumes are briefly reviewed in the following pages.

A. NITROGEN

(a) Effect of nitrogen on growth characters.

Baia (1970) reported that in soybean the plant height was increased by the application of nitrogen. Singh (1971) observed little stimulatory effect on the growth of bengalgram (Cicer arietinum) plants by the application of 22.5 kg N/ha.

Bhattacharya (1971) found that in horsegram (Dolichos biflorus) the vegetative growth of the crop in respect of length of vines and number of branches per plant was significantly influenced by nitrogen at 22.5 kg to 45 kg/ha. The effect of nitrogen was, however, found to be more pronounced in lime dressed soil than under original soil. In gram there was no significant difference between the control and 10 kg N/ha in respect of various characters studied like height and number of branches.

Panda (1972) observed that in Pusa Baisakhi mung increasing level of N from zero to 60 kg/ha significantly increased plant height and number of branches per plant. Hatchcock (1975) reported significant responses to N application, specifically with respect to dry weight and plant height in soybean.

Lanka and Satpathy (1976) found that in pigeon pea application of 20 to 40 kg N/ha increased vegetative growth, height and number of branches per plant. Similar increase in vegetative growth and dry matter content in both inoculated and uninoculated soybean by the application of mineral nitrogen (20 and 179 ppm) has been reported by Huxley et al. (1976).

George (1980) found that in blackgram different levels of nitrogen, phosphorus and potassium had no significant effect on plant height at any stage of crop growth. Nitrogen levels had significant negative influence with increasing rates (20, 30 and 40 kg N/ha) with respect to number of leaves per plant on 45th and 60th day after sowing.

Minchin et al. (1981) noticed that providing inorganic nitrogen during vegetative stage in nodulated cowpea resulted in more leafy plants. The dry weight of plants was also increased when supplemented with nitrogen. Similarly, favourable influence of higher amount of nitrogen on growth characters of grain cowpea like plant height, leaf number and leaf area index has been reported by George (1981).

(b) <u>Effect of nitrogen on yield and yield attributes</u>.

Singh (1970) observed marked increase in the seed yield of gram (*Cicer arietinum*) by the application of 22.5 kg N/ha. Singh (1971) found an increase in the number of fruiting branches of bengalgram with increasing levels of applied nitrogen.

Malik et al. (1972) found that application of 20 to 40 kg N/ha on cowpea had no effect on yield and 100 seed weight. Similarly, in greengram N at 0,10,20 and 30 kg/ha had no significant influence on seed yield (Venugopalan and Morachan, 1974).

Rajendran et al. (1974) opined that in blackgram N at 60 kg/ha was superior to other levels of zero and 30 kg which were on par for seed yield. Singh et al. (1975) found from a field trial conducted with mung that increased supply of N significantly increased grain yield per hectare, number of pods per plant, number of grains per pod and 1000 grain weight. The yield increased with increasing levels of N upto 20 kg/ha whereas further increase in N level (30 kg/ha) showed significantly decreasing trend in respect of all characters studied including grain production.

Application of inorganic nitrogen increased seed yield in cowpea cv. Prima due to an increase in the number of pods per plant and average seed weight (Summerfield, 1975). Lanka and Satpathy (1976) indicated increased grain yield in pigeon pea with 20 kg N/ha while 40 kg N/ha showed depressing effect on yield.

Sharma (1977) obtained significantly higher yield of cowpea with 20 kg N/ha over no N application.

Panwar et al. (1977) found that the optimum dose of N for blackgram was 15 kg/ha which recorded 13.4 per cent increase in grain yield over control. The number of pods per plant was increased by N application at 15 kg/ha with no further improvement by additional dose.

Mudholkar and Ahlawat (1979) observed that application of 25 kg N/ha to bengalgram had no effect on yield. In an experiment conducted by Kumar and Pillai (1979) N at 21.6 kg/ha was found to be the optimum level for maximum grain production in cowpea var. P-118.

Huxley (1980) observed that 10.5 kg N/ha applied as a starter dose increased pod number in cowpea. George (1980) reported that yield attributing characters like number of pods per plant, number of seeds per pod, seed yield per plant and 100 seed weight were not influenced by nitrogen levels in blackgram.

Khurana and Dudeja (1981) observed that in chickpea the starter dose of 20 kg N/ha increased seed yields from 2.24 to 2.47 t/ha in crops grown from uninoculated seeds and 2.67 to 3.07 t in crops grown from inoculated seeds; additional application of 20-40 kg N/ha at flowering gave no further yield increase in the former and decreased yields in the latter.

In a critical review by Kulkarni and Panwar (1981) on the response of pigeon pea to fertilizers in India it was shown that a starter dose of 20 to 25 kg N/ha was beneficial in most cases, giving responses ranging from 60 to 280 kg seeds/ha. Srivastava and Verma (1981) observed that inoculation and N application (zero or 15 kg/ha) increased greengram seed yields significantly over control.

In field trials with *Phaseolus vulgaris* given zero to 200 kg N/ha, N application increased seed yields in 6 of the 7 trials, significant benefits being obtained from applying upto 100 kg N/ha (Scarisbrick et al., 1982). The increased yields mainly resulted from the increase in the number of pods/m^2.

In an analytical review by Rajendran et al., (1982) it was shown that application of 30 to 34 kg N/ha is profitable for rainfed chickpea in India especially on alluvial soils and application of N to irrigated chickpea is not profitable.

Gupta and Singh (1983) opined that gram (*Cicer arietinum* L.) despite being a leguminous crop, gave significant positive response to N addition at 10 and 20 kg/ha. Both the N levels produced statistically similar yield, thus showing the sufficiency of 10 kg N/ha for the crop.

(c) Effect of nitrogen on nodulation and symbiotic nitrogen fixation.

In field experiments with gram (*Cicer arietinum*) Singh (1970) found that application of 22.5 kg N/ha markedly increased nodulation, nitrogen fixation and yield. Nitrogen increased nodulation more by increasing number of nodules.

Muthuswamy (1973) revealed that application of N at the rate of 15 kg and 30 kg/ha was found to reduce the nodule numbers in groundnut plants from 47.16 in control plot to 28.94 and 17.67 in plots receiving 15 kg and 30 kg/ha respectively at 45 days. Similarly, Jayadevan and Sreedharan (1975) reported, from a field trial at Vellayani, that in groundnut the number and weight of nodules per plant were significantly reduced by nitrogen application at 10, 20 and 30 kg/ha. Reduction in mean number and dry weight of nodules in groundnut at 2,4 and 6 weeks after sowing by applied N (0,10 and 20 kg/ha) at Vellayani has also been reported by Punnoose and George (1975).

Huxley et al. (1976) reported that in cowpea nodulated plants obtained about two-third of their total N requirement via direct uptake and one-third through symbiotic system, prior to flowering. Summerfield et al. (1976) observed that cowpea plants receiving no nitrogen in the nutrient solution resulted in poor nodulation by flowering compared to plants receiving 25 ppm nitrogen.

According to Sundaram et al. (1979) application of nitrogenous fertilizer to blackgram crop at more than 50 kg N/ha adversely affected both nodulation and nitrogenase activity of nodules which is likely to reduce the fixation of atmospheric nitrogen by the crop. Maximum number of nodules was recorded at zero nitrogen level as well as at 50 kg N/ha. Similarly, the nodule weight, nitrogenase activity and dry matter production were not adversely affected by zero and 50 kg N/ha treatments, whereas the other levels viz. 100, 150 and 200 kg N/ha reduced these parameters.

George (1980) observed that in blackgram none of the treatments (N, P, K and their combinations) had any significant effect on the dry weight of nodules per plant. Awonaike et al. (1980) found that Phaseolus vulgaris recorded less nodular tissue and lower nitrogenase activity per plant when nitrogen was applied.

Khurana and Dudeja (1981) reported in chickpea that inoculation and or applied N had no significant effect on the number of nodules per plant. Inoculation increased nodule dry weight; applied N decreased it in crops grown from both inoculated and uninoculated seeds. Total N per plant increased with nodulation and or applied nitrogen.

Minchin et al. (1981) observed that inorganic nitrogen provided during the vegetative period stimulated nodulation in cowpea. However, George (1981) found that the number of nodules in cowpea at flowering was not influenced by the various levels of nitrogen tried.

Miller et al. (1982) found that nitrogenase activity decreased with increasing rates of N in cowpea. Path analysis indicated that nitrate effects on nitrogen fixation activity were primarily on nodule mass with the inhibition of nodule growth rather than nodule initiation. Nodule number was not a reliable predictor of nitrogen fixation potential of cowpea genotypes and was negatively correlated with nitrogenase activity.

In a pot culture experiment, Eaglesham et al. (1983) demonstrated that applied nitrogen in the range of 30 to 180 mg/plant may have synergistic effects on nitrogen fixation by vigorously growing cowpea and soybean.

(d) Effect of nitrogen on protein content.

Costache (1970) reported that in soybean the average protein yield increased from 0.44 t/ha with no N to 0.82 t with 128 kg N/ha. Singh (1970) found that in gram application of 22.5 kg N/ha increased the protein content to 16.3 per cent compared with 14.73 per cent in plots given no nitrogen.

Kesavan and Morachan (1973) observed that in soybean protein content was increased by the application of nitrogen. Rajendran et al. (1974) reported that in blackgram the crude protein of seed varied from 22.8 to 28 per cent with increasing levels of nitrogen. Nitrogen at 30 kg/ha was on par with 60 kg/ha but superior to no nitrogen. Similar increase in the seed protein content with increasing rates of N (0,10 and 20 kg/ha) has been reported in groundnut (Punnoose and George, 1974).

Borcean et al. (1977) observed that in pea the highest seed crude protein content of 28.2 per cent was obtained with 16 or 32 kg N/ha. However, Yadava and Singh (1978) found no consistent effect of nitrogen application on protein content in the grains of greengram. Sadaati and Yazdi-Samadi (1978) observed that application of nitrogen increased the seed protein content in soybean.

Sader (1979) reported that crude protein content in grains and total crude protein yields of *Phaseolus vulgaris* increased with increase in the nitrogen rate

(0, 50, 150 and 300 kg N/ha). According to George (1980) the protein content of the grain and bhusa were not significantly influenced by N levels (20, 30 and 40 kg/ha) in blackgram.

Racca and Bodrero (1981) found that in nodulated soybean the seed crude protein content increased from 38.5 to 40 per cent with 0, 50, 100 and 200 kg N/ha applied at flowering.

(e) Effect of nitrogen on nutrient content and uptake.

Norman and Krampitz (1945) reported that in soybean higher N content had resulted from the application of available combined nitrogen. Dart and Mercer (1965) reported that in cowpea N uptake increased with levels of N applied. Bains (1969) reported increase in N content of plants with increase in the rate of applied N in beans.

In gram a small dressing of N at the rate of 10 kg/ha gave higher uptake of total P by the plant at all stages of growth. With 10 kg N/ha as a basal dressing 30 and 60 kg P_2O_5/ha showed an increasing trend in the uptake of total and the fertilizer P in favour of the latter (Sinha, 1971).

Significant increase in N content and total N uptake from applied N (0, 56, 112, 224 and 448 kg/ha) each year was observed in nodulating and non-nodulating Lee soybean isolines (Bhangoo and Albritton, 1976). Similar increased plant N content by higher mineral N (179 ppm) was obtained by Huxley et al. (1976) in soybean.

Although P concentration in soybean (Glycine max (L.)Merr.) plants was reduced owing to N fertilization and inoculation, the uptake was considerably increased (Singh and Saxena, 1977). Yadava and Singh (1978) found no consistent effect of nitrogen on N content in shoot and protein content in the grains of greengram.

Sorensen and Pensas (1978) found that at 7 sites out of 13, plant N concentration of soybean increased by N application (zero to 224 kg/ha) and that the N content of plant was generally linearly related to the rate of N application. Kumar et al. (1979) reported that in cowpea N uptake was significantly influenced by applied nitrogen. Nitrogen at 20 and 30 kg/ha levels were on par but significantly superior to the lower level of 10 kg/ha.

Huxley (1980) reported that only 20 per cent of the starter N (10.5 kg/ha) applied in cowpea was taken up, of which half was found in seeds. The percentage of N was high in leaves and nodules.

Reddy et al. (1981) found that application of 15 or 30 kg N/ha in the form of urea either basal or both basal plus foliar application at physiological stages showed increased N in vegetative and reproductive parts in groundnut (*Arachis hypogea* L.)

George (1981) from his study on cowpea found that uptake of N increased with increasing amounts of nitrogen (10, 20 and 30 kg/ha).

B. PHOSPHORUS

(a) Effect of phosphorus on growth characters.

Bhattacharya (1971) reported that in horsegram (*Dolichos biflorus*) the vegetative growth of the crop in respect of length of vine and number of branches per plant was significantly influenced by nitrogen and phosphorus application both with and without lime. However, it is more pronounced in lime dressed soil.

Application of 30 kg P_2O_5/ha increased plant height in Pusa Baisakhi mung while number of branches showed an increasing trend with increasing levels of P_2O_5 (0, 30, 60 and 90 kg/ha) as reported by Panda (1972). However, Gill and Cheema (1976) noticed no response to added phosphorus with respect to vegetative growth and plant height in summer mung.

Tarila et al. (1977) observed that cowpea (*Vigna unguiculata*) increasing levels of applied P enhanced growth, flower and fruit number as well as leaf number. Shallan et al. (1977) reported that in broadbeans (*Vicia faba* L.) plant height was significantly increased with increase in P levels (0,36,72 and 108 kg P_2O_5/ha). Number of branches per plant was significantly increased by the highest level of P application.

Bhaskar (1979) observed that plant height and leaf area index of greengram variety M-2 was significantly increased by application of phosphorus (0,12.5, 25, 37.5 and 50 kg P_2O_5/ha). In redgram, Vasimalai and Subramonian (1980) found that applied P had pronounced effect on plant height and leaf area index. Application of 50 kg P_2O_5/ha was beneficial or economical. Phosphorus application did not exert significant influence on branching.

Field experiments with field pea showed that various growth attributes like plant height, leaf number, branch number, pod number and plant dry weight were significantly affected by increasing P levels from zero to 100 kg/ha (Singh et al., 1980). Shrivastava et al. (1980) reported in blackgram (Vigna mungo var. radiata Hepper) that plant height increased with increasing P upto 75 kg P_2O_5/ha.

Singh et al. (1981) found that in pigeon pea (Cajanus cajan (L.) Millsp.) application of 13 kg P/ha significantly increased plant height and number of branches compared with no P application at all stages of crop growth, except at 30 days after planting in the case of number of branches. However, no significant additional increase in plant characters and grain yield was observed when phosphate dose increased to 26 kg P/ha.

Subbian and Ramiah (1982) opined that in redgram P fertilization significantly increased plant height and number of primary branches. Ahlawat and Saraf (1982) noticed that phosphate application promoted root growth (dry root weight) and shoot growth in pigeon pea. Root length, however, remained unaffected by P application. Phosphorus at 34 kg P/ha recorded higher root weight than 17 kg/ha at 60 days and at harvest. Phosphorus application resulted in widening the root:shoot ratio.

(b) Effect of phosphorus on yield and yield attributes.

Malik et al. (1972) noticed that in cowpea application of 60 kg P_2O_5/ha markedly increased the seed yield while application of 90 kg P_2O_5/ha decreased the yield. Application of P_2O_5 had no effect on 100 seed weight. Panda (1972) reported that for Pusa Baisakhi mung, grain yield, length of pod and average weight of seed per plant increased with increasing levels of phosphorus (0,30,60 and 90 kg P_2O_5/ha).

Sahu (1973) observed that grain yield and the dry matter content of shoot and root of blackgram and horsegram significantly increased with inoculation and phosphate application at 22.4 kg/ha. Blackgram and horsegram produced 117.75 and 44.3 per cent increase in grain yield over control respectively.

In blackgram (Phaseolus mungo L.) the seed yield has been found to increase with increase in the levels of phosphorus (0,30,60 and 90 kg P_2O_5/ha). The dry matter production was also influenced by P levels (Rajendran et al. 1974).

Venugopalan and Morachan (1974) reported that in greengram P at 20 kg P_2O_5/ha resulted in higher economic yield and further additions of P at 40 and 60 kg P_2O_5/ha caused reduction in seed yield. Phosphorus at 40 kg

P_2O_5/ha increased the dry matter production but 60 kg P_2O_5/ha reduced the total dry matter production as compared to control.

Panwar and Singh (1975) found that in <u>Phaseolus aureus</u> seed yield increased by increasing P_2O_5 rate from zero to 40 kg/ha but with 60 kg P_2O_5/ha the increase was not significant. However, Singh et al. (1975) observed that seed yields in <u>Phaseolus aureus</u> increased with increase in P_2O_5 rates from zero to 60 kg/ha along with favourable effect on other yield attributes like number of pods per plant, number of grains per pod and 1000 grain weight.

In trials with <u>Vigna aureus</u>, Agarwal et al. (1976) observed that yields were increased from 0.77 t with 25 kg P_2O_5 to 0.93 t with 50 kg P_2O_5 and decreased thereafter with 75 kg P_2O_5/ha. Sharma (1977) found that in cowpea application of 30 kg P_2O_5 gave the highest grain yield, but it did not differ significantly when compared with 60 kg P_2O_5/ha. Both these levels recorded significantly higher yield over no P application.

In cowpea, application of 25 kg P_2O_5/ha was found to be significantly superior (to other levels) in increasing the number of pods per plant and number of grains per pod in soils of medium P status. Application of 25 kg P_2O_5 recorded maximum grain yield of 1863 kg/ha and it was on par with 50 kg P_2O_5/ha (Subramonian et al. 1977).

Panwar et al. (1977) showed that in blackgram, at the optimum dose of P (46.3 kg P_2O_5/ha) grain yield increased by 24.3 per cent over no phosphorus. There was a linear increase in grain yield upto the level of 60 kg P_2O_5 but at 90 kg P_2O_5/ha there was a trend of reduction in yield.

Ramanathan et al. (1977) reported that application of 76.4 kg P_2O_5/ha to redgram gave significant increase in pod and grain yield. It was on par with 50.8 kg P_2O_5/ha. However, response tended to be linear indicating that even the highest dose (76.4 kg P_2O_5/ha) could not be considered optimum. The results of the experiment established maximum P utilisation and maximum crop response at 76.4 kg P_2O_5/ha.

Singh et al. (1978) observed that in gram (*Cicer arietinum*) inoculation along with 80 kg P_2O_5 proved to be the most economic combination which could increase grain yield by 33 per cent over control, 18.6 per cent over inoculation alone and 11.8 per cent over inoculation with 40 kg P_2O_5/ha.

In a trial with greengram (*Vigna radiata*) Nair and Aiyer (1979) reported increased yields by the application of 15 kg P_2O_5/ha. But application of 30-45 kg P_2O_5/ha gave no further increase in yield. Application of P had marked effect in increasing the yield attributes (number of pods per plant, length of pod and 1000 grain weight) and grain yield of cowpea (*Vigna sinensis*). However, higher levels of P (60 kg P_2O_5) did not cause additional increase in any of the plant characters and grain yield over lower level of P i.e. 30 kg P_2O_5/ha (Ahlawat et al., 1979).

According to Jayaram and Ramaih (1980) application of 26.9 kg P_2O_5/ha was economically optimum for cowpea (*Vigna sinensis* L.). Application of P increased grain yield significantly in both summer and kharif seasons of 1978. Linear increase in grain yield was observed upto 37.5 kg P_2O_5/ha and beyond that the yield levelled off.

Vasimalai and Subramonian (1980) obtained 50 kg P_2O_5/ha as economic dose of P for greengram. Yields were significantly increased with 50 kg P_2O_5 and decreased with further increase in P rates. Phosphorus application had pronounced effect on number of pods per plant and 1000 grain weight whereas number of grains per pod and length were unaffected by P application.

Shrivastava et al. (1980) noticed that in blackgram (Vigna mungo var. radiata Hepper) yield and yield attributing characters like number of pods per plant and test weight were favourably influenced by higher P levels. The grain yield was maximum at 50 kg P_2O_5/ha beyond which it decreased.

The application of P increased the yield of chickpea (Cicer arietinum L.) significantly over control. Average increases with 4.6, 9 and 13.5 kg P/ha were 162.9, 224.5 and 269.8 kg/ha respectively over the control. The highest yield was obtained at 13.5 kg P/ha in both years ('75-'76 and '76-'77). Application of

P increased dry matter accumulation significantly at all stages of growth. The extent of increase was more with the application of first 4.5 kg P/ha than with the subsequent increase of 4.5 kg P/ha (Singh and Sharma, 1980).

In a field trial with greengram (*Phaseolus aureus*) Srivastava and Verma (1981) indicated that phosphorus application increased grain and straw yields and harvest index with a slight advantage from split application; but these yield grains were not significant.

Singh et al. (1981) noticed that in pigeon pea (*Cajanus cajan* (L.)Millsp) application of 13 kg P/ha significantly increased number of pods per plant, grains per pod, 1000 grain weight and finally grain and stalk yield. However, no significant additional increase in grain yield was observed when phosphate application increased to 26 kg P/ha.

Sharma and Arora (1982) obtained significantly more yield of green pods and grain yield of cowpea by P application over no P; but the difference in yield between 40 and 80 kg P_2O_5/ha was not significant. Significant increase in pigeon pea seed yields by P fertilization was observed by Hegde and Saraf (1982).

From a pot culture study Akbari et al. (1983) found significant influence of P application (0,11,22 and 33 ppm) on the dry matter yield of greengram. According to Gupta and Singh (1983) application of P in graded doses significantly increased the yield of bengalgram (*Cicer arietinum* L.). Highest yield was obtained at 40 kg P_2O_5 and thereafter the yield of the crop declined slightly at 80 kg P_2O_5/ha.

It was shown by Singh et al. (1983) that application of 17 kg P/ha increased grain and straw yields, number of pods per plant and 1000 grain weight in pigeon pea. However, no significant additional increase in grain and straw yields and yield attributes were observed when P was increased to 34 kg/ha.

(c) Effect of phosphorus on nodulation and nitrogen fixation.

Sinha (1971) reported that in gram (*Cicer arietinum*) phosphorus significantly increased number and dry weight of nodules and nitrogen fixation. Sahu (1973) observed that in blackgram and horsegram inoculation alone or in combination with phosphate increased nodulation which contributed to the increase of N in shoots and roots.

The number and weight of nodules per plant in cowpea increased with increasing rates of P_2O_5 upto 111 kg/ha (Sharma and Garg, 1973). Chowdhury et al. (1975) in trials with gram (Cicer arietinum) on sandy clay loam soils reported that increasing P_2O_5 rates from zero to 25 and 50 kg/ha increased root length, weight and nodulation.

Singh et al. (1975) opined that in mung (Phaseolus aureus Roxb.) P application at zero to 75 kg P_2O_5/ha may stimulate nodule production and thus result in higher rate of nitrogen fixation. Field trials with cowpea revealed that nodulation increased with P application upto 60 kg P/ha (Agboola and Obigbesan, 1977).

Yadava and Singh (1978) noticed that application of 30 and 60 kg P_2O_5/ha to greengram (Phaseolus aureus) significantly increased the nodule number over control.

George (1980) reported that phosphorus had significant effect in increasing the number of nodules per plant recording the maximum number of 46.97 nodules with 60 kg P_2O_5/ha in blackgram. Similar increase in number of nodules per plant in blackgram was observed by Shrivastava et al. (1980) upto 75 kg P_2O_5/ha.

Application of 13 kg P/ha to pigeon pea (*Cajanus cajan* (L) Millsp) significantly increased nodules per plant compared with no P application at all stages of crop growth, except at 30 days after planting (Singh et al. 1981)

According to Ahlawat and Saraf (1982) application of P to pigeon pea resulted in developing more extensive root system and bigger and more number of nodules per plant accounting for higher nodule weight per plant. Phosphorus at 34 kg P/ha recorded more number of nodules than 17 kg P/ha at 60 and 100 day stages. Nitrogen yield per plant increased with P application at all growth stages recording higher values with 34 kg compared to 17 kg P/ha.

(d) Effect of phosphorus on protein content.

Singh (1970) found that in gram application of 45 to 90 kg P_2O_5/ha resulted in 15.3 to 16.11 per cent protein content compared with 15.5 per cent without phosphorus. According to Malik et al. (1972) application of P had no effect on cowpea seed protein content.

Punnoose and George (1974) observed in groundnut that the seed protein content increased with increasing rates of P (0, 25, 50, 75 and 100 kg P_2O_5/ha). Jayadevan and Sreedharan (1975) observed that in groundnut the protein content significantly increased by application of P upto 100 kg P_2O_5/ha.

Singh et al. (1975) found in mung (Phaseolus aureus) that protein content significantly increased with increasing rates of P application (zero to 75 kg P_2O_5/ha). Prasad and Sanoria (1981) obtained highest seed protein content (26.32 per cent) in blackgram with inoculation and 150 kg P_2O_5 and lowest 22.93 per cent with 50 kg P_2O_5/ha.

According to Dwidevi and Singh (1982) the effect of varying doses of P (0, 20, 40 and 60 kg/ha) on the per cent of protein content was in the increasing order and was significant in bengalgram.

(e) Effect of phosphorus on nutrient content and uptake.

Sasidhar and George (1972) noticed that in Co-1 lab lab increased rates of P_2O_5 (0,25,50 and 75 kg/ha) increased the P_2O_5 contents of pods and haulms. Increasing the rate of potassium also increased P contents.

Rajendran et al. (1974) found in blackgram (*Phaseolus mungo* L.) that total P content of seed increased with increasing levels of P (0,30,60 and 90 kg P_2O_5/ha). Sharma et al. (1974) found that application of 50 kg P_2O_5/ha increased the uptake of phosphorus by cowpea.

Ravankar and Badhe (1975) reported from pot experiments with urd, mung and soybean that applied P increased phosphorus uptake by plants at different growth stages. According to Ramanathan et al. (1977) application of 76.4 kg P_2O_5 registered significant increase in phosphorus concentration in plant and grain samples of redgram.

Dalal and Quilt (1977) reported that in pigeon pea fertilizer P significantly increased total phosphorus uptake. Nair and Aiyer (1979) obtained an increase in P content in grain and haulm of greengram with increase in P levels (15, 30 and 45 kg P_2O_5/ha) grown in the upland laterites of Kerala State.

Kumar et al. (1979) reported that P application significantly increased phosphorus uptake in cowpea. Phosphorus at 40 kg P_2O_5/ha registered highest uptake followed by 30 kg but were on par. Singh and Sharma (1980) found that higher doses of P were effective in increasing the uptake of nitrogen, phosphorus and potassium in chickpea (*Cicer arietinum*) plants at maturity.

Singh et al. (1981) reported that in field pea (*Pisum arvense* L. var. *Arvense Poir*) P applied at 60 kg P_2O_5/ha gave the maximum uptake of nitrogen. It was shown by Subbian and Ramiah (1981 a) that application of P increased the phosphorus transfer efficiency markedly in redgram and there was not much variation between the two levels of P tested, namely 25 and 50 kg P_2O_5/ha. Phosphorus application increased phosphorus uptake at all growth stages of crop and maximum during pod development stage. The rate of P uptake during the pod development stage showed the greater need of phosphorus for grain development (Subbian and Ramiah 1981 b)

In pigeon pea, phosphatic fertiliser significantly increased nitrogen and phosphorus concentration and uptake of all nutrients (Hegde and Saraf, 1982). Singh et al. (1983) reported that in pigeon pea application of 17 kg P/ha increased N and P uptake. However, no significant additional increase in N uptake was observed when P was increased to 34 kg/ha.

C. POTASSIUM

(a) Effect of potassium on growth characters.

Son et al. (1974) found decrease in vegetative growth of above ground parts of groundnut with increase in potassium levels.

Reddi et al. (1976) in a trial to find out the effect of potassium on growth and yield of soybean observed that differences among potassium levels were found to be significant with regard to plant height. The maximum height of 27.6 cm was observed in zero kg K_2O while 40 kg K_2O/ha had the minimum plant height of 25.3 cm.

According to Nair (1978) height of groundnut plants increased significantly with increase in the level of K_2O from 25 kg to 50 kg and 75 kg/ha eventhough the difference between the higher levels was not significant. Application of 50 kg K_2O significantly increased the number of leaves per plant over 25 kg K_2O/ha.

Among the different levels of N, P and K tried on blackgram, George (1980) found that the number of branches per plant was significantly influenced only by Potassium levels.

(b) Effect of potassium on yield and yield attributes.

Saraf et al. (1968) recorded a significant response in yield of blackgram due to potassic fertilizer. Eira et al. (1974) reported that in black beans response to K was not significant but yields tended to decrease with increasing rates.

Mitkees (1974) observed that plant dry matter and seed yields of snap beans (*Phaseolus vulgaris*) were significantly improved by potassium. In field trials with peas and *Phaseolus vulgaris*, Sheveleva (1974) reported that application of 60 kg K_2O/ha gave the highest increase in seed yields of both the crops grown on light grey soil.

Sawhney et al. (1975) revealed that in blackgram the application of K increased the grain yield in Punjab. Kranz et al. (1976) reported that in beans (Phaseolus vulgaris) during dry season application of 80 kg K_2O/ha increased yield by 7 per cent.

Nemeth and Forster (1976) found that average seed yield, seed weight and number of seeds per plant increased from 414 to 595 g/m^2, 327 to 342 mg and 38 to 53 respectively with increasing rates of applied potassium (0, 75, 150 and 300 kg K_2O/ha) in field beans.

According to Osiname (1978) applied K did not significantly affect the yield of Ife-Brown cowpea (Vigna unguiculata (L.) Walp.). Sharma et al. (1978) found that for gram there was a significant response to the application of 15 kg K_2O/ha on both medium and high K soils, but the magnitude of response was much higher in medium than in high K soils.

Applied K did not exhibit any significant influence on the yield components of cowpea variety, P-118 indicating the adequacy of the soil supplies of the nutrients (Kumar and Pillai, 1979).

George (1980) opined that yield and yield attributes of blackgram showed linear and significant increase with increase in the level of potassium. The maximum grain yield of 1757 kg/ha was recorded at the potassium level of 30 kg K_2O/ha. Potassium also had significant effect on the total dry matter production.

Kapur et al. (1982) observed no significant response of rainfed bengalgram to K application.

(c) Effect of potassium on nodulation and nitrogen fixation.

Nair et al. (1970) opined that in *Arachis hypogea* L. lack of K resulted in reduction in nodulation and nitrogen fixation but not so marked as that of phosphorus. Chesney (1974) from experiments conducted on cowpea at Ebini and Kairuni found that nodulation was increased by K at Kairuni.

The results of field experiments done by Jones et al. (1977) showed that application of phosphorus and potassium individually increased nodulation in soybeans with more response from K than P.

Nair et al. (1980) found that the potassium levels had no effect on the nodule dry weight in groundnut.

(d) Effect of potassium on protein content.

Singh et al. (1969) from the experiment on pea varieties carried out in the Agronomy Farm of I.A.R.I., reported that application of phosphoric acid and potash (zero to 45 kg/ha) did not influence protein content in grain.

Haghparast and Mengel (1973) observed that in *Vicia faba* the protein content of various plant parts were not significantly affected by K but the protein yield per pot was increased by 20 per cent. Bhuiya and Chowdhury (1974) reported that in groundnut K application did not increase protein content.

Markus (1976) reported that in soybean protein was increased by application of N, K or FYM. George (1980) found significant increase in grain protein yield with increase in the level of potassium in blackgram.

Devarajan and Kothandaraman (1981) noticed that in groundnut the crude protein content of kernels was increased from 42.7 to 47.93 per cent by K application.

(e) Effect of potassium on nutrient content and uptake.

Nakagawa et al. (1966) found that in groundnut the application of K increased the content of P and K in the leaves. Bains (1967) reported that the percentage of K in bean plants increased with additional increment of potassium application.

Bains (1969) reported increase in the K content in Phaseolus vulgaris with increase in the rate of applied potassium. Stewart and Reed (1969) in pot experiments out of doors in Southern pea reported that plant content of K increased with the addition of potassium.

Harishanker and Kushwaha (1971) found increased uptake of potassium due to the increased application of K in urd plant. Bhangoo and Albritton (1972) observed that in soybean applied K increased the potassium content of leaves and seeds.

Groneman (1974) in a field trial with soybean reported that potassic fertilizers markedly increased K uptake by plants. Chevalier (1976) in a field trial with soybean reported that application of K increased N uptake at seed ripening from 110.7 kg/ha without applied K to 173.8 kg with 200 kg K_2O/ha.

Potassium application resulted in increased K content of haulm and kernel in groundnut (Habeebullah et al., 1977).

George (1980) noticed that K application significantly increased K uptake by blackgram crop.

D. Combination effect of nitrogen, phosphorus and potassium

(a) On growth characters.

Shukla (1964) reported that in gram nitrogen at the rate of 10 or 20 lb/acre in combination with phosphate at 30 lb/acre level significantly produced higher number of branches than P_1 treatment (30 lb/acre). Ezedinma (1965) found that plant height and number of leaves per plant of cowpea were increased by the application of 20 lb N + 40 lb P_2O_5/acre.

Manjhi and Chowdhury (1971) reported that when NPK combination and P alone were compared to check, did not show superiority over check for the number of primary branches in bengalgram (*Cicer arietinum*).

In Pusa Baisakhi mung, plant height and number of branches per plant increased with increasing levels of nitrogen and phosphorus. The economic level was found to be 30 kg N + 30 kg P_2O_5/ha (Panda, 1972).

Cassman et al. (1978) found that at the four lowest P levels (0.005, 0.02, 0.05, 0.2 ppm phosphate P) nitrogen provided in the nutrient solution did not increase the plant dry weight of nodulated soybean. There were significant differences in dry matter distribution caused by P stress and N source. At all P levels, plant recycling upon symbiotically produced nitrogen as their sole N source had a smaller root percentage of total weight than plants provided with nitrogen.

(b) On yield and yield attributes.

Bhattacharya (1971) reported that in horsegram the highest yields were obtained with a combined application of 33.5 kg P_2O_5 and 11.25 kg K_2O/ha under original soil while in lime dressed soil addition of 22.5 to 44.5 kg N in combination with 33.5 kg P_2O_5/ha proved to be more effective fertiliger treatment with a 120 per cent increase in grain over absolute control.

Manjhi and Chowdhury (1971) noticed that only P levels (25, 50, 75 and 100 kg P_2O_5/ha) showed significant yield differences of bengalgram (*Cicer arietinum*). But differences among P levels without N and K (each at 50 or 100 kg/ha) were not significant. No significant interaction was also observed. NPK combination and P alone when compared to check though did not show superiority over check in grain weight per plant, showed significant difference in grain yield. But P alone and NPK combination were on par.

According to Panda (1972) yield of grain and bhusa, length of pod and average weight of seeds per plant increased with increasing levels of nitrogen and phosphorus. The level of 30 kg N and 30 kg P_2O_5/ha for Pusa Baisakhi mung was the most profitable and economical dose though the highest grain yield of 10.53 q/ha was obtained from the level of 60 kg N + 90 kg P_2O_5/ha.

Kurdikeri et al. (1973) from field trials in cowpea reported the highest yield of 1.58 t/ha with 11 kg N + 44 kg P_2O_5/ha. Chesney (1974) observed from experiments with cowpea at Ebini and Kairuni that PxK interaction was always significant.

Rajendran et al. (1974) noticed an increase in the seed yield of blackgram (Phaseolus mungo L.) with increase in the level of nitrogen and phosphorus. Venugopalan and Morachan (1974) obtained significant effect of

NxP interaction on the seed yield of greengram.

In mung (Phaseolus aureus Roxb.) grain yield was significantly increased over the untreated control with 25 kg N + 50 kg P_2O_5/ha. Protein content was also significantly increased. Yield was not improved by increasing the application rates of phosphorus. It is suggested that P application may stimulate nodule production and thus higher rates of nitrogen fixation (Singh et al. 1975).

Subramonian et al. (1977) in trials with cowpea reported that application of NPK at 10:20:5 kg/ha gave the highest grain yield of 2251 kg/ha and was superior to other levels. Application of NPK beyond 20:40:10 kg/ha decreased the yield of grain.

Touvin and Lencrerot (1977) found that in Vigna unguiculata (L.)Walp. highest dry matter and seed yields were given by 200-400 kg P and K in conjunction with 100 kg N and 2 t CaO/per ha.

Gowda and Gowda (1978) reported that in greengram application of NPK together gave the highest pod and grain yield of 20.5 and 12.7 q/ha respectively.

Viswanathan et al. (1979) obtained maximum yield of cowpea with 37.67 kg N and 37.37 kg P_2O_5/ha. The economic dose of fertilizers were 23.12 kg N and 23.55 kg P_2O_5/ha.

Vaishya et al. (1981) found that in urd (*Vigna mungo* (L)Hepper) increased rates of applied N (20-30 kg/ha) and P_2O_5 (50-75 kg/ha) had no significant effect on yield.

(c) On nodulation and nitrogen fixation.

Bebin and Ignatenko (1969) in trials with soybean given combinations of 10-90 kg N, 40-180 kg P_2O_5 and 55-240 kg K_2O/ha found that application of P and K increased the root nodule number.

According to Muthuswamy (1973) phosphorus application at 30 kg P_2O_5/ha along with potassium at 90 kg K_2O/ha without nitrogen was found to increase the nodule number to the maximum extent in groundnut.

Singh et al. (1975) reported that in *Cicer arietinum* application of N and P increased the number and dry weight of effective nodules per plant upto 90 days after sowing.

Vaishya et al. (1981) observed that increased rate of applied N (20-30 kg/ha) and P_2O_5 (50-75 kg/ha) decreased nodulation in urd(*Vigna mungo* (L) Hepper).

(d) On protein content.

Kurdikeri et al. (1973) reported that the protein content of cowpea was increased from 16.8 to 20 per cent by the application of 11 kg N + 44 kg P_2O_5/ha. Higher doses of N, P_2O_5 or K_2O did not influence the protein content in cowpea.

Mlesinta (1974) reported in *Vicia faba* that protein yields were 0.68 t/ha without fertilizer and 0.94 and 0.90 t/ha with 66 kg N + 48 kg P_2O_5 + 40 kg K_2O applied in autumn and spring respectively.

Niklyaev (1975) in a field trial in Guinea with (a) mung (b) cowpea and (c) bean (*Phaseolus vulgaris*) reported that 600, 690 and 560 kg protein/ha for a, b and c respectively were obtained from the application of 60 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha.

Yadava and Singh (1978) reported that application of P in combination with N resulted in higher N content in shoot and grain protein content in greengram.

Devarajan and Kothandaraman (1981) found from a pot experiment with groundnut that the combined application of 60 kg P_2O_5 and 90 kg K_2O/ha recorded the highest value (52.38 per cent) for the crude protein of kernels.

Gupta and Singh (1982) noticed that in bengalgram (<u>Cicer arietinum</u> L.) addition of N, P and S enhanced the protein content in grains appreciably. The response to the application of graded dose of these nutrients was quadratic in nature. Protein content showed significant correlation with P and S content in grains. Eighteen aminoacids in total were recognized in chromatogram of grain flour when maximum doses of N, P and S were applied together.

(e) <u>On uptake of nitrogen, phosphorus and potassium</u>.

Gnetieva (1971) reported that in bean plants application of NPK irrespective of their rates and proportions in a fertilizer mixture markedly increased N content and had little effect on P and K contents in the seed.

Yadava and Singh (1978) observed that application of N and P increased the uptake of nitrogen by greengram and fixation of nitrogen in the soil over control.

Gupta and Singh (1983) opined that uptake of N was significantly affected by the application of N and P to bengalgram and was greatest at the highest levels (20 kg N and 80 kg P_2O_5/ha). Nitrogen uptake at both the P levels was statistically similar in grain and straw but was significantly higher than that in the control. The interaction of N and P levels affected N uptake significantly. Addition of N and P significantly influenced P uptake in grain and straw also.

E. Effect of nitrogen, phosphorus and potassium on soil fertility status

From field and glasshouse experiments on field bean, Bains (1967) noticed that under glasshouse condition soil test values for available P_2O_5 and available K_2O were affected by the application of respective fertilizer element, particularly at higher levels of applied phosphate and potash which indicated the build up of available nutrient in the soil.

Khare and Rai (1968) studied symbiotic nitrogen fixation by a few leguminous crop like soybean, cowpea, mung and daincha. He found that legume crop when treated with P increased N content of soil significantly. Total amount of N (in plant and soil) fixed symbiotically in the P treated plots over control was more than double.

Garg et al. (1970) from trials conducted with cowpea reported that P application at the rate of 37, 74 and 111 kg P_2O_5/ha caused increase in residual nitrogen and phosphorus.

Chatterjee et al. (1972) reported that application of 40-80 kg P_2O_5/ha to soybeans grown on well dressed alluvial soil increased the soil N content. Sahu and Behera (1972) also observed that inoculation and application of phosphate (22.4 kg/ha) increased the soil N by 58, 29 and 26 per cent over control in crops of cowpea, groundnut and greengram respectively.

A field experiment with 6 legume crops and 4 levels of P (0, 40, 80, 120 kg P_2O_5/ha) revealed an increase in organic C and N content of soil with increased dose of phosphorus. There was a significant increase in P content of soil at all P levels. Available P also increased with increased P treatments (Singh and Khatri, 1972).

Sharma and Yadav (1976) noticed in a field experiment with gram that the available phosphorus content of soil in general increased with the addition of P upto 34.8 kg P in 1972-73 and upto 52.2 kg P/ha in 1973-74.

Singh et al. (1983) observed improvement in total N and available P status of soil by the application of 17 kg P/ha to pigeon pea.

Materials and Methods

MATERIALS AND METHODS

An investigation was undertaken to find out the effect of nitrogen, phosphorus and potassium on the growth, yield and quality of horsegram.

LOCATION

The experiment was conducted in the garden land of the Instructional Farm, College of Agriculture, Vellayani.

SOIL

The soil of the experimental area was red loam. The data on the analysis of the soil before starting the experiment is given in Table 1.

SEASON AND WEATHER

The experiment was conducted during October-December, 1982. The crop was sown on 12th October and harvest was completed by 25th December 1982. The meteorological parameters such as rainfall, maximum and minimum temperature and relative humidity during the above period were recorded. The weekly averages of maximum and minimum temperature and relative humidity and the weekly total of rainfall during the cropping period are given in Appendix II and Fig.1(b). The normal values of the above meteorological parameters for the past 24 years were worked out and are given in Appendix I and Fig.1(a).

Table 1. Analysis of the soil before starting the experiment

Constituents	Content in soil	Method used
Total nitrogen (kg/ha)	2372	Modified micro-Kjeldahl method
Available P_2O_5 (kg/ha)	45	Bray's method
Available K_2O (kg/ha)	96	Ammonium acetate method
pH	5.2	1:2.5 soil solution ratio using pH meter.

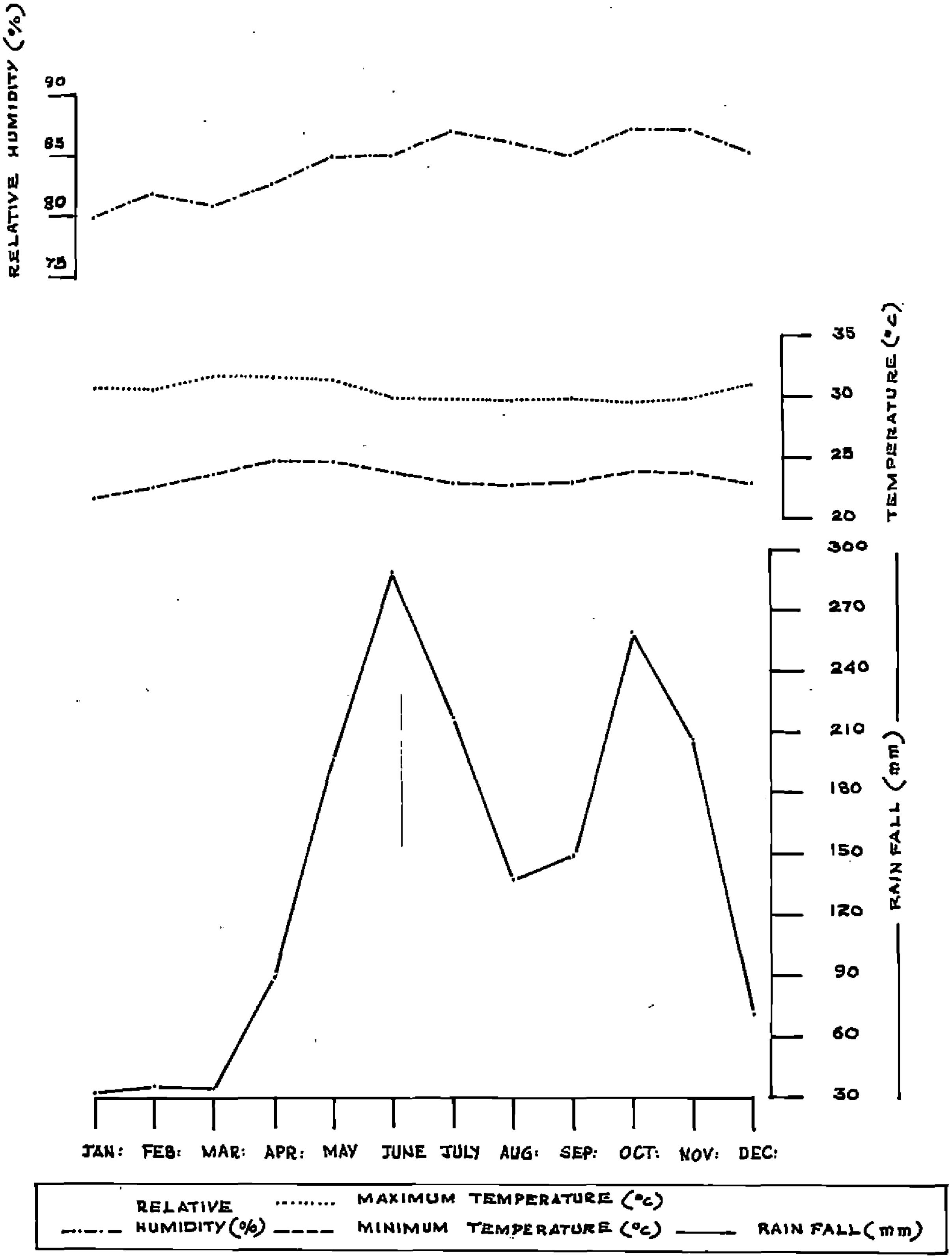

FIG: 1(a) NORMAL WEATHER CONDITIONS
(AVERAGE VALUES FOR THE PAST 24 YEARS)

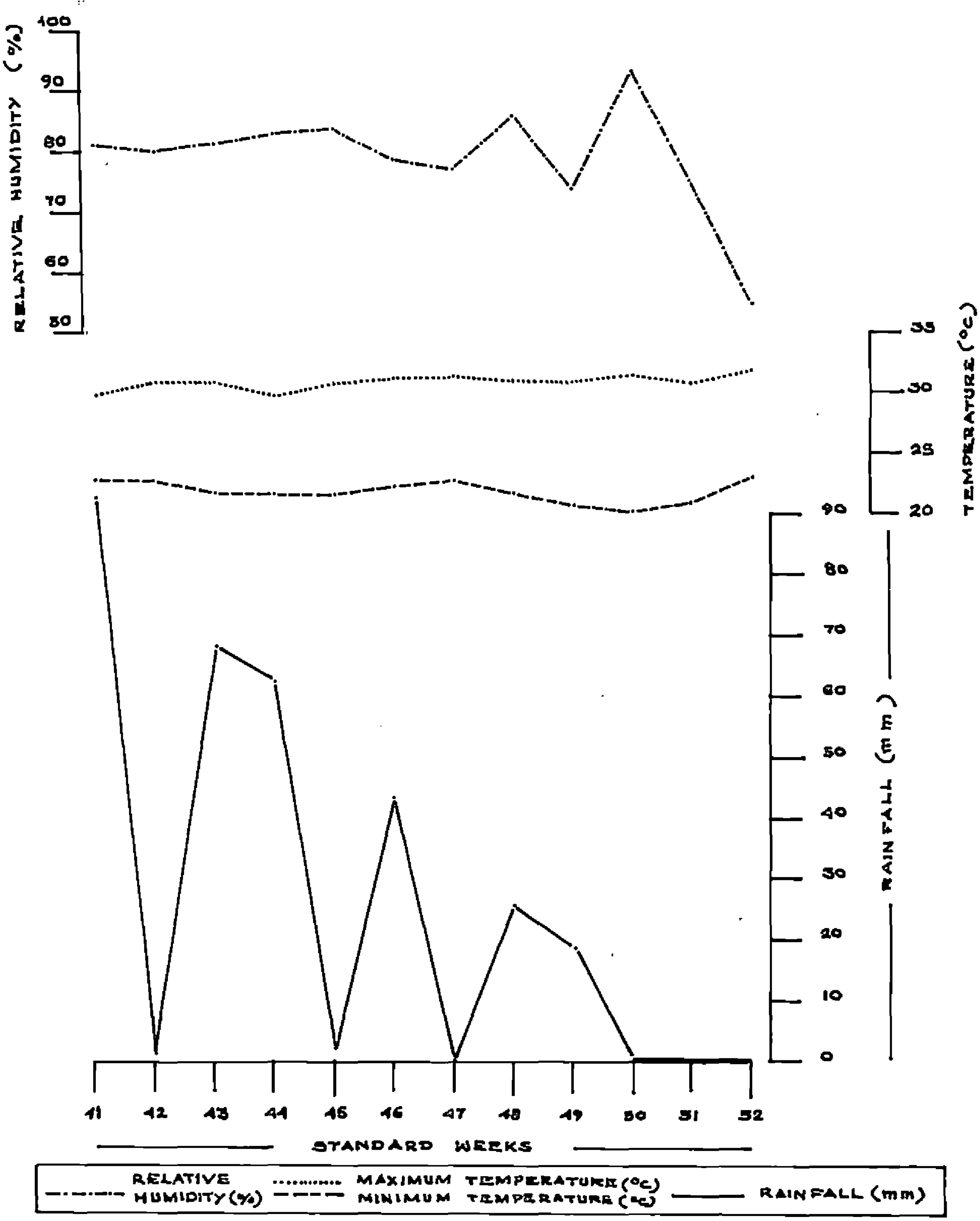

FIG: 1(b). WEATHER CONDITIONS DURING THE CROP PERIOD
(8th OCT. – 31st DEC. 1982)

CROPPING HISTORY OF THE FIELD

The experimental area was under guinea grass for the past three years.

MATERIALS

Variety

The horsegram variety used was Pattambi local. It has a duration of 65-70 days. Seeds are yellowish brown in colour.

Seed

Seeds with 95 per cent germination was obtained from the Regional Agricultural Research Station, Pattambi.

Fertilizers

Fertilizers with the following analysis were used for the experiment.

Urea	- 46 per cent N
Superphosphate	- 16 per cent P_2O_5
Muriate of potash	- 60 per cent K_2O

METHODS

Details of the treatments

The treatment consisted of a factorial combination of three levels of nitrogen, three levels of phosphorus and three levels of potassium.

(i) Levels of nitrogen

N_0 - 0 kg N/ha
N_1 - 15 "
N_2 - 30 "

(ii) Levels of phosphorus

P_0 - 0 kg P_2O_5/ha
P_1 - 25 "
P_2 - 50 "

(iii) Levels of potassium

K_0 - 0 kg K_2O/ha
K_1 - 20 "
K_2 - 40 "

Treatment combinations

1. $N_0P_0K_0$	10. $N_1P_0K_0$	19. $N_2P_0K_0$
2. $N_0P_0K_1$	11. $N_1P_0K_1$	20. $N_2P_0K_1$
3. $N_0P_0K_2$	12. $N_1P_0K_2$	21. $N_2P_0K_2$
4. $N_0P_1K_0$	13. $N_1P_1K_0$	22. $N_2P_1K_0$
5. $N_0P_1K_1$	14. $N_1P_1K_1$	23. $N_2P_1K_1$
6. $N_0P_1K_2$	15. $N_1P_1K_2$	24. $N_2P_1K_2$
7. $N_0P_2K_0$	16. $N_1P_2K_0$	25. $N_2P_2K_0$
8. $N_0P_2K_1$	17. $N_1P_2K_1$	26. $N_2P_2K_1$
9. $N_0P_2K_2$	18. $N_1P_2K_2$	27. $N_2P_2K_2$

Experimental technique

The experiment was laid out as a 3^3 factorial experiment with two replications. The higher order interactions, NPK and NPK^2, were partially confounded in Replication I and II respectively. The lay out plan is given in Fig.2. The details of the lay out are furnished below.

Gross plot size	- 5 x 3.9 M
Net plot size	- 4 x 3.6 M
Replications	- 2
Number of blocks per replication	- 3
Total number of plots	- 54
Spacing	- 25 x 15 cm

Preparation of the field

The experimental area was dug twice and stubbles were removed, clods were broken and the field was laid out into blocks and plots. The plots were levelled before sowing.

Fertilizer application

A uniform basal dose of lime at the rate of 500 kg/ha (Anon, 1981) was applied two weeks before sowing and incorporated well into the soil.

The required quantities of urea, superphosphate and muriate of potash for each plot were mixed thoroughly and applied uniformly by broadcasting in the respective plots just before sowing.

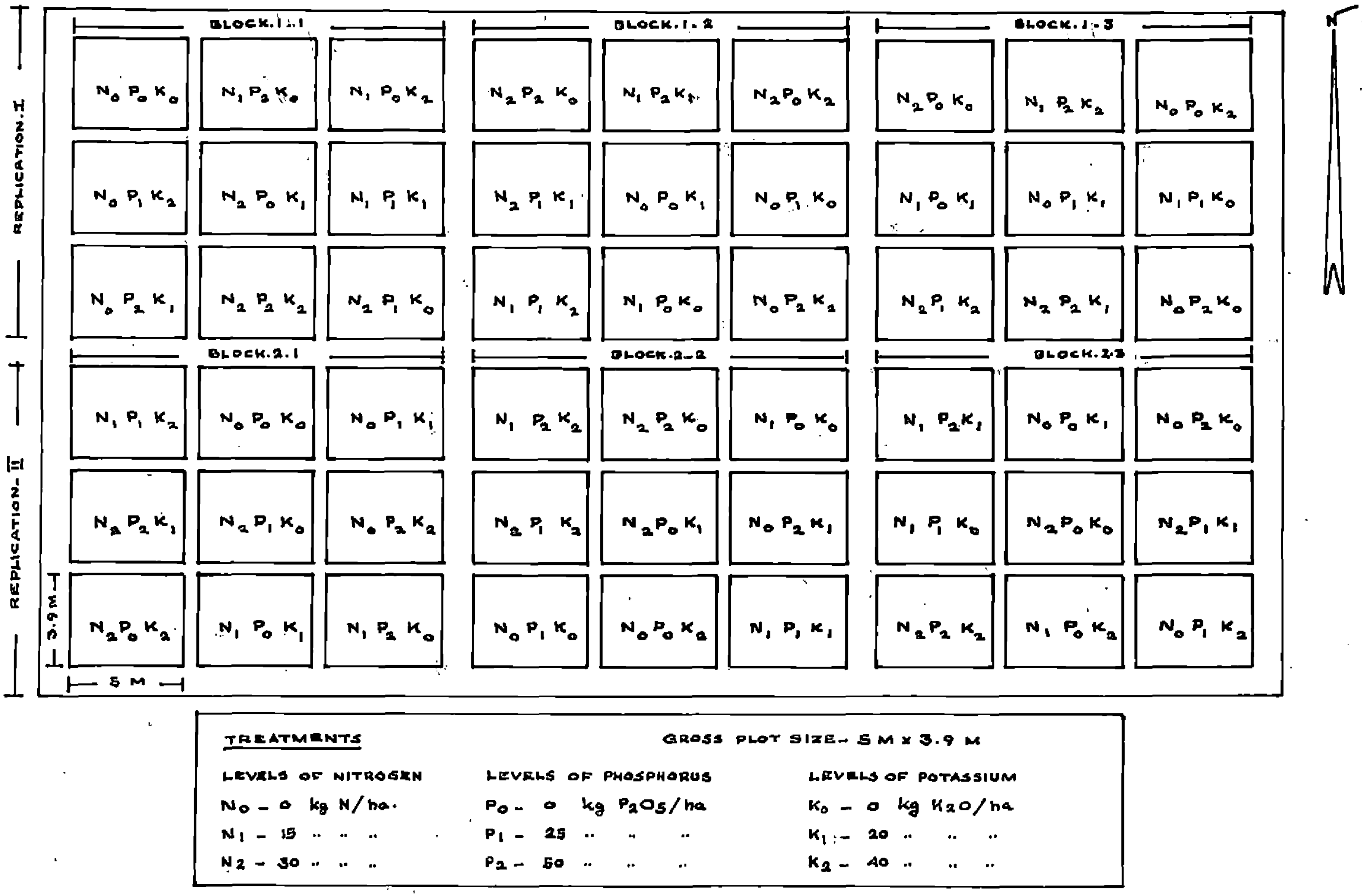

FIG: 2. LAYOUT PLAN - CONFOUNDED FACTORIAL EXPERIMENT

Seeds and sowing

Seeds treated with rhizobial culture were dibbled at the rate of 2 seeds per hole in lines at a spacing of 25 cm between rows and 15 cm between plants and covered with a thin layer of soil. One light irrigation was given immediately after sowing. Thinning and gapfilling were done 7 days after sowing.

Aftercare

Hand weeding was done twice during the growth period of the crop. Malathion 0.25 per cent was sprayed once against aphids. The general stand of the crop was satisfactory.

Harvest

Harvesting was done thrice by picking mature pods of individual plots and was completed by 75th day after sowing. The border rows and the observation plants were harvested separately. The pods were dried, threshed and seeds separated. The grain and the husk from the net plots were weighed and recorded. The bhusa from the net plot was pulled out, sun dried for three days and the weight recorded.

Sampling

One line of plants all round in each plot was left out as border rows. In all the plots one row in the eastern side was set apart as a destructive row for taking plant samples for leaf area determination, nodule count and chemical analysis. The subsequent row was again left out as a border row, thus making the net plot area to 4.00 x 3.6 M with 16 rows and 24 hills per row. Ten plants were selected randomly from the net plot and tagged for biometric observations.

OBSERVATIONS RECORDED

A. Observations on growth characters

(a) Height of plant.

Observation on height of plant was recorded on the tagged plants at four growth stages, namely 20th, 40th and 60th days after sowing and at harvest. The height of plants was measured from the cotyledonous node to the tip of the growing point and the mean height (cm) recorded.

(b) Number of functional leaves per plant.

The total number of functional leaves present in the observation plants were counted at the above four stages and the average worked out.

(c) Leaf area index (LAI).

This observation was also recorded at the four growth stages of the plant. Leaf area was calculated using the punch method (Winter et al., 1956). Two plants were removed from the destructive row, leaves were separated and punched at each stage. The discs as well as the remaining leaf portions, were dried in a hot air oven at 80 $\pm$ 5°C and their respective dry weights recorded. From this leaf area and the LAI were worked out. The leaf area index was worked out using the following formula suggested by Watson (1947).

$$LAI = \frac{\text{Leaf area per plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)}$$

(d) Number of branches per plant.

The total number of branches in the observation plants were counted at harvest and the average worked out.

(e) Number of nodules per plant.

At flowering, ten plants from the destructive row were dug out causing least disturbance to the roots, washed well and the nodules separated, counted and the average worked out.

(f) Dry weight of nodules per plant.

The nodules separated for nodule count were oven dried and the average weight (mg) recorded.

B. Observations on yield and yield attributes

(a) Number of pods per plant.

The total number of pods produced by the observation plants were counted and the average recorded.

(b) Length of pod.

Twenty pods were selected randomly from the observation plants, their length measured and the average worked out and expressed in cm.

(c) Number of seeds per pod.

The total number of seeds obtained from twenty pods selected for pod length were counted and average worked out.

(d) Hundred seed weight.

Weight of 100 seeds selected at random from the observation plants in each plot was determined and expressed in gm.

(e) Grain yield.

The pods harvested from each net plot were dried, threshed, winnowed and the grain weight recorded at 12 per cent moisture content. Yield was expressed in kg/ha.

(f) Bhusa yield.

The plants from the net plot were pulled out after collecting the pods, dried in the sun for three days, weighed and the yield expressed in kg/ha.

(g) Total dry matter yield.

The observation plants were removed from each plot, sun dried and dried to a constant weight in an air oven kept at 80 ± 5°C for 48 hours. The total dry matter yield worked out for each treatment and expressed in kg/ha.

(h) Harvest index (HI).

The harvest index was worked out based on the grain yield and the total dry matter yield in each plot, using the following formula.

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

C. Quality characters

(a) Protein content of the grain.

The percentage of protein in the grain was calculated from the percentage of nitrogen by using the factor 6.25 (Simpson et al., 1965).

(b) Grain protein yield.

The grain protein yield was calculated from the protein content and the total dry weight of the grains and expressed in kg/ha.

(c) Protein content of the bhusa.

The percentage of protein in the bhusa was calculated from the percentage of nitrogen by using the factor 6.25 (Simpson et al., 1965).

(d) Bhusa protein yield.

Bhusa protein yield was calculated based on the protein content and dry weight of bhusa and expressed in kg/ha.

D. Chemical analysis

(a) Plant analysis.

Samples taken for chemical analysis were oven dried at 80 ± 5°C and ground in a Wileymill. The nitrogen, phosphorus and potassium contents of the grain, husk and bhusa were analysed separately.

(i) Nitrogen content.

The total nitrogen content of the samples was determined by a modified micro-Kjeldahl method (Jackson, 1967).

(ii) Phosphorus content.

The phosphorus content was determined by Vanado-molybdophosphoric yellow colour method (Jackson, 1967) using Klett Summerson Photoelectric colorimeter.

(iii) Potassium content.

Potassium content in plant samples was determined using 'EEL' flame photometer.

(iv) Uptake studies.

The total uptake of nitrogen, phosphorus and potassium at harvest was calculated based on the content of these nutrients in the grain, husk and bhusa and their dry weights expressed in kg/ha.

(b) Soil analysis.

The total nitrogen, phosphorus and potassium content of a composite soil sample collected prior to the experiment and soil samples collected from individual plots after the experiment were analysed. Total nitrogen was determined by modified micro-Kjeldahl method (Jackson, 1967) and available phosphorus by Bray's method (Jackson, 1967). Available potassium was determined by Ammonium acetate method (Jackson, 1967).

E. Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for partially confounded 3^3 factorial experiment and significance was tested by 'F' test (Cochran and Cox, 1965). Important correlations were also worked out.

Response surface and standardization of fertilizer response

Response surface, $Y = b_0+b_1N+b_2P+b_3K+b_{11}N^2+b_{22}P^2+b_{33}K^2+b_{12}NP+b_{13}NK+b_{23}PK$ was fitted to estimate the optimum dose of N, P and K to obtain maximum profit. The optimum combination of N, P and K (mathematical and economic optimum doses) was estimated by solving the equations:

$$\frac{d_Y}{d_N} = 0, \frac{p_N}{p_Y} \quad .... \quad (1)$$

$$\frac{d_Y}{d_P} = 0, \frac{p_P}{p_Y} \quad .... \quad (2)$$

$$\frac{d_Y}{d_K} = 0, \frac{p_K}{p_Y} \quad .... \quad (3)$$

where p_Y - price per kg of grain,

p_N - " " N

p_P - " " P_2O_5

p_K - " " K_2O, and

the L.H.S. values are the derivatives of Y with respect to N, P and K.

Results

RESULTS

The data on the observations were statistically analysed and the results are given below.

I. Growth characters

(a) Height of plant.

The observations on height of plant were recorded on 20th, 40th and 60th days after sowing and at harvest. The data were analysed separately and the mean values are presented in Tables 2(a) to 2(d) and the analysis of variance table in Appendix III.

The results showed that the height of plant increased with increasing rates of nitrogen (0,15 and 30 kg/ha) on 20th and 40th days after sowing though not significantly. On 60th day the height of the plant significantly increased with increase in the rates of N application. Nitrogen at 30 kg/ha produced a maximum height of 88.88 cm. At harvest N_1 produced significantly taller plants over control and was on par with N_2.

The effect of phosphorus in increasing the height of plant showed significance on 40th day, 60th day and at harvest. On 40th day the height of the plant significantly

Table 2(a)

Height of the plant (cm) 20th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	8.43	8.82	9.74	9.00
25	9.27	8.82	8.65	8.91
50	8.47	9.05	9.65	9.06
K_2O kg/ha				
0	8.04	8.22	8.81	8.36
20	8.73	9.23	9.51	9.16
40	9.40	9.23	9.72	9.45
Mean	8.73	8.90	9.35	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	8.27	8.31	8.49	8.36
20	9.28	9.19	9.00	9.16
40	9.44	9.23	9.68	9.45
Mean	9.00	8.91	9.06	

C.D. (0.05) for marginal means = 0.561
C.D. (0.05) for combination = 0.971

Table 2(b)

Height of the plant (cm) 40th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	38.25	35.92	34.90	36.35
25	38.77	37.26	41.37	39.13
50	39.41	42.02	42.12	41.18
K_2O kg/ha				
0	33.47	31.92	35.52	33.64
20	39.47	42.67	39.04	40.40
40	43.48	40.61	43.83	42.64
Mean	38.81	38.40	39.47	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	31.65	35.19	34.07	33.64
20	39.42	41.48	40.29	40.40
40	38.00	40.73	49.19	42.64
Mean	36.35	39.13	41.18	

C.D. (0.05) for marginal means = 1.899
C.D. (0.05) for combination = 3.290

Table 2(c)
Height of the plant (cm) 60th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	76.07	72.70	85.20	77.99
25	76.27	96.98	88.93	87.39
50	79.50	83.32	92.52	85.11
K_2O kg/ha				
0	71.07	86.25	83.68	80.33
20	78.50	80.05	86.38	81.64
40	82.27	86.70	96.58	88.52
Mean	77.28	84.33	88.88	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	73.22	88.11	79.67	80.33
20	79.52	86.23	79.18	81.64
40	81.23	87.83	96.48	88.52
Mean	77.99	87.39	85.11	

C.D.(0.05) for marginal means = 3.784
C.D.(0.05) for combination = 6.785

Table 2(d)
Height of the plant (cm) at harvest

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	84.10	83.93	93.50	87.18
25	89.17	105.48	95.36	96.67
50	87.23	91.90	98.20	92.44
K_2O kg/ha				
0	81.40	92.42	90.86	88.23
20	90.83	97.23	94.57	94.21
40	88.27	91.67	101.63	93.86
Mean	86.83	93.77	95.69	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	82.67	93.93	88.08	88.23
20	90.00	102.85	89.78	94.21
40	88.87	93.23	99.47	93.86
Mean	87.18	96.67	92.44	

C.D. (0.05) for marginal means = 6.044
C.D. (0.05) for combination =10.469

increased with increasing rates of phosphorus whereas on 60th day and at harvest the effects of P_1 and P_2 were on par.

The effect of potassium was significant on the height of plant on 20th, 40th and 60th days after sowing. On 20th day K_1 and K_2 were on par but significantly superior to control. On 40th day the effect of potassium showed a linear trend registering a maximum height of 42.64 cm by 40 kg K_2O/ha. On 60th day the treatment K_2 was significantly superior to K_1 and control which were on par. The effect of potassium was not significant at harvest.

The interactions NxP, NxK and PxK were found significant only on 40th and 60th days after sowing. The treatment combination N_2P_2 produced a maximum height of 42.12 cm on 40th day which was on par with N_1P_2 and N_2P_1. Similarly on 60th day the treatment combination N_1P_1 produced a maximum height of 96.98 cm which was on par with N_2P_2 (92.52 cm).

In the case of NxK interaction, the treatment combination N_2K_2 produced a maximum height of 43.83 cm on 40th day which was on par with N_0K_2, N_1K_1 and N_1K_2. On 60th day the treatment combination N_2K_2 produced significantly taller plants than any other combinations of nitrogen and potassium.

With regard to PxK interaction, the treatment combination P_2K_2 was significantly superior on 40th and 60th days after sowing.

(b) <u>Number of functional leaves per plant.</u>

The observations on number of functional leaves were taken on 20th, 40th and 60th days after sowing and at harvest. The data were analysed separately and the mean values are presented in Tables 3(a) to 3(d). The analysis of variance table is given in Appendix IV.

Treatment N_2 showed significant increase in number of leaves per plant at all growth stages except on 20th day when it was on par with N_1.

The effect of phosphorus was also found significant with respect to number of leaves per plant at all stages of crop growth. Treatment P_1 produced significantly higher number of leaves over control and was on par with P_2 at all stages of crop growth except on 40th day. On 40th day P_2 was on par with P_1 which in turn was on par

Table 3(a)
Number of functional leaves per plant - 20th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	3.65	4.73	4.90	4.43
25	4.63	4.80	4.85	4.76
50	4.82	5.05	4.87	4.91
K_2O kg/ha				
0	3.78	4.58	4.77	4.38
20	4.60	5.12	4.77	4.83
40	4.72	4.88	5.08	4.89
Mean	4.37	4.86	4.87	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	3.93	4.45	4.75	4.38
20	4.52	5.02	4.95	4.83
40	4.83	4.82	5.03	4.89
Mean	4.43	4.76	4.91	

C.D. (0.05) for marginal means = 0.267
C.D. (0.05) for combination = 0.453

Table 3(b)
Number of functional leaves per plant - 40th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	14.87	17.52	25.74	19.38
25	18.52	17.32	25.80	20.55
50	18.54	23.66	21.45	21.22
K_2O kg/ha				
0	15.78	17.19	23.27	18.75
20	16.58	21.02	23.95	20.52
40	19.58	20.29	25.76	21.88
Mean	17.31	19.50	24.33	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	18.05	19.19	19.01	18.75
20	19.38	20.90	21.26	20.52
40	20.70	21.55	23.38	21.88
Mean	19.38	20.55	21.22	

C.D. (0.05) for marginal means = 1.191
C.D. (0.05) for combination = 2.063

Table 3(c)

Number of functional leaves per plant - 60th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	19.55	27.22	29.37	25.38
25	26.25	25.20	32.47	27.97
50	25.52	29.64	28.24	27.80
K_2O kg/ha				
0	22.61	26.17	28.05	25.61
20	23.12	29.15	34.13	28.80
40	25.59	26.73	27.90	26.74
Mean	23.77	27.35	30.03	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	24.37	26.87	25.60	25.61
20	26.29	29.77	30.34	28.80
40	25.48	27.28	27.46	26.74
Mean	25.38	27.97	27.80	

C.D. (0.05) for marginal means = 1.694
C.D. (0.05) for combination = 2.934

Table 3(d)

Number of functional leaves per plant - at harvest

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	9.00	9.87	10.77	9.88
25	10.33	10.40	12.23	10.99
50	10.63	10.77	10.83	10.74
K_2O kg/ha				
0	9.27	10.20	11.45	10.31
20	10.20	10.47	11.58	10.75
40	10.50	10.37	10.80	10.56
Mean	9.99	10.34	11.28	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	9.07	11.32	10.53	10.31
20	10.53	11.12	10.60	10.75
40	10.03	10.53	11.10	10.56
Mean	9.88	10.99	10.74	

C.D. (0.05) for marginal means = 0.605
C.D. (0.05) for combination = 1.048

with control.

Treatment K_1 was found significantly superior with respect to number of leaves per plant on 20th and 60th days after sowing. On 40th day K_2 produced significant increase in leaf number. Though the effect of potassium was not significant at harvest K_1 produced more number of leaves per plant.

With regard to interactions, NxP interaction had significant influence on number of leaves at all stages except at harvest. The effect of different combinations of N and P were on par but superior to control on 20th day. The treatment combination N_2P_1 produced a maximum of 25.8 leaves closely followed by N_2P_0 (25.74) which were on par on 40th day. On 60th day the effects of treatment combinations N_2P_1 and N_1P_2 were found on par but significantly superior to other combinations.

NxK interaction was found significant only on 60th day. The maximum number of leaves of 34.13 was produced by the treatment combination N_2K_1 on 60th day.

(c) Leaf Area Index.

Data on leaf area index worked out on 20th, 40th and 60th days after sowing and at harvest were analysed separately and the mean values are presented in Tables 4(a) to 4(d). The analysis of variance table is given in Appendix V.

The effect of nitrogen had significant influence on leaf area index at all stages of crop growth. On 20th day N_1 gave the highest LAI which was significantly superior to N_2 and control. Leaf area index showed an increasing trend with increase in N rates on 40th day, 60th day and at harvest.

Phosphorus application also produced significant influence on LAI at all growth stages. On 20th day P_1 and P_2 were on par and significantly superior to control. On 40th and 60th days P_2 produced significant increase in LAI over P_1 and control which were on par. At harvest P_1 and P_2 were on par, both being superior to control.

Potassium had significant influence on LAI at all stages except at harvest. Leaf area index showed significant increase with increasing rates of potassium on 20th, 40th and 60th days after sowing.

The interactions NxP had significant influence on leaf area index at all growth stages. The treatment combination N_1P_2 was found significantly superior over other

Table 4(a)

Leaf area index - 20th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	0.06	0.08	0.09	0.08
25	0.07	0.09	0.09	0.09
50	0.06	0.11	0.09	0.09
K_2O kg/ha				
0	0.06	0.08	0.06	0.07
20	0.07	0.09	0.11	0.09
40	0.07	0.12	0.10	0.10
Mean	0.06	0.10	0.09	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	0.05	0.06	0.09	0.07
20	0.07	0.08	0.11	0.09
40	0.10	0.12	0.06	0.10
Mean	0.08	0.09	0.09	

C.D. (0.05) for marginal means = 0.0097
C.D. (0.05) for combination = 0.0167

Table 4(b)

Leaf area index - 40th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	0.62	1.10	1.37	1.03
25	0.82	1.11	1.17	1.03
50	0.85	1.42	1.50	1.26
K_2O kg/ha				
0	0.58	0.97	1.45	1.00
20	0.84	1.16	1.26	1.09
40	0.88	1.49	1.34	1.24
Mean	0.77	1.21	1.35	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	0.89	0.92	1.18	1.00
20	1.12	0.93	1.21	1.09
40	1.08	1.25	1.37	1.24
Mean	1.03	1.03	1.26	

C.D. (0.05) for marginal means = 0.077
C.D. (0.05) for combination = 0.133

Table 4 (c)

Leaf area index - 60th day after sowing

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	1.25	1.25	1.57	1.36
25	1.03	1.47	1.76	1.42
50	1.09	1.72	1.86	1.56
K_2O kg/ha				
0	1.00	1.27	1.82	1.36
20	1.08	1.56	1.61	1.42
40	1.29	1.62	1.76	1.55
Mean	1.12	1.48	1.73	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	1.28	1.35	1.46	1.36
20	1.25	1.44	1.56	1.42
40	1.55	1.47	1.64	1.55
Mean	1.36	1.42	1.56	

C.D. (0.05) for marginal means = 0.066
C.D. (0.05) for combination = 0.114

Table 4 (d)

Leaf area index at harvest

	N kg/ha			
P_2O_5 kg/ha	0	15	30	Mean
0	0.16	0.23	0.29	0.23
25	0.26	0.26	0.28	0.27
50	0.29	0.27	0.26	0.27
K_2O kg/ha				
0	0.22	0.25	0.29	0.26
20	0.24	0.26	0.27	0.26
40	0.24	0.25	0.28	0.26
Mean	0.24	0.25	0.28	

	P_2O_5 kg/ha			
K_2O kg/ha	0	25	50	Mean
0	0.22	0.27	0.28	0.26
20	0.22	0.28	0.26	0.26
40	0.25	0.26	0.27	0.26
Mean	0.23	0.27	0.27	

C.D. (0.05) for marginal means = 0.013

C.D. (0.05) for combination = 0.020

combinations on 20th day. The treatment combination N_2P_2 produced the highest LAI on 40th day but was on par with N_1P_2 and N_2P_0. On 60th day the treatment combination N_2P_2 produced the highest LAI though on par with N_2P_1. At harvest the effects of the treatment combinations N_0P_2, N_1P_2, N_2P_0 and N_2P_1 were on par, but significantly superior to other combinations.

The interaction NxK was significant only on 20th, 40th and 60th days after sowing. On 20th day the effects of the treatment combinations N_1K_2 and N_2K_1 were on par but significantly superior to other combinations. On 40th day the treatment combination N_1K_2 produced significantly higher LAI but was on par with N_2K_0. The treatment combinations N_2K_0 and N_2K_2 were on par but significantly superior to other combinations on 60th day.

The interaction PxK was significant at all growth stages. The treatment combination P_1K_2 produced significantly higher LAI but was on par with P_2K_1 on 20th day. The effects of the treatment combinations P_1K_2 and P_2K_2 were on par on 40th day but produced a higher LAI over other combinations. On 60th day the effects of P_0K_2, P_2K_1 and P_2K_2 were on par but superior to other combinations. At harvest the effects of all the treatment combinations were on par except P_0K_0, P_0K_1 and P_0K_2.

(d) Number of branches per plant.

The data on number of branches per plant was analysed and the mean values are given in Table 5. The analysis of variance table is given in Appendix VI.

Nitrogen, phosphorus and potassium had significant influence on number of branches per plant. The number of branches per plant showed an increasing trend with increase in the rates of nitrogen, phosphorus and potassium.

The interactions NxP, NxK and PxK were significant with respect to this character. Application of 30 kg N/ha alone (N_2P_0) produced 6.95 branches which was on par with N_2P_1. The treatment combination N_2K_2 recorded the maximum number of branches (7.13) which was on par with N_2K_1 (6.87). The treatment combination P_2K_2 produced a higher number of branches which was on par with P_1K_2 and P_2K_0.

(e) Number of nodules per plant.

The mean numbers are presented in Table 6 and the analysis of variance table in Appendix VI.

Number of nodules per plant was significantly increased over control by the application of 15 kg N/ha but decreased with further increase in the level of nitrogen.

Table 5

Number of branches per plant

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	4.30	5.78	6.95	5.68
25	5.03	6.43	6.78	6.08
50	6.45	6.18	6.18	6.27
K_2O kg/ha				
0	5.38	6.08	5.92	5.79
20	5.00	6.03	6.87	5.97
40	5.40	6.28	7.13	6.27
Mean	5.26	6.13	6.64	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	5.13	6.00	6.25	5.79
20	5.80	6.00	6.10	5.97
40	6.10	6.25	6.47	6.27
Mean	5.68	6.08	6.27	

C.D. (0.05) for marginal means = 0.179

C.D. (0.05) for combination = 0.311

Table 6

Number of nodules per plant

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	21.47	28.38	22.23	24.03
25	32.60	33.15	28.37	31.37
50	31.58	36.03	23.85	30.49
K_2O kg/ha				
0	25.50	29.63	23.90	26.34
20	28.32	35.55	24.97	29.61
40	31.83	32.38	25.58	29.93
Mean	28.55	32.52	24.82	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	19.20	29.83	30.00	26.34
20	24.88	32.45	31.50	29.61
40	28.00	31.83	29.97	29.93
Mean	24.03	31.37	30.49	

C.D. (0.05) for marginal means = 1.480
C.D. (0.05) for combination = 2.560

Table 7

Dry weight of nodules per plant (mg)

	N kg/ha			
P_2O_5 kg/ha	0	15	30	Mean
0	19.96	30.24	24.78	24.99
25	28.92	39.23	31.87	33.34
50	38.70	42.95	34.97	38.88
K_2O kg/ha				
0	26.36	33.96	27.70	29.34
20	29.06	38.22	31.98	33.09
40	32.16	40.23	31.94	34.78
Mean	29.19	37.47	30.54	

	P_2O_5 kg/ha			
K_2O kg/ha	0	25	50	Mean
0	20.66	30.55	36.81	29.34
20	25.38	33.04	40.84	33.09
40	28.94	36.42	38.97	34.78
Mean	24.99	33.34	38.88	

C.D. (0.05) for marginal means = 0.733
C.D. (0.05) for combination = 1.270

Phosphorus application significantly increased the nodule number over control but P_1 and P_2 were on par.

The effect of potassium showed a similar trend as that of phosphorus. The data showed that NxP, NxK and PxK interactions had also significant influence on nodule number. The treatment combination N_1P_2 produced the maximum number of nodules per plant. The treatment combination N_1K_1 produced a higher nodule number which was significantly superior to other combinations of nitrogen and potassium. The treatment combination P_1K_1 produced significantly higher number of nodules but was on par with P_1K_2, P_2K_0, P_2K_1 and P_2K_2.

(f) Dry weight of nodules per plant.

The mean values are presented in Table 7 and the analysis of variance table in Appendix VI.

The dry weight of nodules per plant was significantly increased by nitrogen application upto 15 kg N/ha and the highest level reduced the dry weight of nodules.

The dry weight of nodules per plant significantly increased by increasing levels of phosphorus and potassium upto the highest rates tried in the experiment.

The interactions NxP, NxK and PxK were also significant with respect to this character. The treatment combinations N_1P_2, N_1K_2 and P_2K_1 were found significantly superior to other combinations.

II. Yield and yield attributes

(a) Number of pods per plant.

The mean number of pods are given in Table 8 and the analysis of variance table in Appendix VII. Though the effect of nitrogen was not significant in this character the pod number was increased over control by the application of 15 kg N/ha.

Phosphorus had significant influence on number of pods per plant. Treatment P_1 and P_2 were on par but significantly superior to control.

Potassium also had significant influence on pod number where K_1 and K_2 were on par and significantly superior to control.

The interactions NxP, NxK and PxK were also found significant with respect to this character. The effects of the treatment combinations N_0P_1, N_1P_1 and N_2P_2 were on par but significantly superior to other combinations.

Table 8

Number of pods per plant

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	31.43	34.33	31.97	32.58
25	42.33	40.93	39.10	40.79
50	38.20	36.10	40.88	39.06
K_2O kg/ha				
0	32.47	36.70	35.42	34.86
20	38.43	38.70	39.47	38.87
40	41.07	37.97	37.07	38.70
Mean	37.32	37.79	37.32	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	27.00	40.00	37.58	34.86
20	32.80	42.03	41.77	38.87
40	37.93	40.33	37.83	38.70
Mean	32.58	40.79	39.06	

C.D. (0.05) for marginal means = 1.325
C.D. (0.05) for combination = 2.294

Table 9

Length of pod (cm)

	N kg/ha			
P_2O_5 kg/ha	0	15	30	Mean
0	4.84	5.20	5.54	5.20
25	5.10	5.48	5.29	5.29
50	5.18	5.21	5.28	5.22
K_2O kg/ha				
0	4.60	5.15	5.39	5.05
20	5.19	5.23	5.71	5.37
40	5.34	5.52	5.01	5.29
Mean	5.04	5.30	5.37	

	P_2O_5 kg/ha			
K_2O kg/ha	0	25	50	Mean
0	5.03	5.04	5.07	5.05
20	5.37	5.32	5.43	5.37
40	5.19	5.52	5.17	5.29
Mean	5.20	5.29	5.22	

C.D. (0.05) for marginal means = 0.187
C.D. (0.05) for combination = 0.324

Similarly the treatment combination N_0K_2 was on par with N_2K_1. The treatment combinations P_1K_0, P_1K_1, P_1K_2 and P_2K_1 were on par.

(b) Length of pod

The mean values are presented in Table 9 and the analysis of variance table in Appendix VII.

Treatment N_1 significantly increased the length of pod over control but was on par with N_2.

Though the effect of phosphorus was not significant increase in pod length was noticed at P_1.

Potassium exhibited significant influence in this yield attribute but K_1 and K_2 were on par.

In this case, NxP and NxK interactions showed significant influence. The treatment combination N_2P_0 produced longer pods which was on par with N_1P_1, N_2P_1 and N_2P_2. The treatment combination N_1K_2 produced significant increase in pod length but was on par with N_2K_0 and N_2K_1.

(c) Number of seeds per pod.

The mean numbers are presented in Table 10 and the analysis of variance table in Appendix VII.

Table 10
Number of seeds per pod

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	5.12	5.82	5.50	5.48
25	5.72	6.03	5.63	5.79
50	5.72	5.48	5.52	5.57
K_2O kg/ha				
0	5.17	5.70	5.28	5.38
20	5.80	5.82	5.57	5.73
40	5.58	5.82	5.80	5.73
Mean	5.52	5.78	5.55	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	4.95	5.80	5.40	5.38
20	5.82	5.78	5.58	5.73
40	5.67	5.80	5.73	5.73
Mean	5.48	5.79	5.57	

C.D.(0.05) for marginal means = 0.241
C.D.(0.05) for combination = 0.418

Table 11
Hundred seed weight (gm)

	N kg/ha			
P_2O_5 kg/ha	0	15	30	Mean
0	4.00	4.18	4.13	4.11
25	4.25	4.20	4.07	4.17
50	4.13	4.32	4.35	4.27
K_2O kg/ha				
0	4.00	4.10	4.15	4.08
20	4.15	4.32	4.22	4.23
40	4.23	4.28	4.18	4.23
Mean	4.13	4.23	4.18	

	P_2O_5 kg/ha			
K_2O kg/ha	0	25	50	Mean
0	3.87	4.08	4.30	4.08
20	4.22	4.28	4.18	4.23
40	4.23	4.15	4.32	4.23
Mean	4.11	4.17	4.27	

C.D. (0.05) for marginal means = 0.108
C.D. (0.05) for combination = 0.187

Though nitrogen had no significant effect on number of seeds per pod increase in seed number per pod was observed at N_1.

Treatment P_1 significantly increased the number of seeds per pod over control and was on par with P_2.

Potassium application significantly increased the number of seeds per pod over control but K_1 and K_2 were on par.

The effects of NxP and PxK interactions had significant influence on number of seeds per pod. The treatment combination N_1P_1 recorded the maximum number of seeds per pod (6.03) which was on par with N_0P_1, N_0P_2, N_1P_0 and N_2P_1. The effects of all the treatment combinations of phosphorus and potassium, except P_0k_0 and P_2K_0 were on par in influencing the number of seeds per pod.

(d) Hundred seed weight.

The mean values are given in Table 11 and the analysis of variance table in Appendix VII.

Nitrogen at 15 kg/ha produced greater test weight over control though the effect of N was not significant.

The hundred seed weight was significantly increased over control by the application of phosphorus but P_1 and P_2 were on par.

Treatments K_1 and K_2 were on par but significantly superior to control.

The test weight was also significantly influenced by the interactions NxP and PxK. The treatment combination N_2P_2 recorded the highest test weight. In the case of PxK interaction, the effects of all the treatment combinations were on par except P_0K_0 and P_1K_0.

(e) Grain yield.

The mean yields are presented in Table 12 and the analysis of variance table in Appendix VIII.

The grain yield was significantly influenced by the application of nitrogen. Nitrogen at 15 kg/ha produced a significant increase in grain yield over control. But the grain yield showed a decreasing trend with the higher level of nitrogen tried.

The grain yield varied significantly between different levels of phosphorus tried. Treatment P_1 recorded the highest grain yield followed by P_2 which was inferior to P_1. Both these phosphorus levels were significantly

Table 12

Grain yield (kg/ha)

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	630.17	669.83	623.67	641.22
25	755.33	948.83	842.33	848.83
50	689.50	856.83	855.83	800.72
K_2O kg/ha				
0	618.67	717.33	679.00	671.67
20	729.17	976.50	904.00	869.89
40	727.17	731.67	739.83	749.22
Mean	691.67	825.17	773.94	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	556.50	751.93	706.67	671.67
20	691.50	955.17	963.00	869.89
40	675.67	839.50	732.50	749.22
Mean	641.22	848.83	800.72	

C.D. (0.05) for marginal means = 18.083
C.D. (0.05) for combination = 31.635

Table 13

Bhusa yield (kg/ha)

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	830.17	912.67	915.50	886.11
25	934.00	957.50	1188.33	1026.61
50	934.33	1129.67	1063.83	1042.61
K_2O kg/ha				
0	826.83	947.33	917.67	897.28
20	880.17	994.33	1102.17	992.22
40	991.50	1058.17	1147.83	1065.83
Mean	899.50	999.94	1055.89	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	811.83	922.83	957.17	897.28
20	912.33	1099.50	964.83	992.22
40	934.17	1057.50	1205.83	1065.83
Mean	886.11	1026.51	1042.61	

C.D. (0.05) for marginal means = 16.850

C.D. (0.05) for combination = 29.180

superior to control.

Potassium application also followed a similar pattern as that of nitrogen and phosphorus.

The interactions NxP, NxK and PxK were found to have significant influence on grain yield. The treatment combination N_1P_1 produced significantly higher grain yield (948.83 kg/ha) over other combinations of nitrogen and phosphorus. Similarly N_1K_1 produced significantly higher grain yield (976.50 kg/ha) over other combinations of nitrogen and potassium. With regard to PxK interaction$, P_1K_1 produced significantly higher grain yield (955.17 kg/ha) but was on par with P_2K_1.

(f) Bhusa yield.

The mean yields are presented in Table 13 and the analysis of variance table in Appendix VIII.

The bhusa yield significantly increased with increase in the rates of nitrogen application upto the highest level.

Treatments P_1 and P_2 were on par both being significantly superior to control.

Bhusa yield registered significant increase with increasing dose of potassium upto the highest level tried.

With regard to interactions NxP, NxK and PxK, the treatment combinations N_2P_1, N_2K_2 and P_2K_2 respectively produced significantly higher bhusa yield over other combinations.

(g) <u>Total dry matter yield.</u>

The mean values are given in Table 14 and the analysis of variance table in Appendix VIII.

Nitrogen at 15 kg/ha significantly increased the total dry matter yield but 30 kg N/ha showed a decrease in this aspect.

In the case of phosphorus, the highest dry matter yield was recorded by P_1 which was significantly superior to P_2 and control.

Potassium exhibited a similar trend as that of nitrogen and phosphorus.

Interactions NxP, NxK and PxK were significant. With regard to NxP interaction, the treatment combination N_1P_1 produced the maximum dry matter yield. The treatment combination N_2K_1 produced significantly higher dry matter yield which was on par with N_1K_1. As regards PxK interaction, the combinations P_1K_2 and P_2K_1 were on par but significantly superior to other combinations.

Table 14

Total dry matter yield (kg/ha)

		N kg/ha		
P_2O_5 kg/ha	0	15	30	Mean
0	1573.83	1716.66	1724.16	1671.55
25	1884.16	2240.66	1987.83	2037.55
50	1733.50	2030.16	2152.00	1971.89
K_2O kg/ha				
0	1587.83	1793.83	1760.66	1714.00
20	1754.83	2190.50	2130.66	2025.33
40	1849.83	2003.16	1973.00	1941.67
Mean	1730.50	1995.83	1954.67	

		P_2O_5 kg/ha		
K_2O kg/ha	0	25	50	Mean
0	1519.17	1814.00	1808.83	1714.00
20	1761.66	2088.00	2226.33	2025.33
40	1733.83	2210.67	1880.50	1941.67
Mean	1671.55	2037.55	1971.89	

C.D. (0.05) for marginal means = 38.238
C.D. (0.05) for combination = 66.230

Table 15

Harvest index

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	0.40	0.39	0.36	0.38
25	0.40	0.42	0.42	0.41
50	0.40	0.42	0.40	0.41
K_2O kg/ha				
0	0.39	0.40	0.38	0.39
20	0.41	0.44	0.42	0.42
40	0.39	0.39	0.36	0.39
Mean	0.40	0.41	0.38	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	0.37	0.41	0.39	0.39
20	0.39	0.45	0.43	0.42
40	0.39	0.38	0.39	0.39
Mean	0.38	0.41	0.41	

C.D. (0.05) for marginal means = 0.005
C.D. (0.05) for combination = 0.008

(h) Harvest Index.

The mean values are presented in Table 15 and the analysis of variance table in Appendix VIII.

Application of 15 kg N/ha showed significant increase in harvest index over control but the harvest index decreased with further increase in nitrogen dose.

Application of phosphorus also increased the HI significantly over control but the effects of P_1 and P_2 were on par.

Potassium also showed a similar trend as that of nitrogen.

The interactions NxP, NxK and PxK were found to have significant influence on harvest index. The effects of treatment combinations N_1P_1, N_1P_2 and N_2P_1 were on par but significantly superior to other combinations of nitrogen and phosphorus. The treatment combinations N_1K_1 and P_1K_1 produced significantly higher harvest index in the case of NxK and PxK interactions respectively.

III. Quality characters

(a) Protein content of grain.

The mean percentage values are presented in Table 16

Table 16

Protein content of grain (per cent)

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	21.29	23.44	25.55	23.43
25	22.67	23.10	24.63	23.47
50	23.44	24.23	25.21	24.29
K_2O kg/ha				
0	22.14	24.07	25.02	23.74
20	22.68	23.82	25.42	23.97
40	22.58	22.88	24.95	23.47
Mean	22.47	23.59	25.13	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	22.87	23.77	24.59	23.74
20	23.75	23.48	24.68	23.97
40	23.65	23.14	23.62	23.47
Mean	23.43	23.47	24.29	

C.D(0.05) for marginal means = 0.204
C.D.(0.05) for combination = 0.353

Table 17

Grain protein yield (kg/ha)

P_2O kg/ha	N kg/ha 0	15	30	Mean
0	134.92	156.88	159.42	150.41
25	171.12	219.08	207.38	199.19
50	161.56	208.45	216.23	195.41
K_2O kg/ha				
0	137.86	172.89	169.45	160.07
20	165.51	233.04	229.58	209.38
40	164.22	178.48	184.01	175.57
Mean	155.86	194.80	194.35	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	127.50	178.31	174.40	160.07
20	164.32	225.02	238.79	209.38
40	159.40	194.25	173.06	175.57
Mean	150.41	199.19	195.41	

C.D.(0.05) for marginal means = 4.256
C.D.(0.05) for combination = 7.486

protein yield over control but N_1 and N_2 were on par.

Phosphorus application also exhibited a similar trend as that of nitrogen.

Significant effect of potassium in increasing the grain protein yield was obtained upto K_1 but K_2 registered a significant decrease in the grain protein yield.

The interactions NxP, NxK and PxK had significant effect on the grain protein yield. The treatment combination N_1P_1 produced significantly higher grain protein yield but was on par with N_2P_2. In the case of NxK interaction, the treatment combination N_1K_1 produced significantly higher grain protein yield but was on par with N_2K_1. The treatment combination P_2K_1 produced significantly higher grain protein yield over other combinations of phosphorus and potassium.

(c) Protein content of bhusa.

The mean values are presented in Table 18 and the analysis of variance table in Appendix IX.

The effect of the treatments N_1 and N_2 in influencing the protein content of bhusa were on par but superior to control.

and the analysis of variance table in Appendix IX.

It was observed that the protein content of grain increased with increasing levels of nitrogen upto the highest dose.

Treatment P_2 registered a significant increase in the protein content over P_1 and control which were on par.

The effect of potassium in increasing the grain protein content was noticed only upto 20 kg K_2O/ha.

The interactions NxP, NxK and PxK also showed significant influence in the grain protein content. The effects of the treatment combinations N_2P_0 and N_2P_2 were on par but superior to other combinations of nitrogen and phosphorus. The treatment combination N_2K_1 was significantly superior to other combinations of nitrogen and potassium. The effects of the treatment combinations P_2K_0 and P_2K_1 were on par which recorded significantly higher grain protein content over other P and K combinations.

(b) Grain protein yield.

The mean values are presented in Table 17 and the analysis of variance table in Appendix IX.

Nitrogen application significantly increased the grain

Table 18

Protein content of bhusa (per cent)

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	5.12	6.23	6.19	5.85
25	6.19	6.32	6.49	6.33
50	6.21	6.39	6.54	6.38
K_2O kg/ha				
0	5.15	6.43	6.55	6.04
20	6.35	6.26	6.39	6.33
40	6.02	6.25	6.27	6.18
Mean	5.84	6.31	6.40	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	5.10	6.48	6.56	6.04
20	6.18	6.40	6.42	6.33
40	6.27	6.12	6.15	6.18
Mean	5.85	6.33	6.38	

C.D. (0.05) for marginal means = 0.113
C.D. (0.05) for combination = 0.196

Table 19

Bhusa protein yield (kg/ha)

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	43.86	56.82	56.53	52.41
25	57.88	60.48	77.08	65.15
50	57.47	71.34	69.46	66.26
K_2O kg/ha				
0	43.87	60.69	60.19	54.92
20	55.92	62.25	70.64	62.94
40	59.42	66.20	72.24	65.95
Mean	53.07	63.05	67.69	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	42.45	59.81	62.48	54.92
20	56.31	70.54	61.97	62.94
40	58.45	65.09	74.32	65.95
Mean	52.41	65.15	66.26	

C.D. (0.05) for marginal means = 1.637
C.D. (0.05) for combination = 2.835

As regards the effect of phosphorus, the response showed a similar trend as that of nitrogen.

Treatment K_1 registered significant increase in the protein content of bhusa whereas K_2 was significantly inferior to K_1.

The interactions NxP, NxK and PxK were significant. In the case of NxP interaction, the treatment combination N_2P_2 produced significantly higher bhusa protein content which was on par with N_1P_2 and N_2P_1. The effect of the treatment combination N_2K_0 was significantly superior but was on par with N_2K_1. The treatment combination P_2K_0 recorded the maximum protein content of bhusa which was on par with P_1K_0, P_1K_1 and P_2K_1.

(d) Bhusa protein yield.

The mean yields are presented in Table 19 and the analysis of variance table in Appendix IX.

The bhusa protein yield increased significantly with increasing levels of nitrogen.

Treatment P_1 recorded a significant increase in bhusa protein yield which was on par with P_2.

Potassium application showed a similar response as that of nitrogen.

The interactions NxP, NxK and PxK were significant. The treatment combination N_2P_1 produced significantly higher bhusa protein yield. The treatment combination N_2K_2 registered significantly higher bhusa protein yield which was on par with N_1K_1. The treatment combination P_2K_2 produced significantly higher bhusa protein yield over other combinations of phosphorus and potassium.

IV. Uptake studies

(a) Uptake of nitrogen.

The mean values are presented in Table 20 and the analysis of variance table in Appendix X.

A significant increase in uptake of nitrogen with incremental doses of N was observed only upto 15 kg/ha.

Nitrogen uptake showed significant increase with graded doses of phosphorus application upto 50 kg P_2O_5/ha.

Potassium application significantly increased the nitrogen uptake over control but K_1 and K_2 were on par.

With regard to interactions, NxP and NxK were significant. The treatment combination N_1P_2 recorded the maximum N uptake. The treatment combination N_1K_2 registered significantly higher N uptake but was on par with

Table 28

Uptake of nitrogen (kg/ha)

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	26.00	35.84	37.11	32.98
25	34.96	44.59	45.15	41.57
50	35.46	58.71	45.59	46.59
K_2O kg/ha				
0	26.38	39.48	39.03	34.97
20	34.84	47.79	48.95	43.86
40	35.19	51.86	39.87	42.31
Mean	32.14	46.38	42.62	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	27.68	37.11	40.11	34.97
20	35.78	44.82	50.98	43.86
40	35.48	42.76	48.67	42.31
Mean	32.98	41.57	46.59	

C.D. (0.05) for marginal means = 2.627

C.D. (0.05) for combination = 4.550

N_1K_1 and N_2K_1.

(b) Uptake of phosphorus.

The mean values are presented in Table 21 and the analysis of variance table in Appendix X.

Increasing doses of nitrogen registered significant increase in phosphorus uptake.

Application of phosphorus and potassium significantly increased phosphorus uptake over control but the effects of the lower levels of these nutrients were on par with their higher levels.

The interactions NxP, NxK and PxK also showed significance in the uptake of phosphorus. The treatment combination N_2P_1 registered the maximum uptake of P which was on par with N_2P_2. The treatment combination N_2K_1 resulted in a significantly higher uptake of P over other combinations of nitrogen and potassium. The effects of the treatment combinations P_1K_2 and P_2K_1 were found to be on par but superior to other combinations.

(c) Uptake of potassium.

The mean values are given in Table 22 and the analysis of variance table in Appendix X.

Table 21

Uptake of phosphorus (kg/ha)

	N kg/ha			
P_2O_5 kg/ha	0	15	30	Mean
0	4.38	6.59	6.46	5.81
25	7.88	7.85	8.90	8.21
50	7.31	8.30	8.76	8.12
K_2O kg/ha				
0	5.58	6.72	7.26	6.52
20	6.50	8.13	8.84	7.82
40	7.49	7.89	8.02	7.80
Mean	6.53	7.58	8.04	

	P_2O_5 kg/ha			
K_2O kg/ha	0	25	50	Mean
0	6.53	7.24	7.79	6.52
20	6.16	8.24	9.07	7.82
40	6.73	9.14	7.52	7.80
Mean	5.81	8.21	8.12	

C.D. (0.05) for marginal means = 0.129
C.D. (0.05) for combination = 0.223

Table 22

Uptake of potassium (kg/ha)

	N kg/ha			
P_2O_5 kg/ha	0	15	30	Mean
0	16.55	21.74	21.62	19.97
25	22.93	30.30	31.69	28.30
50	20.53	34.26	32.07	28.96
K_2O kg/ha				
0	16.95	25.95	26.66	23.19
20	21.05	30.23	29.93	27.07
40	22.01	30.11	28.79	26.97
Mean	20.00	28.77	28.46	

	P_2O_5 kg/ha			
K_2O kg/ha	0	25	50	Mean
0	16.24	26.06	27.26	23.19
20	20.64	28.87	31.70	27.07
40	23.02	29.98	27.90	26.97
Mean	19.97	28.30	28.96	

C.D. (0.05) for marginal means = 1.443

C.D. (0.05) for combination = 2.499

Nitrogen application significantly increased uptake of potassium over control but N_1 and N_2 were on par.

Treatments P_1 and P_2 were on par both being superior to control.

Potassium also showed a similar trend as that of nitrogen and phosphorus.

Among interactions, NxP and PxK were found significant with respect to uptake of potassium. The treatment combination N_1P_2 recorded the maximum uptake of potassium which was on par with N_2P_2. The effects of the treatment combinations P_1K_2 and P_2K_1 were on par but registered significantly higher uptake of potassium over other combinations of phosphorus and potassium.

V. Soil analysis

(a) <u>Total nitrogen content of the soil after the experiment.</u>

The mean values are presented in Table 23 and the analysis of variance table in Appendix XI.

Significant increase in the total nitrogen content of the soil was obtained at N_2 level while the lower level and control were on par.

Table 23

Total nitrogen content of the soil after the experiment (kg/ha)

	N kg/ha			
P_2O_5 kg/ha	0	15	30	Mean
0	2159.33	2285.33	2352.00	2265.55
25	2285.33	2310.00	2520.00	2371.78
50	2159.33	2116.66	2268.00	2181.33
K_2O kg/ha				
0	2226.00	2100.00	2436.00	2254.00
20	2320.00	2452.66	2352.00	2374.89
40	2058.00	2159.33	2352.00	2189.78
Mean	2201.33	2237.33	2380.00	

	P_2O_5 kg/ha			
K_2O kg/ha	0	25	50	Mean
0	2184.00	2436.00	2142.00	2254.00
20	2453.33	2453.33	2218.00	2374.89
40	2159.33	2226.00	2184.00	2189.78
Mean	2265.55	2371.78	2181.33	

C.D.(0.05) for marginal means = 44.008

C.D.(0.05) for combination = 76.225

Treatment P_1 significantly increased the total nitrogen content of the soil over control. Total nitrogen content decreased at the higher level of P application.

Potassium also showed the same in line with phosphorus.

The interactions NxP, NxK and PxK were also found to be significant. The treatment combination N_2P_1 recorded the maximum nitrogen content of the soil after the experiment. The treatment combination N_1K_1 recorded significantly higher nitrogen content but was on par with N_2K_0. The treatment combination P_1K_1 registered significantly higher soil nitrogen content which was on par with P_0K_1 and P_1K_0.

(b) <u>Available phosphorus content of the soil after the experiment.</u>

The mean values are presented in Table 24 and the analysis of variance table in Appendix XI.

The effect of nitrogen in increasing the available phosphorus status of the soil was noticed only upto 15 kg N/ha.

Similarly the lower level of phosphorus (25 kg P_2O_5/ha) showed significant increase in available phosphorus content

Table 24

Available phosphorus content of the soil after the experiment (kg/ha)

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	52.26	54.29	60.65	55.74
25	53.62	65.83	65.49	61.64
50	53.58	62.78	56.24	57.53
K_2O kg/ha				
0	54.55	61.42	60.82	58.93
20	50.39	60.66	62.86	57.97
40	54.51	60.82	58.70	58.01
Mean	53.15	60.97	60.79	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	56.07	60.91	59.81	58.93
20	58.79	60.74	54.38	57.97
40	52.34	63.28	58.41	58.01
Mean	55.74	61.64	57.53	

C.D. (0.05) for marginal means = 2.527
C.D. (0.05) for combination = 4.377

Table 25

Available potassium content of the soil after the experiment (kg/ha)

P_2O_5 kg/ha	N kg/ha 0	15	30	Mean
0	135.53	135.37	136.47	135.79
25	135.93	135.67	142.00	137.87
50	115.40	139.33	144.67	133.13
K_2O kg/ha				
0	115.20	132.70	129.93	125.94
20	132.53	135.47	148.47	138.82
40	139.13	142.20	144.73	142.02
Mean	128.96	136.79	141.04	

K_2O kg/ha	P_2O_5 kg/ha 0	25	50	Mean
0	120.97	135.00	121.87	125.94
20	142.60	133.60	140.27	138.82
40	143.80	145.00	137.27	142.02
Mean	135.79	137.87	133.13	

C.D. (0.05) for marginal means = 5.675
C.D. (0.05) for combination = 9.830

of the soil as compared to control. But the available phosphorus content decreased by the application of 50 kg P_2O_5/ha.

The effect of potassium was not significant in influencing the available phosphorus status of soil.

The interactions NxP and PxK were significant in this respect. The treatment combination N_1P_1 recorded the maximum available phosphorus content of the soil which was on par with N_1P_2 and N_2P_1. The treatment combinations P_1K_0, P_1K_1, P_1K_2 and P_2K_0 were on par but significantly superior to other combinations of phosphorus and potassium.

(c) Available potassium content of the soil after the experiment.

The mean values are presented in Table 25 and the analysis of variance table in Appendix XI.

Significant effect on the available potassium content of the soil after the experiment was revealed only in the case of nitrogen and potassium application. The effects of lower levels of nitrogen and potassium were on par with their higher levels in this respect but superior to control.

Although the effect of NxP interaction was significant, the effects of all the different combinations of NxP were on par except N_0P_2 which registered significantly lower available potassium content in the soil. The treatment combinations P_0K_1, P_0K_2, P_1K_2, P_2K_1 and P_2K_2 were on par but registered significant increase in available potassium content in the soil over other combinations of phosphorus and potassium.

VI. Correlation studies

Correlation study was conducted between grain yield and yield attributes, grain yield and uptake of nutrients, protein content of grain and that of bhusa and also between total dry matter production and uptake of nutrients. The correlation coefficients are given in Table 26.

Grain yield was significantly and positively correlated with number of pods per plant, number of seeds per pod, hundred seed weight and uptake of nitrogen, phosphorus and potassium and the correlation coefficients were 0.6101, 0.2739, 0.4080, 0.8540, 0.4751 and 0.7579 respectively.

Protein content of the grain was positively and significantly correlated with the protein content of bhusa and 'r' value was 0.8553.

Table 26

Values of simple correlation coefficients

Sl. No.	Characters correlated	Correlation coefficients
1.	Grain yield x Number of pods per plant	0.6101**
2.	Grain yield x Number of seeds per pod	0.2739*
3.	Grain yield x Length of pod	0.2090NS
4.	Grain yield x Hundred seed weight	0.4080**
5.	Grain yield x Nitrogen uptake	0.8540**
6.	Grain yield x Phosphorus uptake	0.4751**
7.	Grain yield x Potassium uptake	0.7579**
8.	Protein content of the grain x Protein content of the bhusa	0.8553**
9.	Total dry matter yield x Nitrogen uptake	0.7357*
10.	Total dry matter yield x Phosphorus uptake	0.8830*
11.	Total dry matter yield x Potassium uptake	0.8360**

* Significant at 0.05 level

** Significant at 0.01 level

NS-Not significant

Total dry matter yield of the crop was positively and significantly correlated with nitrogen, phosphorus and potassium uptake and the values were 0.7357, 0.8830 and 0.8360 respectively.

VII. Response surface and standardization of fertilizer response

The fitted quadratic response surface is as follows:

$$Y = 469.4840 + 12.9897\,N + 13.2480\,P + 20.4369\,K - 0.4105\,N^2 - 0.2046\,P^2 - 0.3986\,K^2 + 0.1152\,NP - 0.4060\,NK - 0.7780\,PK.$$

The mathematical and economic optimum doses worked out are given in Table 27.

Table 27

Optimum doses of nitrogen, phosphorus and potassium

Items	Price Rs./kg	Mathematical optimum dose kg/ha	Economic optimum dose kg/ha
Grain	4.00		
N	4.90	19.50	19.38
P_2O_5	5.60	33.87	33.70
K_2O	2.00	21.68	21.67

Discussion

DISCUSSION

The results obtained from the present investigation are discussed below.

I. Growth characters

(a) Height of plant.

The results (Table 2) revealed that the height of plant increased with increasing levels of nitrogen application. Significant increase in plant height was obtained on 60th day and at harvest. On 60th day nitrogen at 30 kg/ha produced the tallest plant. The effects of two levels of nitrogen (15 and 30 kg/ha) though significant at harvest, were on par. The influence of nitrogen in promoting vegetative growth of plants is a well established phenomenon which needs no further explanation. The effect of nitrogen in increasing the plant height at harvest was less significant as compared to early stages. This might be due to the lesser rate of vegetative growth in the later stages of crop growth which failed in giving a higher response to the highest level of nitrogen at this stage. Similar increase in plant height by nitrogen nutrition have been reported by Bhattacharya (1971) in horsegram, Panda (1972) in Pusa Baisakhi mung and Lanka and Satpathy (1976) in pigeon pea.

The effect of phosphorus was also significant in increasing the plant height. In the earlier stages of observation such as that of 40th day, maximum height was observed in the plants receiving the highest dose of phosphorus. But in the later stages the effect of phosphorus application was significant only upto 25 kg P_2O_5/ha. As regards the response of crops to phosphorus, it is well known that the best response is obtained in the early stages of growth which decreases gradually with the approach of maturity (Black, 1968). In the later stages as more of phosphorus has been utilised in grain production its effect on vegetative growth was not manifested. Increase in plant height by phosphorus application on various crops such as horsegram, field pea, blackgram, pigeon pea and redgram have been reported by Bhattacharya (1971), Singh et al. (1980), Shrivastava et al. (1980), Singh et al. (1981) and Subbian and Ramiah (1982) respectively.

Incremental doses of potassium also showed significant influence on the growth of plant. In the early stages of growth the effects of the treatments 20 and 40 kg K_2O/ha were on par but superior to control. On 40th and 60th days height of the plant was increased by the application of potassium upto 40 kg K_2O/ha. At harvest there was no significant difference between the treatments. It is well known that the nutrient potassium promotes the growth of meristematic tissue (Tisdale and Nelson, 1975). But in the earlier stages of growth a low level of potassium proved sufficient for optimum growth. In the later stages potassium might have been utilised to a large extent for grain formation and hence no significant effect on plant height was exhibited. Similar response of groundnut to potassium application has been reported by Nair (1978).

The interactions NxP, NxK and PxK showed significance only on 40th and 60th days after sowing which might be due to the additive effect of the individual nutrients.

(b) Number of functional leaves per plant.

The results (Table 3) clearly revealed the significant influence of nitrogen on number of functional leaves per plant at all stages of crop growth. The highest level of nitrogen resulted in maximum number of functional leaves per plant. Nitrogen being on important constituent of chlorophyll has a pivotal role in the production of more number of leaves in plants. Similar positive response to nitrogen application has been reported by earlier workers like Minchin et al. (1981) and George (1981) in cowpea.

The effect of phosphorus was also significant in this respect at all growth stages. In general the treatment receiving 25 kg P_2O_5/ha resulted in maximum number of leaves per plant. In the present investigation the dose of 25 kg P_2O_5/ha might have been sufficient for the normal growth and leaf production in horsegram. This is in agreement with the findings of Singh et al. (1980) in field pea.

Number of functional leaves per plant was significantly influenced by potassium application at all stages of crop growth. Application of 20 kg K_2O/ha was found superior on 20th and 60th days after sowing while 40 kg K_2O/ha produced maximum number of leaves on 40th day. In the later stages of growth much of the nutrient might have been translocated to the grains which resulted in the non-significant effect of potassium on the leaf number at harvest. Increase in the number of leaves by potassium nutrition has been reported by Nair (1978) in groundnut.

As regards the interactions, NxP interaction showed significant effect at all stages except at harvest. This might be due to the cumulative effect of the individual nutrients, nitrogen and phosphorus. NxK interaction showed significant response only on 60th day. It can be seen that there was positive response to the application of both nitrogen and potassium on 60th day. This might have resulted in the significance of NxK interaction also at this stage. At other stages, eventhough nitrogen showed significant response, the lack of response of potassium might have resulted in the non-significant effect of NxK interaction.

(c) Leaf Area Index.

The results (Table 4) clearly showed the significant influence of increasing levels of nitrogen on leaf area index at all stages except on 20th day when LAI was the highest at lower level of N application. According to Russel (1973) as nitrogen supply increases, the extra protein produced allows the plant leaves to grow larger and hence to have larger surface area available for photosynthesis. For many crops, the amount of leaf area available for photosynthesis is roughly proportional to the amount of nitrogen supplied (Russel, 1973). Increase in leaf area index might also be due to an increase in the number of leaves as already discussed. The importance of nitrogen as a factor in influencing leaf area index has been reported by George(1981) in cowpea.

The effect of phosphorus in increasing leaf area index was significant at all growth stages. The highest leaf area index was noticed in the treatment receiving 25 kg P_2O_5/ha on 20th day and at harvest while on 40th and 60th days the highest leaf area index was noticed at the highest level of phosphorus application. Phosphorus is known to develop a more extensive root system and thus enables the plants to extract water and nutrients from deeper depths (Arnon, 1955) which in turn might have contributed for higher leaf area index. The pronounced effect of applied phosphorus on leaf area index in greengram var. M-2 and redgram have been reported by Bhaskar (1979) and Vasimalai and Subramonian (1980) respectively.

Potassium also exerted significant influence on this character at all growth stages except at harvest. The treatment receiving 40 kg K_2O/ha proved to be superior in this growth attribute. Watson (1947) pointed out that potassium increases the size of leaves in early part of growing season though this effect had disappeared at harvest.

The interactions NxP and PxK were also significant in influencing leaf area index at all stages whereas NxP interaction was significant at all stages except at harvest. The significant effects of the interactions at all stages might be due to the cumulative effect of these individual nutrients as discussed earlier. The lack of response of NxK interaction at harvest might be due to the fact that most of the potassium absorbed by the plant at this stage might have been utilised for grain formation rather than for vegetative growth.

(d) Number of branches per plant.

The number of branches per plant (Table 5) was significantly increased by the application of increasing rates of nitrogen upto 30 kg N/ha. Significant influence of nitrogen application on number of branches per plant in horsegram, Pusa Baisakhi mung and pigeon pea have been reported by Bhattacharya (1971), Panda (1972) and Lanka and Satpathy (1976) respectively.

Significant increase in the number of branches per plant was also observed by the application of phosphorus upto the highest level tried in the experiment. Similar response to phosphorus application in horsegram, Pusa Baisakhi mung, broadbeans, field pea and redgram has been obtained by Bhattacharya (1971), Panda (1972), Bhaskar (1979), Singh et al. (1980) and Subbian and Ramiah (1982) respectively.

Increasing levels of potassium upto 40 kg K_2O/ha significantly increased the number of branches. This might be due to the favourable effect of potassium in increasing meristematic activity, maintaining adequate water relations etc. helping better plant growth including branching.

The interactions NxP, NxK and PxK were also found to have significant influence on the number of branches.

This could be due to the cumulative effect of these individual nutrients.

(e) Number of nodules per plant.

The data presented in Table 6 showed that the number of nodules per plant was significantly increased by nitrogen application at 15 kg N/ha. But higher dose of nitrogen (30 kg/ha) reduced the number of nodules. Increase in number of nodules by the application of a lower dose of nitrogen shows the importance of giving a starter dose of nitrogen for effective nodulation in horsegram. Similar findings were earlier reported by Singh (1970) in gram and Minchin et al. (1981) in cowpea. Reduction in nodule number by the application of higher dose of nitrogen might be due to the sluggish activity of nitrogen fixing bacteria when provided with readily assmilable nitrogen. Similar results were reported by Muthuswamy (1973), Jayadevan and Sreedharan (1975) and Punnoose and George (1975) in groundnut, Sundaram et al. (1979) in blackgram and Miller et al. (1982) in cowpea.

Significant increase in nodule number by the application of 25 kg P_2O_5/ha reveals the need of phosphorus nutrition for proper nodulation in pulses as evidenced from the studies of Sinha (1971) in gram, Sahu (1973) in horsegram and blackgram, Yadava and Singh (1978) in greengram, George (1980) and Shrivastava (1980) in blackgram and Singh et al. (1981) and Ahlawat and Saraf (1982) in pigeon pea.

Potassium also had significant influence on the nodule number. The effects of two levels of potassium (20 and 40 kg K_2O/ha) were on par in this respect which shows the adequacy of a lower dose of potassium for increased nodule formation in horsegram.

The nodule number was significantly influenced by the interactions NxP, NxK and PxK which suggests the necessity for balanced use of these nutrients for proper nodulation. Significant increase in nodule number by the combined application of nitrogen and phosphorus has been reported by Singh et al. (1973) in *Cicer arietinum*. The favourable influence of PxK interaction on nodule number was also evident from the experiments conducted by Bebin and Ignatenko (1967) in soybean and Muthuswamy (1973) in groundnut.

(f) Dry weight of nodules per plant.

It is evident from Table 7 that nitrogen application had significant influence on dry weight of nodules per plant upto 15 kg N/ha and the dry weight showed a declining trend by the application of a higher dose of nitrogen (30 kg/ha). This might again be due to the inefficient activity of nitrogen fixing bacteria when provided with readily assimilable form of nitrogen. Similar results in groundnut were reported by Jayadevan and Sreedharan (1975) and Punnoose and George (1975) on the basis of their studies conducted in the red loam soils of Vellayani.

The study revealed the significant influence of phosphorus nutrition in increasing the dry weight of nodules upto the highest level of phosphorus applied (50 kg P_2O_5/ha). The increased levels of phosphorus might have increased the activity of Rhizobia and thus the dry weight of nodules. This is in agreement with the findings of Sahu (1973) in horsegram and blackgram and Chowdhury et al. (1975) in gram.

Potassium also had significant influence on dry weight of nodules per plant upto the highest level tried in the experiment which stresses the importance of potassium nutrition for effective nitrogen fixation in horsegram.

As in the case of number of nodules per plant, the interactions NxP, NxK and PxK were found significant which might be due to the cumulative effect of these individual nutrients on this character.

II. Yield and yield attributes

(a) Number of pods per plant.

It is evident from Table 8 that nitrogen had no significant influence on number of pods per plant. Only a slight increase was observed by the application of 15 kg N/ha over control. This is in agreement with the findings of Panwar et al. (1977) and George (1980) in blackgram.

Significant increase (25.2 per cent over control) in pod number per plant was observed by the application of 25 kg P_2O_5/ha which was on par with 50 kg P_2O_5/ha. Similar response to phosphorus application has been obtained by Subramonian et al. (1977) and Ahlawat et al.

fuller expression of genetic potential.

Although the effect of phosphorus was not significant with respect to length of pod,for balanced fertilization 25 kg P_2O_5/ha is necessary as revealed from the present study.

The length of pod increased significantly by the application of potassium upto 20 kg K_2O/ha only. The pod length being a genetic character, potassium might not have exerted much influence on it.

The interactions NxP and NxK were also found to have significant influence on this character. Although phosphorus had no significant influence on length of pod, the effect became significant when applied in combination with nitrogen. The non-significant effect of PxK interaction might be due to the non-significant effect of phosphorus. Significant effects of NxP and NxK interactions reveal the importance of nitrogen fertilization along with phosphorus and potassium. Increase in length of pod with increasing levels of nitrogen and phosphorus has been reported by Panda (1972) in Pusa Baisakhi mung.

(c) Number of seeds per pod.

An appraisal of the Table 10 revealed that nitrogen had no significant effect on number of seeds per pod. This might be due to the non-significant effect of nitrogen on pod length as reported by George (1980) in blackgram. An increase in seed number was observed by the application of 15 kg N/ha.

Phosphorus and potassium at 25 kg P_2O_5 and 20 kg K_2O/ha significantly increased number of seeds per pod by 5.7 and 6.5 per cent respectively over control. Nitrogen application was helpful for increasing the pod length while phosphorus and potassium decided the seed number per pod. Such favourable influence of the lower level of phosphorus on seed number per pod has been reported by Subramonian et al. (1977) in cowpea and Singh et al. (1981) in pigeon pea.

The interactions NxP and PxK showed significant effects on the seed number per pod.

(d) Hundred seed weight.

It can be seen from Table 11 that only phosphorus and potassium application produced significant increase in hundred seed weight. Nitrogen decided the sink capacity. Further formation and filling of grains was under the influence of phosphorus and potassium. In this case also the lower levels of phosphorus and potassium were found superior. Similar response of cowpea and pigeon pea to phosphorus application has been reported by Ahlawat et al. (1979) and Singh et al. (1983) respectively.

Only NxP and PxK interactions were found significant with respect to this character.

(e) Grain yield.

The results (Table 12, Fig.3) indicated that grain yield was significantly increased by 19.3 per cent over control by the application of 15 kg N/ha. Further increase in nitrogen level registered a decrease in grain yield. Increase in number of pods per plant, length of pod, number of seeds per pod and hundred seed weight by the application of 15 kg N/ha had resulted in higher grain yield at this level of nitrogen application. Hence nitrogen application beyond 15 kg/ha was found ineffective in producing higher grain yields. Higher grain yields of gram, mung, pigeon pea, blackgram,

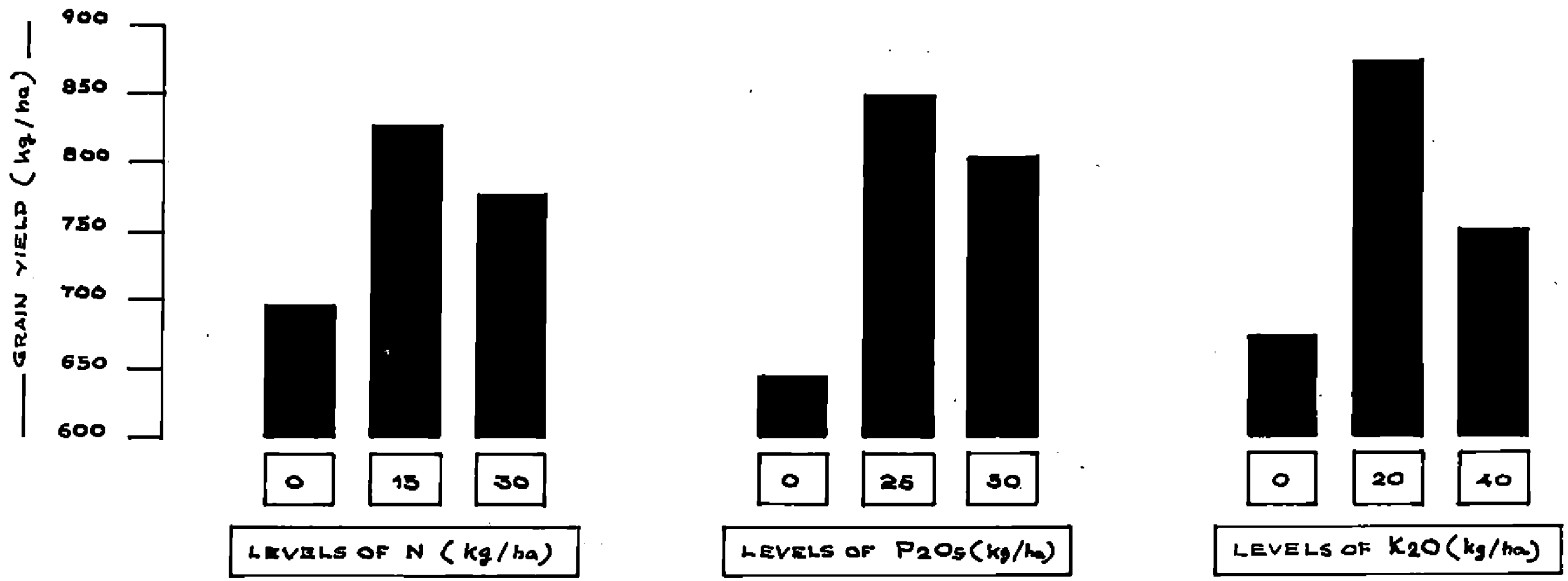

FIG: 3. EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM ON GRAIN YIELD (kg/ha) cowpea and chickpea were obtained by the application of a lower level of nitrogen by Singh (1970), Singh et al. (1975), Lanka and Satpathy (1976), Panwar et al. (1977), Kumar and Pillai (1979) and Khurana and Dudeja (1981) respectively.

Phosphorus application produced significant increase (32.4 per cent over control) in grain yield at 25 kg P_2O_5/ha but showed a declining trend at 50 kg P_2O_5/ha. The significant effect of 25 kg P_2O_5/ha on various yield attributes like pod number per plant, seed number per pod and hundred seed weight had resulted in the highest grain yield at this level. So phosphorus at 25 kg P_2O_5/ha is found to be sufficient for horsegram to produce higher yields. Similar results were obtained by Sahu (1973) in blackgram and horsegram, Venugopalan and Morachan (1974) in greengram, Singh et al. (1981) and Singh et al. (1983) in pigeon pea.

Potassium application also showed a similar trend as that of nitrogen and phosphorus and 20 kg K_2O/ha produced the highest yield (29.5 per cent increase over control). The cumulative effect of 20 kg K_2O/ha on various yield attributes like number of pods per plant, number of seeds per pod and hundred seed weight had significantly increased the seed yield at this level of potassium. Significant increase in grain yield by the application of potassium has been reported by Sharma et al. (1978) in gram and George (1980) in blackgram.

In the case of NxP, NxK and PxK interactions, the treatment combinations N_1P_1, N_1K_1 and P_1K_1 respectively were found significantly superior over other combinations. This might be due to the cumulative significant effects of lower levels of these individual nutrients.

It can be seen from Table 26 that grain yield showed significant and positive correlation with the yield attributes like number of pods per plant, number of seeds per pod and hundred seed weight. Similar high positive correlation between grain yield and yield attributes was recorded by George (1980) in blackgram.

(f) Bhusa yield.

It is evident from the Table 13 that bhusa yield registered significant increase upto the highest level of nitrogen tried. Significant increase in bhusa yield by the application of the highest level of nitrogen

(30 kg N/ha) might be due to the significant influence of this level of nitrogen on various growth characters like height, leaf number and branch number which have a direct correlation with bhusa yield.

It is found that the effects of lower and higher levels of phosphorus were on par in this respect. Singh et al. (1981) and Singh et al. (1983) had reported significant effect of a lower dose of phosphorus application on the stalk yield of pigeon pea, as observed in the present study.

The bhusa yield was significantly increased by the application of potassium upto the highest level tried in the experiment. The favourable effect of potassium application on growth characters had resulted in significant increase in bhusa yield at the highest level of potassium application.

The treatment combinations N_2P_1, N_2K_2 and P_2K_2 were found significantly superior in this respect which might be due to the cumulative effect of the favourable influence of these individual nutrients on bhusa yield.

(g) Total dry matter yield.

An appraisal of Table 14 and Fig.4 revealed that the total dry matter yield was significantly increased by nitrogen application at 15 kg/ha. But further increase in nitrogen had a depressing effect on total dry matter yield. In the present study, although application of 30 kg N/ha significantly increased many of the growth characters it showed a depressing effect on the yield and yield attributes. The nitrogen dose of 15 kg/ha produced significant in the yield and yield attributes and hence in the total dry matter yield.

Total dry matter yield was significantly increased by the application of a lower level of phosphorus (25 kg P_2O_5/ha) while a decreasing trend was shown with further increase in phosphorus level. Application of 25 kg P_2O_5/ha significantly increased many of the growth characters and the yield and yield attributes which ultimately resulted in higher total dry matter yield at this level. The favourable effect of phosphorus application on total dry matter yield has been reported by Rajendran et al. (1974) in blackgram, Venugopalan and Morachan (1974) in greengram, Sahu (1973) in black-

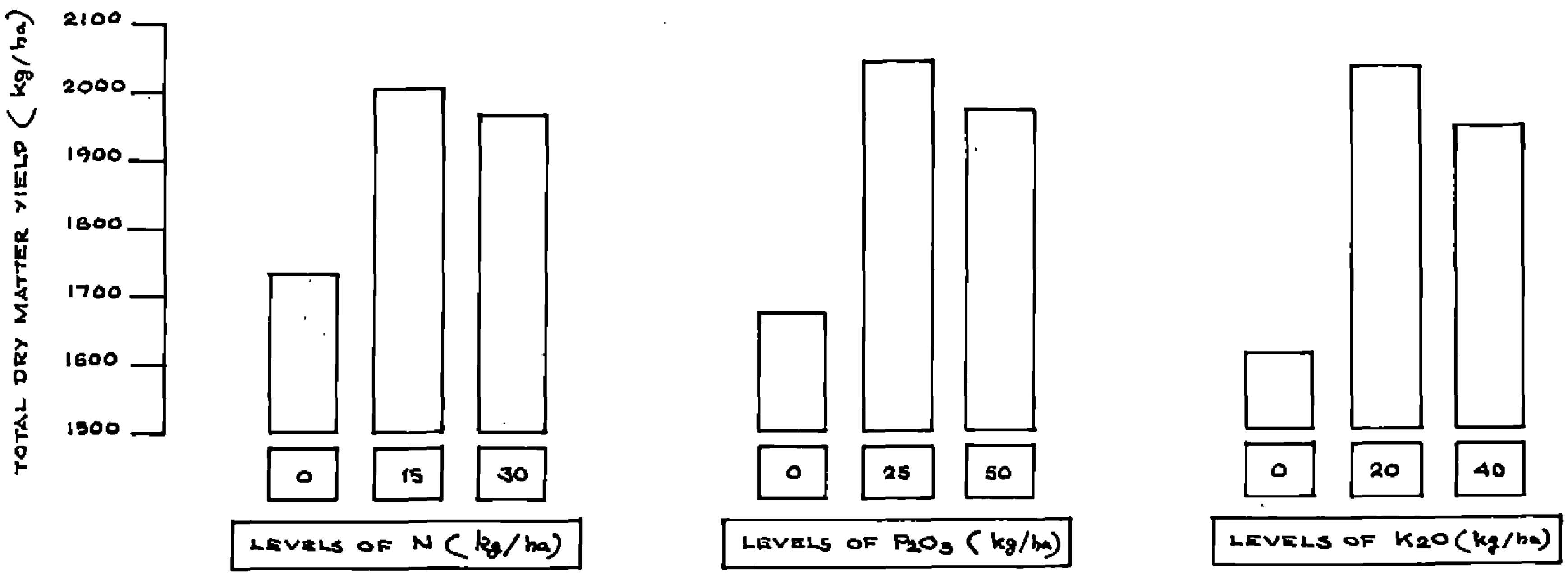

FIG: 4 EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM ON TOTAL DRY MATTER YIELD (kg/ha) gram and horsegram and Singh and Sharma (1980) in chickpea.

Potassium at 20 kg K_2O/ha recorded the highest dry matter yield. In this case also, the lower level of potassium (20 kg K_2O/ha) had significant effect on many of the growth characters and the yield and yield attributes. Improvement in total dry matter production by potassium application has been reported by Mitkees (1974) in snap bean and George (1980) in blackgram.

As in the case of grain yield and bhusa yield, the interactions NxP, NxK and PxK showed significant effect on total dry matter yield. The treatment combinations N_1P_1, N_1K_1 and P_2K_1 were found to be significantly superior. Increase in dry matter yield of Vigna unguiculata (L.) Walp. by the combined application of nitrogen, phosphorus and potassium has been reported by Touvin and Lencrerot (1977).

(h) Harvest index.

The data presented in Table 15 showed that harvest index increased significantly by the application of lower levels of nitrogen, phosphorus and potassium viz., 15 kg N/ha, 25 kg P_2O_5/ha and 20 kg K_2O/ha only. This might be due to the significant increase in grain yield by the application of the lower levels of nitrogen, phosphorus and potassium which clearly reveals the sufficiency of a lower level of nutrition for this crop.

The significant effects of the interactions NxP, NxK and PxK on harvest index might be due to the significant effects of these interactions on grain yield and total dry matter yield. In this case, the treatment combinations N_1P_1, N_1K_1 and P_1K_1 were found superior.

III. Quality characters

(a) Protein content of grain.

It can be seen from Table 16 and Fig.5 that increasing levels of nitrogen application significantly increased the protein content of grain upto the highest level tried. This might be due to the favourable effect of nitrogen on protein synthesis. Similar increase in seed protein content with increasing rates of nitrogen application has been reported by Punnoose and George (1974) in groundnut, Sader (1979) in *Phaseolus vulgaris* and Racca and Bodrero (1981) in soybean.

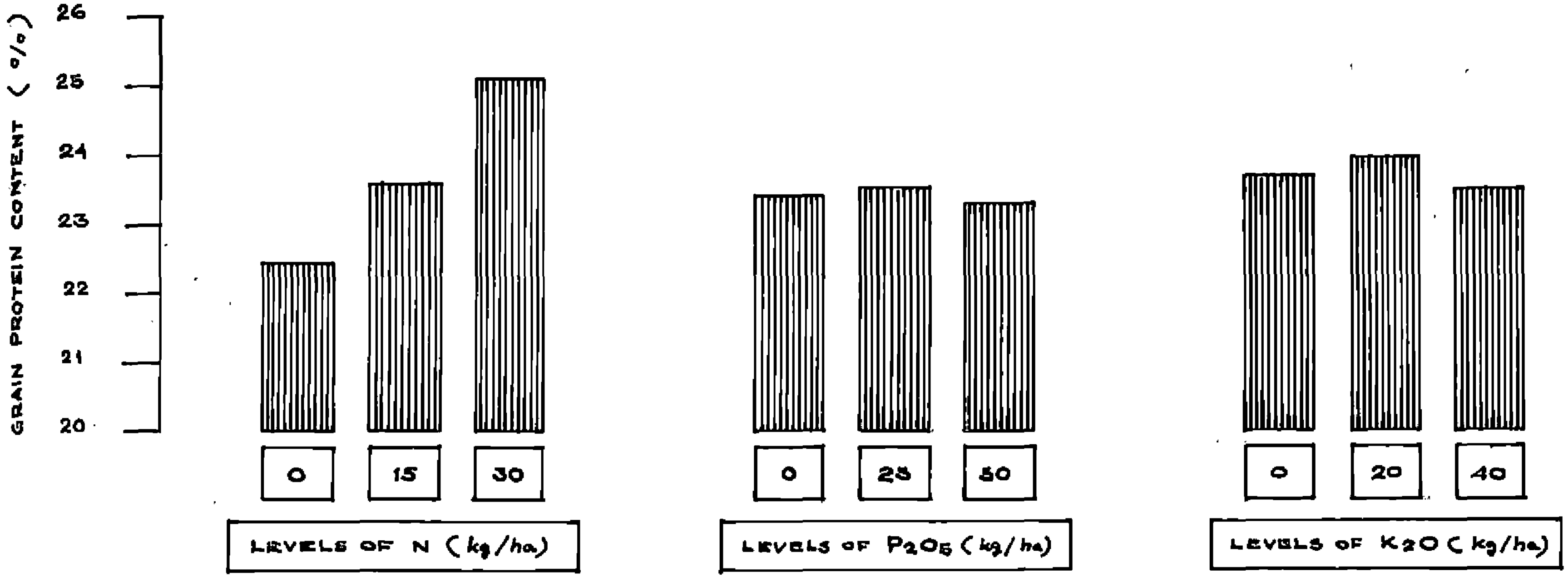

FIG: 5. EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM ON GRAIN PROTEIN CONTENT

Phosphorus at 50 kg P_2O_5/ha significantly increased the grain protein content. Uptake of nitrogen was more at 50 kg P_2O_5 (Table 20). It can be seen from Table 7 that increasing rates of phosphorus application resulted in greater nitrogen fixation thus making more nitrogen available to the plants thereby resulting in higher protein content in grain. This is in agreement with the findings of Punnoose and George (1974) and Jayadevan and Sreedharan (1975) in groundnut, Singh et al. (1975) in mung, Prasad and Sanoria (1981) in blackgram and Dwidevi and Singh (1982) in bengalgram.

The seed protein content was significantly increased by potassium application at 20 kg K_2O/ha which show that 20 kg K_2O was sufficient to give optimum protein content of seeds.

In this case also, significant effects of the interactions NxP, NxK and PxK were noticed. Higher protein content in the grains of cowpea and greengram by the combined application of nitrogen and phosphorus has been reported by Kurdikeri et al. (1973) and Yadava and Singh (1978) respectively.

(b) Grain protein yield.

It is evident from Table 17 that grain protein yield was significantly increased by nitrogen application. The effects of two levels of nitrogen tried (15 and 30 kg/ha) were on par. Although the grain protein content was significantly increased with increasing rates of nitrogen application (Table 16), the grain yield showed significant increase only upto 15 kg N/ha (Table 12) beyond which it decreased. This might have resulted in the non-significant difference in grain protein yield between the two levels of nitrogen.

The grain protein yield was significantly increased by phosphorus application. However, the effects of the two levels of phosphorus tried in the experiment were on par. Grain protein content was maximum at 50 kg P_2O_5 while grain yield was maximum at 25 kg P_2O_5/ha. Hence there was no significant increase in grain protein yield by increasing the rate of phosphorus application from 25 to 50 kg P_2O_5/ha.

Significant increase in grain protein yield was observed at 20 kg K_2O/ha and showed a declining trend at 40 kg K_2O/ha. It can be seen from Tables 12 and 16 that significant increases in grain yield and grain protein content were observed at 20 kg K_2O whereas at 40 kg K_2O/ha both these showed a decreasing trend.

The treatment combinations N_1P_1, N_1K_1 and P_2K_1 produced significantly higher protein yields over other combinations. This might be due to the cumulative effect of the significant influence of nitrogen, phosphorus and potassium on the grain protein yield.

(c) Protein content of bhusa.

The data presented in Table 18 indicates that nitrogen application significantly increased the bhusa protein content but the effects of 15 and 30 kg N/ha were on par. It is well known that nitrogen has a profound influence on protein synthesis.

Phosphorus application registered a significant increase in the protein content of bhusa. The effects of the two levels of phosphorus tried were on par in this respect. Phosphorus showed an increasing trend on nitrogen uptake (Table 20) which might have resulted in an increase in bhusa protein content at the highest level of phosphorus application.

Potassium at 20 kg K_2O/ha registered significant increase in bhusa protein content while it decreased at 40 kg K_2O/ha. This might be due to the lesser influence of potassium on this quality attribute.

As in the case of protein content of the grain, the bhusa protein content was also significantly influenced by the interactions NxP, NxK and PxK respectively.

(d) Bhusa protein yield.

The results (Table 19) showed that bhusa protein yield significantly increased with increasing levels of nitrogen application. This might be due to the increase in bhusa protein percentage (Table 18) and significant increase in bhusa yield (Table 13) with increasing levels of nitrogen application.

Phosphorus application produced a significant increase in bhusa protein yield at 25 kg P_2O_5/ha. In this case, significant increases in bhusa protein percentage and bhusa yield were noticed only at 25 kg P_2O_5/ha.

Potassium at 40 kg K_2O/ha registered significant increase in bhusa protein yield. Though the bhusa protein content reduced at the higher level of potassium application there was significant increase in bhusa yield with increasing rates of potassium.

In the case of NxP, NxK and PxK interactions, significant increase in bhusa protein yield was produced by the treatment combinations N_2P_1, N_1K_1 and P_2K_2 respectively.

IV. Uptake studies

(a) Uptake of nitrogen.

It can be seen from Table 20 that there was significant increase in the uptake of nitrogen only at 15 kg N/ha. At this level of nitrogen application, there was significant increase in the number and dry weight of nodules per plant which indicated that there was substantial fixation of nitrogen. Hence the application of nitrogen at this level supplied with the amount of nitrogen fixed symbiotically is adequate to produce higher yields of grain obtained in this treatment. So there was no substantial increase in nitrogen uptake at higher level of nitrogen application. This is in agreement with the findings of Dart and Mercer (1965) in cowpea, Sorensen and Pensas (1978) in soybean and George (1981) in cowpea.

Phosphorus application resulted in significant increase in nitrogen uptake upto the highest level (50 kg P_2O_5/ha). The favourable influence of increasing levels of phosphorus application on nitrogen uptake was revealed from the studies of Singh and Sharma (1980) in chickpea and Singh et al. (1981) in field pea.

Application of potassium significantly increased the uptake of nitrogen. But the effects of two levels of potassium tried were on par. The best dose of potassium for the maximum uptake of nitrogen is found to be 20 kg K_2O/ha which resulted in an increase in the total dry matter production and grain yield as seen in Tables 14 and 12 respectively.

The interactions NxP and NxK were found to be significant and the treatment combinations N_1P_2 and N_1K_1 were superior. Increase in nitrogen uptake by the application of nitrogen and phosphorus has been reported by Yadava and Singh (1978) in greengram and Gupta and Singh (1983) in bengalgram.

(b) Uptake of phosphorus.

The results (Table 21) show that increasing levels of nitrogen application significantly increased uptake of phosphorus. Similar positive influence of nitrogen in increasing the phosphorus uptake was reported by Sinha (1971) in gram.

Uptake of phosphorus significantly increased only upto 25 kg P_2O_5/ha. This might be due to the fact that at higher levels of phosphorus application, fixation of phosphorus in the soil reduces its availability. This is in agreement with the findings of Kumar et al. (1979) in cowpea and Subbian and Ramiah (1981 a) in redgram.

Potassium application at 20 kg K_2O/ha significantly increased phosphorus uptake. Increased phosphorus content in the leaves of groundnut by the application of potassium has been reported by Nakagawa et al. (1966).

The treatment combinations N_2P_1, N_2K_1 and P_1K_2 were found significantly superior over other combinations in influencing the phosphorus uptake by the crop.

(c) Uptake of potassium.

The results (Table 22) revealed that the uptake of potassium was significantly increased by the application of nitrogen only upto 15 kg/ha. This might be due to the possible blocking of potassium ions at higher concentrations of ammonium ions in the soil (Tisdale and Nelson, 1975).

Phosphorus application had significant effect on the uptake of potassium. But the effects of two levels tried (25 and 50 kg P_2O_5/ha) were on par. Significant increase in the uptake of all nutrients by phosphorus fertilization in pigeon pea has been reported by Hegde and Saraf (1982).

The potassium uptake of plants was significantly increased by the application of 20 kg K_2O/ha but was on par with 40 kg K_2O/ha. Enhanced uptake of potassium by potassic fertilization has been reported by Harishankar and Kushwaha (1971) in blackgram, Groneman (1974) in soybean and George (1980) in blackgram.

In the case of interactions, NxP and PxK were significant in this respect. The treatment combinations N_1P_2 and P_1K_2 were found to be significantly superior.

V. Soil analysis

(a) Total nitrogen content of the soil after the experiment.

The data presented in Table 23 revealed that the total nitrogen content of the soil after the experiment showed significant increase by the application of a higher level of nitrogen (30 kg N/ha). It can be seen from Table 20 that the uptake of nitrogen was not significant beyond 15 kg/ha. Hence there was significant increase in the total nitrogen content of the soil at the higher level of nitrogen.

The total nitrogen status of soil after the experiment was significantly increased by the application of a lower level of phosphorus (25 kg P_2O_5/ha) beyond which it showed a decreasing trend. Nitrogen uptake showed significant increase by the application of increasing doses of phosphorus. This might be the reason for the decline in total nitrogen status of the soil at the higher level of phosphorus. Increase in soil nitrogen content by phosphorus fertilisation has been reported by Khare and Rai (1968), Garg et al.(1970), Sahu and Behera (1972), Singh and Khatri (1972) and Singh (1983).

Potassium application at 20 kg K_2O/ha significantly increased the total nitrogen content of the soil. The content of total nitrogen, however, decreased with further increase in the potassium level. This might be due to the fact that the uptake of nitrogen increased when the potassium dose was increased from 20 to 40 kg K_2O/ha though not significantly.

The total nitrogen content of the soil after the experiment was significantly influenced by the interactions NxP, NxK and PxK which might be due to the significant influence of these individual nutrients.

(b) Available phosphorus content of the soil after the experiment.

It is evident from Table 24 that a lower level of nitrogen application increased the available phosphorus status of the soil. As nitrogen application increased, the uptake of phosphorus also increased (Table 21).

The available phosphorus status of the soil after the experiment was significantly increased only by 25 kg P_2O_5 and decreased at 50 kg P_2O_5/ha. This may be due to the fixation of phosphorus at higher levels of phosphorus application. Improvement in available phosphorus status of soil by phosphorus application has been reported by Singh and Khatri (1972), Sharma and Yadav (1976) and Singh (1983).

The interactions NxP and PxK were found significant in this respect and the treatment combinations N_1P_1 and P_1K_0 were found significantly superior. This might be due to the significant effects of nitrogen and phosphorus and non-significant effect of potassium on the available phosphorus status.

(c) Available potassium content of the soil after the experiment.

An appraisal of the Table 25 indicated that available potassium content of the soil after the experiment was significantly increased by the application of 15 kg nitrogen which was on par with 30 kg N/ha. Reduction in availability of potassium at higher levels nitrogen application might be the probable reason for the non-significant difference between the two levels of nitrogen tried.

Similarly potassium at 20 kg K_2O/ha significantly increased the available potassium content in the soil after the experiment. Application of potassium at

40 kg K_2O/ha did not register any significant increase in the available potassium content. This might be due to the fixation of potassium in the soil at higher levels of application. As a mobile cation, K^+ is also easily susceptible to the leaching loss.

The interactions NxP and NxK were significant in this respect. Though phosphorus had no significant effect on the available potassium content, the effect became significant when applied along with nitrogen.

VI. Response surface and economics of nitrogen, phosphorus and potassium application

(a) Response surface and standardization of fertilizer response.

Main effects of N, P and K and their interactions were found to have significant effect on the grain yield of horsegram. So the changes in the response(Yield) at graded doses of N, P and K are explained by the quadratic response surface fitted. It can be seen from Table 27 that the mathematical and the economic optimum doses worked out are almost equivalent. Generally we expect a lower dose for economic optimum compared to mathematical optimum.

(b) Economics of nitrogen, phosphorus and potassium application.

The economics of nitrogen, phosphorus and potassium application presented in Table 28 revealed that the combined application of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O/ha ($N_1P_1K_1$) gave the highest net profit (Rs.2449) followed by 15 kg N, 50 kg P_2O_5 and 20 kg K_2O/ha (Rs.2153.20). The increase in net profit by the application of $N_1P_1K_1$ over control was Rs.2099.90. Hence it can be stated that $N_1P_1K_1$ is the best combination of nitrogen, phosphorus and potassium to obtain maximum profit.

From these results, it can be concluded that a combination of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare is the most advantageous fertilizer dose for horsegram var. Pattambi local in the red loam soils of Vellayani.

Summary

SUMMARY

An investigation was undertaken in the Instructional Farm of the College of Agriculture, Vellayani during October-December, 1982 to find out the effect of graded doses of nitrogen (0, 15 and 30 kg/ha), phosphorus (0, 25 and 50 kg P_2O_5/ha) and potassium (0, 20 and 40 kg K_2O/ha) on growth, yield and quality of horsegram. The trial was conducted as a 3^3 confounded factorial experiment with two replications. The higher order interactions, NPK and NPK^2, were partially confounded in replication ~~and~~ I and replication II respectively. The results of the study are summarised below.

1. The height of plant was significantly increased by nitrogen application at later stages of crop growth. Application of phosphorus also showed significant effect on the height of plant at all stages except on 20th day. Similarly the plant height was significantly increased by potassium application at all stages of crop growth except at harvest.
2. Nitrogen and phosphorus had significant effects on number of functional loaves per plant at all

growth stages. Application of 30 kg N/ha produced more number of leaves at all stages except at the early stage. Potassium also showed its effect in increasing the leaf number at all stages except at harvest.

3. Nitrogen showed an increasing trend on leaf area index with increasing levels at all growth stages. Phosphorus also showed its superiority over control in increasing LAI at all growth stages. Potassium at 40 kg K_2O/ha significantly increased LAI at all stages except at harvest.

4. A linear trend in number of branches per plant was observed with increasing doses of nitrogen, phosphorus and potassium.

5. Application of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare gave a higher nodule count per plant.

6. Nitrogen at 15 kg, phosphorus at 50 kg P_2O_5 and potassium at 40 kg K_2O per hectare significantly increased the dry weight of nodules per plant.

7. Phosphorus at 25 kg P_2O_5 and potassium at 20 kg K_2O per hectare produced the highest number of

pods per plant, number of seeds per pod and hundred seed weight. Application of nitrogen did not show significant effect on these yield attributes.

8. Application of nitrogen at 15 kg was as effective as 30 kg/ha in producing longer pods. Phosphorus had no significant effect on this character. Potassium at 20 kg K_2O/ha showed significant increase in pod length over control.

9. Application of nitrogen at 15 kg/ha produced significant increase (19.3 per cent over control) in grain yield. Phosphorus at 25 kg P_2O_5 was as effective as 50 kg P_2O_5/ha in producing higher grain yield and it recorded 32.4 per cent increase over control. Potassium at 20 kg K_2O/ha was sufficient to produce higher grain yield (29.5 per cent increase over control). Combined application of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare gave the highest grain yield.

10. Nitrogen and potassium showed a linear trend in bhusa yield and bhusa protein yield. The significant positive response of phosphorus

was observed at 25 kg P_2O_5/ha in both the cases.

11. Application of nitrogen at 15 kg, phosphorus at 25 kg P_2O_5 and potassium at 20 kg K_2O per hectare produced significant increase in total dry matter yield, harvest index, grain protein yield and protein content of bhusa. The interactions NxP, NxK and PxK were also significant.

12. Grain protein content was significantly increased by higher levels of nitrogen and phosphorus. Potassium at 20 kg K_2O/ha recorded the highest grain protein content. The interactions NxP, NxK and PxK were also significant.

13. Uptake of nitrogen was enhanced by the application of 15 kg N, 50 kg P_2O_5 and 20 kg K_2O per hectare.

14. Higher levels of nitrogen (30 kg/ha) significantly increased phosphorus uptake. Phosphorus at 25 kg P_2O_5 and potassium at 20 kg K_2O per hectare gave the highest values for phosphorus uptake.

15. The effects of two levels each of nitrogen, phosphorus and potassium tried were on par in influencing the uptake of potassium but showed significant superiority over control.

16. Total nitrogen content of the soil significantly increased with increasing levels of nitrogen application. Application of phosphorus at 25 kg P_2O_5 and potassium at 20 kg K_2O per hectare resulted in higher total nitrogen content of the soil.

17. Available phosphorus content of the soil was significantly increased by the application of 15 kg N and 25 kg P_2O_5 per hectare. Potassium had no significant effect on this aspect.

18. The effects of lower levels of nitrogen and potassium were on par with their higher levels in increasing the available potassium content of the soil after the experiment while phosphorus application was not significant in this respect.

19. Correlation studies revealed that grain yield and yield attributes, grain yield and uptake of

nutrients, total dry matter yield and uptake of nutrients and protein contents of grain and bhusa were significantly and positively correlated.

20. Quadratic response surface was fitted and the economic optimum dose worked out was 19.38 kg N, 33.70 kg P_2O_5 and 21.67 kg K_2O per hectare.

21. The economics of fertilizer application worked out showed that maximum net profit (Rs.2449) was obtained by the combined application of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare.

The present investigation indicated that horsegram var. Pattambi local requires a fertilizer dose of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare in the red loam soils of Vellayani for giving the highest grain yield and maximum profit.

Future line of work

Trials may be conducted with other combinations of nitrogen, phosphorus and potassium over a wide range using high yielding varieties of this crop. Rhizobium-seed inoculation treatments may also be included to assess the growth and yield performance of horsegram along with the recommended dose of fertilizers.

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Originals not seen.

Appendices

APPENDIX I

Weather Data: Normal values for past 24 years (1956-1980)

Month	Temperature °C Maximum	Temperature °C Minimum	Rainfall (mm)	Relative Humidity (per cent)
January	30.93	22.46	34.62	79.88
February	31.34	22.87	36.00	82.05
March	32.17	24.00	35.06	81.36
April	32.27	25.02	89.16	83.29
May	31.75	24.92	197.70	85.07
June	30.42	23.95	292.20	85.13
July	29.72	23.46	220.90	87.18
August	29.77	23.22	138.63	86.02
September	30.12	23.36	150.28	85.77
October	29.70	23.76	264.14	87.41
November	29.91	23.81	208.05	86.97
December	30.66	23.26	71.85	84.78

APPENDIX II

Weather conditions during the crop period (8th October- 31st December, 1982)

Week No.	Dates	Average Temperature °C		Total Rainfall (mm)	Average Relative humidity (per cent)
		Maximum	Minimum		
41	Oct. 8 - Oct. 14	30.34	22.64	92.0	81
42	Oct.15 - Oct. 21	31.40	22.80	2.5	80
43	Oct.22 - Oct. 28	31.18	21.99	69.5	81
44	Oct.29 - Nov. 4	30.05	22.14	63.0	83
45	Nov. 5 - Nov. 11	31.31	22.40	3.0	84
46	Nov.12 - Nov. 18	31.46	22.53	43.5	79
47	Nov.19 - Nov. 25	31.38	22.79	-	77
48	Nov.26 - Dec. 2	30.87	22.26	26.0	85
49	Dec. 3 - Dec. 9	30.97	21.11	19.5	74
50	Dec.10 - Dec.16	31.41	20.49	-	93
51	Dec.17 - Dec.23	31.19	20.74	-	75
52	Dec.24 - Dec.31	31.93	22.76	-	54

APPENDIX III

Abstract of analysis of variance table for height of the plant at 4 stages

Source	df	Mean square			
		Height (cm) 20th day after sowing	Height (cm) 40th day after sowing	Height (cm) 60th day after sowing	Height (cm) at harvest
Block	5	1.586	51.560**	32.200	61.787
N	2	1.879	5.281	616.406**	392.656*
P	2	0.121	105.875**	434.187**	409.125*
N x P	4	1.756	26.344*	278.765**	187.984
K	2	5.791**	395.469**	348.999**	204.969
N x K	4	0.190	28.390*	103.234*	86.016
P x K	4	0.194	62.328**	173.125**	143.578
NPK F	2	1.588	30.215*	7.250	32.719
NP^2K	2	0.039	59.469**	109.344	71.875
NPK^2 F	2	0.271	19.141	77.906	33.750
NP^2K^2	2	1.537	13.500	17.187	83.999
Error	22	0.660	7.578	32.241	76.753

F Partially estimable

** Significant at 0.01 level

* Significant at 0.05 level

APPENDIX IV

Abstract of analysis of variance table for number of functional leaves per plant at 4 stages.

Source	df	Mean square			
		Number of leaves per plant 20th day after sowing	Number of leaves per plant 40th day after sowing	Number of leaves per plant 60th day after sowing.	Number of leaves per plant at harvest
Block	5	0.240	14.562**	1.558	0.792
N	2	1.501**	232.111**	177.305**	8.010**
P	2	1.102**	15.646*	37.854**	6.170**
N x P	4	0.715**	63.245**	50.764**	1.855
K	2	1.422**	44.354**	47.080**	0.926
N x K	4	0.380	7.196	29.531**	1.360
P x K	4	0.225	1.930	3.788	1.990
NPK F	2	0.049	18.367**	6.855	0.596
NP^2K	2	0.181	9.113	2.361	0.471
NPK^2 F	2	0.366	7.428	0.613	0.443
NP^2K^2	2	0.134	0.342	7.652	2.779*
Error	22	0.144	2.981	6.029	0.770

F Partially estimable

** Significant at 0.01 level

* Significant at 0.05 level.

APPENDIX V

Abstract of analysis of variance table for leaf area index at 4 stages

Source	df	Mean square			
		Leaf area index 20th day after sowing	Leaf area index 40th day after sowing	Leaf area index 60th day after sowing	Leaf area index at harvest
Block	5	0.0001	0.074**	0.093**	0.0010*
N	2	0.0060**	1.664**	1.676**	0.0090**
P	2	0.0010*	0.300**	0.183**	0.0110**
N x P	4	0.0010*	0.079**	0.177**	0.0100**
K	2	0.0040**	0.258**	0.174**	0.0001
N x K	4	0.0010**	0.190**	0.119**	0.0010
P x K	4	0.0040**	0.052*	0.030*	0.0020*
NPK F	2	0.0010**	0.082**	0.158**	0.0010
NP^2K	2	0.0010	0.028	0.092**	0.0004
NPK^2 F	2	0.0004**	0.088**	0.073**	0.0010
NP^2K^2	2	0.0040**	0.008	0.055**	0.0020*
Error	22	0.0001	0.012	0.009	0.0003

F Partially estimable
** Significant at 0.01 level
* Significant at 0.05 level

APPENDIX VI

Abstract of analysis of variance table for number of branches per plant, number of nodules per plant and dry weight of nodules per plant.

Source	df	Mean square		
		Number of branches per plant	Number of nodules per plant	Dry weight of nodules per plant(mg)
Block	5	0.384**	16.380*	11.682**
N	2	8.747**	267.322**	355.576**
P	2	1.664**	289.445**	879.019**
N x P	4	3.562**	44.043**	34.094**
K	2	1.057**	71.012**	139.404**
N x K	4	0.904**	23.182**	4.467*
P x K	4	0.370**	32.146**	20.266**
NPK F	2	0.738**	3.168*	1.695
NP^2K	2	0.057	40.422**	1.131
NPK^2 F	2	0.178	53.775**	4.439*
NP^2K^2	2	0.661**	15.912	8.260**
Error	22	0.067	4.602	1.129

F Partially estimable
** Significant at 0.01 level
* Significant at 0.05 level

APPENDIX VII

Abstract of analysis of variance table for number of pods per plant, length of pod, number of seeds per pod and hundred seed weight

Source	df	Mean square			
		Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Hundred seed weight (gm)
Block	5	8.525	0.025	0.241	0.019
N	2	1.438	0.532**	0.369	0.050
P	2	337.437**	0.046	0.481*	0.118*
N x P	4	21.813**	0.208*	0.365*	0.070*
K	2	92.500**	0.523**	0.729**	0.130*
N x K	4	27.531**	0.674**	0.161	0.021
P x K	4	63.625**	0.103	0.363*	0.110**
NPK F	2	4.400	0.267*	0.099	0.011
NP^2K	2	0.906	0.206	0.013	0.006
NPK^2F	2	4.291	0.130	0.299	0.016
NP^2K^2	2	19.625**	0.021	0.071	0.039
Error	22	3.687	0.073	0.122	0.025

F Partially estimable
** Significant at 0.01 level
* Significant at 0.05 level

APPENDIX VIII

Abstract of analysis of variance table for grain yield, bhusa yield, total dry matter yield and harvest index

Source	df	Mean square			
		Grain yield (kg/ha)	Bhusa yield (kg/ha)	Total dry matter yield (kg/ha)	Harvest index
Block	5	796.799	8508.793**	7974.397	0.0001
N	2	81639.968**	113023.940**	367063.840**	0.0004**
P	2	212567.840**	133447.930**	685431.360**	0.0041**
N x P	4	17063.984**	39427.968**	77867.952**	0.0015**
K	2	179599.840**	128519.910**	467311.360**	0.0023**
N x K	4	17571.968**	10747.995**	40495.984**	0.0008**
P x K	4	17495.984**	34059.968**	92403.968**	0.0010**
NPK F	2	3704.498*	5431.998**	45103.968**	0.0000
NP^2K	2	2463.998*	17455.984**	67991.968**	0.0019**
NPK^2 F	2	2713.997*	14095.993**	1743.998	0.0000
NP^2K^2	2	16439.981**	26887.968**	69295.952**	0.0009**
Error	22	687.045	596.363	3071.998	0.0001

F Partially estimable
** Significant at 0.01 level
* Significant at 0.05 level

APPENDIX IX

Abstract of analysis of variance table for protein content of grain, grain protein yield, protein content of bhusa and bhusa protein yield.

Source	df	Mean square			
		Protein content of grain (per cent)	Grain protein yield (kg/ha)	Protein content of bhusa (per cent)	Bhusa protein yield (kg/ha)
Block	5	0.448**	170.000**	0.832**	133.962**
N	2	32.320**	9945.997**	1.654**	917.062**
P	2	4.426**	13310.995**	1.566**	1142.094**
N x P	4	3.015**	1090.500**	0.506**	159.328**
K	2	1.232**	8021.498**	0.381**	733.062**
N x K	4	1.014**	789.000**	1.063**	77.547**
P x K	4	1.426**	2606.746**	1.320**	163.078**
NPK F	2	0.396*	598.187**	0.733**	125.219**
NP^2K	2	0.244	1501.499**	1.745**	208.375**
NPK^2 F	2	0.555**	92.594	0.874**	68.094**
NP^2K^2	2	1.441**	2121.997**	1.430**	211.281**
Error	22	0.087	38.065	0.027	5.628

F Partially estimable
** Significant at 0.01 level
* Significant at 0.05 level

APPENDIX X

Abstract of analysis of variance table for uptake of nitrogen, uptake of phosphorus and uptake of potassium.

Source	df	Mean square		
		Uptake of nitrogen (kg/ha)	Uptake of phosphorus (kg/ha)	Uptake of potassium (kg/ha)
Block	5	17.087	0.175**	2.545
N	2	980.375**	10.868**	445.453**
P	2	851.937**	33.392**	452.203**
N x P	4	127.125**	1.887**	33.449**
K	2	406.219**	10.010**	88.113**
N x K	4	81.719**	1.314**	3.616
P x K	4	6.438	3.673**	20.971**
NPK F	2	49.051	0.296**	36.652**
NP^2K	2	56.406*	1.384**	3.389
NPK^2 F	2	40.906	0.145*	6.021
NP^2K^2	2	45.344	0.810**	5.924
Error	22	14.501	0.035	4.375

F Partially estimable
** Significant at 0.01 level
* Significant at 0.05 level

APPENDIX XI

Abstract of analysis of variance table for total nitrogen, available phosphorus and available potassium content of the soil after the experiment.

Source	df	Mean square		
		Total nitrogen content of the soil (kg/ha)	Available phosphorus content of the soil (kg/ha)	Available potassium content of the soil (kg/ha)
Block	5	19609.596**	106.337**	16.462
N	2	160639.950**	358.687**	680.875**
P	2	163839.810**	165.250**	105.344
N x P	4	16575.984*	90.516**	428.140**
K	2	158975.880**	5.406	1308.000**
N x K	4	87423.952**	27.906	164.234
P x K	4	52735.952**	58.703**	249.781*
NPK F	2	105415.910**	94.094**	382.562*
NP^2K F	2	41855.952**	14.063	11.094
NPK^2 F	2	11743.993	10.687	19.219
NP^2K^2	2	151039.880**	5.406	89.781
Error	22	4069.086	13.415	67.676

F Partially estimable
** Significant at 0.01 level
* Significant at 0.05 level

NUTRITIONAL REQUIREMENT FOR HORSEGRAM

(*Dolichos biflorus* Roxb.)

BY

KUMARI SWADIJA. O

ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE
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DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
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1984

ABSTRACT

A field experiment was conducted at the College of Agriculture, Vellayani during 1982 to study the effect of three levels each of nitrogen (0, 15 and 30 kg/ha), phosphorus (0, 25 and 50 kg P_2O_5/ha) and potassium (0, 20 and 40 kg K_2O/ha) on growth, yield and quality of horsegram. The trial was conducted as a 3^3 partially confounded factorial experiment with two replications.

Application of nitrogen, phosphorus and potassium had profound influence on all growth characters like height of plant, number of functional leaves and branches per plant and leaf area index. The highest nodule count was obtained by the application of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare while the dry weight of nodules per plant was maximum at 15 kg N, 50 kg P_2O_5 and 40 kg K_2O per hectare.

Yield attributes such as number of pods per plant, number of seeds per pod and hundred seed weight were significantly increased by the application of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare while length of pod was significantly increased by the application of

15 kg N and 20 kg K_2O per hectare only. The highest grain yield, total dry matter production, harvest index and grain protein yield were obtained at 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare. Application of 30 kg N, 50 kg P_2O_5 and 20 kg K_2O per hectare resulted in the highest protein content of grain.

Application of nitrogen at 15 kg significantly increased nitrogen and potassium uptake while 30 kg N/ha recorded the highest phosphorus uptake. Similarly phosphorus at 25 kg P_2O_5 showed its superiority in increasing phosphorus and potassium uptake and 50 kg P_2O_5/ha registered the highest nitrogen uptake. Potassium at 20 kg K_2O/ha significantly increased the uptake of nitrogen, phosphorus and potassium.

Positive and significant correlations between grain yield and yield attributes, grain yield and nutrient uptake and total dry matter yield and nutrient uptake were noted.

The study indicated that application of 15 kg N, 25 kg P_2O_5 and 20 kg K_2O per hectare is the best fertilizer dose for horsegram var. Pattambi local which resulted in the highest net return in the red loam soils of Vellayani.