# NUTRITIONAL REQUIREMENT OF BLACK GRAM [*Vigna mungo* (L.) Hepper]



By

ANNAMMA GEORGE

THESIS

submitted in partial fulfilment of the
requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
Vellayani - Trivandrum

1980

## DECLARATION

I hereby declare that this thesis entitled "Nutritional requirement of black gram (*Vigna mungo* (L.) Hepper)" is a bona fide 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 any degree, diploma, associateship, fellowship or other similar title at any other University or Society.

A. George.
(Annamma George)



Vellayani,
28th February, 1980.

## CERTIFICATE

Certified that this thesis, entitled "Nutritional requirement of black gram (Vigna mungo (L.) Hepper) is a record of research work done independently by Smt. ANNAMMA GEORGE 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.

(K.P. MADHAVAN NAIR)

Chairman
Advisory Committee
Associate Professor of Agronomy

Vellayani,

February, 1983.

APPROVED BY:

CHAIRMAN:

Shri. [illegible] Madhavan Nair

Members:

1. Dr. C. Sreedharan

2. Dr. [illegible] Koshy 12.3.80

3. Prof. C.J. Thomas

## ACKNOWLEDGEMENT

It is my pleasant duty to express my deep sense of gratitude to my guide and Chairman Shri. K.P. Madhavan Nair, Associate Professor of Agronomy, for his patient guidance and enthusiastic encouragement without which it would not have been possible to undertake this study.

I would like to express my sincere thanks to Dr. C.Sreedharan, Professor of Agronomy for the constant encouragement he gave me in this study.

My thanks are due also to Prof. E.J. Thomas, Head, Department of Agricultural Statistics for his help in the planning of the experiment and the statistical interpretations of the data. My sincere thanks to Shri. V.K.G. Unnithan and Shri. M.P. Abdurazak, Assistant Professors in Agricultural Statistics, for their help in analysing the statistical data in the computer.

Dr. M.M.Koshy, Professor (Research Co-ordination) and Mr. M. Abdul Salam, Assistant Professor of Agronomy, helped me with the difficult work of correcting the proof. To them I offer my sincere thanks.

My deep sense of gratitude to Shri. Abdul Hameed, Assistant Professor of Agricultural Chemistry for his helpful suggestions in chemical analysis.

To all other staff members of the Department of Agronomy I express my thanks for their help in the conduct of the experiment.

I am grateful to Dr. N. Sadanandan, Dean, Faculty of Agriculture for providing all facilities for this study.

I am also grateful to the Kerala Agricultural University for the fellowship made available and for the two years leave granted to me for pursuing the M.Sc.(Ag.) course at the College of Agriculture.

ANNAMMA GEORGE

# C O N T E N T S

| | | Page |
|---|---|---|
| INTRODUCTION | ... | 1 |
| REVIEW OF LITERATURE | ... | 4 |
| MATERIALS AND METHODS | ... | 40 |
| RESULTS | ... | 51 |
| DISCUSSION | ... | 84 |
| SUMMARY | ... | 108 |
| REFERENCES | ... | i - xvi |
| APPENDICES | ... | I - IX |

# LIST OF TABLES


| Table No. | | | Page |
|---|---|---|---|
| 1. | Analysis of soil before starting the experiment. | ... | 41 |
| 2(a). | Height of the plant (cm) 15th day after sowing. | ... | 52 |
| 2(b). | Height of the plant (cm) 30th day after sowing. | ... | 52 |
| 2(c). | Height of the plant (cm) 45th day after sowing. | ... | 53 |
| 2(d). | Height of the plant (cm) 60th day after sowing. | ... | 53 |
| 2(e). | Height of the plant (cm) at harvest. | ... | 54 |
| 3(a). | Number of leaves per plant - 15th day after sowing. | ... | 56 |
| 3(b). | Number of leaves per plant - 30th day after sowing. | ... | 56 |
| 3(c). | Number of leaves per plant - 45th day after sowing. | ... | 57 |
| 3(d). | Number of leaves per plant - 60th day after sowing. | ... | 57 |
| 3(e). | Number of leaves per plant at harvest | ... | 58 |
| 4. | Number of branches per plant. | ... | 60 |
| 5. | Number of nodules per plant. | ... | 62 |
| 6. | Dry weight of nodules per plant. | ... | 62 |
| 7. | Number of pods per plant. | ... | 64 |
| 8. | Length of pod (cm) | ... | 64 |
| 9. | Number of seeds per pod | ... | 65 |
| 10. | Seed yield per plant (g) | ... | 65 |

| Table No. | | | Page |
|---|---|---|---|
| 11. | 100 seed weight(g). | ... | 67 |
| 12. | Grain yield (kg/ha). | ... | 69 |
| 13. | Bhusa yield (kg/ha). | ... | 69 |
| 14. | Harvest index. | ... | 70 |
| 15. | Total dry matter production (kg/ha). | ... | 70 |
| 16. | Uptake of nitrogen (kg/ha). | ... | 72 |
| 17. | Uptake of phosphorus (kg/ha). | ... | 72 |
| 18. | Uptake of potash (kg/ha) | ... | 74 |
| 19. | Protein content of grain (per cent) | ... | 76 |
| 20. | Grain protein yield (kg/ha) | ... | 76 |
| 21. | Protein content of bhusa (per cent) | ... | 78 |
| 22. | Fodder protein yield (kg/ha) | ... | 78 |
| 23. | Total nitrogen content of the soil after the experiment (kg/ha) | ... | 80 |
| 24. | Available phosphorus content of the soil after the experiment (kg/ha) | ... | 80 |
| 25. | Available potassium content of the soil after the experiment (kg/ha) | ... | 81 |
| 26. | Values of simple correlation coefficients. | ... | 83 |
| 27. | Economics of fertiliser application | ... | 107 |

## LIST OF ILLUSTRATIONS


Fig.1. Weather condition during the crop season and the average for the last five years.

Fig.2. Lay out plan.

Fig.3. Effect of N, P and K on height of plants at various growth stages.

Fig.4. Effect of N, P and K on number of leaves per plant at various growth stages.

Fig.5. Effect of N, P and K on number of branches per plant.

Fig.6. Effect of N, P and K on number of nodules per plant.

Fig.7. Effect of N, P and K on dry weight of nodules per plant.

Fig.8. Effect of N, P and K on number of pods per plant.

Fig.9. Effect of N, P and K on length of pod.

Fig.10. Effect of N, P and K on number of seeds per pod.

Fig.11. Effect of N, P and K on seed yield per plant.

Fig.12. Effect of N, P and K on 100 seed weight.

Fig.13. Effect of N, P and K on yield of grain and bhusa

Fig.14. Effect of N, P and K on total dry matter production.

Fig.15. Effect of N, P and K on nitrogen uptake.

Fig.16. Effect of N, P and K on phosphorus uptake.

Fig.17. Effect of N, P and K on potash uptake.

Fig.18. Effect of N, P and K on protein content of grain

Fig.19. Effect of N, P and K on protein content of bhusa.

Fig.20. Effect of N, P and K on grain protein yield.

Fig.21. Effect of N, P and K on fodder protein yield.

Fig.22. Response of potash on yield of grain.

# INTRODUCTION

# INTRODUCTION

Pulses, perhaps the richest source of vegetable protein are the dried seeds of several leguminous plants such as green gram, black gram, horse gram, red gram, bengal gram, cowpea etc. They contain about 24 to 30 per cent protein which is nearly three times as much as in cereals. According to Aykroyd and Doughty (1964) a balanced diet should contain 3 ounces of pulses per day per adult to meet the protein requirement. But the present production of pulses in India is only 11 million tonnes with a per hectare yield of 478 kg which is not at all sufficient as per the above standard. The area and production of pulses in Kerala are only 36.53 thousand hectares and 16.27 thousand tonnes respectively. This emphasizes the necessity for increasing the production of pulses.

Pulses have the unique built in mechanism for directly using the inexhaustible stock of atmospheric nitrogen. Every year in India these crops use some 12 lakh tonnes of atmospheric nitrogen worth Rs.250/- crores without any cost. These crops have been popular with farmers for centuries because they fit suitably in crop rotations and crop mixtures.

Black gram or urd (*Vigna mungo*), one of the most important and highly nutritious pulse crops, is of great commercial significance. It is widely grown in about 2 million hectares in India with a total production of 0.66 million tonnes.

It is consumed by all sections of the society in a variety of ways. It is of excellent quality and high digestability containing about 24 per cent protein. Its calorific value is 340/100 g. The bhusa, the husk and the small broken grains are used for feeding cattle. The crop is also grown for hay, green manure and cover crop. The average seed yield varies between 3 and 4 quintals per hectare but it is possible to increase the production of this crop to an extent of 15 quintals per hectare or even more by adopting scientific production technology.

One of the important reasons for the very low yield of black gram is due to the neglected manuring of this crop. The crop is deep rooted and has low awater requirement and relatively short duration. These special characters of the crop indicate its suitability in rice fallows during third crop season.

In Kerala there are about 2.73 lakh hectares of paddy fields remaining uncultivated during the third crop season due to many reasons. If this area can be fully utilised for raising a good pulse crop like black gram the pulse requirement of the State can be enhanced to a great extent.

Not much work has been done regarding the manurial requirement of black gram in rice fallows under Kerala condition and an investigation on this crop with the following objectives was undertaken.

1. To fix optimum doses of N, P and K for black gram grown in rice fallows during third crop season.

2. To find out the effect of major nutrients on growth and yield of black gram.

3. To study the uptake of N, P and K by the crop.

4. To assess the effect of N, P and K on quality of seeds.

5. To study the economics of production of black gram.

# REVIEW OF LITERATURE

## REVIEW OF LITERATURE

Black gram an important pulse crop is found to respond to the application of nitrogen, phosphorus and potash. Some of the works conducted in India and abroad on the influence of these nutrients on the growth yield, quality and nutrient uptake of this crop are briefly reviewed here. Since published work on the response of black gram to these nutrients are meagre it has become necessary to include works on similar legumes also in this review.

### A. Nitrogen

#### (a) Effect of nitrogen on growth

Pulses, like other plants, need ample supply of nitrogen for better growth. However the major part of this is met by Rhizobia present in the root nodules. But before the plants develop enough root nodules a starter dose of nitrogen is required to meet the requirements of the young seedlings.

Shukla (1964) reported that in gram (*Cicer arietinum* Linn.) the height of plants was very much influenced by application of nitrogen. The nitrogen application at the rate of 10 or 20 pounds per acre did not appreciably increase the number of branches in gram. In pot trials with soyabeans Dala (1970) reported that plant height was increased by application of nitrogen. Slobko (1970) observed that in soyabean high rates of nitrogen increased plant growth.

Bhattacharya (1971) found that in horse gram (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 per hectare. The effect of nitrogen has however been found to be more pronounced under lime dressed soil than under unlimed soil. In gram there was no significant difference between the control and 10 kg nitrogen per ha in respect of various characters studied like height and number of branches.

Panda (1972) reported that in Pusa Baisakhi Mung increasing level of nitrogen from 0 to 60 kg nitrogen per ha significantly increased plant height from 27.6 cm to 30.4 cm and branches per plant from 3.5 to 4.0 respectively. Hathcock (1975) reported no significant differences between nitrogen treatments (0, 8, 16 and 24 pounds per acre) for fresh weight, dry weight and plant height in soyabean.

Lenka and Satpathy (1976) observed that in pigeon pea application of 20 or 40 kg nitrogen per ha increased vegetative growth, height and number of branches per plant. Ratner (1977) in studies carried out for many years revealed that mineral nitrogen enhanced growth of leaves, root and stem in soybean, peas, broad bean, clover and vetches.

(b) Effect of nitrogen on nodulation

Mishra and Singh (1960) observed that in soyabean application of 60 kg N/ha had little effect on root length or nodule number per plant. Smith et al. (1966) observed that the number of nodules were not significantly affected by application of 0 to 600 lb N/ac. in soybean. Dobin and Ignatenko (1969) in trials with soybean reported that application of nitrogen at 10 to 30 kg N/ha decreased the root nodule number.

Sistachs (1970) reported that for black beans (<u>Phaseolus vulgaris</u>) nodulation was completely suppressed by N fertilizers at 90 kg N/ha except in plots inoculated with Azotobacter where 10 per cent of the plant bore active nodules. Toan (1970) from pot trial found that nodule formation in soybean was decreased by N.

Muthuswamy (1973) from the results of the pot culture experiment conducted at the Agricultural College and Research Institute, Coimbatore revealed that application of nitrogen 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 23.94 and 17.67 in 15 kg and 30 kg nitrogen per ha respectively at 45 days. Dubes and Neuberg (1973) in trials with pea observed that high rates of N (15, 60 kg N/ha) at early stages of growth inhibited nodulation.

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 N (10, 20 or 30 kg N). In a field trial with <u>Phaseolus vulgaris</u> N at higher rates (40 or 80 kg N/ha) suppressed the development of root nodules (Moinov and Pedlov, 1975). In a field trial at Vellayani Punnoose and George (1975) reported that in groundnut applied N ( at 0, 10 or 20 kg N/ha) reduced the mean number and dry weight of nodules at 2, 4 and 6 weeks after sowing. Ramamohana Rao and Mader (1975) reported that in soyabean maximum nodule was attained 67th day after sowing, thereafter the nodules declined in number through disintegration. Plants in control plot (no N) produced the largest number of nodules and the number decreased with increased N level at each stage of observation, the decrease being significant at 67 days after seeding. The number of nodules present in 60, 120 and 180 kg N/ha level worked out to be 90.5, 79.4 and 60.4 per cent of the control respectively. Fresh weight recorded at 52, 67 and 82 days after sowing also followed a similar pattern as nodule number.

Sewa Ram and Gajendra Giri (1975) in a field trial carried out at Agronomy Farm, IARI, on black gram (*Phaseolus mungo*) reported that nodulation was more under the treatment 25 kg N + 100 kg $P_2O_5$ and more than 32 nodules over control were found. In trials with *Cicer arietinum* application of N and P increased the number and dry weight of effective nodules/ plant upto 90 days after sowing (Singh *et al.*, 1975). Williamson and Diatloff (1975) in field trials with inoculated and uninoculated soyabean found that applied nitrogen ( 0 to 134 kg N/ha) decreased nodulation, the most severe effect being with inoculated soyabean.

In a field trial with beans (Phaseolus vulgaris) Papanicolaou et al. (1977) reported that nodule weight per plant decreased with increasing rate of applied N (0, 15, 30, 60 or 120 kg N/ha).

(c) Effect of nitrogen on yield and yield attributes

Moolani and Jana (1965) in the laterite soils of West Bengal observed reduction in yield of green gram by 9 per cent which received 25 kg nitrogen per hectare without phosphorus.

Jothmalani et al. (1969) revealed that inoculated crops of soyabean showed no response to nitrogen, the seed yields were not affected by nitrogen at 0, 22 or 44 kg nitrogen per hectare.

Horner and Mojtehedi (1970) in trials with chick pea, dry beans and cowpea found that nitrogen had no significant effect on yields. Hattribhop and Ferraris (1970) reported that applied nitrogen at 0 or 75 kg nitrogen per hectare increased seed yields, hay yields and total dry matter production in mung bean (Vigna radiata).

Malik et al. (1972) found that application of 20 to 40 kg nitrogen per ha on cowpea had no effect on yield and 100 seed weight.

In In Pusa-Baisakhi Mung increasing level of nitrogen significantly increased the yield of grain, average weight of seed per plant, and the highest yield obtained from 60 kg nitrogen per ha. But from the economic point of view the most profitable level of fertility for growing Pusa Baisakhi was 30 kg nitrogen per ha (Panda, 1972).

Prabhanjan *et al*. (1973) observed that for bengal gram nitrogen at 30 kg per ha resulted in higher number of branches, pods per plant, 100 grain weight and yield.

Venugopal and Morachan (1974) in trials with green gram reported that yield differences to the applied levels of nitrogen (0, 10, 20 and 30 kg nitrogen per ha) was found nonsignificant, nitrogen at higher levels of 20 and 30 kg per ha have increased the 1000 grain weight significantly in the variety Rajendran. Rajendran *et al*. (1974) reported that in black gram nitrogen at 60 kg per ha was superior to the remaining levels of 0 and 30 kg which were on par for seed yield.

Addy (1975) reported that application of nitrogen to cowpeas in the early wet season had no significant effect on seed yield. Johnson and Evans (1975) reported that yields of cowpea were highest at 67 kg nitrogen per ha. Sawhney *et al*. (1975) revealed that in blackgram nitrogen application increased yield significantly over control, the grain yield increased with increase in nitrogen up to 34 kg but the difference between 17 kg and 34 kg nitrogen per hectare levels were not significant.

Singh *et al*. (1975) in a field trial conducted with *mung* found that increased supply of nitrogen 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 level of nitrogen upto 20 kg per hectare whereas further increase in nitrogen level (30 kg nitrogen per hectare) showed significantly decreasing trend in respect of all the characters studied including grain production.

Lenka and Satpathy (1976) reported that in pigeon pea application of 20 kg nitrogen per ha only increased the grain yield by 190 kg per hectare, at 40 kg level its depressing effect on yield was observed. The response of sticks to nitrogen was linear. In trials with Phaseolus aureus (Vigna radiata) there was no response to the application of 15 to 30 kg nitrogen per ha (Panwar et al., 1976).

Jamoja Sharma (1977) reported that in cowpea application of 20 kg nitrogen per ha recorded significantly higher yield over no nitrogen. Mohammed Yaseen (1977) observed that arhar under rainfed condition showed trend of response in favour of application of 25 kg nitrogen per hectare along with inocula but the treatment differences were not statistically significant.

Panwar et al. (1977) in a field experiment on black gram showed that optimum dose of nitrogen was 15 kg nitrogen per ha which increased the grain yield by 13.4 per cent over control. The number of pods per plant was increased by nitrogen application at 15 kg per ha with no further improvement by additional dose.

Viswanathan et al. (1970) from trials carried out for three years on cowpea showed significant response to applied nitrogen. The yield recorded at 0, 20 and 40 kg nitrogen per ha were 664, 755 and 762 kg per ha. The difference between nitrogen at 20 kg and 40 kg was nonsignificant.

(d) Effect of nitrogen on protein

In field trials with soybean Costache and Nica (1968) reported that an increase in applied nitrogen usually increased protein content. Singh and Singh (1968) reported in soyabean that the protein in grain was significantly increased by 2.23 per cent due to the application of 10 kg N/ha.

Bains (1969) observed that nitrogen content of *Phaseolus vulgaris* increased with the rate of N fertilizer applied.

Singh et al. (1969) from an experiment on pea varieties carried out in the Agronomy farm of I.A.R.I. reported that the protein percentage in grains increased progressively with an increase in the level of nitrogen from 0-22 kg N/ha.

Costache (1970) found that in soyabean the average protein yield increased from 0.44 t/ha with no nitrogen to 0.82 t with 123 kg N/ha. Singh (1970) reported 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 on plots given no nitrogen.

Nabib *et al.* (1971) observed that in soyabean the protein content of seeds increased with increase in applied N (0, 10, 20 or 30 kg N/ha) especially in plants given no phosphorus.

Meera *et al.* (1972) reported that in soyabean applied nitrogen increased grain nitrogen and protein content. Malik *et al.* (1972) in a trial with cowpea reported that application of nitrogen and/or P had no effect on seed protein content.

Kesavan and Morachan (1973) reported that in soyabean protein content increased with increase in the rate of nitrogen. Kurdikeri *et al.* (1973) reported that higher doses of N, $P_2O_5$ or $K_2O$ did not influence protein content in cowpea.

Mleonita (1974) reported in *vicia faba* that protein yields were 0.68 t/ha without fertiliser 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. Seed protein content was 28.68 - 28.79 per cent. Punnoose and George (1974) observed that in groundnut the seed protein content increased with increasing rates of nitrogen (0, 10 or 20 kg N/ha). Rajendran *et al.* (1974) reported that in black gram the crude protein content of seed sample was found to vary 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.

Niklyaev (1975) in a field trial in Guinea with (a) *mung* (b) cowpea and (c) bean 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 $P_2O_5$ + 50 kg $K_2O$/ha.

Markus (1976) reported that in soyabean protein yield was increased by application of nitrogen, K or FYM.

Sorcean *et al.* (1977) reported that in peas the highest seed crude protein content of 28.2 per cent was obtained with 16 or 32 kg N/ha.

(e) Uptake of nitrogen

Dart and Mercer (1965) reported that in cowpea N uptake increased with levels of N applied.

Nekogarva *et al.* (1966) observed that in groundnut application of K increased the content of N in the leaves.

Field experiments conducted on cotton soils in Nagpur on groundnut revealed that application of $P_2O_5$ with N or alone was found to influence the uptake of nitrogen (Puntamkar and Bathkal, 1967). Shempel and Kukresh (1967) reported that in leguminous plants a combined application of P & K increased the nitrogen content more than P or K alone, K was more effective than P.

Singh and Jain (1960) in trials with cowpea reported that plant nitrogen content increased markedly with increase in rate of applied $P_2O_5$ upto 67 kg/ha and slightly with further increase to 100.5 kg/ha.

Daine (1969) reported increase in N content in plants with increase in the rate of applied nitrogen in beans.

Sasidhar and George (1972) reported that in CO-1 lab lab increasing rates of $P_2O_5$ (0, 25, 50 and 75 kg/ha) increased N content of pods and haulms. Sedov (1972) reported that in haricot bean (Phaseolus vulgaris) the nitrogen uptake by a crop yielding 2.45 t seed and 4.45 t D.M/ha was 128.2 kg N.

Kadue and Badhe (1973) reported from pot trials with Urd (Vigna mungo) that application of 50 kg $P_2O_5$ and/or 1-2 kg Mo per hectare increased plant uptake of nitrogen.

Rajendran and Krishnamoorthy (1975) from culture trials on blackgram reported that the uptake of N was significantly influenced by the levels of P in the shoot, seed and husks samples, where as in the seed sample alone nitrogen levels were significant. The uptake of nitrogen increases with increase in levels of P in all the samples. This is mainly due to the influence of applied P on the dry matter production. Ravankar and Badhe (1975) reported from pot experiments with urid, mung and soyabean that applied P increased N uptake by plant at different growth stages.

Chevalier (1976) in a field trial with soyabean 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. Kalyan Singh and Prasad (1976) reported from a field trial with pigeon pea that application of 100 kg $P_2O_5$/ha increased the N uptake significantly at harvest. Nitrogen uptake in grain at harvest was affected by the P application and the use of each successive dose of 25 kg $P_2O_5$ per ha increased the N uptake.

Georgiev (1977) in trials with groundnut reported that applied P promoted more intensive accumulation of nitrogen in the above ground parts.

B. Phosphorus

(a) Effect of phosphorus on growth characters

Deshpande and Bathkal (1965) observed significant increase in height on mung (Phaseolus aureus Roxb) with the application of 40 pound and 60 pound $P_2O_5$ per acre over control. The height increased from 21.5 cm in control to 25 cm and 26.2 cm in 40 and 60 lb $P_2O_5$ per acre respectively. There has been increase in number of branches with increasing levels of $P_2O_5$ from 3.57 in control to 3.95, 4.42 and 4.64 in 20, 40 and 60 pound $P_2O_5$ per acre respectively but the increase was not significant.

In pot experiments out of doors in southern pea (Vigna sinensis) it was found that plant growth increased significantly with increasing $P_2O_5$ (0, 25, 50, 100 and 200 pound per acre) (Stewart and Reed, 1969).

Bhattacharya (1971) reported that in horse gram (Dolichos biflorus) the vegetative growth of the crop in respect of length of vine, 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.

Panda (1972) observed that in Musa Baisakhi mung increasing the phosphorus increased the height from 28 cm in control to 28.5 cm and 29.2 cm in 30 and 60 kg $P_2O_5$ per ha respectively. At 90 kg $P_2O_5$ per ha the height was same as that in 60 kg $P_2O_5$ per ha treated plots. There has been increase in the number of branches with increasing levels of $P_2O_5$ from 3.5 in control to 3.7, 3.8 and 4.9 in 30, 60 and 90 kg $P_2O_5$ per ha respectively.

Kesavan and Morachan (1973) reported that in soyabean the levels of phosphoric acid (0, 50, 100 and 150 kg per ha) had significant negative influence on the plant height, successive addition of phosphoric acid gradually reduced the plant height but the difference was not significant.

Gill and Chopra (1976) reported that in summer mung there was no response to added phosphorus with respect to vegetative growth and plant height. Mahatanya (1976) reported that in bean plant (Phaseolus vulgaris) $P_2O_5$ treatment (30 or 60 kg $P_2O_5$ per ha) increased plant height.

Tarila et al. (1977) observed that in cowpea (Vigna unguiculata) increasing levels of applied phosphorus enhanced growth, flower and fruit number as well as leaf number.

Rollin Bhaskar (1979) observed that plant height and leaf area index of green gram variety M2 was significantly increased by application of phosphorus (0, 12.5, 25, 37.5 and 50 kg $P_2O_5$ per ha).

(b) Effect of phosphorus on nodulation

Deshpande and Bathkal (1965) in an experiment on *mung* been found that the number of nodules per plant significantly increased from 3.73 in control to 4.77 and 5.36 in 40 and 60 lb $P_2O_5$.

Bebin and Ignatenko (1969) in trials with soyabean 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.

Katti *et al.* (1970) in a field trial with 2 soyabean varieties reported that the number and weight of nodules per plant were higher when the crops were given 80 kg $P_2O_5$ per ha than when given no P.

Sinha (1971) reported that in gram (*Cicer arietinum*) P significantly increased number and dry weight of nodules and nitrogen fixation.

In pot trials with *urid* (*Vigna mungo*) and *mung* (*Vigna radiata*) Ravankar *et al.* (1972) reported that application rate of 120 kg $P_2O_5$/ha for urid and 80 kg $P_2O_5$/ha for mung were optimum for increasing nodulation and nitrogen fixation.

Muthuswamy (1973) from a pot culture experiment on groundnut revealed that phosphorus application at the rate of 30 kg/ha along with potash at 90 kg/ha without nitrogen was found to increase the nodule numbers to the maximum extend.

Almeida et al. (1973) found that in beans (Phaseolus vulgaris) nodule dry matter was increased by, P and lime (80 and 160 kg $P_2O_5$ and 2 t lime per ha). In India field trials showed that rhizobium inoculation or phosphate application (22.4 kg $P_2O_5$/ha) increased the number of nodules/plant in black gram (Sahu, 1973). The number and weight of nodules/plant in cowpeas 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 the $P_2O_5$ rates from 0 to 25 and 50 kg/ha increased root length, weight and nodulation. Koinov and Petkov (1975) from a field trial with Phaseolus vulgaris reported that P or Mo stimulated the development of root nodules. Ramachandra Rao and Mader (1975) reported that in soybean P level increased nodule number slightly. Large nodule weight of 1.46 g and 1.44 g per plant were recorded with 90 and 45 kg $P_2O_5$/ha level respectively and both these levels are significantly superior to control and were at par with each other. Singh et al. (1975) in trials with Cicer arietinum proved that application of N and P increased the number up to 90 days after sowing. Raj Singh et al. (1975) reported in moong (Phaseolus aureus Roxb.) P application at 0 - 75 kg $P_2O_5$/ha may stimulate nodule production and thus higher rate of N fixation.

(c) <u>Effect of phosphorus on yield and yield attributes</u>

Deshpande and Bathkal (1965) in an experiment conducted on *mung* have reported that the response to levels of phosphate seems to be linear indicating increase in pulse yield and green weight with increase in dose of $P_2O_5$. The number of pods per plant increased from 3.63 in control to 4.5, 4.77 and 5.36 and weight of pods increased from 62.8 in control to 77.8, 99.9 and 104.7 with 20, 40 and 60 pound $P_2O_5$ per acre doses respectively. Moolani and Jana (1965) noted that on an acidic laterite with a high fixation capacity for phosphate 100 kg $P_2O_5$ per ha significantly increased yield of green gram when applied with or without nitrogen. The yield increased from 654.2 kg per ha in control to 800.2 per ha with 100 kg $P_2O_5$ per ha.

Prasad *et al.* (1968) reported highest response to $P_2O_5$ upto 67.2 kg $P_2O_5$ per ha in chick pea, *Phaseolus mungo*, *Phaseolus aureus*, lentil, lathyrus and *Dolichos biflorus*.

A significant treatment differences for 75 kg $P_2O_5$ per ha in black gram yield was observed by Anand Prakash (1969). Dehl *et al.* (1969) reported that in *Phaseolus mungo* yields were increased progressively from 1140 to 1532 kg grain/ha with increase in the rate of applied $P_2O_5$ from 0 to 34 kg per ha, yields declined by further increasing the rate of $P_2O_5$ to 68 kg/ha.

Results of fertilizer trial with beans (*Phaseolus vulgaris*) proved that P as 0, 100 or 200 kg $P_2O_5$/ha gave a negative response to seed yield (Barrios *et al.*, 1970).

Gill et al. (1971) reported that phosphate application either to soil or as foliar spray increased the yield of cowpea.

Bhatia and Chowdhury (1972) reported that in mung (Pusa Baisakhi) $P_2O_5$ has boosted the grain yield over control. With the application of 33 kg $P_2O_5$ per ha the control yields were increased from 5.58 q per ha to 7.28 q per ha during 1969 and 1970 respectively. When $P_2O_5$ was applied at the rate of 66 kg $P_2O_5$ per ha the yield increased to 9.7 and 8.47 q per ha in 1969 and 1970 respectively. In a trial with cowpea Malik et al. (1972) found that application of 60 kg $P_2O_5$ per ha markedly increased the seed yield, application of 90 kg $P_2O_5$ per ha decreased them. Application of $P_2O_5$ had no effect on 100 seed weight.

Panda (1972) found that for Pusa Baisakhi mung grain yield, number of branches per plant, length of pod and average weight of seed per plant increased with increasing level of phosphorus. The grain yield increased from 5.65 q in control to 7.04 q, 7.74q and 8.39 q with 30, 60 and 90 kg $P_2O_5$ per ha respectively.

Hurdikeri et al. (1973) reported that in cowpea application of 22 kg $P_2O_5$ per ha recorded highest cowpea yield during 1968 while during 1970 application of 11 kg nitrogen with 44 kg $P_2O_5$ per ha recorded the highest yield. This increased yield was related to increase in flower production, retention of pods and seeds per plant and higher 1000 grain weight.

Black gram and green gram responded well for 34 and 30 kg $P_2O_5$/ha respectively as soil application in rice fallow condition (Anon., 1974). Potkov (1974) reported that in trials with *Phaseolus vulgaris* increasing the rate of P slightly decreased yields. Rajendran *et al.* (1974) reported that in black gram the seed yield has been found to increase with increase in levels of $P_2O_5$/ha (0, 30, 60 and 90 kg). Venugopal and Morachan (1974) in trials with green gram reported that $P_2O_5$ level had significant influence on seed yield; P applied at 20 kg $P_2O_5$/ha has given an yield increase of 83 kg/ha over control, the response to higher levels of P (40 and 60 kg $P_2O_5$/ha) was only 50 kg seed yield/ha. P increased the dry matter production but P at 60 kg $P_2O_5$/ha level reduced the total dry matter production as compared to control.

Addy (1975) proved that application of P to cowpeas in the early wet season had no significant effect on seed yield and applied P tended to decrease it. Johnson and Evans (1975) reported that in cowpea, fertilizer P had no effect on yield. Kalyan Singh and Rajendra Prasad (1975) reported that P application significantly increased the grain yield of pigeon pea up to 100 kg $P_2O_5$ per ha. Panwar and Kanwar Singh (1975) in trials with *Phaseolus aureus* observed that seed yield increased from 583 to 632 and 776 kg/ha by increasing $P_2O_5$ rate from 0 to 20 and 40 kg/ha respectively, further yield increase with 60 kg $P_2O_5$/ha was not significant.

Sawney et al. (1975) revealed that in black gram sufficient increase in grain yield was recorded due to P application. Singh et al. (1975) reported that seed yields in *Phaseolus aureus* increased from 515 to 781 kg/ha with increase in $P_2O_5$ rate from 0 to 60 kg/ha along with favourable effect on other yield attributes like number of pods per plant, number of grain per pod, 1000 grain weight. Srivastava and Singh (1975) reported that application of 30 - 60 kg $P_2O_5$/ha gave nonsignificant increase in seed yields by gram under dry land conditions in Rajasthan.

Agarwal et al. (1976) in trials with *Vigna aureus* reported that yields were increased from 0.77 t with 25 kg $P_2O_5$/ha to 0.95 t with 50 kg $P_2O_5$/ha and decreased thereafter with 75 kg $P_2O_5$/ha. In trials with gram (*Cicer arietinum*) Chundawat et al. (1976) reported that average seed yield of gram was increased from 1.48 to 1.85 t/ha by increasing $P_2O_5$ rate from 15 to 30 kg/ha. Gill and Cheema (1976) reported that in summer mung (*Phaseolus aureus*) there was no response to added $P_2O_5$. Kaul and Sekhon (1976) observed that on *Phaseolus aureus* P application increased the grain yield significantly, the increase being significant upto 40 kg $P_2O_5$/ha and were not further increased with 60 - 80 kg $P_2O_5$/ha. Singh (1976a) reported that in different moong varieties 30 kg $P_2O_5$/ha gave significantly higher yield over control; variety ML.5 produced higher yield with 60 kg $P_2O_5$/ha over control and 30 kg $P_2O_5$/ha. Higher level of $P_2O_5$ has not proved its significance with Jawahar 45 and Pusa Baisakhi. Singh (1976b) reported that in different cowpea varieties there was no significant difference between P levels (0, 30, 60 kg/ha) however 60 kg $P_2O_5$/ha recorded the highest grain yield.

Anonymous (1977) revealed that on soils with low available P, red gram gave significant yield to the application of 100 kg $P_2O_5$/ha, however on medium fertility soil the response was limited to application of 50 kg $P_2O_5$/ha. Janmeja Sharma (1977) reported that in cowpea application of 30 kg $P_2O_5$/ha gave 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. Subramaniyan et al. (1977) found that 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/ plant and number of grains/pod in soils of medium P status. Application of 25 kg $P_2O_5$/ha recorded maximum grain yield of 1063 kg/ha and it was on par with 50 kg $P_2O_5$/ha. Panwar et al. (1977) in field experiment with black gram showed that at the optimum dose of phosphorus (46.3 kg $P_2O_5$/ha) grain yield increased by 24.3 per cent (298 kg/ha) with 6.44 kg/ha $P_2O_5$ response over no phosphorus. There was a linear increase in grain yield upto the level of 60 kg $P_2O_5$/ha but at the higher level of 90 kg $P_2O_5$/ha there was a trend of reduction in yield to the extend of 7.5 per cent as compared to 60 kg $P_2O_5$/ha.

(d) Effect of phosphorus on protein

In field trials with soyabean Costache and Nica (1968) reported that P fertilizers increased the accumulation of protein. Singh and Singh (1968) reported that in soybean P at the highest two doses (60 and 80 kg $P_2O_5$/ha) increased the protein content over the other doses of P.

Singh et al. (1969) from an experiment on pea varieties carried out on the Agronomy Farm of I.A.R.I. New Delhi reported that application of phosphoric acid at 0 - 90 kg/ha did not influence protein content in grain.

Singh (1970) found that in gram application of 45 - 90 kg $P_2O_5$/ha resulted in 15.3 - 16.11 per cent protein content compared with 15.5 per cent without $P_2O_5$.

Garg et al. (1971) reported that in peas protein content in grains increased due to P application at 20 and 40 kg $P_2O_5$/ha. Singh et al. (1971) in field experiments conducted at the experiment station, U.P. Agricultural University observed that in soybean the protein content of seed tended to increase with increased levels of P i.e. 0, 40, 80, 160 kg/ha.

Arora and Luthra (1972) in experiments conducted in the improvement in the quality of Phaseolus aureus reported that application of N, P and S gave seed protein contents 19.88 to 24.3 per cent compared with 16.69 per cent with the nutrient solution given no N, P or S. Application of 30 ppm N + 60 ppm P + 90 ppm S gave the highest protein content. Malik et al. (1972) in a trial with cowpea reported that application at P had no effect on seed protein content.

Bricen and Sanchez (1973) reported that in cowpea one tonne lime and 80 - 160 kg $P_2O_5$/ha were significant to increase seed protein yield. Kesavan and Morachan (1973) reported that in soyabean protein content increased with increase in the rate of $P_2O_5$ upto 150 kg/ha. Kurdikeri et al. (1975) reported from field trials in cowpea that seed protein content was increased by 16.8 per cent to 20 per cent due to fertilizer application of 11 N + 44 $P_2O_5$/ha, higher doses of N and $P_2O_5$ or $K_2O$ did not influence protein content.

Punnoose and George (1974) observed in groundnut that the seed protein content increased with increasing rates of P (0, 25, 50, 75 or 100 kg $P_2O_5$/ha).

Nikiyaev (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. In trials with Phaseolus aureus (Vigna radiata) Panwar and Singh (1975) reported that seed protein contents increased from 18.38 to 19.4 per cent with increasing P rates from 0 to 20 and 40 kg $P_2O_5$/ha. Savankar and Bedhe (1975) from pot experiments with urid, mung and soybean reported that application of 80 kg $P_2O_5$/ha to Vigna radiata and soybean and 120 kg $P_2O_5$ per ha to Vigna mungo increased seed content of protein.

Kapoor and Gupta (1977) from pot experiments on soyabean reported that crude protein and true protein contents of the seed increased under the influence of P.

(c) Uptake of phosphorus

Singh and Jain (1968) in trials with cowpea reported that plant P content increased markedly with increase in rate of applied $P_2O_5$, upto 67 kg/ha and slightly with further increase to 100.5 kg/ha.

Omueti and Oyenuga (1970) reported that in groundnut and cowpea applied P increased the seed content of P. Sinha (1970) reported that in peas 10 kg N/ha had no effect in the uptake of total P by the plant. There were no significant differences in the total P content of the plant resulted from the application of 30 or 60 kg $P_2O_5$/ha, however 60 kg $P_2O_5$/ha has showed a trend of increase in the total P content of the plant as compared to that of 30 kg $P_2O_5$/ha.

Sinha (1971) reported that 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 kg and 60 kg $P_2O_5$/ha showed a trend in increase in the uptake of total and the fertilizer P in favour of the latter.

Sasidhar and George (1972) reported in Co-1 lab lab that increasing the rate 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 $K_2O$ increased P contents.

Rajendran et al. (1973) in radioassay studies of the shoot and seeds of Phaseolus mungo indicated that the uptake of fertilizer P increased with increase in applied P at 0, 30 60 and 90 kg/ha.

Rajendran et al. (1974) reported that in black gram the total P content of seed sample varied from 0.100 to 0.368 per cent. Significant treatment difference were observed for levels of P only, 90 kg $P_2O_5$/ha was superior to 30 kg $P_2O_5$/ha followed by 60 kg $P_2O_5$ and no $P_2O_5$. Sharma et al. (1974) found that application of 50 kg $P_2O_5$/ha increased the plant uptake of P in cowpea.

Rajendran and Krishnamoorthy (1975) from pot culture trials with blackgram reported that the uptake of P in the shoot, seed and husk samples were significant for P only, with increase in levels of P the uptake of P increased in all the samples. Since the concentration of total P and dry matter production were significantly influenced by P, the uptake has also increased in all the cases. Ravankar and Badhe (1975) reported from pot experiments with urid, mung and soyabean that applied P increased P uptake by plants at different growth stages.

Badanur et al. (1976) in trials with blackgram on red sandy loam soil reported that application of 1 t lime + 96 kg $P_2O_5$ per ha increased P uptake.

Dalal and Quilt (1977) reported that in pigeon pea fertilizer P significantly increased dry matter yield and total P uptake.

Rollin Bhaskar (1979) observed that in green gram variety M-2 the uptake of nutrients like N, P and K was found to be higher with increased levels of P (0, 12.5, 25, 37.5 and 50 kg $P_2O_5$/ha).

C. Potassium

(a) Effect of potassium on growth characters

Reiss and Sherwood (1965) found that plant height of soyabean was not significantly influenced by the application of K.

In a 3 year field trial with soyabeans K fertilisers had little effect on growth (Groneman, 1974).

Sen et al. (1974) reported that in groundnut vegetative growth of above ground parts decreased as K levels increased.

Sankara Reddi et al. (1976) in a trial to find out the effect of level of K on growth and yield of soyabean observed that difference among potassium levels were found to be significant with regard to plant height only. The maximum height of 27.6 cm was observed in 0 kg $K_2O$/ha while 40 kg $K_2O$/ha had the minimum plant height of 25.3 cm.

Nair (1978) reported that potassium increased the height of groundnut plants 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 $K_2O$/ha significantly increased the number of leaves per plant over 25 kg $K_2O$ per ha.

(b) Effect of potassium on nodulation

Nair et al. (1970) reported that in groundnut (Arachis hypogea) the number of nodules produced per plant was significantly reduced due to lack of P, Mo or K at all stages of crop growth. The amount of N fixed is significantly reduced due to lack of either P or K.

Muthuswamy (1973) from a pot culture experiment conducted on groundnut revealed that $P_2O_5$ application at the rate of 30 kg per ha along with potash at 90 kg per ha without nitrogen was found to increase the nodule numbers to the maximum extent.

Chesney (1974) from experiments conducted on cowpea at Ebini and Kairuni found that nodulation was increased by K at Kairuni.

(c) Effect of potassium on yield and yield attributes

Reiss and Sherwood (1965) found that K given alone increased seed weight of soybean. Tewari (1965) reported that for soybean K gave no response when applied at the rate of 0, 20 and 40 lb/acre.

Shekhawat et al. (1967) in Rajasthan found that for peas application of 33.56 kg $K_2O$/ha increased pod yield by approximately 8 per cent in black soils supplied with 22.38 kg N/ha.

Mascarenhas et al. (1968) from their trials on soybean revealed that yield response to levels of $K_2O$ was small and linear, the levels were 0, 60 and 120 kg $K_2O$/ha. Saraf et al. (1968) recorded a significant response in yield of black gram due to potassic fertilizer.

Maples and Keogh (1969) reported that in soybean K increased yields significantly; yield increased upto 13.3 bu/ac and most of the response occurred with the first 60 lb $K_2O$/acre.

In the fertilizer trial conducted by Barrios et al. (1970) it was found that in beans (Phaseolus vulgaris) K gave a negative response in seed yield to 0 or 70 kg $K_2O$/ha. Narappan (1970) recommended 44 kg $K_2O$/ha for rainfed redgram while he did not recommend any potassic fertilizer for black gram.

Demooy and Pesek (1971) observed significant yield increase from applied K i.e. 4 bu seed/ac with 100 lb K/ac in soyabean. Panda et al. (1971) found that higher levels of K (40 kg/ha) tended to increase the pod yield in groundnut. Odurukwe (1973) in trials with soybean found that seed yield increased with applied K. Sutton et al.(1973) reported that in Phaseolus vulgaris increasing the rate of K above the lowest level of 93 kg K/ha failed to increase yields consistently.

Chesney (1974) from experiments conducted at Kairuni and Ebini on cowpea reported that seed yields were significantly increased by K. Dira et al. (1974) in a dry season field trial on Phaseolus vulgaris reported that yield tended to decrease as levels of K increased. Nitkees (1974) in finding out the requirements of snap beans (Phaseolus vulgaris) for fertilizers observed that plant dry matter and seed yields were significantly improved by K. In trials with peas and *Phaseolus vulgaris* Shoveleva (1974) reported that application of 60 kg $K_2O$/ha gave the highest yield increase in seed yield of peas and *Phaseolus vulgaris* grown on light grey soil. Sundaram *et al.* (1974) reported that in cowpea application of P and K (0, 30) did not affect the green matter and dry matter yield.

In a field trial with cowpea, Johnson and Evans (1975) reported that K increased yields in cowpea when soil K content was low. Sawhney *et al.* (1975) revealed that in black gram the application of K increased the grain yield in Punjab.

Fauconnier (1976) reported that in a field trial with soyabean application of 100 kg $K_2O$/ha increased yields to 1.98 t/ha compared with 1.50 t in the control given no K and 200 kg $K_2O$ gave 2.03 t seed/ha. Krens *et al.* (1976) found that in beans (*Phaseolus vulgaris*) during dry season application of 60 kg $K_2O$/ha increased yield by 7 per cent. Korkus (1976) from field trials on soyabean reported that application of K increased yields to 1.81 t/ha with 150 kg $K_2O$/ha compared with 1.71 t without K. In a trial with field bean (*Vicia faba*) given 0, 75, ,150 or 300 kg $K_2O$/ha. 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 30 to 53 respectively with increasing rates of applied $K_2O$ (0, 75, 150 and 300 kg $K_2O$/ha) in field beans. Sankara Reddi et al. (1976) observed that in soyabean, node number per plant, total and filled pods per plant, and test weight increased with addition of potassium but the increase were not significant.

Terman (1977) in field trial with soybean observed that added K increased the rate of dry matter accumulation and seed yield.

Chevalier (1978) in field trials with soybean reported that at maturity seed and stem dry matter increased with increasing K rate, showing a favourable effect of K on ripening. Graves et al. (1978) in field trials on soils low in K observed that applied K (0 or 60 lb/ac) increased yield of all varieties of soyabean. Gutstein (1978) found that in groundnut pod yield increased with K application Mustafa et al. (1978) reported that in groundnut considerable significant yield increase was observed due to the application of K and maximum yield was obtained at 300 kg K/ha and beyond this it was not beneficial. Sharma et al. (1978) reported 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.

(d) Effect of potassium on protein

Scheffer et al. (1960) reported that the yield and crude protein content of peas harvested green and ripe were influenced by the levels of P and K.

Singh *et al.* (1969) from an experiment on pea varieties carried out on the Agronomy Farm of I.A.R.I. reported that application of phosphoric acid and potash (0 - 45 kg/ha) did not influence protein content in grain.

Haghparast and Mengel (1973) reported that in *Vicia faba* the protein content of the various plant parts were not significantly affected by K but the protein yield/pot was increased 20 per cent.

Bhuiya and Chowdhury (1974) reported that in groundnut K application did not increase protein content. Mlesnita (1974) in *Vicia faba* reported that protein yields were 0.68 t/ha without fertilizer and 0.94 and 0.90 t/ha with 66 kg N + 40 kg $P_2O_5$ + 40 kg $K_2O$ applied in autumn and spring respectively.

Nikolyaev (1975) in a field trial in Guinea with (a) *mung* (b) cowpea and (c) bean (*Phaseolus vulgaris*) reported that 600, 690 and 530 kg protein per 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.

Marinus (1976) reported that in soybean protein yield was increased by application of N, K or FYM.

(c) Uptake of potassium

Naka Gawa *et al.* (1966) reported 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 potash application. Field experiments conducted on black cotton soils in Nagpur in groundnut revealed that application of N, P and K alone or in combination have found to increase the $K_2O$ uptake, by application of K with N has given a good response (Puntamkar and Bathkal, 1967).

Baine (1969) reported increase in the K content in *Phaseolus vulgaris* with increase in the rate of applied K. Peck and MacDonald (1969) reported that in field trials pea plants given 0, 60, 240 and 960 lb Kcl/acre contained 0.6, 0.8, 1.1 and 1.6 per cent K. In glass house experiments it was found that plant K content was increased by applied K and P. Stewart and Reed (1969) in pot experiments out of doors in Southern pea reported that plant content of K increased with the addition of K.

Harishankar and Kushwaha (1971) found increased uptake of K due to the increased application of K in urd plant.

Bhangoo and Albritton (1972) reported that in soybean applied K increased the K contents of leaves and seeds.

Kadwe and Badhe (1973) from pot trials with urd (*Vigna mungo*) reported that application of 50 kg $P_2O_5$ and/or 1 - 2 kg Mo/ha increased plant uptake of K.

Groneman (1974) in a field trial with soybean reported that K fertilizers markedly increased K uptake by plants.

Rajendran and Krishnamoorthy (1975) from pot culture trials with blackgram reported that significant treatment differences were noticed in the uptake of K for levels of P in the shoot, seed and husks samples. In general K uptake was increased with increase in levels of P in all the samples.

Fogeria (1977) from field trials with soybean reported that increasing rate of P (0 - 125 kg/ha) increased plant K content. Georgiev (1977) in trials with groundnut reported that applied P promoted more intensive accumulation of K in pods.

D. <u>Combination effect of nitrogen, phosphorus and potash on growth</u>

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 P1 treatment (30 lb/acre).

Ezedinma (1965) found that plant height and number of leaves per plant of cowpea were increased by NP (20 lb N + 40 lb $P_2O_5$).

E. <u>Combination effect of nitrogen, phosphorus and potash on yield and yield attributes</u>

Shukla (1964) reported that in gram the best treatment combination for pod production was $N_2P_1$ (20 lb N + 30 lb $P_2O_5$) followed by $N_2P_2$ (20 lb N + 60 lb $P_2O_5$).

Banerjee et al. (1967) reported that for groundnut in West Bengal the interaction effect of PK showed that increased level of P upto 67.2 kg/ha and potash upto 44.0 kg/ha applied together significantly increased the yield/ha.

Singh and Singh (1969) revealed that for soyabean the interaction of 10 kg N/ha and 80 kg $P_2O_5$/ha significantly increased the grain yield by 36.23 per cent over the control.

Rajagopalan et al. (1970) reported that in black gram at Coimbatore application of 2 ton of compost in combination with 20 lb $P_2O_5$ and 10 lb N/acre gave increased yield over no manure plots.

Bhattacharya (1971) reported that in horse gram 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 nitrogen in combination with 33.5 kg $P_2O_5$/ha proved to be more effective fertilizer treatment with a 120 per cent increase in grain yield over absolute control. Pande et al. (1971) reported that in groundnut, among the NPK combination tried the level of N 20 + $P_2O_5$ 40 + $K_2O$ 40 kg/ha was found to be the best. Marchuk and Saichuk (1971) in trials with peas given 30 kg N, 60 kg $P_2O_5$ and 60 kg $K_2O$ in various combinations. The highest yields were obtained from the combined application of NP and K.

Malik et al. (1972) found that in cowpea application of 20 kg N + 60 kg $P_2O_5$/ha gave the highest yield of 1.35 t/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) in experiments with cowpea at Ebini and Kairuni reported that P x K interaction was always significant. Rajendran et al. (1974) reported that in black gram seed yields increased with increasing N levels in combination with increasing P levels only. Shivashankar et al. (1974) reported that soybean yields were increased from 3.70 t/ha with no fertilizer to 4.48 t/ha with 40 kg $P_2O_5$ in combination with 20 kg N + 40 kg $K_2O$/ha. Venugopal and Morachan (1974) reported that in green gram the NP interaction was highly significant. $N_0P_1$ (30 N + 20 kg $P_2O_5$), $N_2P_3$ (20 kg N + 60 kg $P_2O_5$), $N_3P_2$ (30 kg N + 40 kg $P_2O_5$) combinations gave more than 800 kg seed yield per ha while $N_3P_3$ (30 kg N + 60 kg $P_2O_5$) combination gave only 691 kg/ha which corresponds to yield of control. $N_0P_1$ was the most economical.

Singh (1976) reported that in urid, treatment $N_2P_2$ (30 kg N + 40 kg $P_2O_5$/ha) recorded the highest grain yield of 3.68 q/ha. Analysis of data from PK trials with horsegram for seed production showed that economic optimum fertiliser rate was 31.8 kg $P_2O_5$ + 10.6 kg $K_2O$/ha.

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

Thima Gowda and Krishna Gowda (1978) reported that in green gram application of NPK together gave the highest pod and grain yield. The treatment 30 kg N + 60 kg $P_2O_5$ + 20 kg $K_2O$/ha gave the highest pod and grain yield of 20.5 and 12.7 q/ha respectively.

F. Effect of nitrogen, phosphorus and potash on soil fertility status

Bains (1967) observed from field and glass house experiment on field bean that under glass house condition soil test values for available $P_2O_5$ and available $K_2O$ were affected by the application of respective fertiliser element particularly at higher levels of applied phosphate and potash which indicated build up of available nutrient in the soil.

Garg *et al.* (1970) from trials conducted with cowpea reported that P application at the rate of 37, 74 or 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 soyabeans grown on well drained alluvial soil increased the soil nitrogen content. Sahu and Behera (1972) also observed that inoculation and application of phosphate (22.4 kg/ha) increased the soil nitrogen by 58, 29 and 25 per cent over control in crops of cowpea, groundnut and green gram respectively.

An experiment conducted on sandy loam soil with black gram and horse gram revealed that inoculation and application of 22.4 kg $P_2O_5$/ha alone or in combination increased nitrogen content from 20 to 38 per cent in the case of black gram and from 7 to 19 per cent in the case of horse gram (Sahu, 1973).

Sharma and Yadav (1976) reported that in a field experiment conducted with gram 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.

# MATERIALS AND METHODS

# MATERIALS AND METHODS

<u>Object</u>

The present investigation was undertaken to find out the effect of nitrogen, phosphorus and potash on growth, yield and quality and to assess the nutrient uptake of Black gram grown in rice fallows during third crop season.

<u>Experimental site</u>

The experiment was conducted in the rice fields of Instructional Farm, College of Agriculture, Vellayani.

<u>Soil</u>

The soil of the experimental area belongs to sandy clay loam. Data on the analysis of the soil before starting the experiment are given in Table 1.

<u>Season and climatology of the crop</u>

The crop was sown on 29th January 1979 and harvested on 7th April 1979. The meteorological parameters such as rainfall, maximum and minimum temperature and relative humidity for the above period were recorded. The average weekly values and their variation from the past five years from sowing to harvest were worked out and presented in Appendix I and Figure 1.

<u>Cropping history of the experimental site</u>

The experimental area was under a bulk crop of paddy during the previous season.

Table 1. Analysis of soil before starting the experiment

| Constituents | Content in soil | Method used |
|---|---|---|
| Total nitrogen | 0.13 per cent | Modified micro kjeldahl method |
| Available $P_2O_5$ | 0.0027 per cent | Bray's method |
| Available $K_2O$ | 0.001 per cent | Ammonium acetate method |
| pH | 5.2 | 1:2 soil solution ratio using pH meter |

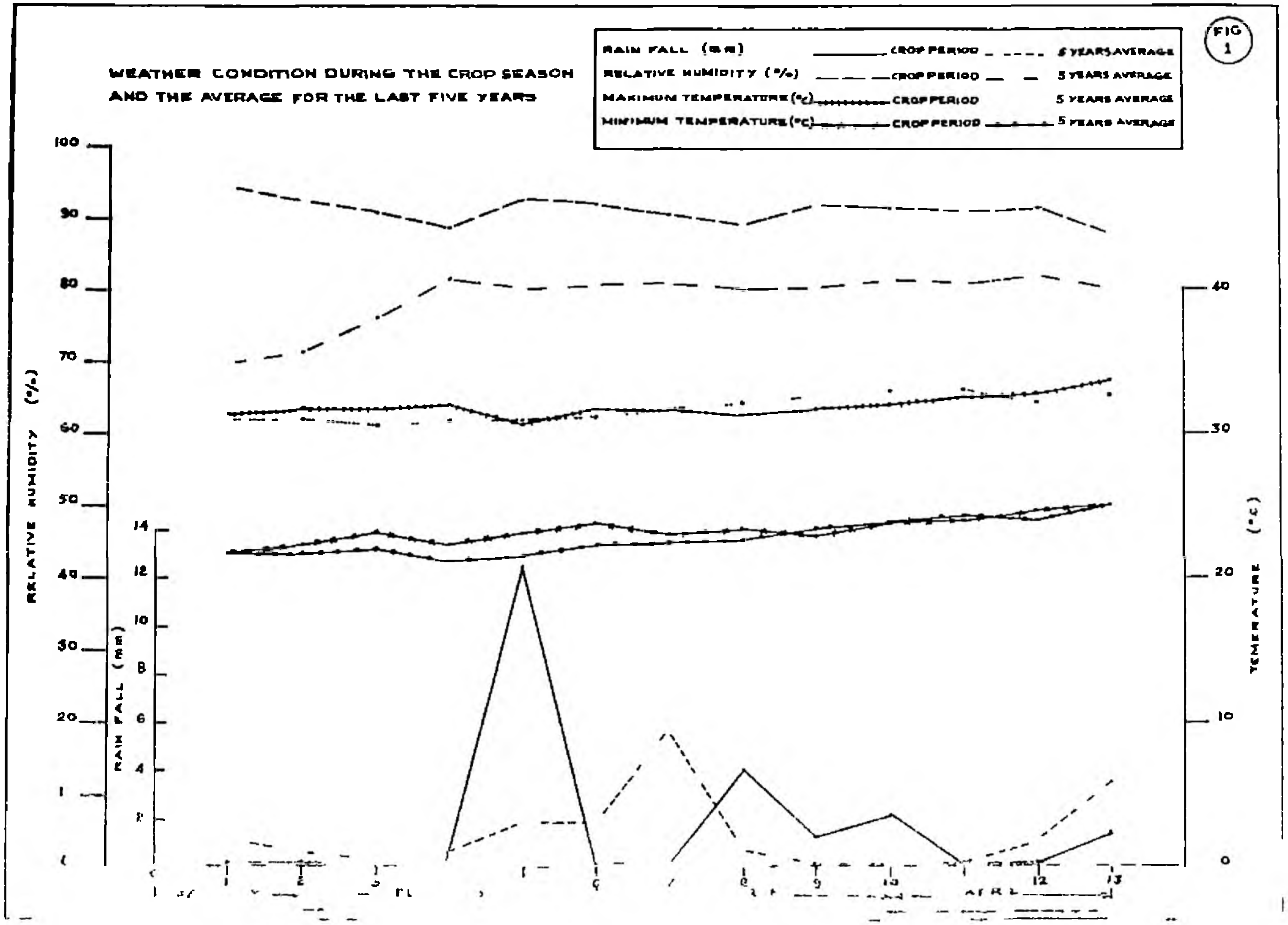


FIG 1
WEATHER CONDITION DURING THE CROP SEASON
AND THE AVERAGE FOR THE LAST FIVE YEARS
RAIN FALL (mm) CROP PERIOD 5 YEARS AVERAGE
RELATIVE HUMIDITY (%) CROP PERIOD 5 YEARS AVERAGE
MAXIMUM TEMPERATURE (°C) CROP PERIOD 5 YEARS AVERAGE
MINIMUM TEMPERATURE (°C) CROP PERIOD 5 YEARS AVERAGE
RELATIVE HUMIDITY (%)
RAIN FALL (mm)
TEMPERATURE (°C)

## MATERIALS

### Variety

The black gram variety used was KM-1 (Kudumiamalai 1) which was a selection from the progeny derived from the cross (G.31 x Khargone) x G.31, released from the Agricultural Experiment Institute Kudumiamalai, Tamil Nadu. It is a variety of approximately 65 - 70 days duration with good yielding ability. It is more or less an erect, compact, medium tall variety. The pods are pubescent with 5 - 6 cm long. The seeds are bold in size with rough seed surface.

### Seeds

Seeds with 90 per cent germination were obtained from the District Agricultural Officer, Annapannai, Kudumiamalai, Tamil Nadu.

### Fertilizers

Fertilizers with the following analysis were used for the experiment.

| | | |
|---|---|---|
| Ammonium sulphate analysing | - | 20.5 per cent N |
| Superphosphate analysing | - | 16 per cent $P_2O_5$ |
| Muriate of potash analysing | - | 60 per cent $K_2O$ |
| Dolomite analysing | - | 45 per cent CaO |

## METHODS

### Details of treatments

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

(i) Levels of nitrogen

$n_1$ - 20 kg N/ha

$n_2$ - 30 ..

$n_3$ - 40 ..

(ii) Levels of phosphorus

$p_1$ - 30 kg $P_2O_5$/ha

$p_2$ - 45 ..

$p_3$ - 60 ..

(iii) Levels of potash

$k_1$ - 10 kg $K_2O$/ha

$k_2$ - 20 ..

$k_3$ - 30 ..

Treatment combinations

1. $n_1p_1k_1$
2. $n_1p_1k_2$
3. $n_1p_1k_3$
4. $n_1p_2k_1$
5. $n_1p_2k_2$
6. $n_1p_2k_3$
7. $n_1p_3k_1$
8. $n_1p_3k_2$
9. $n_1p_3k_3$
10. $n_2p_1k_1$
11. $n_2p_1k_2$
12. $n_2p_1k_3$
13. $n_2p_2k_1$
14. $n_2p_2k_2$
15. $n_2p_2k_3$
16. $n_2p_3k_1$
17. $n_2p_3k_2$
18. $n_2p_3k_3$
19. $n_3p_1k_1$
20. $n_3p_1k_2$
21. $n_3p_1k_3$
22. $n_3p_2k_1$
23. $n_3p_2k_2$
24. $n_3p_2k_3$
25. $n_3p_3k_1$
26. $n_3p_3k_2$
27. $n_3p_3k_3$

Experimental technique

The experiment was laid out in 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 procedure followed for the allocation of various treatments to different plots was in accordance with Yates (1964). The lay out plan is given in Fig.2. The details of the lay out are furnished below.

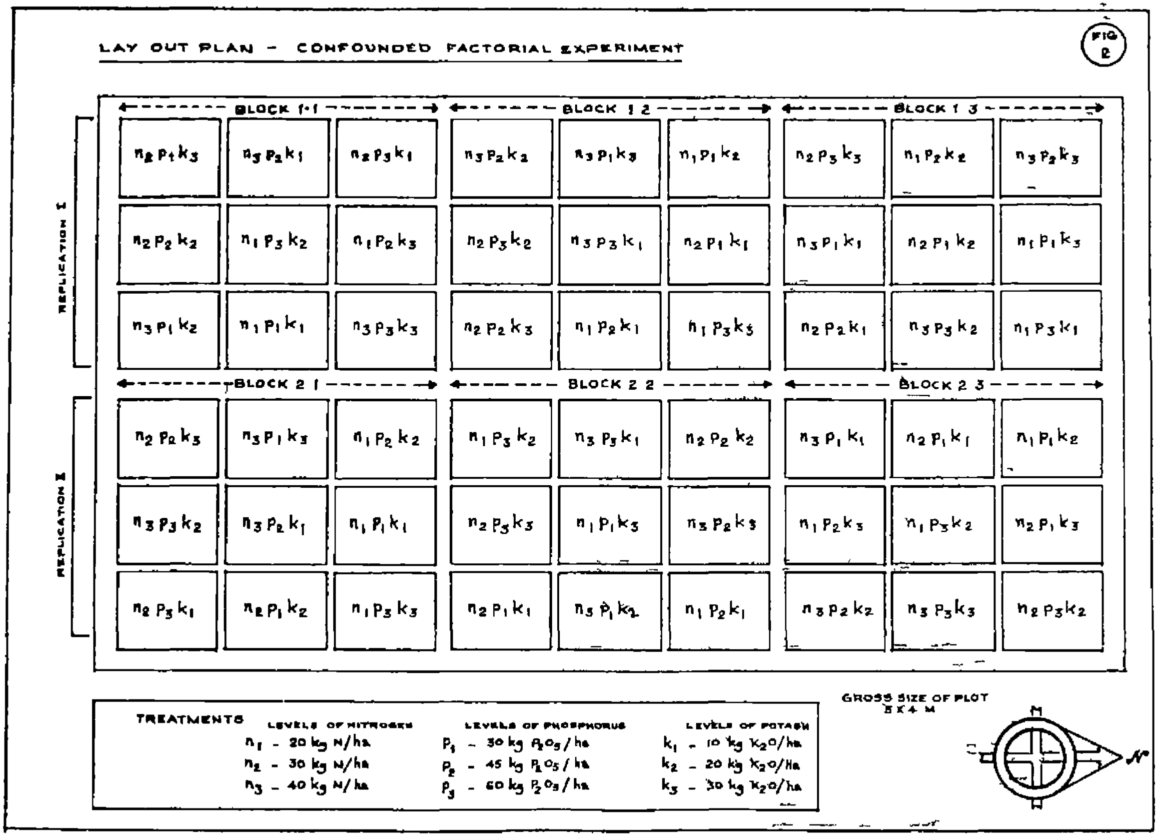
| | |
|---|---|
| Gross plot size | - 5 x 4 M |
| Net plot size | - 4.8 x 3.2 M |
| Total number of plots | - 54 |
| Number of blocks | - 6 |
| Replications | - 2 |
| Spacing | - 20 x 10 cm |
| Number of plants in the gross plot | - 2000 |
| Number of plants in the net plot | - 1536 |

Preparatory cultivation

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.

Fertiliser application

A uniform basal dose of dolomite at the rate of 400 kg per ha was applied two weeks before sowing and incorporated well into the soil.



LAY OUT PLAN - CONFOUNDED FACTORIAL EXPERIMENT
FIG 2
REPLICATION I
BLOCK 1·1
n2 p1 k3
n3 p2 k1
n2 p3 k1
n2 p2 k2
n1 p3 k2
n1 p2 k3
n3 p1 k2
n1 p1 k1
n3 p3 k3
BLOCK 1 2
n3 p2 k2
n3 p1 k3
n1 p1 k2
n2 p3 k2
n3 p3 k1
n2 p1 k1
n2 p2 k3
n1 p2 k1
n1 p3 k3
BLOCK 1 3
n2 p3 k3
n1 p2 k2
n3 p2 k3
n3 p1 k1
n2 p1 k2
n1 p1 k3
n2 p2 k1
n3 p3 k2
n1 p3 k1
REPLICATION II
BLOCK 2 1
n2 p2 k3
n3 p1 k3
n1 p2 k2
n3 p3 k2
n3 p2 k1
n1 p1 k1
n2 p3 k1
n2 p1 k2
n1 p3 k3
BLOCK 2 2
n1 p3 k2
n3 p3 k1
n2 p2 k2
n2 p3 k3
n1 p1 k3
n3 p2 k3
n2 p1 k1
n3 p1 k2
n1 p2 k1
BLOCK 2 3
n3 p1 k1
n2 p1 k1
n1 p1 k2
n1 p2 k3
n1 p3 k2
n2 p1 k3
n3 p2 k2
n3 p3 k3
n2 p3 k2
TREATMENTS
LEVELS OF NITROGEN
n1 - 20 kg N/ha
n2 - 30 kg N/ha
n3 - 40 kg N/ha
LEVELS OF PHOSPHORUS
p1 - 30 kg P2O5/ha
p2 - 45 kg P2O5/ha
p3 - 60 kg P2O5/ha
LEVELS OF POTASH
k1 - 10 kg K2O/ha
k2 - 20 kg K2O/ha
k3 - 30 kg K2O/ha
GROSS SIZE OF PLOT
5 X 4 M
N

The required quantity of ammonium sulphate, superphosphate and muriate of potash for each treatment were weighed, mixed thoroughly and applied uniformly by broadcasting in the respective plots just before sowing.

Seeds and sowing

Seeds treated with rhizobial culture (*Rhizobium phaseoli*) were dibbled at the rate of 2 seeds per hill in lines at a spacing of 20 x 10 cm on 29-1-1979. One light irrigation was given immediately after sowing. Thinning and gap filling was done 7 days after sowing.

After cultivation

Hand weeding was done twice during the growth period of the crop.

Plant protection

Sevin 0.2 per cent was sprayed thrice to protect the crop against pod boring caterpillars.

Stand of the crop

The general stand of the crop was satisfactory.

Harvest

Harvesting was done thrice by picking matured pods of individual plots and was completed by 70th day after sowing. The border rows and the plants selected for observation were harvested separately. The pods were dried, threshed and seeds separated. The grain and husk obtained from the net plot were weighed and recorded. The *bhusa* from the net plot was pulled out dried in the sun for three days and weight recorded.

Observations

One line of plants all round in each plot were left out as border row plants. In all the plots one row in the eastern side were set apart as a destructive row for taking plant samples for the nodule count and the subsequent row was again left out as a border row, thus making the net plot area to 4.0 x 3.2 M with 16 rows and 48 hills per row. Ten plants were selected randomly from the net plot for biometric observations.

A. Observation on growth characters.

(a) Height of plants

This observation was taken from the 10 plants selected for biometric observation from the net plot. Observation on height of plants were recorded on the same plants at five growth stages namely, 15th day, 30th day (at flowering), 45th day, 60th day after sowing and also at harvest. The height of the plants were measured from the base to the growing tip of the plants and the mean height recorded.

(b) Number of leaves per plant

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

(c) Number of branches per plant

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

(d) Number of nodules per plant

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

(e) Dry weight of nodules per plant

The nodules separated from ten plants for nodule count were oven dried and the average weight noted.

B. Observation 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 the average worked out.

(d) Seed yield per plant

The pods harvested from the observation plants in each plot were dried, threshed, winnowed and the seeds weighed at 12 percent moisture content and the average seed yield per plant worked out.

(e) 100 seed weight

This observation was taken by counting 100 seeds from the observation plants and recording the weight.

(f) Grain yield

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

(g) Bhusa yield

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

(h) Total dry matter production

The samples were sun dried and dried to a constant weight in an air oven kept at 80±5°C for 48 hours. Dry matter content was computed for each treatment and dry matter production worked out and expressed in kg/ha.

(i) Harvest index

The harvest index was worked out based on the grain, husk and bhusa yield obtained from the net plot using the following formula and expressed in per cent.

$$H\ I\ (\%) = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

C. Chemical studies

(a) Plant analysis

Samples collected for chemical studies were oven dried at 80°C±5 ground in a wiley mill and used for chemical analysis. The nitrogen, phosphorus and potash contents of grain, husk and bhusa were separately analysed.

(i) Nitrogen content

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

(ii) Phosphorus and potash content

Phosphorus was determined by Vanado molybdo phosphoric yellow colour method (Jackson, 1967).

Potash was determined by using 'EEL' flame photometer.

(b) Uptake studies

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

(c) Soil analysis

The total nitrogen, available phosphorus and available 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).

D. 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 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) Fodder protein yield

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

E. Statistical analysis

Data relating to different characters 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.

# RESULTS

RESULTS

The observations recorded were analysed statistically and the results are given below. The mean values are given in tables 2(a) to 25. The analysis of variance tables are presented in Appendix II to IX. Correlation studies are presented in table 26. The economics of nitrogen, phosphorus and potash application are also given in table 27.

I. Growth characters

(a) Height of plants

The observations on height of plants were recorded on the 15th, 30th, 45th and 60th day after sowing and at harvest. The data were analysed separately and the mean values are presented in tables 2(a) to 2(e) and the analysis of variance tables in Appendix II.

It was observed that the height of plants was not directly influenced by nitrogen, phosphorus or potash at any stage of crop growth. However, the combined effect of phosphorus and potash was found significant at all stages of growth.

The treatment combination $P_2K_1$ (45 kg $P_2O_5$ and 10 kg $K_2O$) recorded the maximum height of 20.6 cm closely followed by the combination $p_3k_3$ (60 kg $P_2O_5$) and 30 kg $K_2O$/ha) with 20.1 cm on the 15th day. On the 30th (flowering) and 45th days also the treatment combination $p_3k_3$ (60 kg $P_2O_5$ and 30 kg $K_2O$/ha) recorded the maximum height of 36.0 cm and

Table 2(a)

Height of the plant (cm) 15th day after sowing

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 19.0 | 17.8 | 18.2 | 18.3 |
| 45 | 19.5 | 18.1 | 19.7 | 19.1 |
| 60 | 19.9 | 19.9 | 19.0 | 19.6 |
| $K_2O$ kg/ha | | | | |
| 10 | 20.2 | 17.8 | 18.5 | 18.8 |
| 20 | 19.4 | 19.0 | 19.1 | 19.2 |
| 30 | 18.9 | 19.1 | 19.4 | 19.1 |
| Mean | 19.5 | 18.6 | 19.0 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 16.6 | 20.6 | 19.2 | 18.8 |
| 20 | 19.2 | 18.8 | 19.6 | 19.2 |
| 30 | 19.2 | 18.0 | 20.1 | 19.1 |
| Mean | 18.3 | 19.1 | 19.6 | |

C.D.(0.05) for marginal means = 1.07
C.D.(0.05) for combination = 1.85

Table 2(b)

Height of the plant (cm) 30th day after sowing

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 34.9 | 32.5 | 32.2 | 33.2 |
| 45 | 34.2 | 31.8 | 34.8 | 33.6 |
| 60 | 34.5 | 35.4 | 34.9 | 34.9 |
| $K_2O$ kg/ha | | | | |
| 10 | 33.4 | 32.5 | 32.4 | 32.8 |
| 20 | 35.7 | 33.2 | 34.7 | 34.5 |
| 30 | 34.6 | 33.9 | 34.8 | 34.4 |
| Mean | 34.5 | 33.2 | 34.0 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 28.6 | 35.7 | 34.0 | 32.8 |
| 20 | 35.4 | 33.4 | 34.8 | 34.5 |
| 30 | 35.6 | 31.7 | 36.0 | 34.4 |
| Mean | 33.2 | 33.6 | 34.9 | |

C.D.(0.05) for marginal means = 2.45
C.D.(0.05) for combination = 4.24

Table 2(c)

Height of the plant (cm) 45th day after sowing

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 38.7 | 36.7 | 35.9 | 37.1 |
| 45 | 38.7 | 36.1 | 39.6 | 38.1 |
| 60 | 40.6 | 40.5 | 38.8 | 39.9 |
| $K_2O$ kg/ha | | | | |
| 10 | 38.6 | 36.1 | 35.7 | 36.8 |
| 20 | 40.8 | 38.1 | 39.0 | 39.3 |
| 30 | 38.6 | 39.2 | 39.5 | 39.1 |
| Mean | 39.3 | 37.8 | 38.1 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 31.5 | 40.1 | 39.0 | 36.8 |
| 20 | 39.7 | 38.5 | 39.8 | 39.3 |
| 30 | 40.4 | 35.8 | 41.1 | 39.1 |
| Mean | 37.1 | 38.1 | 39.9 | |

C.D.(0.05) for marginal means = 2.81
C.D.(0.05) for combination = 4.87

Table 2(d)

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

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 40.2 | 39.9 | 37.4 | 39.1 |
| 45 | 40.7 | 37.8 | 41.5 | 40.0 |
| 60 | 42.9 | 41.6 | 40.9 | 41.8 |
| $K_2O$ kg/ha | | | | |
| 10 | 40.8 | 37.1 | 37.9 | 38.6 |
| 20 | 42.4 | 39.7 | 40.5 | 40.9 |
| 30 | 40.6 | 42.6 | 41.3 | 41.5 |
| Mean | 41.3 | 39.8 | 39.9 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 32.4 | 42.4 | 41.0 | 38.6 |
| 20 | 41.3 | 39.9 | 41.4 | 40.9 |
| 30 | 43.8 | 37.7 | 43.0 | 41.5 |
| Mean | 39.1 | 40.0 | 41.8 | |

C.D.(0.05) for marginal means = 3.13
C.D.(0.05) for combination = 5.42

Table 2(e)

Height of the plant at harvest (cm)

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 41.0 | 41.1 | 39.8 | 40.3 |
| 45 | 41.7 | 39.0 | 42.9 | 41.5 |
| 60 | 44.1 | 43.2 | 42.8 | 43.1 |
| $K_2O$ kg/ha | | | | |
| 10 | 41.6 | 38.3 | 38.5 | 39.5 |
| 20 | 43.2 | 41.4 | 42.2 | 42.3 |
| 30 | 42.0 | 44.4 | 42.9 | 43.1 |
| Mean | 42.3 | 41.4 | 41.2 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 39.3 | 43.1 | 42.0 | 39.5 |
| 20 | 42.2 | 42.1 | 42.6 | 42.3 |
| 30 | 45.4 | 39.3 | 44.7 | 43.1 |
| Mean | 40.3 | 41.5 | 43.1 | |

C.D.(0.05) for marginal means = 3.09
C.D.(0.05) for combination = 5.35

and 41.1 cm respectively. The treatment combination $p_1k_3$ (30 kg $P_2O_5$ and 30 kg $K_2O$/ha) recorded the maximum height on the 60th day as well as at harvest.

(b) Number of leaves per plant

The observations on number of leaves were recorded on the 15th, 30th, 45th and 60th day after sowing and at harvest. The data were analysed separately and the mean values are presented in tables 3(a) to 3(e). The analysis of variance table is given in Appendix III.

The number of leaves was not directly influenced by nitrogen, phosphorus or potash but the P x K interaction was significant at 15th day. The treatment combination $p_3k_3$ (60 kg $P_2O_5$ and 30 kg $K_2O$/ha) recorded the maximum number of 3.28 leaves.

On the 30th day (flowering) neither the individual effect nor their interactions were significant with respect to this character.

At 45th day the effect of nitrogen alone was significant and the lower levels of 20 and 30 kg nitrogen per ha were on par but both were superior to the treatment of 40 kg nitrogen per ha.

At 60th day also nitrogen had significant effect in increasing the number of leaves and showed the very same trend as that of 45th day. The N x K interaction was also significant during this stage and the treatment combination $n_2k_1$ (30 kg nitrogen and 10 kg potash per ha) recorded the

**Table 3(a)**

Number of leaves per plant - 15th day after sowing

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 3.17 | 3.08 | 3.05 | 3.09 |
| 45 | 3.20 | 3.25 | 3.10 | 3.18 |
| 60 | 3.18 | 3.15 | 3.22 | 3.18 |
| $K_2O$ kg/ha | | | | |
| 10 | 3.12 | 3.10 | 3.12 | 3.11 |
| 20 | 3.23 | 3.22 | 3.07 | 3.17 |
| 30 | 3.20 | 3.17 | 3.17 | 3.18 |
| Mean | 3.18 | 3.16 | 3.12 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 2.98 | 3.27 | 3.08 | 3.11 |
| 20 | 3.08 | 3.25 | 3.18 | 3.17 |
| 30 | 3.22 | 3.03 | 3.28 | 3.18 |
| Mean | 3.09 | 3.18 | 3.18 | |

C.D.(0.05) for marginal means = 0.084
C.D.(0.05) for combination = 0.146

**Table 3(b)**

Number of leaves per plant 30th day after sowing

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 6.72 | 6.17 | 5.98 | 6.29 |
| 45 | 6.67 | 6.38 | 6.17 | 6.41 |
| 60 | 6.10 | 6.53 | 6.55 | 6.39 |
| $K_2O$ kg/ha | | | | |
| 10 | 6.08 | 6.77 | 5.85 | 6.23 |
| 20 | 6.93 | 6.22 | 6.58 | 6.58 |
| 30 | 6.47 | 6.20 | 6.27 | 6.28 |
| Mean | 6.49 | 6.36 | 6.23 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 5.97 | 6.48 | 6.25 | 6.23 |
| 20 | 6.52 | 6.48 | 6.73 | 6.58 |
| 30 | 6.38 | 6.25 | 6.20 | 6.28 |
| Mean | 6.29 | 6.41 | 6.39 | |

C.D.(0.05) for marginal means = 0.498
C.D.(0.05) for combination = 0.863

## Table 3(c)

Number of leaves per plant 45th day after sowing

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 7.97 | 7.76 | 6.25 | 7.67 |
| 45 | 8.38 | 7.90 | 7.50 | 7.93 |
| 60 | 8.42 | 8.25 | 7.40 | 8.02 |
| $K_2O$ kg/ha | | | | |
| 10 | 8.33 | 8.42 | 6.93 | 7.89 |
| 20 | 8.52 | 7.97 | 7.00 | 8.09 |
| 30 | 7.92 | 7.55 | 7.42 | 7.63 |
| Mean | 8.26 | 7.93 | 7.30 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 7.43 | 8.38 | 7.67 | 7.89 |
| 20 | 7.70 | 7.97 | 8.62 | 8.09 |
| 30 | 7.87 | 7.43 | 7.58 | 7.63 |
| Mean | 7.67 | 7.93 | 8.02 | |

C.D. (0.05) for marginal means = 0.530
C.D. (0.05) for combination = 0.918

## Table 3(d)

Number of leaves per plant 60th day after sowing

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 6.97 | 7.15 | 6.12 | 6.74 |
| 45 | 7.17 | 7.03 | 6.67 | 6.96 |
| 60 | 7.53 | 6.77 | 6.62 | 6.97 |
| $K_2O$ kg/ha | | | | |
| 10 | 7.13 | 7.67 | 5.83 | 6.88 |
| 20 | 7.57 | 6.70 | 7.13 | 7.13 |
| 30 | 6.97 | 6.58 | 6.43 | 6.66 |
| Mean | 7.22 | 6.98 | 6.47 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 6.58 | 7.18 | 6.87 | 6.88 |
| 20 | 6.80 | 7.25 | 7.35 | 7.13 |
| 30 | 6.85 | 6.43 | 6.70 | 6.66 |
| Mean | 6.74 | 6.96 | 6.97 | |

C.D. (0.05) for marginal means = 0.429
C.D. (0.05) for combination = 0.743

Table 3(o)

Number of leaves per plant at harvest

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 3.95 | 4.20 | 3.38 | 3.84 |
| 45 | 3.82 | 4.20 | 3.92 | 3.98 |
| 60 | 4.17 | 3.60 | 3.68 | 3.82 |
| $K_2O$ kg/ha | | | | |
| 10 | 4.15 | 4.62 | 3.10 | 3.96 |
| 20 | 4.23 | 3.85 | 4.20 | 4.09 |
| 30 | 3.55 | 3.53 | 3.68 | 3.59 |
| Mean | 3.98 | 4.00 | 3.66 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 4.22 | 4.30 | 3.35 | 3.96 |
| 20 | 3.73 | 4.17 | 4.38 | 4.09 |
| 30 | 3.58 | 3.47 | 3.72 | 3.59 |
| Mean | 3.84 | 3.98 | 3.82 | |

C.D. (0.05) for marginal means = 0.428
C.D. (0.05) for combination = 0.742

maximum number of 7.66 leaves followed by $n_1k_2$ (20 kg nitrogen and 20 kg potash per ha) with 7.56 leaves.

The N x K and P x K interaction alone were significant at harvest. The treatment combination $n_2k_1$ (30 kg nitrogen and 10 kg potash per ha) recorded the maximum number of 4.62 followed by $n_1k_2$ (20 kg nitrogen and 20 kg potash per ha) with 4.23 leaves. Similarly $p_3k_2$ (60 kg phosphorus and 20 kg potash per ha) recorded the maximum number of 4.38 closely followed by $p_2k_1$ (45 kg phosphorus and 10 kg potash) with 4.30 leaves.

(c) <u>Number of branches per plant</u>

Data on mean number of branches are presented in table 4 and the analysis of variance table is given in Appendix IV.

The results show that the effect of potash alone was significant in increasing the number of branches per plant. Potash at 30 kg per ha was significantly superior to 10 kg per ha. It was also observed that the effect of potash on increasing the number of branches per plant was linear.

(d) <u>Number of nodules per plant</u>

The mean numbers are presented in table 5 and the analysis of variance table in Appendix IV.

The effect of phosphorus alone was significant with respect to this character. Application of 60 kg $P_2O_5$ per ha significantly increased the number of nodules over the lower

Table 4

Number of branches per plant

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 2.93 | 3.07 | 3.03 | 3.01 |
| 45 | 2.80 | 2.67 | 2.93 | 2.80 |
| 60 | 2.77 | 2.87 | 2.77 | 2.80 |

| $K_2O$ kg/ha | 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 10 | 2.40 | 2.53 | 2.53 | 2.49 |
| 20 | 2.97 | 2.87 | 2.97 | 2.93 |
| 30 | 3.13 | 3.20 | 3.23 | 3.19 |
| Mean | 2.83 | 2.87 | 2.91 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 2.43 | 2.60 | 2.43 | 2.49 |
| 20 | 3.13 | 2.77 | 2.90 | 2.93 |
| 30 | 3.47 | 3.03 | 3.07 | 3.19 |
| Mean | 3.01 | 2.80 | 2.80 | |

C.D. (0.05) for marginal means = 0.246
C.D. (0.05) for combination = 0.426

levels of 45 and 30 kg $P_2O_5$ per ha which were on par. The number increased from 18.83 to 26.44 and 46.97 with increase in the level of phosphorus from 30 kg per ha to 45 and 60 kg per ha respectively.

With regard to nitrogen and potash though there was no significant effect, the highest level of 40 kg nitrogen per ha reduced the nodule number over the lower levels while the number increased slightly with the increase in the level of potash.

(c) Dry weight of nodules per plant

The mean values are presented in table 6 and the analysis of variance table in Appendix IV.

It was observed that neither the levels of nitrogen, phosphorus and potash nor their interactions had any significant influence in increasing the weight of nodules per plant. However it was observed that higher levels of nitrogen slightly reduced the nodule weight when compared to the lower levels. But increasing the level of phosphorus slightly increased the nodule weight while potash application did not help much to increase the same.

## II. Yield and yield attributes

(a) Number of pods per plant

The mean number of pods recorded are given in table 7 and the analysis of variance table in Appendix V.

The effect of potash alone was significant in increasing

### Table 5

Number of nodules per plant

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 25.42 | 15.92 | 15.17 | 18.83 |
| 45 | 32.92 | 28.50 | 17.92 | 26.44 |
| 60 | 41.33 | 56.00 | 43.58 | 46.97 |
| $K_2O$ kg/ha | | | | |
| 10 | 26.17 | 33.67 | 25.50 | 28.44 |
| 20 | 41.08 | 30.75 | 23.42 | 31.75 |
| 30 | 32.42 | 36.00 | 27.75 | 32.06 |
| Mean | 33.22 | 33.47 | 25.56 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 20.42 | 21.42 | 43.50 | 28.44 |
| 20 | 22.50 | 27.92 | 44.83 | 31.75 |
| 30 | 13.58 | 30.00 | 52.58 | 32.06 |
| Mean | 18.83 | 26.44 | 46.97 | |

C.D. (0.05) for marginal means = 15.916
C.D.(0.05) for combination = 27.567

### Table 6

Dry weight of nodules per plant (mg)

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 41.25 | 29.17 | 35.00 | 35.14 |
| 45 | 41.67 | 43.33 | 30.83 | 38.61 |
| 60 | 59.58 | 70.00 | 43.75 | 57.78 |
| $K_2O$ kg/ha | | | | |
| 10 | 42.92 | 48.75 | 37.08 | 42.92 |
| 20 | 45.83 | 49.17 | 35.42 | 43.47 |
| 30 | 53.75 | 44.58 | 37.08 | 45.14 |
| Mean | 47.50 | 47.50 | 36.53 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 44.58 | 35.42 | 48.75 | 42.92 |
| 20 | 35.00 | 40.00 | 55.42 | 43.47 |
| 30 | 25.83 | 40.42 | 69.17 | 45.14 |
| Mean | 35.14 | 38.61 | 57.78 | |

C.D.(0.05) for marginal means = 22.097
C.D.(0.05) for combination = 38.274

the number of pods per plant, while nitrogen and phosphorus remained uniform with respect to this character.

The data show that potash at 30 kg per ha recorded the maximum number of pods (10.97) which was significantly superior to 20 kg per ha (9.87) which in turn was superior to 10 kg per ha (9.04).

(b) Length of pod

The mean values are presented in table 8 and the analysis of variance table is given in Appendix V.

The effect of potash was significant in increasing the length of pod while nitrogen and phosphorus had no significant effect with respect to this character.

Potash at 30 kg per ha recorded the maximum length of 9.4 cm which was on par with 20 kg per ha, and both were superior to 10 kg per ha.

(c) Number of seeds per pod

The mean numbers are presented in table 9 and the analysis of variance table is given in Appendix V.

The effect of potash alone was significant while nitrogen and phosphorus remained ineffective to increase the number of seeds per pod.

Potash at 30 kg per ha recorded the maximum number of 7.27 seeds which was on par with 20 kg per ha and both were superior to 10 kg per ha.

## Table 7

Number of pods per plant

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 10.19 | 10.21 | 10.33 | 10.24 |
| 45 | 9.64 | 9.82 | 10.06 | 9.84 |
| 60 | 9.66 | 10.07 | 9.67 | 9.80 |
| **$K_2O$ kg/ha** | | | | |
| 10 | 9.24 | 8.86 | 9.04 | 9.04 |
| 20 | 9.70 | 9.91 | 9.98 | 9.87 |
| 30 | 10.56 | 11.33 | 11.04 | 10.97 |
| Mean | 9.83 | 10.03 | 10.02 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 9.08 | 8.92 | 9.13 | 9.04 |
| 20 | 9.09 | 9.87 | 9.65 | 9.87 |
| 30 | 11.76 | 10.74 | 10.42 | 10.97 |
| Mean | 10.24 | 9.84 | 9.80 | |

C.D. (0.05) for marginal means = 0.571
C.D. (0.05) for combination = 0.988

## Table 8

Length of pod (cm)

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 5.3 | 5.3 | 5.3 | 5.3 |
| 45 | 5.2 | 5.3 | 5.3 | 5.3 |
| 60 | 5.2 | 5.3 | 5.3 | 5.3 |
| **$K_2O$ kg/ha** | | | | |
| 10 | 5.1 | 5.1 | 5.1 | 5.1 |
| 20 | 5.2 | 5.4 | 5.4 | 5.3 |
| 30 | 5.3 | 5.4 | 5.4 | 5.4 |
| Mean | 5.2 | 5.3 | 5.3 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | |
|---|---|---|---|---|
| 10 | 5.1 | 5.2 | 5.1 | 5.1 |
| 20 | 5.4 | 5.3 | 5.3 | 5.3 |
| 30 | 5.4 | 5.4 | 5.4 | 5.4 |
| Mean | 5.3 | 5.3 | 5.3 | |

C.D. (0.05) for marginal means = 0.09
C.D. (0.05) for combination = 0.16

Table 9

Number of seeds per pod

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 7.17 | 7.10 | 7.20 | 7.16 |
| 45 | 7.03 | 7.18 | 7.18 | 7.13 |
| 60 | 7.13 | 7.12 | 7.17 | 7.14 |
| $K_2O$ kg/ha | | | | |
| 10 | 7.03 | 6.95 | 6.95 | 6.98 |
| 20 | 7.13 | 7.12 | 7.27 | 7.17 |
| 30 | 7.17 | 7.33 | 7.33 | 7.28 |
| Mean | 7.11 | 7.13 | 7.10 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 6.95 | 6.98 | 7.00 | 6.98 |
| 20 | 7.22 | 7.08 | 7.22 | 7.17 |
| 30 | 7.30 | 7.33 | 7.20 | 7.28 |
| Mean | 7 16 | 7 13 | 7·14 | |

C.D. (0.05) for marginal means = 0.118
C.D. (0.05) for combination = 0.205

Table 10

Seed yield per plant (g)

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 1.72 | 1.72 | 1.75 | 1.73 |
| 45 | 1.58 | 1.63 | 1.67 | 1.63 |
| 60 | 1.59 | 1.69 | 1.57 | 1.62 |
| $K_2O$ kg/ha | | | | |
| 10 | 1.49 | 1.40 | 1.43 | 1.44 |
| 20 | 1.60 | 1.65 | 1.65 | 1.63 |
| 30 | 1.80 | 1.99 | 1.91 | 1.90 |
| Mean | 1.63 | 1.68 | 1.66 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 1.45 | 1.41 | 1.46 | 1.44 |
| 20 | 1.64 | 1.63 | 1.63 | 1.63 |
| 30 | 2.09 | 1.84 | 1.77 | 1.90 |
| Mean | 1.73 | 1.63 | 1.62 | |

C.D.(0.05) for marginal means = 0.136
C.D.(0.05) for combination = 0.256

(d) Seed yield per plant

The mean weights are presented in table 10 and the analysis of variance table is given in Appendix V.

Seed yield per plant was significantly influenced by levels of potash, but nitrogen and phosphorus levels had no significant effect with respect to this character. The maximum seed yield of 1.90 g was recorded at a $K_2O$ level of 30 kg per ha which was significantly superior to 20 kg per ha which in turn was significantly superior to 10 kg per ha.

(e) 100 seed weight

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

The 100 seed weight was significantly increased by increased levels of potash but nitrogen and phosphorus remained uniform. The potash levels, 30 kg and 20 kg, were on par and both were superior to 10 kg per ha. Potash at 30 kg per ha recorded the maximum 100 grain weight of 4.62 g.

(f) Grain yield

The mean grain yields are presented in table 12 and the analysis of variance table in Appendix VI.

As in the case of the various yield attributing factors, potash alone had direct and significant effect in increasing the grain yield. Potash at the rate of 30 kg per ha recorded the maximum grain yield of 1757 kg per ha which was significantly superior to the potash level of 20 kg per ha (1514 kg/ha) which in turn was superior to the lowest level

Table 11

100 seed weight (g)

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 4.58 | 4.59 | 4.59 | 4.59 |
| 45 | 4.50 | 4.57 | 4.58 | 4.55 |
| 60 | 4.49 | 4.54 | 4.55 | 4.53 |
| $K_2O$ kg/ha | | | | |
| 10 | 4.50 | 4.45 | 4.41 | 4.45 |
| 20 | 4.49 | 4.66 | 4.62 | 4.59 |
| 30 | 4.57 | 4.59 | 4.70 | 4.62 |
| Mean | 4.52 | 4.56 | 4.58 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 4.58 | 4.38 | 4.39 | 4.45 |
| 20 | 4.56 | 4.63 | 4.58 | 4.59 |
| 30 | 4.61 | 4.64 | 4.61 | 4.62 |
| Mean | 4.59 | 4.55 | 4.53 | |

C.D. (0.05) for marginal means = 0.115
C.D. (0.05) for combination = 0.199

of 10 kg per ha (1359 kg/ha).

There was no significant response to the applied nitrogen and phosphorus for grain yield. However nitrogen had shown an increasing trend upto 30 kg per ha beyond which the yield declined. But it was observed that there was a decreasing trend with increase in the level of applied phosphorus.

(g) <u>Bhusa yield</u>

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

<u>Bhusa</u> yield showed no significant effect with increase in the level of either nitrogen, phosphorus, potash or their interactions.

But there was a trend for increasing yields with the increase in the level of nitrogen. Similarly increase in the level of phosphorus from 30 to 45 kg per ha increased the <u>bhusa</u> yield, but when the phosphorus level was increased to 60 kg per ha the yield declined.

(h) <u>Harvest index</u>

The mean values are presented in table 14 and the analysis of variance table in Appendix VI.

Neither the individual effect of nitrogen, phosphorus and potash ... nor their interactions was significant in increasing the harvest index. But increasing the level of nitrogen slightly decreased the harvest index and higher levels of potash slightly increased it.

Table 12

Grain yield (kg/ha)

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 1572 | 1592 | 1573 | 1579 |
| 45 | 1458 | 1516 | 1597 | 1524 |
| 60 | 1488 | 1579 | 1504 | 1523 |
| **$K_2O$ kg/ha** | | | | |
| 10 | 1418 | 1293 | 1355 | 1355 |
| 20 | 1439 | 1529 | 1575 | 1514 |
| 30 | 1662 | 1864 | 1746 | 1757 |
| Mean | 1506 | 1562 | 1558 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 1347 | 1309 | 1408 | 1355 |
| 20 | 1511 | 1518 | 1514 | 1514 |
| 30 | 1[illegible]79 | 1744 | 1649 | 1757 |
| Mean | 1579 | 1524 | 1523 | |

C.D. (0.05) for marginal means = 147.5
C.D. (0.05) for combination = 255.1

Table 13

Bhusa yield (kg/ha)

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 2402 | 2505 | 2390 | 2432 |
| 45 | 2515 | 2656 | 2796 | 2656 |
| 60 | 2477 | 2528 | 2672 | 2559 |
| **$K_2O$ kg/ha** | | | | |
| 10 | 2467 | 2623 | 2553 | 2548 |
| 20 | 2524 | 2469 | 2654 | 2549 |
| 30 | 2404 | 2595 | 2652 | 2550 |
| Mean | 2465 | 2563 | 2620 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 2496 | 2729 | 2419 | 2548 |
| 20 | 2318 | 2651 | 2678 | 2549 |
| 30 | 2483 | 2569 | 2580 | 2550 |
| Mean | 2432 | 2656 | 2559 | |

C.D.(0.05) for marginal means = 179.9
C.D.(0.05) for combination = 311.6

Table 14

Harvest index

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 36.2 | 35.5 | 36.3 | 36.0 |
| 45 | 34.9 | 34.6 | 34.7 | 34.8 |
| 60 | 35.3 | 35.7 | 34.5 | 35.1 |
| $K_2O$ kg/ha | | | | |
| 10 | 34.8 | 33.0 | 33.8 | 33.8 |
| 20 | 34.6 | 35.2 | 35.2 | 35.0 |
| 30 | 37.1 | 37.5 | 36.5 | 37.0 |
| Mean | 35.5 | 35.2 | 35.2 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 33.9 | 32.7 | 35.0 | 33.8 |
| 20 | 35.9 | 34.7 | 34.4 | 35.0 |
| 30 | 38.2 | 36.8 | 36.1 | 37.0 |
| Mean | 36.0 | 34.8 | 35.1 | |

C.D. (0.05) for marginal means = 3.16
C.D. (0.05) for combination = 6.10

Table 15

Total dry matter production (kg/ha)

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 4489 | 4640 | 4456 | 4528 |
| 45 | 4441 | 4624 | 4931 | 4665 |
| 60 | 4441 | 4611 | 4671 | 4574 |
| $K_2O$ kg/ha | | | | |
| 10 | 4347 | 4306 | 4371 | 4341 |
| 20 | 4443 | 4538 | 4748 | 4576 |
| 30 | 4581 | 5031 | 4939 | 4850 |
| Mean | 4457 | 4625 | 4686 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 4307 | 4452 | 4265 | 4341 |
| 20 | 4357 | 4677 | 4694 | 4576 |
| 30 | 4920 | 4866 | 4764 | 4850 |
| Mean | 4528 | 4665 | 4575 | |

C.D. (0.05) for marginal means = 256.1
C.D. (0.05) for combination = 447.1

(i) Total dry matter production

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

Nitrogen and phosphorus had no significant influence in increasing the dry matter production. But there was a trend for dry matter production to increase with increase in the level of nitrogen. Similarly in the case of phosphorus also an increasing trend was observed upto 45 kg beyond which the total dry matter production declined.

The effect of potash in increasing the total dry matter production was significant. The potash level of 30 kg per ha recorded the maximum dry matter yield and was significantly superior to 20 and 10 kg per ha which were on par.

## III. Uptake studies

(a) Uptake of nitrogen

The mean values are presented in table 16 and the analysis of variance table in Appendix VII.

Effect of potash alone was significant in increasing the nitrogen uptake. Potash at 30 kg per ha recorded the maximum uptake of 125.77 kg per ha which was significantly superior to 10 and 20 kg $K_2O$ per ha which were on par.

Though the levels of nitrogen and phosphorus could not significantly influence the uptake, increase in the level of nitrogen showed an increasing trend. Similarly higher doses of phosphorus also increased the nitrogen uptake upto

Table 16

Uptake of nitrogen (kg/ha)

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 113.55 | 119.16 | 117.97 | 116.89 |
| 45 | 113.31 | 123.60 | 125.25 | 120.72 |
| 60 | 114.56 | 121.28 | 121.90 | 119.25 |
| $K_2O$ kg/ha | | | | |
| 10 | 108.20 | 115.50 | 115.71 | 113.14 |
| 20 | 115.19 | 117.09 | 121.57 | 117.95 |
| 30 | 118.03 | 131.45 | 127.84 | 125.77 |
| Mean | 113.81 | 121.35 | 121.71 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 111.31 | 115.88 | 112.22 | 113.14 |
| 20 | 112.14 | 121.23 | 120.49 | 117.95 |
| 30 | 127.23 | 125.05 | 125.03 | 125.77 |
| Mean | 116.89 | 120.72 | 119.25 | |

C.D. (0.05) for marginal means = 7.691
C.D. (0.05) for combination = 13.322

Table 17

Uptake of phosphorus (kg/ha)

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 6.26 | 6.81 | 6.70 | 6.59 |
| 45 | 6.34 | 6.80 | 6.87 | 6.70 |
| 60 | 6.33 | 6.92 | 7.23 | 6.83 |
| $K_2O$ kg/ha | | | | |
| 10 | 6.12 | 6.55 | 6.70 | 6.46 |
| 20 | 6.45 | 6.79 | 7.25 | 6.83 |
| 30 | 6.36 | 7.26 | 6.86 | 6.83 |
| Mean | 6.31 | 6.87 | 6.94 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 6.30 | 6.56 | 6.52 | 6.46 |
| 20 | 6.69 | 6.98 | 6.82 | 6.83 |
| 30 | 6.78 | 6.56 | 7.15 | 6.83 |
| Mean | 6.59 | 6.70 | 6.83 | |

C.D. (0.05) for marginal means = 0.359
C.D. (0.05) for combination = 0.623

45 kg per ha, beyond which the uptake declined.

(b) Uptake of phosphorus

The mean uptake values are presented in table 17 and the analysis of variance table in Appendix VII.

The uptake of phosphorus was significantly influenced by the levels of nitrogen. Nitrogen at 40 kg per ha recorded the maximum uptake of 6.94 kg per ha which was on par with 30 kg per ha but both superior to 20 kg N/ha.

Though the levels of phosphorus and potash did not influence the phosphorus uptake significantly, the increase in the level of these nutrients slightly increased the uptake.

(c) Uptake of potash

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

The effect of potash alone was significant in increasing the potash uptake by the plants. Potash at 30 kg per ha recorded the maximum potash uptake of 27.09 kg per ha which was significantly superior to 20 kg $K_2O$ per ha which in turn was significantly superior to 10 kg $K_2O$ per ha.

The nitrogen and phosphorus did not influence the potash uptake by plants significantly.

IV. Quality characters

(a) Protein content of grain

The mean protein percentages are given in table 19 and the analysis of variance table in Appendix VIII.

Table 18

Uptake of potash (kg/ha)

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 22.93 | 22.80 | 23.12 | 22.96 |
| 45 | 23.76 | 23.76 | 23.31 | 23.61 |
| 60 | 21.70 | 22.93 | 21.54 | 22.06 |
| $K_2O$ kg/ha | | | | |
| 10 | 20.42 | 18.18 | 18.33 | 18.97 |
| 20 | 21.76 | 23.46 | 22.45 | 22.56 |
| 30 | 26.25 | 27.04 | 27.20 | 27.09 |
| Mean | 22.80 | 23.16 | 22.66 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 19.16 | 18.95 | 18.81 | 18.97 |
| 20 | 20.94 | 22.88 | 23.85 | 22.56 |
| 30 | 28.76 | 29.00 | 23.51 | 27.09 |
| Mean | 22.96 | 23.61 | 22.06 | |

C.D. (0.05) for marginal means = 2.730
C.D. (0.05) for combination = 4.763

Neither the individual effect of nitrogen, phosphorus and potash nor their interactions was found to have any significant influence on the protein content of grains. However there was a slight increase in the protein content with increase in the level of nitrogen ( upto 30 kg) and phosphorus while a reverse trend was noticed with incremental doses of potash.

(b) Grain protein yield

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

The effect of potash was significant in increasing the grain protein yield while the various levels of nitrogen and phosphorus remained uniform. The maximum grain protein yield of 410.86 kg per ha was recorded at 30 kg $K_2O$ per ha which was significantly superior to 20 kg $K_2O$ per ha which in turn was significantly superior to 10 kg $K_2O$ per ha.

The increased levels of nitrogen slightly increased the grain protein yield while doses of phosphorus showed a reverse trend.

(c) Protein content of bhusa

The mean percentage values are presented in table 21 and the analysis of variance table in Appendix VIII.

Table 19

Protein content of grain (%)

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 22.87 | 23.67 | 23.67 | 23.40 |
| 45 | 23.46 | 23.96 | 23.42 | 23.61 |
| 60 | 23.75 | 23.67 | 24.08 | 23.83 |
| $K_2O$ kg/ha | | | | |
| 10 | 22.71 | 24.62 | 24.04 | 23.79 |
| 20 | 23.83 | 23.46 | 23.79 | 23.69 |
| 30 | 23.54 | 23.21 | 23.33 | 23.36 |
| Mean | 23.36 | 23.76 | 23.72 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 23.29 | 24.00 | 24.08 | 23.79 |
| 20 | 23.75 | 23.71 | 23.62 | 23.69 |
| 30 | 23.17 | 23.12 | 23.79 | 23.36 |
| Mean | 23.40 | 23.61 | 23.83 | |

C.D. (0.05) for marginal means = 0.842
C.D. (0.05) for combination = 1.459

Table 20

Grain protein yield (kg/ha)

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 361.14 | 374.42 | 371.31 | 368.96 |
| 45 | 343.19 | 359.16 | 372.69 | 358.35 |
| 60 | 352.20 | 372.32 | 361.94 | 362.15 |
| $K_2O$ kg/ha | | | | |
| 10 | 321.22 | 314.75 | 324.20 | 320.06 |
| 20 | 343.74 | 358.16 | 373.74 | 358.55 |
| 30 | 391.57 | 433.00 | 408.00 | 410.86 |
| Mean | 352.18 | 368.63 | 368.65 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 311.28 | 311.74 | 337.15 | 320.06 |
| 20 | 359.64 | 359.53 | 356.47 | 358.55 |
| 30 | 435.95 | 403.78 | 392.84 | 410.86 |
| Mean | 368.95 | 358.35 | 362.15 | |

C.D. (0.05) for marginal means = 30.976
C.D. (0.05) for combination = 53.653

The data show that the protein content of bhusa was influenced by neither nitrogen, phosphorus and potash nor by their interactions. However higher levels of phosphorus slightly increased the protein content of bhusa while potash showed a reverse trend. But there was a slight increase in the protein content of bhusa with increased level of nitrogen upto 30 kg per ha beyond which there was a slight decline.

(d) Fodder protein yield

The mean yields are presented in table 22 and the analysis of variance table in Appendix VIII.

The fodder protein yield was not significantly influenced either by the levels of nitrogen, phosphorus and potash or by their interactions. But an increase in protein yield was noticed with increase in the level of nitrogen while a reverse trend was observed with higher levels of potash. In the case of phosphorus protein yield was increased by increasing the level from 30 to 45 kg per ha but a further increase declined it.

V. Soil analysis

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

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

The total nitrogen content of the soil was not directly influenced by the levels of nitrogen, phosphorus or potash.

## Table 21

**Protein content of Bhusa (%)**

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 13.44 | 13.65 | 14.37 | 13.82 |
| 45 | 13.54 | 14.69 | 13.65 | 13.96 |
| 60 | 13.75 | 14.17 | 14.06 | 13.99 |
| $K_2O$ kg/ha | | | | |
| 10 | 13.44 | 14.69 | 14.69 | 14.27 |
| 20 | 13.96 | 13.96 | 13.65 | 13.86 |
| 30 | 13.33 | 13.09 | 13.75 | 13.65 |
| Mean | 13.58 | 14.17 | 14.03 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 14.37 | 14.27 | 14.17 | 14.27 |
| 20 | 13.65 | 14.06 | 13.86 | 13.86 |
| 30 | 13.44 | 13.54 | 13.96 | 13.65 |
| Mean | 13.82 | 13.96 | 13.99 | |

C.D. (0.05) for marginal means = 0.776
C.D. (0.05) for combination = 1.344

## Table 22

**Fodder protein yield (kg/ha)**

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 348.35 | 370.39 | 368.25 | 362.33 |
| 45 | 365.07 | 413.41 | 410.16 | 396.22 |
| 60 | 365.29 | 385.39 | 400.01 | 383.57 |
| $K_2O$ kg/ha | | | | |
| 10 | 356.66 | 407.18 | 398.98 | 387.61 |
| 20 | 375.05 | 373.41 | 388.38 | 379.21 |
| 30 | 346.21 | 388.60 | 391.05 | 375.29 |
| Mean | 359.57 | 389.73 | 392.81 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 384.58 | 412.55 | 365.69 | 387.61 |
| 20 | 343.06 | 398.25 | 396.33 | 379.21 |
| 30 | 359.34 | 377.85 | 388.68 | 375.29 |
| Mean | 362.33 | 396.22 | 383.57 | |

C.D. (0.05) for marginal means = 34.633
C.D. (0.05) for combination = 59.987

But the combined effect of phosphorus and potash was found to be significant. The treatment combination $p_3k_3$ (60 kg $P_2O_5$ and 30 kg $K_2O$) recorded the maximum soil nitrogen content of 2700 kg per ha followed by $p_1k_2$ (30 kg $P_2O_5$ and 20 kg $K_2O$) and $p_2k_2$ (45 kg $P_2O_5$ and 20 kg $K_2O$).

(b) Available phosphorus content in the soil after the experiment

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

There was no significant effect for the different levels of nitrogen, phosphorus and potash and their interactions on the available phosphorus content of the soil. But the available phosphorus tended to increase with increase in the level of applied phosphorus. Higher doses of nitrogen showed an upward trend in increasing the available phosphorus content of the soil.

Potash did not have any regular effect on the available phosphorus content.

(c) Available potassium content in the soil after the experiment

The mean data are presented in table 25 and the analysis of variance table in Appendix IX.

Neither the individual effect of nitrogen, phosphorus and potash nor their interactions influenced the available potash content of the soil. But there was a trend for increase in the available potash content of the soil with increase in the levels of nitrogen, phosphorus and potash.

Table 23

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

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 20 | 30 | 40 | Mean |
| 30 | 2300 | 2667 | 2533 | 2500 |
| 45 | 2600 | 2600 | 2500 | 2567 |
| 60 | 2500 | 2400 | 2567 | 2489 |
| $K_2O$ kg/ha | | | | |
| 10 | 2433 | 2533 | 2433 | 2467 |
| 20 | 2500 | 2533 | 2567 | 2533 |
| 30 | 2467 | 2600 | 2600 | 2556 |
| Mean | 2467 | 2556 | 2533 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 2433 | 2500 | 2467 | 2467 |
| 20 | 2667 | 2633 | 2300 | 2533 |
| 30 | 2400 | 2567 | 2700 | 2556 |
| Mean | 2500 | 2567 | 2489 | |

C.D. (0.05) for marginal means = 147.1
C.D. (0.05) for combination = 254.7

Table 24

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

| | N kg/ha | | | |
|---|---|---|---|---|
| $P_2O_5$ kg/ha | 10 | 20 | 30 | Mean |
| 30 | 46 | 64 | 49 | 53 |
| 45 | 60 | 62 | 74 | 65 |
| 60 | 69 | 70 | 59 | 66 |
| $K_2O$ kg/ha | | | | |
| 10 | 63 | 64 | 63 | 63 |
| 20 | 58 | 57 | 57 | 57 |
| 30 | 54 | 75 | 63 | 64 |
| Mean | 58 | 69 | 61 | |

| | $P_2O_5$ kg/ha | | | |
|---|---|---|---|---|
| $K_2O$ kg/ha | 30 | 45 | 60 | Mean |
| 10 | 47 | 74 | 69 | 63 |
| 20 | 55 | 62 | 55 | 57 |
| 30 | 58 | 60 | 75 | 64 |
| Mean | 53 | 65 | 66 | |

S.D. (0.05) for marginal means = 14.7
C.D. (0.05) for combination = 25.5

Table 25

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

| $P_2O_5$ kg/ha | N kg/ha 20 | 30 | 40 | Mean |
|---|---|---|---|---|
| 30 | 83 | 85 | 109 | 97 |
| 45 | 101 | 104 | 123 | 110 |
| 60 | 123 | 117 | 101 | 114 |
| **$K_2O$ kg/ha** | | | | |
| 10 | 95 | 97 | 107 | 100 |
| 20 | 108 | 106 | 112 | 108 |
| 30 | 109 | 114 | 113 | 112 |
| Mean | 104 | 106 | 111 | |

| $K_2O$ kg/ha | $P_2O_5$ kg/ha 30 | 45 | 60 | Mean |
|---|---|---|---|---|
| 10 | 85 | 109 | 106 | 100 |
| 20 | 116 | 112 | 97 | 108 |
| 30 | 90 | 108 | 138 | 112 |
| Mean | 97 | 110 | 114 | |

C.D.(0.05) for marginal means = 25.1
C.D.(0.05) for combination = 40.0

## VI. Correlation studies

The values of simple correlation coefficients are presented in table 26.

Grain yield was significantly and positively correlated with the number of pods, number of seeds per pod, length of pod, 100 seed weight, nitrogen uptake, phosphorus uptake and potash uptake and the correlation coefficients were 0.9565, 0.5180, 0.4670, 0.3609, 0.7093, 0.4040, 0.6032 respectively.

Protein content of the grain was positively and significantly correlated with the protein content of the bhusa and the 'r' value was 0.4702.

Dry matter production of the crop was positively and significantly correlated with nitrogen and potash uptake and the values are 0.8393 and 0.7562 respectively.

Table 26

Values of simple correlation coefficients

| Sl.No. | Characters correlated | Correlation coefficients |
|---|---|---|
| 1. | Grain yield x Number of pods per plant | 0.9565** |
| 2. | Grain yield x Number of seeds per pod | 0.5189** |
| 3. | Grain yield x Length of pod | 0.4678** |
| 4. | Grain yield x 100 seed weight | 0.3609** |
| 5. | Grain yield x N uptake by crop | 0.7093** |
| 6. | Grain yield x $P_2O_5$ uptake by crop | 0.4840** |
| 7. | Grain yield x $K_2O$ uptake by crop | 0.6032** |
| 8. | Protein content of the grain x Protein content of the bhusa | 0.4702** |
| 9. | Dry matter production of the crop x N uptake by crop | 0.8392** |
| 10. | Dry matter production of the crop x $K_2O$ uptake by crop | 0.7562** |

**Significant at 0.01 level

# DISCUSSION

# DISCUSSION

The present investigation was an attempt to find out the effect of N, P and K on the growth, yield and quality of black gram grown in rice fallows during the third crop season. The results obtained from the study are discussed below.

## I. Growth characters

(a) Height of plants

(Table 2(a) to 2(c), Fig.3, Appendix II)

It can be seen from the results that there was no significant difference in plant height due to levels of nitrogen at any stage of plant growth under study. This may probably be due to the fact that the lowest level of nitrogen tried (20 kg per ha) might have been sufficient to attain maximum plant height. This is in agreement with the findings of Bhattacharya (1971) in gram and of Hathcock (1975) in soyabean.

The non-significant effect of different levels of phosphorus on plant height shows that 30 kg $P_2O_5$ per ha is sufficient for obtaining optimum plant height. Similar non-significant response to added phosphorus was observed by Gill and Cheema (1976) in summer mung. But an increase in trend noted with increase in levels of phosphorus from 30 to 60 kg per has was in agreement with the findings of Panda (1972) in Pusa Baisakhi mung, Ferrari et al. (1976) in soyabean and of Mahatanya (1976) in bean plant.

The effect of different levels of potash on plant height was also not significant at any stage of crop growth. Similar results were reported by Weiss and Sherwood (1965) and Grossman (1974) in soyabean. But the increasing trend noted with increase in levels of potash on plant height may be due to the well known effect of potassium in promoting the growth of meristematic tissue (Tisdale and Nelson, 1975).

Though the individual effects of phosphorus and potash were not significant in increasing the plant height, their combined effect was significant at all stages of growth. It can be seen from the mean tables that there was an increase in trend in plant height with increase in levels of phosphorus and potash and as such the cumulative effect of these nutrients might have increased the plant height significantly. It can be seen that the minimum height was recorded for the lowest levels of phosphorus and potash throughout all the stages of crop growth. From the early stages of growth upto the 45th day after sowing the highest levels of P and K were found to increase the height of plants significantly over that at the lower levels. 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). But the effect of potash is found to be different. As maturity advances the height of plants increases with increase in the level of potash even for the lowest level of phosphorus. This shows that P and K might have enhanced the microbial activity in the soil which helped the plant in fixing atmospheric nitrogen and better utilisation.

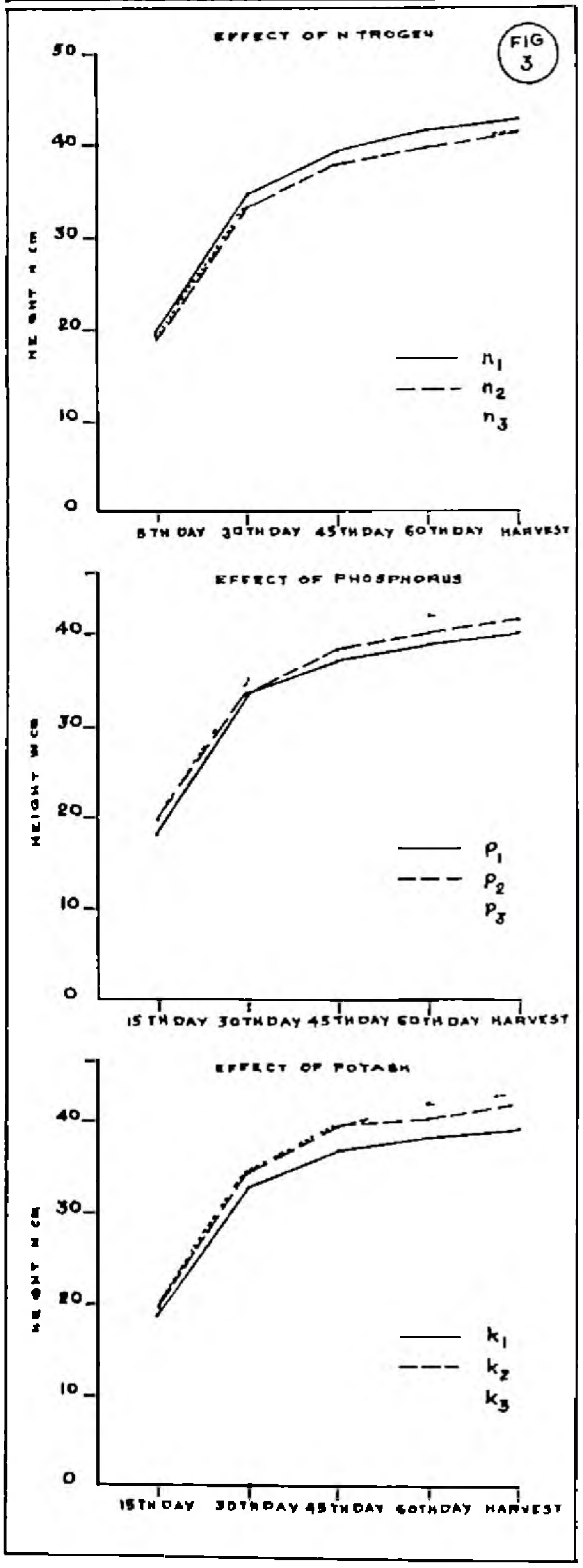
(b) Number of leaves per plant

(Table 3(a) to 3(c), Fig. 4, Appendix III).

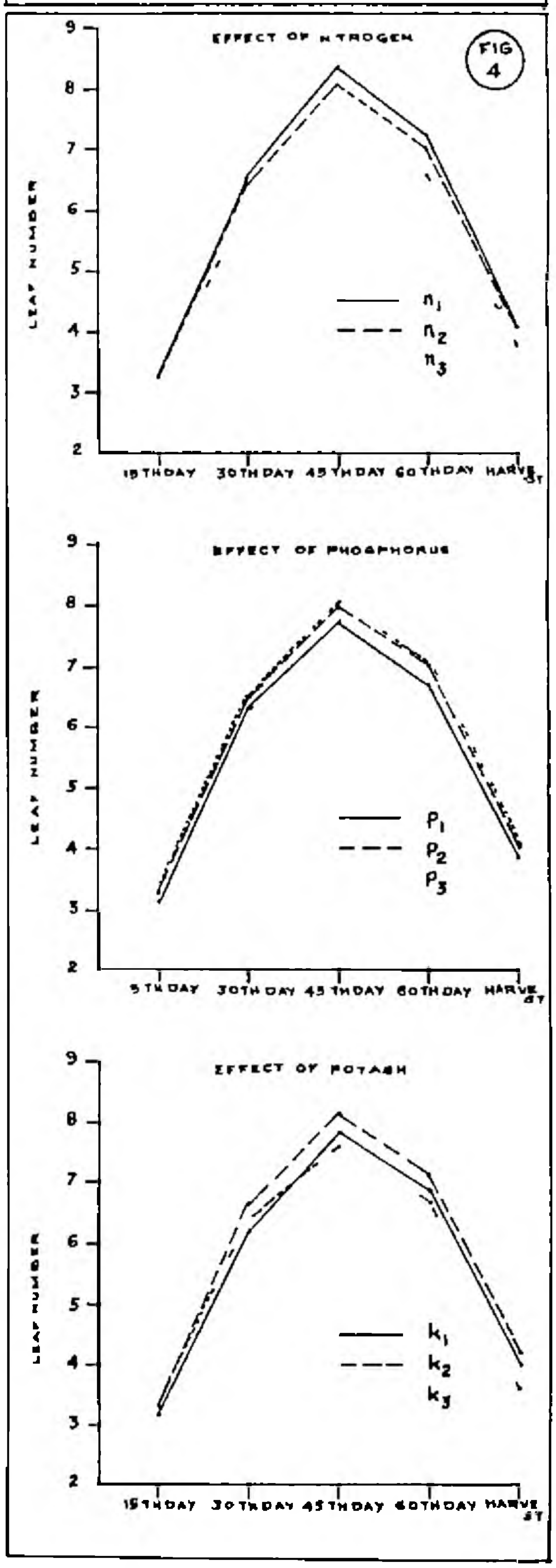
From the tables it can be noted that nitrogen levels had no effect on altering the number of leaves in the early stages of crop growth. However, at 45th and 60th days after sowing the highest level of nitrogen reduced significantly the average leaf number over the lower levels and again at harvest there was no difference due to nitrogen levels. The number of leaves is a genetic character and so normally it is not affected by the nitrogen levels. The reduction in the number at the highest level of nitrogen application on 45th and 60th day may be due to the better transformation of the nitrogen by destructive senescence from the leaves to grain filling, and at harvest stage the difference may have levelled off.

The effects of different levels of phosphorus and potash were not significant on the number of leaves per plant at any of the growth stages studied. But there was an increase in trend with doses of phosphorus in all the stages in respect of this character, while medium dose of potash was found to produce higher leaf number compared to other levels from 30th day onwards indicating that beyond 20 kg $K_2O$ per ha

HEIGHT OF PLANTS AT VARIOUS GROWTH STAGES




NUMBER OF LEAVES AT VARIOUS GROWTH STAGES



it may not be necessary.

The interaction between nitrogen and potassium was found to be significant at 60th day after planting and at harvest. At both these stages 30 kg N + 10 kg $K_2O$ recorded the maximum number of leaves. The decrease in trend with increase in levels of nitrogen might have been more than compensated by potassium application, thereby indicating the necessity of potassium nutrition along with nitrogen to increase the number of leaves per plant.

The P x K interaction was significant at 15th day after sowing and also at harvest. The treatment combination $p_3k_3$ (60 kg $P_2O_5$ and 30 kg $K_2O$/ha) and $p_3k_2$ (60 kg $P_2O_5$ and 20 kg $K_2O$/ha)recorded the maximum number of leaves at 15th day after sowing and at harvest respectively. The significance noted in the P x K interaction may probably be due to the cumulative effect of these nutrients in increasing the number of leaves.

(c) Number of branches per plant

(Table 4, Fig. 5, Appendix IV)

The results show that the different levels of nitrogen did not significantly influence the number of branches per plant which was in conformity with the findings of Shukla (1964) and Bhattacharya (1971) in gram. Similarly the various levels of phosphorus under study did not influence this character significantly, but an increase in the dose of phosphorus resulted in a slight reduction in the number of branches. These may perhaps be due to the fact that the lowest levels of nitrogen and phosphorus applied have been sufficient for obtaining the maximum number of branches.

The effect of potash in influencing this character was significant. There was a linear relationship between the levels of potash and the number of branches per plant. When the level of potash was raised from 10 to 20 and then to 30 kg per ha the number of branches increased from 2.49 to 2.93 and 3.19 respectively recording a significant difference between successive levels. Potash is known to increase meristematic tissue, maintaining adequate water relations etc. helping better plant growth including branching. Thus the favourable effect of potash upto 30 kg per ha in the development of branches is clearly brought out.

(d) Number of nodules per plant

(Table 5, Fig.6, Appendix IV)

The results reveal that the different levels of nitrogen did not significantly influence the number of nodules per plant and this is in agreement with the findings of Mishra and Singh (1968) and Smith et al. (1968) in soyabean. However a reduction of 30.9 per cent in the number of nodules was noticed when the level of nitrogen was increased from 20 to 30 kg per ha. This may be due to the fact that nitrogen fixing bacteria, when provided with readily assimilable nitrogen, become less active in fixing atmospheric nitrogen, thus retarding the formation of nodules. This is in agreement with the findings of Bebin and Ignatenko (1969), Toen (1970), Rubes (1974) and Ramamohan Rao and Meder (1975) in soyabean and of Muthuswamy (1975), Jayadevan and Sreedharan (1975) and Punnoose and George (1975) in groundnut.

It can be seen that the increase in the level of phosphorus significantly increased the number of nodules per plant. Phosphorus at 60 kg/ha recorded the maximum number of 46.97 nodules followed by 45 and 30 kg $P_2O_5$ per ha with 26.44 and 18.63 nodules respectively. The increased levels of phosphorus might have increased the activity of rhizobia and thus the number of nodules. Similar increase in the number of nodules with increase in the levels of phosphorus was observed by Deshpande and Bathkal (1965) in mung bean, Sharma and Garg (1973) in cowpea and by Chowdhury et al. (1975) in gram.

The effect of potash in increasing the number of nodules per plant was not significant. But a slight increase (12.73 per cent) was noticed when the $K_2O$) level was increased from 10 to 30 kg/ha and this is in agreement with the findings of Chesney (1974) in cowpea.

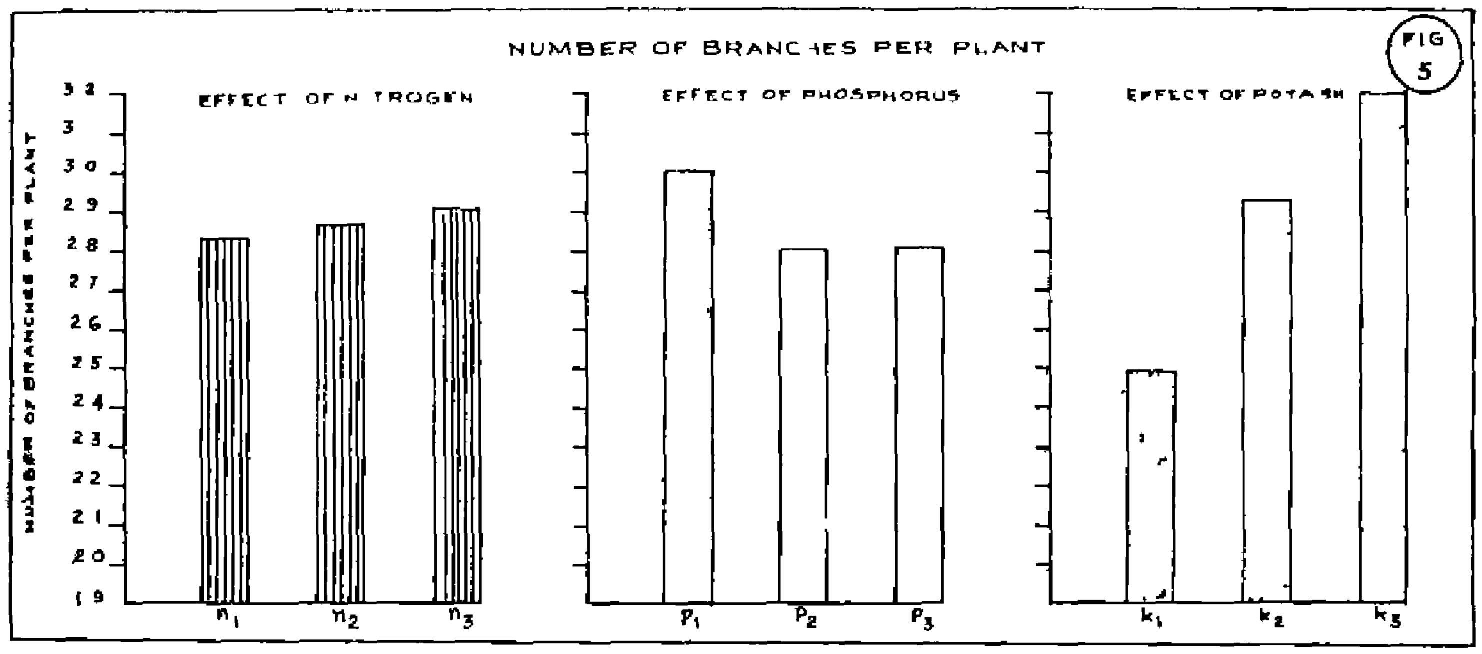
(c) Dry weight of nodules per plant

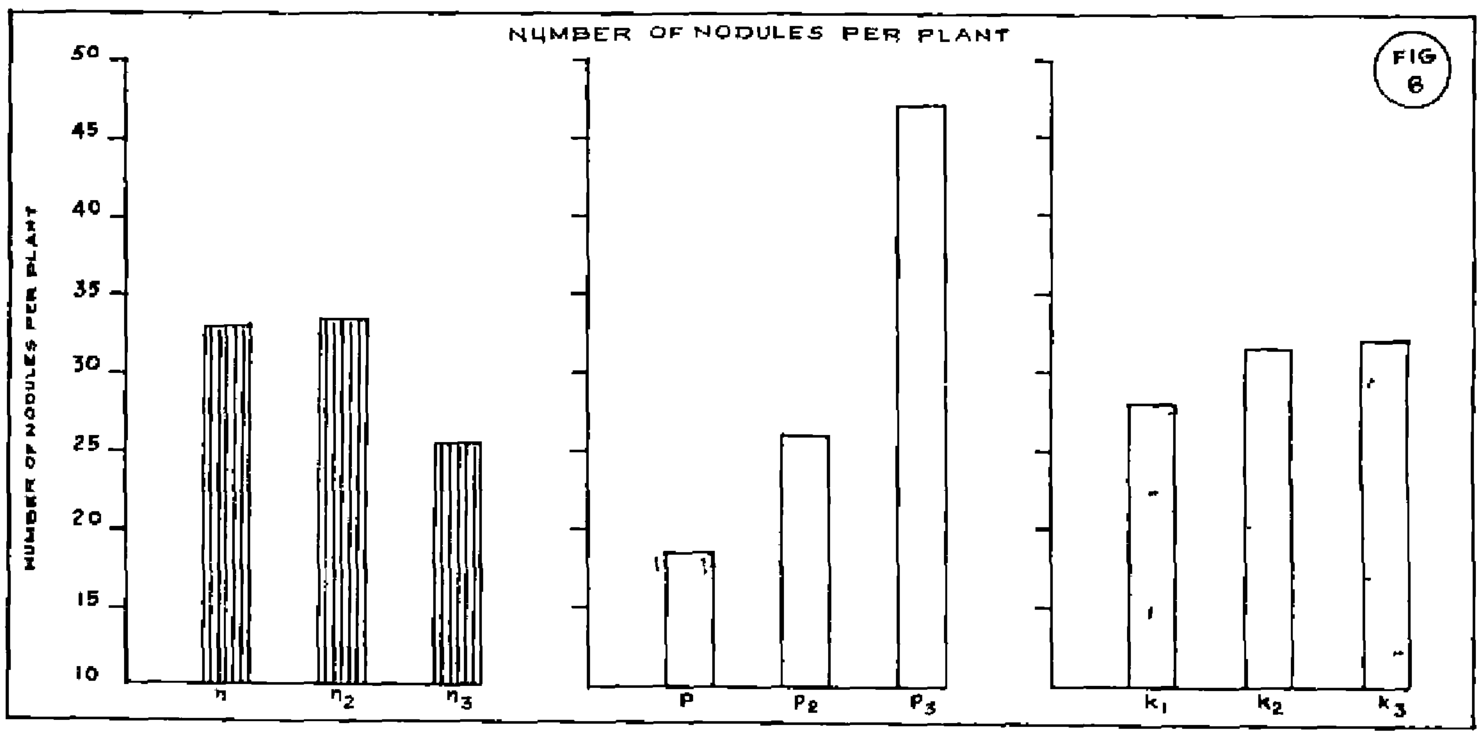
(Table 6, Fig.7, Appendix IV)

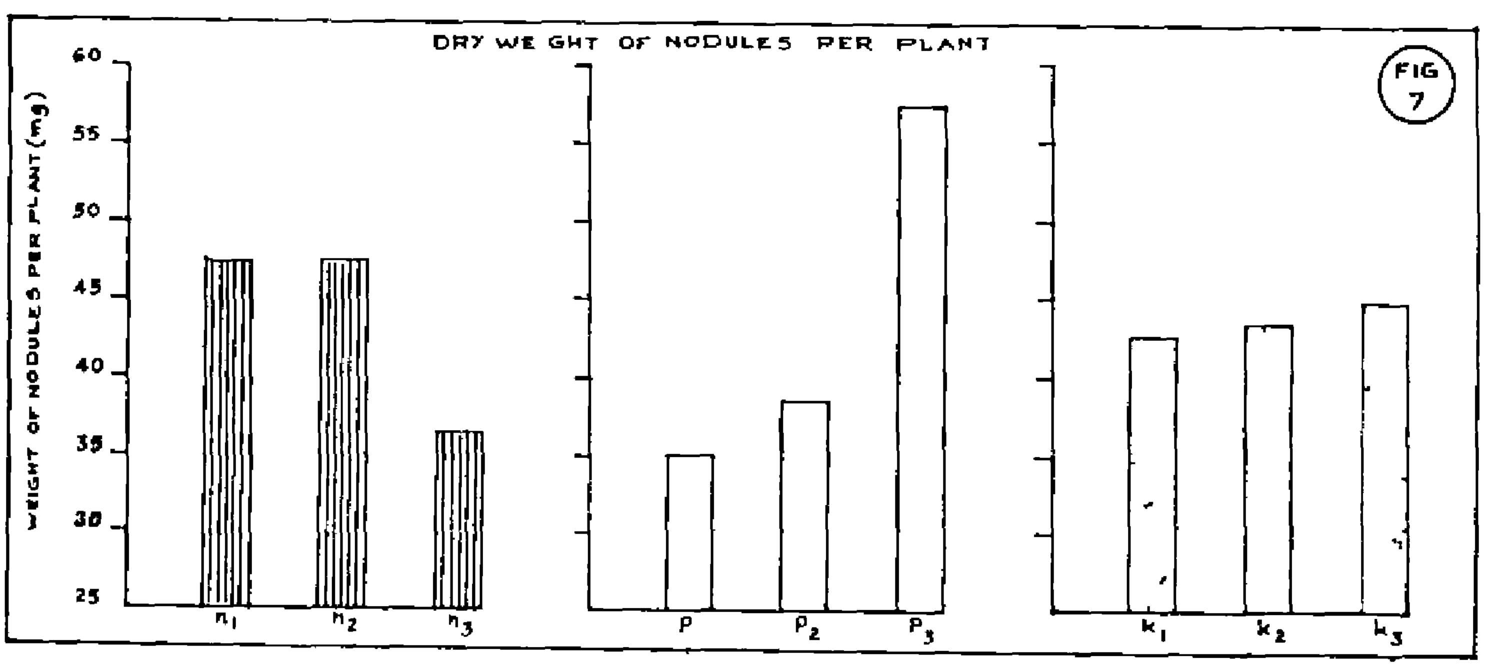
The data show that neither the individual nutrients nor their combinations at the various levels did influence the weight of nodules per plant. However, when the level of nitrogen was increased from 20 to 40 kg per ha the weight of nodules per plant was reduced from 47.50 mg to 36.93 mg showing the same pattern of reduction as noticed in the case of the number of nodules per plant. This again may be due to the fact that nitrogen fixing bacteria when provided with readily assimilable nitrogen become less active in fixing atmospheric nitrogen thus retarding the formation of nodules. Similar results were reported by Rubes (1974) in soyabean, Jayadevan and Sreedharan (1975) and Punnoose and George (1975) in groundnut, and by Papanicolaou et al. (1977) in beans (*Phaseolus vulgaris*).

Though the incremental doses of phosphorus did not significantly influence the weight of nodules per plant there was actually an increase from 35.14 mg to 57.78 mg when the level of phosphorus was increased from 30 to 60 kg per ha. The favourable effect of phosphorus in increasing the number of nodules per plant might have contributed to the increase in dry weight of nodules per plant. Similar results were obtained by Almeida et al. (1973) in beans, Sharma and Garg (1975) in cowpea, Choudhury et al. (1975) in gram, and by Ramamohan Rao and Nadar (1975) in soyabean.

The levels of potash could not vary much the weight of nodules per plant. When the level was increased from 10 to 30 kg the increase in weight was only from 42.92 mg to 45.14 mg which is very low compared to the effect of nitrogen and phosphorus. This indicates that potash does not have much


NUMBER OF BRANCHES PER PLANT
FIG 5
EFFECT OF NITROGEN
EFFECT OF PHOSPHORUS
EFFECT OF POTASH
NUMBER OF BRANCHES PER PLANT
32
31
30
29
28
27
26
25
24
23
22
21
20
19
n1
n2
n3
P1
P2
P3
k1
k2
k3


NUMBER OF NODULES PER PLANT
FIG 6
NUMBER OF NODULES PER PLANT
50
45
40
35
30
25
20
15
10
n
n2
n3
P
P2
P3
k1
k2
k3


DRY WEIGHT OF NODULES PER PLANT
FIG 7
WEIGHT OF NODULES PER PLANT (mg)
60
55
50
45
40
35
30
25
n1
n2
n3
P
P2
P3
k1
k2
k3

effect on nodulation.

## II. Yield and yield attributes

### (a) Number of pods per plant

(Table 7, Fig. 8, Appendix V)

The results reveal that the different levels of nitrogen did not significantly influence this character. But an increase in number from 9.83 to 10.03 was noted when the level of nitrogen was increased from 20 to 30 kg per ha after which there was no effect. The non significant effect of the levels of nitrogen on this character shows that the lowest level of nitrogen tried was sufficient to produce optimum number of pods per plant. This is in agreement with the findings of Panwar et al. (1977) in black gram.

The non significant effect of phosphorus on number of pods per plant shows that the lowest level of phosphorus (30 kg per ha) was sufficient to obtain maximum number of pods.

The decline in the number of pods from 10.24 to 9.80 when the phosphorus level was increased from 30 to 60 kg/ha indicates the negative influence of this nutrient on pod formation beyond the lowest level tried. The P uptake or P requirement of the crop being very low (6 - 7 kg per ha) the lowest level of 30 kg may be sufficient to supply the quantity required by the crop and so the effect was not significant with the levels tried.

From the results it is seen that the effect of potash was significant with respect to the number of pods per plant. There was a linear relationship between the levels of potash and the number of pods per plant. When the level of potash was increased from 10 to 20 kg and then to 30 kg per ha the number of pods increased from 9.04 to 9.67 and 10.97 respectively, recording a significant difference between successive levels. The favourable effect of potash in increasing the number of pods per plant has thus been brought out and this is in agreement with the findings of Gutstein (1970) in groundnut and of Sankara Reddi et al. (1976) in soyabean.

(b) Length of pod

(Table 8, Fig. 9, Appendix V)

The data show that the effect of nitrogen in increasing the length of pod remained uniform at the different levels. Similarly the various levels of phosphorus did not show any significant effect on this character. Thus the non-favourable effect of nitrogen and phosphorus beyond the lowest levels tried (20 kg nitrogen and 30 kg phosphorus per ha) is brought out, to increase the pod length.

Application of graded doses of potash recorded significant increase in length of pod. The highest mean pod length of 5.4 cm was observed at 30 kg $K_2O$ per ha. The significant effect of K on pod length indicates the importance of this nutrient in increasing seed yield of black gram.

(c) Number of seeds per pod

(Table 9, Fig. 10, Appendix V)

It can be seen from the results that the effect of the various levels of nitrogen under study was uniform on the number of seeds per pod. All the three levels of nitrogen gave more or less identical numbers of seeds per pod. Since the length of pod and the number of seeds per pod are related, the effect of levels of nitrogen was also found to be not significant in seed number. The non significant effect of nitrogen on this character might be due to the non significant influence of this nutrient on length of pod, as evidenced from Table 8. As in the case of nitrogen, the effect of phosphorus also was not significant with respect to this character. Since there was no significant difference in length of pod for the different levels of phosphorus, the number of seeds per pod were also not affected by the different levels of phosphorus tried.

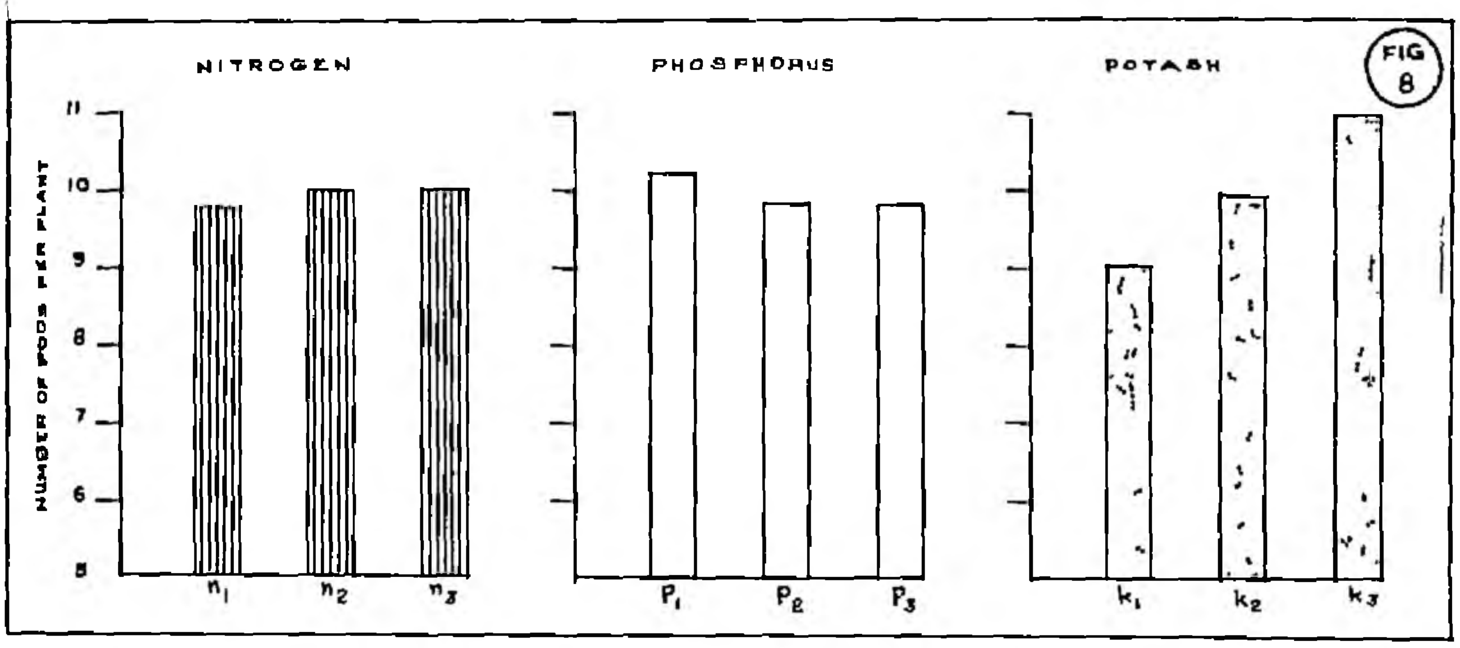
The significant effect of potash in increasing the number of seeds per pod may be due to the significant effect of this nutrient in increasing the length of pod, as evidenced from Table 8.

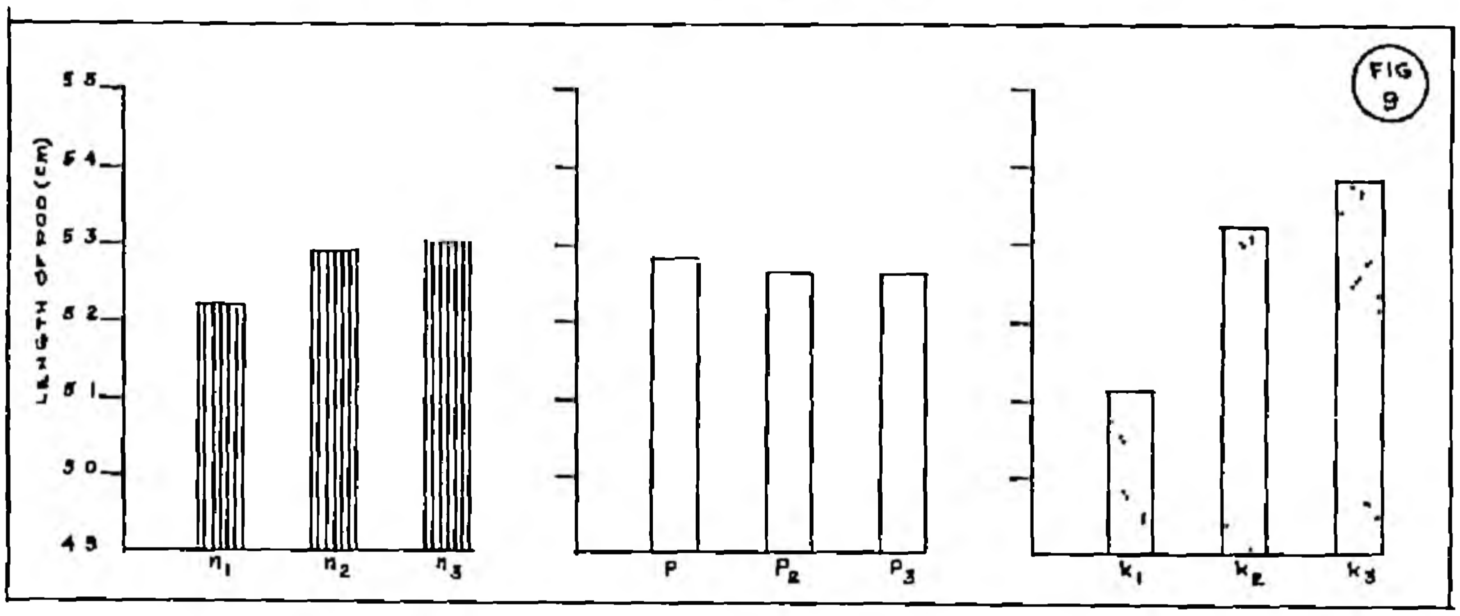
(d) Seed yield per plant

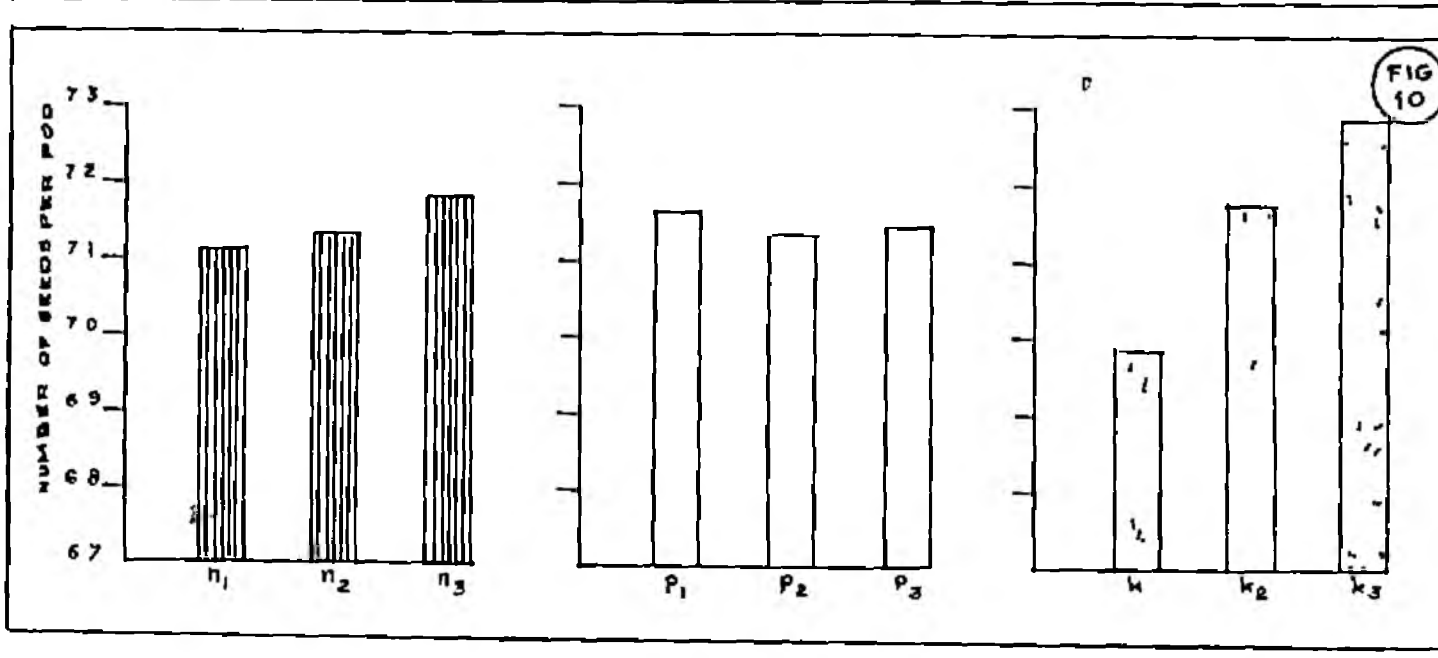
(Table 10, Fig. 11, Appendix V)

The non significant effect of levels of nitrogen on seed yield per plant may be due to the non significant effect of this nutrient on the number of pods per plant,

EFFECT OF NITROGEN PHOSPHORUS AND POTASH ON YIELD ATTRIBUTES



length of pod and the number of seeds per pod.

There was also no significant effect for the different levels of phosphorus with respect to this character, which again may be due to the non significant effect of phosphorus on the above mentioned yield attributes.

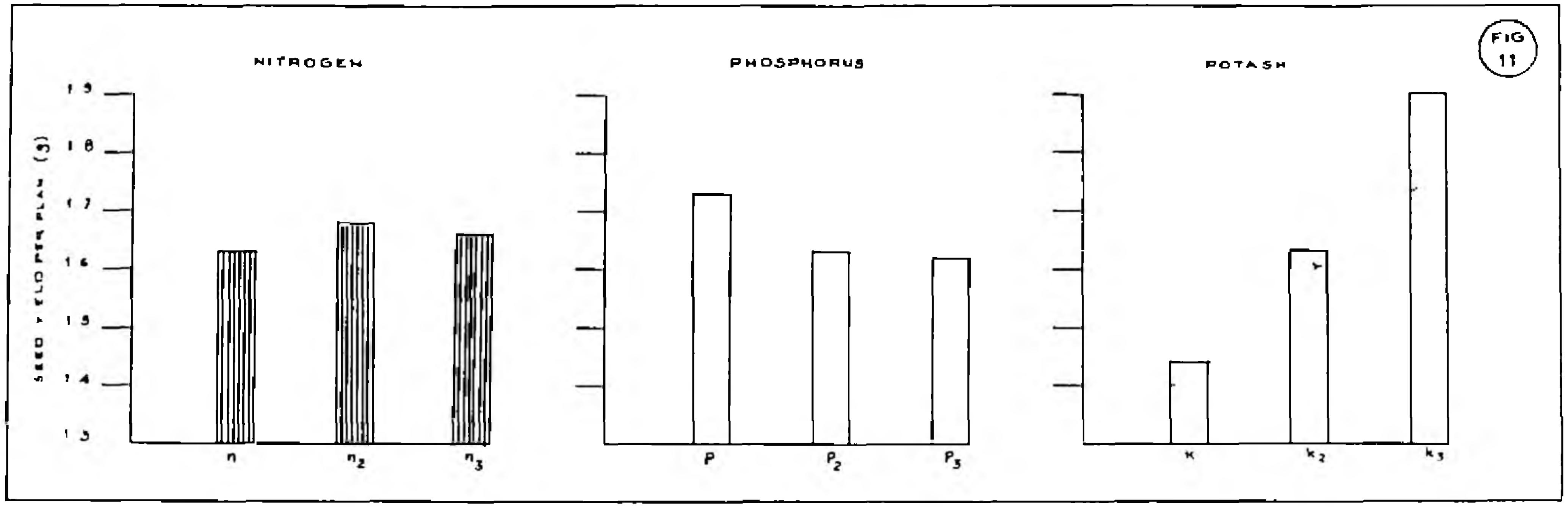
From the results obtained it is seen that the effect of potash was significant in increasing the seed yield per plant. There was a linear relationship between the levels of potash and the yield of seed. When the level of potash was increased from 10 to 20 kg and then to 30 kg per ha the seed yield per plant also increased from 1.44 g to 1.63 g and 1.90 g respectively recording a significant difference between successive levels. It can be seen from Table 7, 8 and 9 that potash application significantly increased the number of pods per plant, length of pod and number of seeds per pod. The cumulative effect of potash on these characters might have significantly contributed to the increase in the yield of seed. Similar increase in seed weight per plant with increasing rate of applied $K_2O$ was obtained by Nemeth and Forster (1976) in field beans.

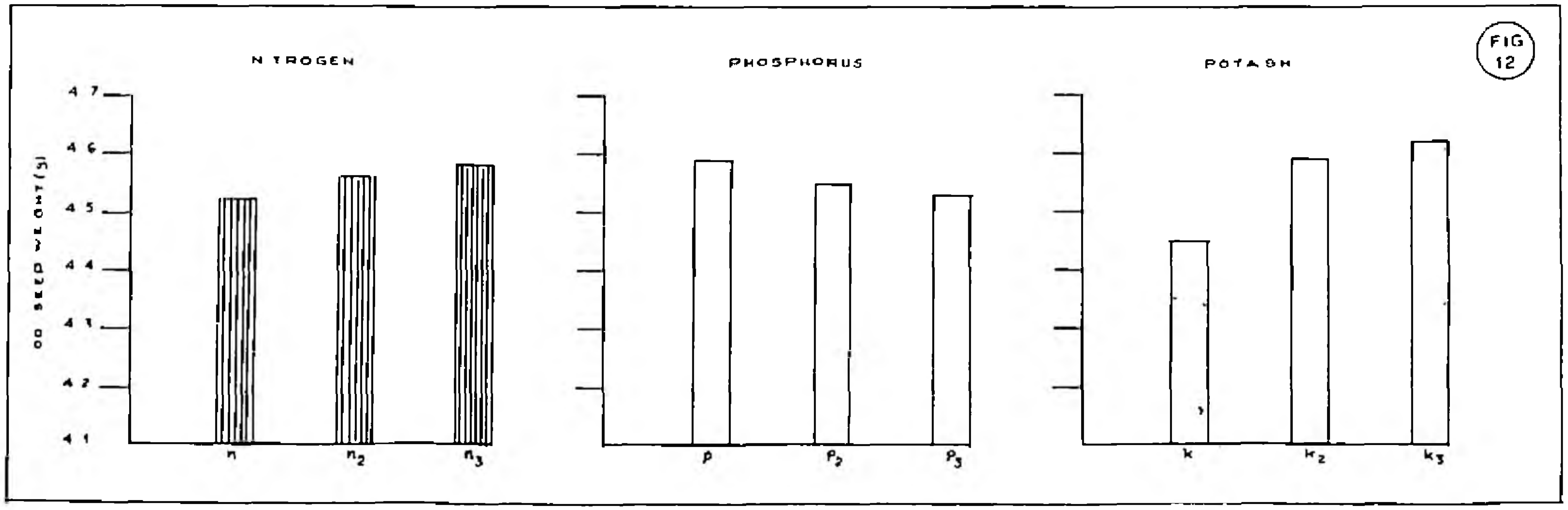
(c) <u>100 seed weight</u>

(Table 11, Fig.12, Appendix V)

The results reveal that the mean valuesof 100 seed weight recorded were not affected by the various levels of nitrogen and phosphorus indicating that the lowest level of these nutrients applied might have been sufficient to obtain

EFFECT OF NITROGEN PHOSPHORUS AND POTASH ON YIELD ATTRIBUTES



optimum 100 seed weight. Similar non significant response with levels of nitrogen and phosphorus was observed by Malik et al. (1972) in cowpea.

On the other hand, the effect of potash on this character, was significant. Potash at 20 or 30 kg per ha was superior to 10 kg per ha and the maximum 100 seed weight of 4.62 g was recorded by the potash level of 30 kg per ha. Thus the favourable effect of potash in the formation and development of seed is brought out. This result is in agreement with the findings of Boles and Sherwood (1965) and Sankara Reddi et al. (1976) in soyabean, and of Nemeth and Forster (1976) in field beans.

(f) Grain yield

(Table 12, Fig. 13, Appendix VI)

The results reveal that the various levels of nitrogen tried produced no significant difference in the yields of seeds. The non significant differences recorded between levels of N on yield contributing factors, namely number of pods per plant, length of pod, number of seeds per pod, weight of seed per plant and 100 seed weight, might have resulted in a more or less uniform grain yield with levels of nitrogen. However there was a slight increase in yield from 1906 to 1962 kg/ha when the level of nitrogen was increased from 20 to 30 kg per ha showing the favourable effect of this nutrient on seed formation after which the yield was reduced. The non significant effect of the various levels of nitrogen under study shows that the lowest level of nitrogen tried might have been sufficient to obtain optimum seed yield in black gram. This is in agreement with the findings of Hosmer and Mojtehedi (1970) in chick pea, dry beans and cowpea, Malik et al. 1972) in cowpea, Venugopal and Morachan (1974) and Panwar et al. (1976) in Phaseolus aureus.

The non significant effect of phosphorus on seed yield may be due to the non significant effect of phosphorus on the yield contributing factors, namely number of pods per plant, length of pod, number of seeds per pod, grain yield per plant and 100 grain weight. The grain yield showed a reduction from 1579 kg to 1524 when the P level was increased from 30 to 45 kg and beyond 45 kg there was no further appreciable reduction which indicates that beyond 30 kg $P_2O_5$ the crop does not require any phosphorus application. Similar non significant response for levels of phosphorus was observed by Bohl et al. (1969) in black gram, Anon (1974) in black gram and green gram, Jannojai Sharma (1974), Addy (1975), Jonson and Evans (1975) and Singh (1976b) in cowpea. Petkov (1974) in Phaseolus vulgaris and by Gill and Chana (1976) in summer mung.

It can be seen that the effect of different levels of potash was significant on grain yield. A linear relationship between levels of potash and grain yield was noticed. When the level of potash was increased from 10 to 20 kg and then to 30 kg per ha the yield was increased from 1355 kg to 1514 kg and 1757 kg/ha respectively recording significant difference between successive levels. It can be seen from Tables 7, 8, 9, 10 and 11 that potash application had significantly increased the number of pods per plant, length of pod, number of seeds per pod, seed yield per plant and 100 seed weight. The cumulative effect of potash on these yield contributing factors might have significantly increased the seed yield. Similar results were obtained by Saraf et al. (1968) and Sawhney et al. (1975) in black gram, Chesney (1974) and Johnson and Evans (1975), in cowpea, Mitkees (1974) in snap beans, Shevelova (1974) in peas and Phaseolus vulgaris, Nemeth and Forster (1976) in field beans and by Forman (1977) and Mustafa et al. (1978) in groundnut.

It can be seen from Table 26 that grain yield shows significant and positive correlation with the yield contributing factors like number of pods per plant, number of seeds per pod, length of pod and 100 seed weight. Similar high positive correlation between yield and the above-mentioned yield attributes were recorded by Verma and Dubey (1970) in black gram.

(g) Bhusa yield

(Table 13, Fig. 13, Appendix VI)

The results show that none of the three factors nor their interactions had any significant effect in increasing the bhusa yield. The non significant effects noticed with levels of N, P and K on this character may probably be due to the non significant effects of these nutrients on the majority of the growth characters.

Though the levels of nitrogen could not significantly increase the bhusa yield, the highest level of 40 kg nitrogen increased the yield by 155 kg per ha over the lowest level. In contrast to this phosphorus could increase the yield upto 45 kg $P_2O_5$ per ha over 30 kg by 224 kg though the differences were not significant. At 60 kg/ha phosphorus depressed the yield of bhusa. This shows that beyond 20 kg nitrogen and 30 kg $P_2O_5$ the bhusa yield will not be significantly increased. In the case of potash though the grain yield was influenced the bhusa yield remained more or less constant for all the levels tried.

(h) Harvest index

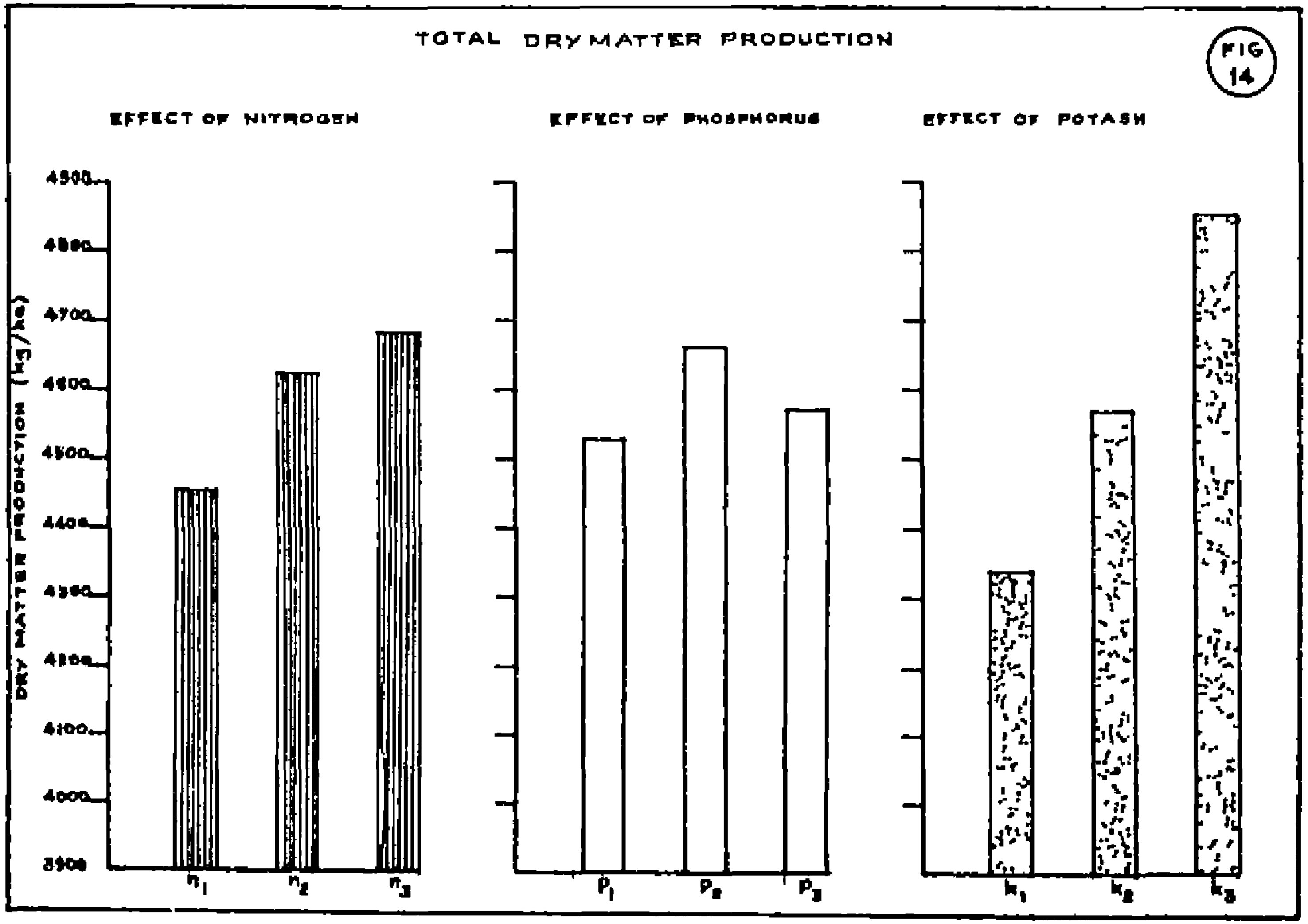
(Table 14, Appendix VI)

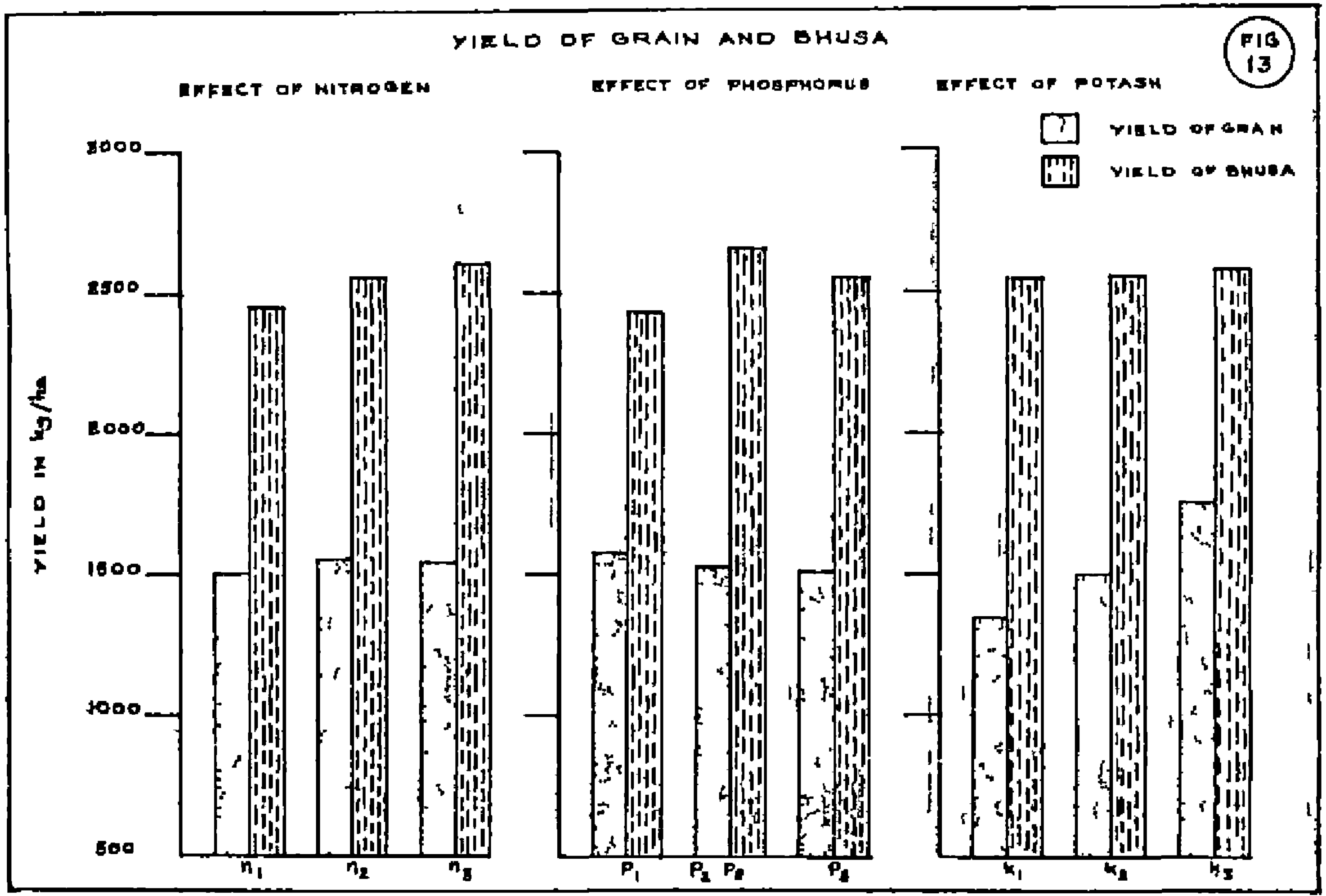
The non significant effects of levels of nitrogen and phosphorus on harvest index indicate that the levels of nutrients tried had no influence on the economic yield of this crop. But a slight increase in the ratio, with increased levels of potash though not significant, shows the influence of this nutrient in increasing the seed yield.

(i) Total dry matter production

(Table 15, Fig. 14, Appendix VI)

The results reveal that the effect of nitrogen and phosphorus in increasing the dry matter was not significant.


TOTAL DRY MATTER PRODUCTION
FIG 14
EFFECT OF NITROGEN
EFFECT OF PHOSPHORUS
EFFECT OF POTASH
DRY MATTER PRODUCTION (kg/ha)
4900
4800
4700
4600
4500
4400
4300
4200
4100
4000
3900
$n_1$
$n_2$
$n_3$
$p_1$
$p_2$
$p_3$
$k_1$
$k_2$
$k_3$



YIELD OF GRAIN AND BHUSA
FIG 13
EFFECT OF NITROGEN
EFFECT OF PHOSPHORUS
EFFECT OF POTASH
YIELD OF GRAIN
YIELD OF BHUSA
YIELD IN kg/ha
3000
2500
2000
1500
1000
500
n1
n2
n3
P1
P2
P3
P4
k1
k2
k3

It can be seen that almost all the growth and yield promoting characters remained uniform with levels of nitrogen and phosphorus and as such the total dry matter production was not significantly influenced by nitrogen and phosphorus.

The significant difference between levels of potash on total dry matter production may be due to the significant influence of this nutrient on yield and yield promoting characters as evidenced from their mean tables. The above result is in agreement with the findings of Mitkees (1974) in snap beans, and Tarman (1977) in soybean.

### III. Uptake studies

#### (a) Uptake of nitrogen

(Table 16, Fig. 15, Appendix VII)

The results show that though there was an initial increase in nitrogen uptake when the level of nitrogen was increased from 20 to 30 kg per ha, the effect was non significant and this shows that the crop did not continue to absorb this nutrient in proportion to its supply. The non significant effect of phosphorus on nitrogen uptake may be due to the non significant effect of this nutrient on dry matter production.

The significant increase in the nitrogen uptake with increase in levels of potash may be due to the significant influence of this nutrient on the meristematic activity of the plant which resulted in the increase in total dry matter production with a proportionate increase in nitrogen uptake. This is in agreement with the findings of Chevalier (1976) in soyabean.

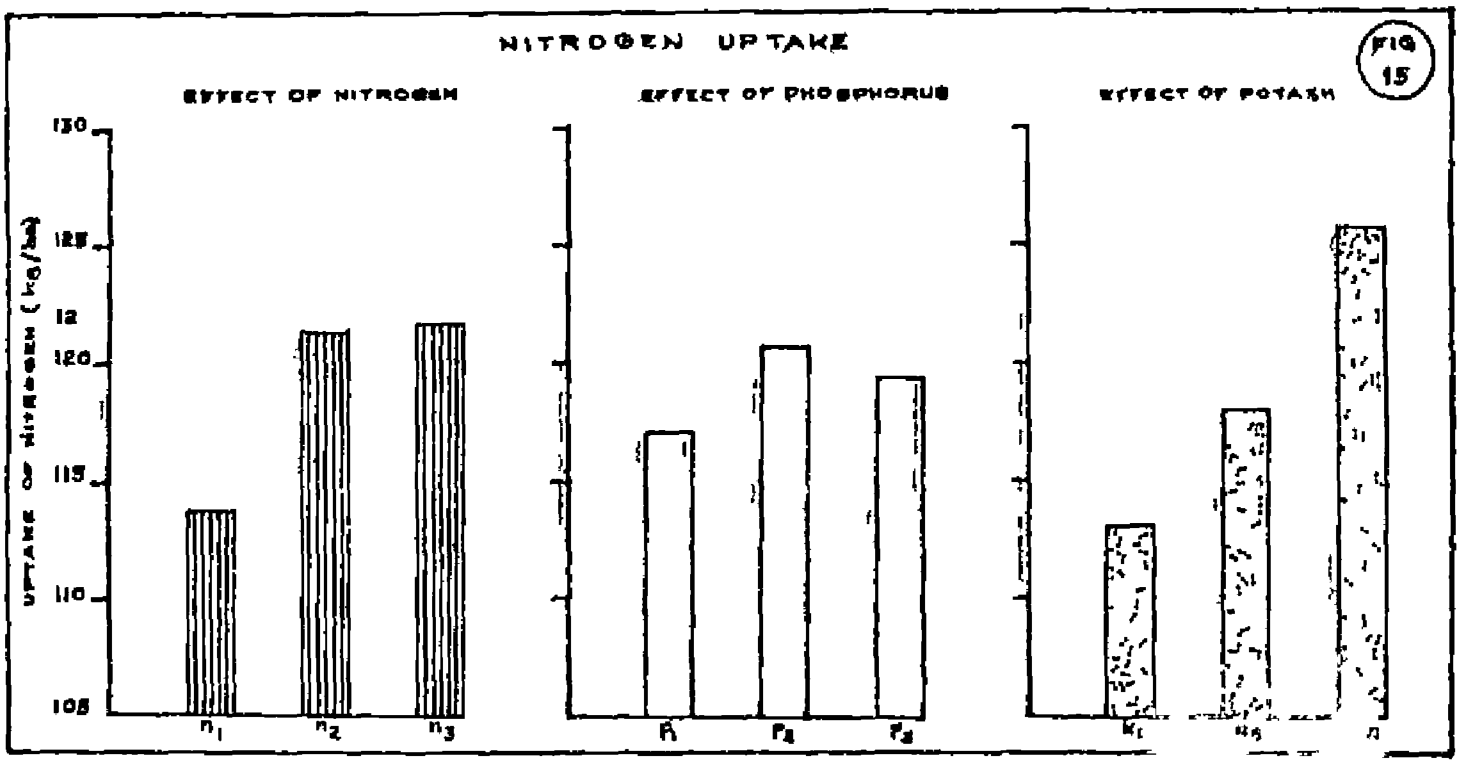
(b) Uptake of phosphorus

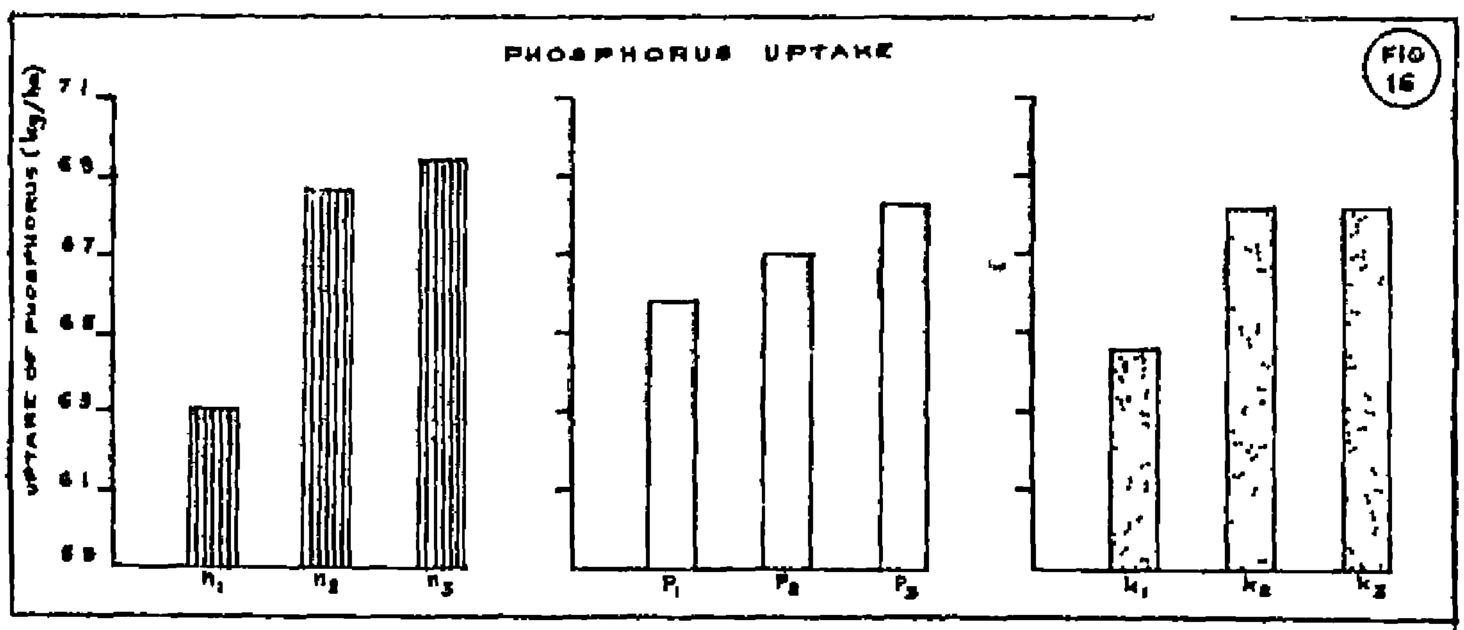
(Table 17, Fig. 16, Appendix VII)

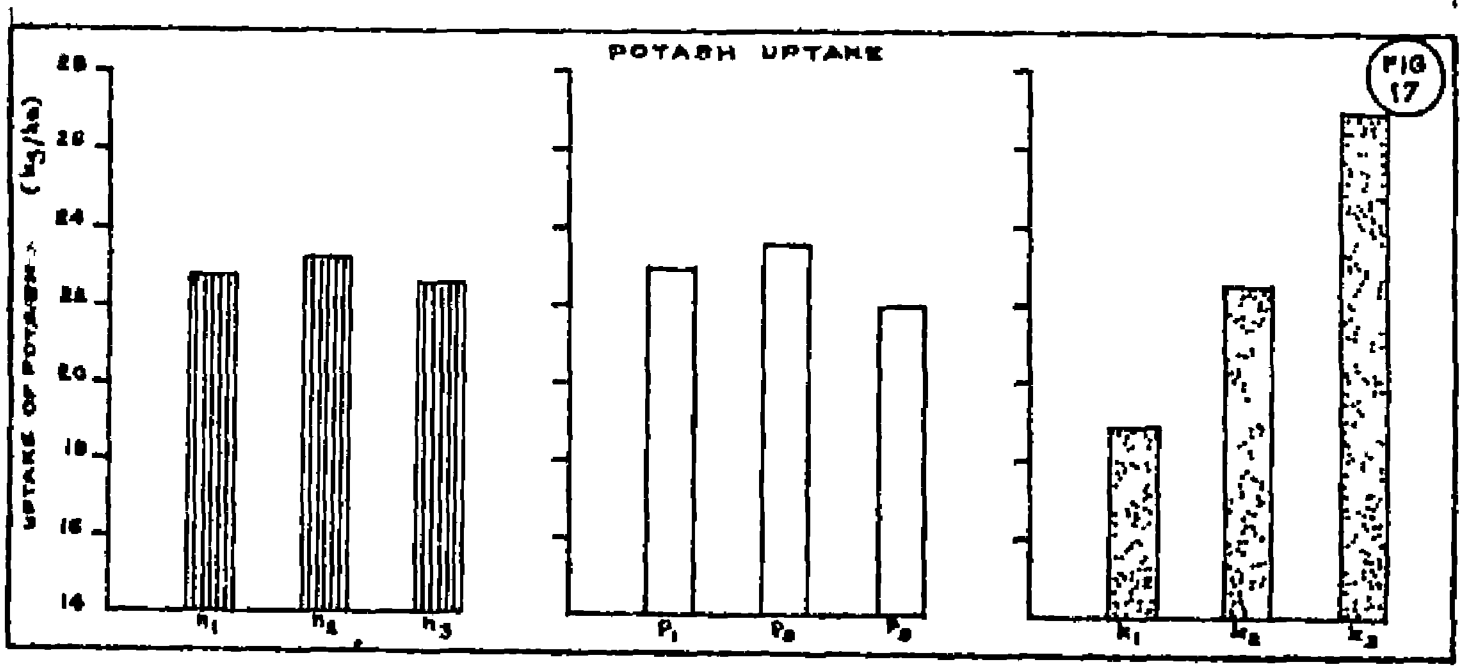
It is seen that increase of nitrogen to 30 kg significantly increased the uptake of phosphorus over 20 kg nitrogen and beyond 30 kg the increase was not significant. Addition of ammoniacal nitrogen (ammonium sulphate) at planting has beneficial effects on the absorption of P by plants. Grunes (1959) has listed various reasons for the effect of nitrogen on phosphorus uptake. Similar positive influence of nitrogen in increasing the phosphorus uptake of plants was reported by Sinha (1971) in gram.

The non significant effect of phosphorus on the P uptake may be due to the non significant influence of this nutrient on the dry matter production. The trend for increase with increase in levels of applied phosphorus indicates the absorption of this nutrient in proportion to its supply. This is in agreement with the findings of Rajendran et al. (1975) in Phaseolus mungo and of Sharma et al. (1974) in green gram.

The non significant influence of the levels of potash on phosphorus uptake shows that potash had no influence on the absorption of this nutrient.


NITROGEN UPTAKE
FIG 15
EFFECT OF NITROGEN
EFFECT OF PHOSPHORUS
EFFECT OF POTASH
UPTAKE OF NITROGEN (kg/ha)
130
125
120
115
110
105
$n_1$
$n_2$
$n_3$
$P_1$
$P_2$
$P_3$
$k_1$


PHOSPHORUS UPTAKE
FIG 16
UPTAKE OF PHOSPHORUS (kg/ha)
$n_1$
$n_2$
$n_3$
$P_1$
$P_2$
$P_3$
$k_1$
$k_2$
$k_3$


POTASH UPTAKE
FIG 17
UPTAKE OF POTASH (kg/ha)
$n_1$
$n_2$
$n_3$
$P_1$
$P_2$
$P_3$
$k_1$
$k_2$
$k_3$

(c) Uptake of potash

(Table 18, Fig. 17, Appendix VII)

The non significant effect of various levels of nitrogen on potassium uptake may be due to the possible blocking of potassium ions at higher concentrations of ammonium ions in the soil (Tisdale and Nelson, 1975).

Rehoja (1966) reported that the potassium uptake of plants is normally independent of the concentration of available or total phosphorus in the soil. The non significant effect of P on potash uptake observed in this study is in agreement with the above findings.

The potash uptake of plants increased significantly with increased levels of potash application. The linear and significant increase in the grain yield, as well as in potash uptake, observed between successive levels of potash indicates the continued absorption of this nutrient up to the highest dose applied. The correlation between grain yield and $K_2O$ uptake is also positive and highly significant. Moreover the luxury consumption of potassium by plants is well known. These together might have resulted in high uptake of this nutrient. Similar results have been reported by Rehoja (1966), Harishankar and Kushwaha (1971) in urd and by Gronoman (1974) in soyabean.

IV. Quality characters

(a) Protein content of the grain

(Table 19, Fig. 18, Appendix VIII)

The non significant effect of nitrogen, phosphorus and potassium and their interactions on the protein content of the grain show that the lowest level of these nutrients tried was sufficient to give optimum protein content of seeds. But a slight trend for increase noticed on the protein content of seeds due to the increased levels of nitrogen from 20 kg to 30 kg brings out the favourable effect of nitrogen in the protein content of seeds. Application above 30 kg reduces the protein content indicating that beyond 30 kg the effect on protein production is adversely affected.

Application of phosphorus also slightly increased the protein content of seeds showing thereby a favourable effect for this nutrient on this character. Similar non significant effect on the seed protein content with the application of nitrogen and P was reported by Malik et al. (1972) in cowpea and Singh et al. (1969) in pea. Similar to nitrogen and phosphorus levels of potash also did not influence significantly the protein content of the grain. But contrary to nitrogen and phosphorus, potash showed a decreasing trend.

When K helped to increase the grain yield, it reduced the protein content. Similar non significant response of potassium on protein content was reported by Bhuiya and Chowdhury (1974) in groundnut.

(b) Grain protein yield

(Table 20, Fig. 20, Appendix VIII)

The grain protein yield was not significantly affected by the various levels of nitrogen and phosphorus. It can be seen from Tables 19 and 11 that the protein content of grain and yield of grain were not affected by the levels of nitrogen and phosphorus and hence the grain protein yield also showed the same trend.

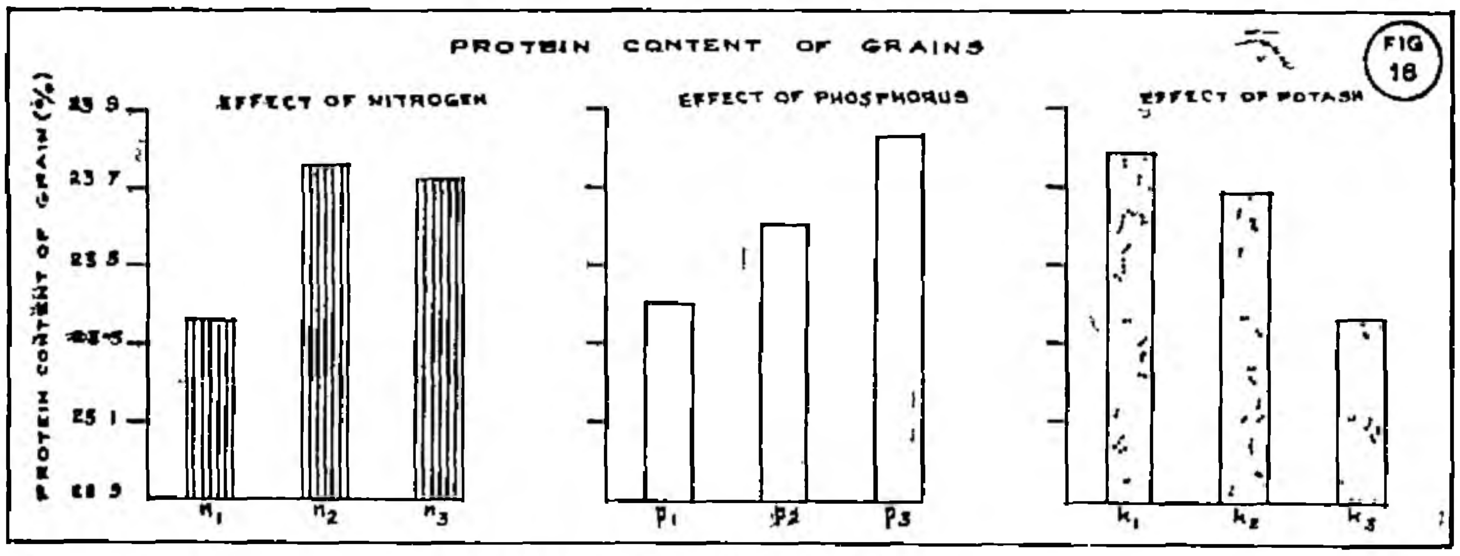
The significant effect of potash on this character might be due to the significant linear effect of this nutrient on yield of seeds. The steady and progressive increase in grain protein yield noticed upto the highest level of this nutrient (30 kg per ha) reveals the influence of potassium in obtaining maximum grain protein yield. Though the protein content was reduced due to levels of K the protein yield was compensated by the higher grain yield. This is in agreement with the findings of Haghparast and Mengel (1973) in Vicia faba and Moraes (1976) in soyabean.

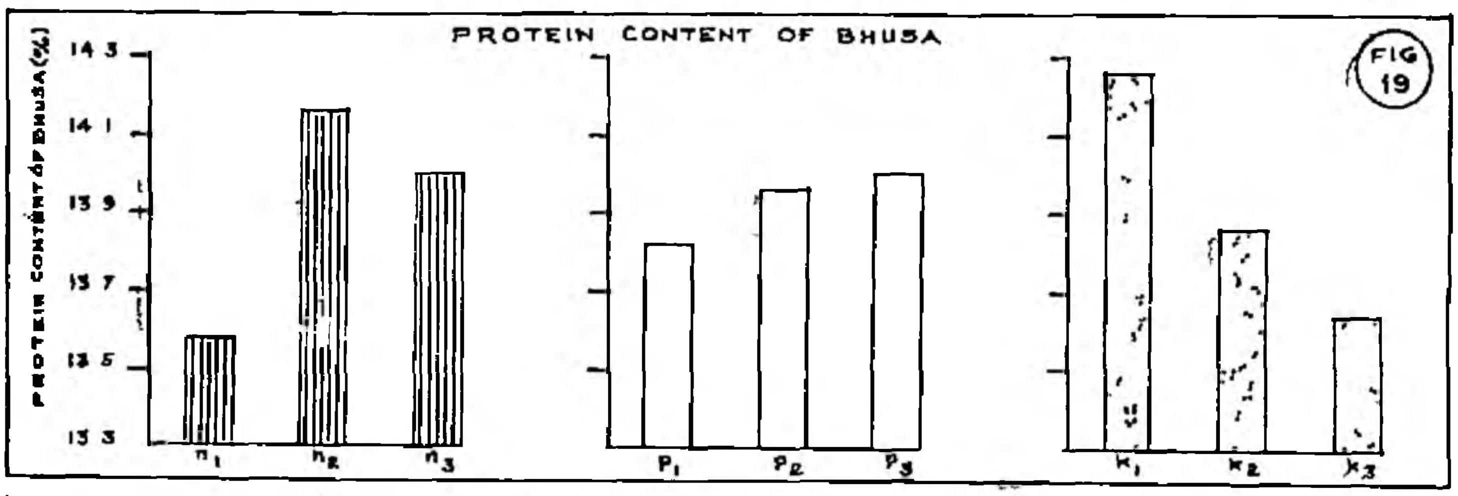
(c) Protein content of bhusa and fodder protein yield

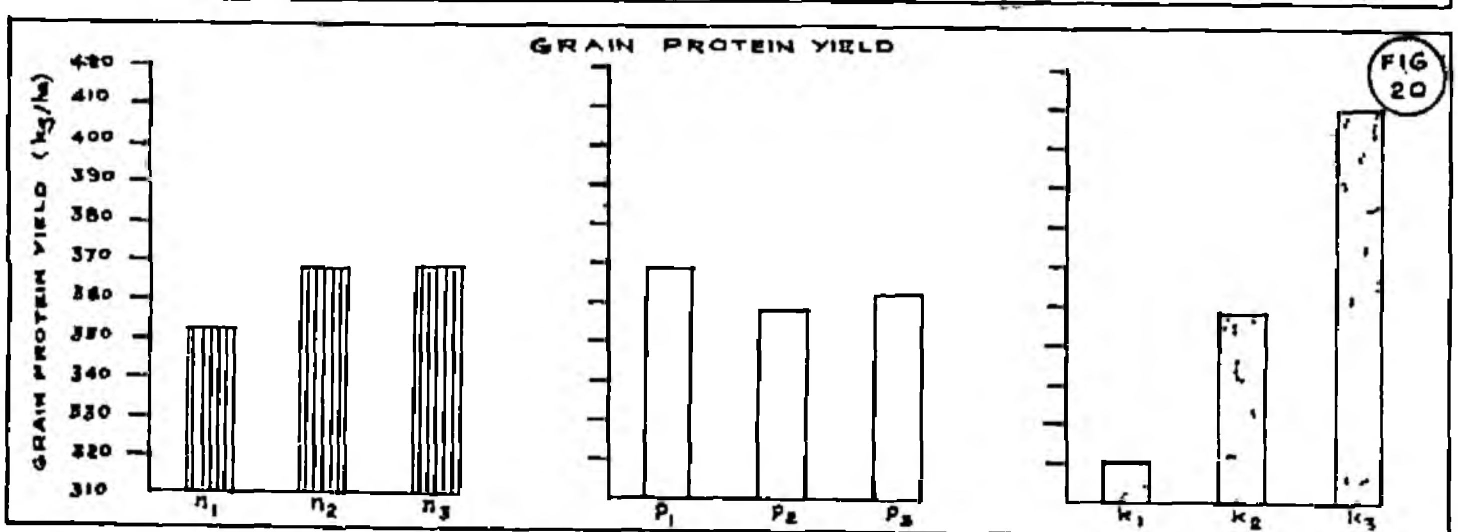
(Tables 21 and 22, Fig. 19 and 21, Appendix VIII)

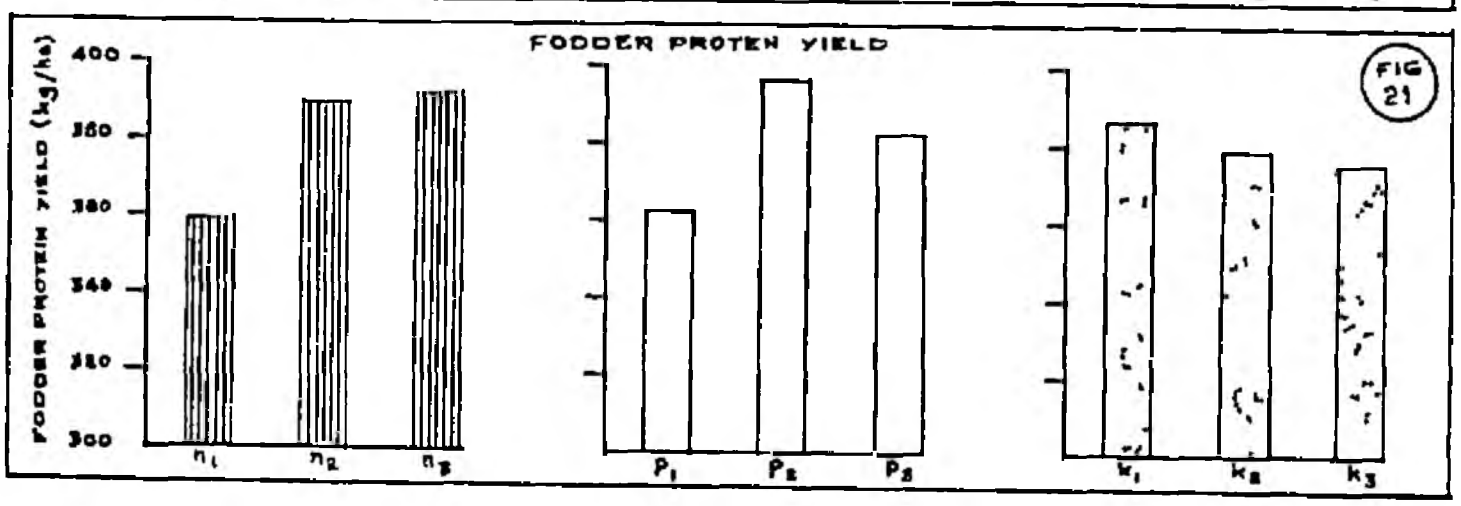
The data presented in the above tables revealed that none of the treatments or their interactions significantly influenced the protein content of bhusa and fodder protein yield. However the increasing trend noticed on these characters with increasing levels of nitrogen may be due to the favourable effect of nitrogen in protein formation and bhusa yield.

The non significant effect of phosphorus on the above characters might be due to the non significant effect of this nutrient on nitrogen uptake. Beyond 45 kg $P_2O_5$/ha, the fodder


PROTEIN CONTENT OF GRAINS
FIG 18
EFFECT OF NITROGEN
EFFECT OF PHOSPHORUS
EFFECT OF POTASH
PROTEIN CONTENT OF GRAIN (%)
n1 n2 n3
P1 P2 P3
K1 K2 K3


PROTEIN CONTENT OF BHUSA
FIG 19
PROTEIN CONTENT OF BHUSA (%)
n1 n2 n3
P1 P2 P3
K1 K2 K3


GRAIN PROTEIN YIELD
FIG 20
GRAIN PROTEIN YIELD (kg/ha)
420
410
400
390
380
370
360
350
340
330
320
310
n1 n2 n3
P1 P2 P3
K1 K2 K3


FODDER PROTEN YIELD
FIG 21
FODDER PROTEIN YIELD (kg/ha)
400
300
n1 n2 n3
P1 P2 P3
K1 K2 K3

protein yield was decreased.

It may be noted that as the level of potash was increased from 10 to 30 kg, the protein yield was decreased, though not significantly. This is due to the proportionate decrease in the protein content of bhusa as well as the constant values of bhusa yield which indicates that $K_2O$ had no significant influence on the fodder protein yield. A similar result has been reported by Naghparast and Mengel (1973) in Vicia faba.

## V. Soil analysis

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

(Table 23, Appendix IX)

The total nitrogen content of the soil was not significantly influenced by the levels of nitrogen. It can be seen from Tables 5, 6 and 14 that the number and weight of nodules per plant and nitrogen uptake were not significantly influenced by levels of nitrogen and therefore also the nitrogen content of the soil.

The non significant influence of phosphorus on nitrogen content of the soil may be due to its non significant effect on weight of nodules and nitrogen uptake. Similarly the levels of potassium also remained uniform with respect to total N content of the soil as K had no influence on the number of nodules per plant and weight of nodules per plant.

The maximum nitrogen content of the soil noticed in the treatment combination $p_2k_2$ may be due to the favourable and combined influence of high levels of phosphorus and potash on the number and weight of nodules per plant. Thus the importance of biological fixation of nitrogen in increasing the nitrogen content of the soil with a combined application of P and K is brought out.

(b) Available phosphorus content of the soil after the experiment (Table 24, Appendix II)

The non significant influence of nitrogen, phosphorus and potash and their interactions on available P content of the soil show that the treatments under trial had no influence on this character. It can be seen from Table 2a to 15 that phosphorus had no effect on any of the growth and yield characters studied. This may probably be due to the fact that the lowest level of phosphorus tried was sufficient to maintain an adequate supply of this nutrient for this crop.

(c) Available potassium content of the soil after the experiment (Table 25, Appendix II)

The available potassium status of the soil also remained uniform showing the non significant influence of the various treatments tried on this character. As a mobile cation $K^+$ is easily susceptible to loss through leaching. Moreover the crop also removed sufficient quantities of potash so the small quantity of applied $K_2O$ could not produce any significant effect on its content in the soil.

<u>Response curve and economics of nitrogen, phosphorus and potash application.</u>

The response of black gram to nitrogen was found to be non significant and hence it is not possible to estimate the optimum dose of nitrogen. So the lowest level of nitrogen tried i.e. 20 kg/ha can be considered as the economic dose of nitrogen for black gram.

The response to phosphorus was also found to be non significant and hence the lowest level tried i.e. 30 kg/ha can be considered as the economic dose for this crop.

Regarding the response to potash, there was significant difference in yield and the response was linear viz.,

$$\hat{y} = 201.41\,x + 1542.15 \quad \text{where } x = \frac{k-20}{10}.$$

The economics of nitrogen, phosphorus and potash application presented in Table 27 reveal that with nitrogen the level of 30 kg N/ha gave the maximum net profit of Rs.3126.20. With phosphorus the lowest level of 30 kg $P_2O_5$/ha gave the maximum net profit of Rs.3215.72. With regard to potash, since there was a linear increase in grain yield with higher levels of potash the maximum net profit of Rs.3696.30 was obtained at the highest level of 30 kg $K_2O$/ha.

RESPONSE OF POTASH ON YIELD OF GRAIN

FIG 22

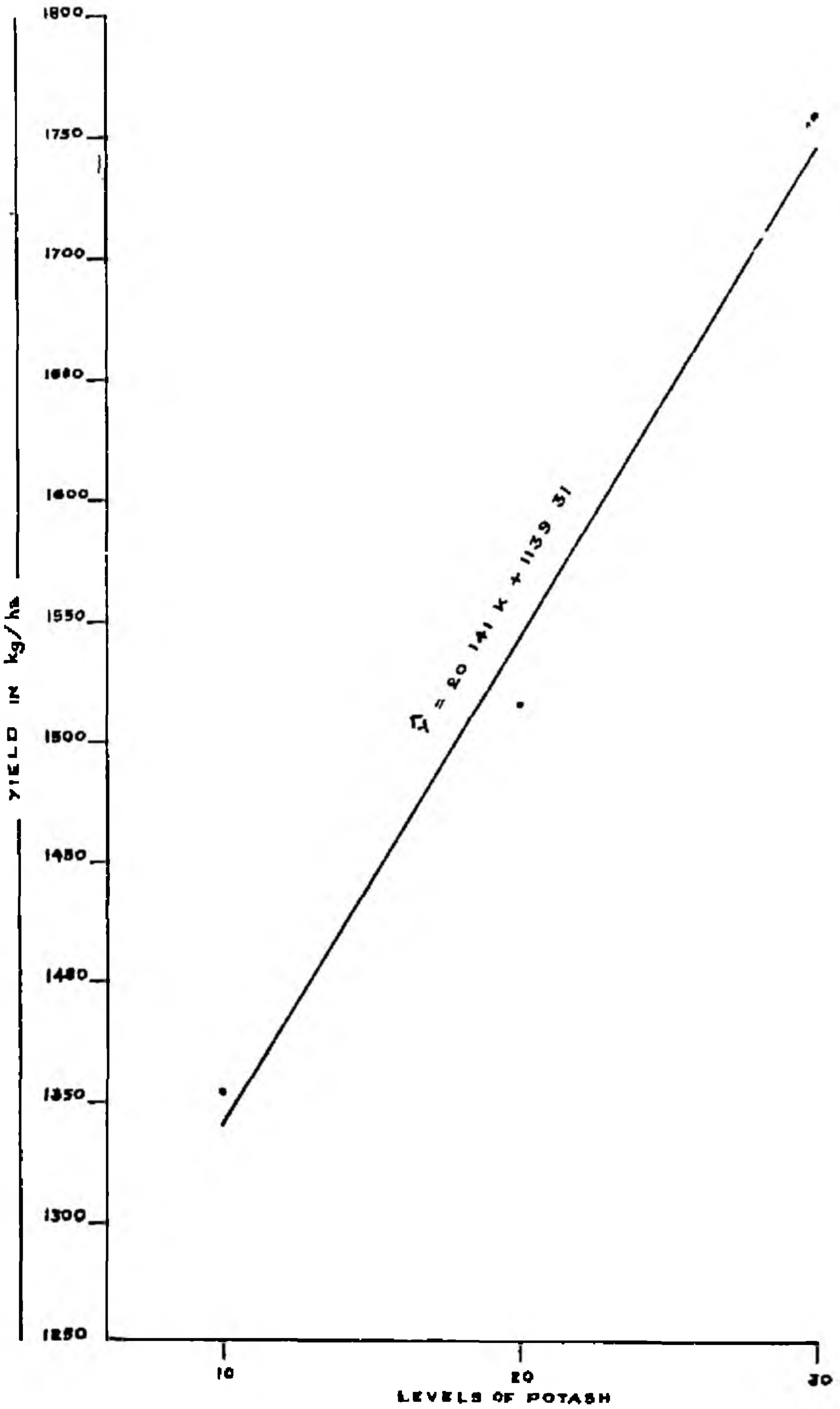


Table 27

Economics of fertilizer application/ha

| Treatments | Cost of production excluding the treatment | Additional cost of treatment | Total cost of production | Yield of grain kg/ha | Yield of bhusa kg/ha | Value of grain @ Rs.3/kg | Value of bhusa @ Rs.0.10/kg | Total value of grain and bhusa | Additional profit from the treatment over the lowest level | Net profit |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rs | Rs | Rs | | | Rs | Rs | Rs | Rs | Rs |
| N kg/ha | | | | | | | | | | |
| 20 | 1677.00 | 92.60 | 1769.68 | 1506 | 2465 | 4518 | 246.50 | 4764.50 | — | 2994.82 |
| 30 | 1677.00 | 139.02 | 1816.02 | 1562 | 2563 | 4686 | 256.30 | 4942.30 | 177.00 | 3126.28 |
| 40 | 1677.00 | 185.37 | 1862.37 | 1558 | 2620 | 4764 | 262.00 | 4936.00 | 172.00 | 3073.63 |
| $P_2O_5$ kg/ha | | | | | | | | | | |
| 30 | 1661.35 | 103.13 | 1764.48 | 1579 | 2432 | 4737 | 243.20 | 4980.20 | — | 3215.72 |
| 45 | 1661.35 | 154.69 | 1816.04 | 1524 | 2656 | 4572 | 265.60 | 4857.60 | -142.59 | 3021.56 |
| 60 | 1661.35 | 206.25 | 1867.60 | 1523 | 2559 | 4569 | 255.90 | 4824.90 | -155.30 | 2957.30 |
| $K_2O$ kg/ha | | | | | | | | | | |
| 10 | 1788.70 | 13.67 | 1802.37 | 1355 | 2548 | 4065 | 254.80 | 4319.80 | — | 2517.43 |
| 20 | 1788.70 | 27.33 | 1816.03 | 1514 | 2549 | 4542 | 254.90 | 4796.90 | 477.10 | 2980.87 |
| 30 | 1788.70 | 41.00 | 1829.70 | 1757 | 2550 | 5271 | 255.00 | 5526.00 | 1206.20 | 3696.30 |
| Mean | 1709.02 | 107.02 | 1816.03 | 1542 | 2549.11 | 4625 | 254.91 | 4880.91 | | 3064.88 |

Price of 1 kg N = Rs.4.63

Price of 1 kg $P_2O_5$ = Rs.3.44

Price of 1 kg $K_2O$ = Rs.1.37

Price of 1 kg grain = Rs.3.00

Price of 1 kg bhusa = Rs.0.10

# SUMMARY

# SUMMARY

An investigation was undertaken in the Instructional Farm, attached to the College of Agriculture, Vellayani during the period from 29th January to 7th April 1979 to find out the effect of graded doses of nitrogen (20, 30 and 40 kg/ha) phosphorus (30, 45 and 60 kg/ha) and potash (10, 20 and 30 kg/ha) on growth, yield and quality of black gram. The experiment was laid out in 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 results of the study are summarised below.

1. Different levels of nitrogen, phosphorus and potash had no significant effect on plant height at any of the stages of crop growth. But the P x K interaction was significant at all stages of growth. The highest level of K in combination with the highest level of phosphorus gave maximum height in the early stages but in the later stages the lowest level of phosphorus in combination with the highest level of K gave the maximum plant height.

2. Nitrogen levels had significant negative influence with increasing rates with respect to number of leaves per plant on 45th and 60th day after sowing. Phosphorus and potash had no significant effect on number of leaves. But P x K interaction was significant at 15th day after sowing and also

at harvest. The N x K interaction was also significant at 60th day after sowing and at harvest.

3. The number of branches increased significantly with increase in levels of only potash recording the maximum number of branches of 3.19 with 30 kg $K_2O$ per ha.

4. In the number of nodules per plant, phosphorus alone had significant effect recording the maximum number of 46.97 nodules with 60 kg $P_2O_5$/ha.

5. None of the treatments had any significant effect on the dry weight of nodules per plant.

6. Neither nitrogen nor phosphorus had any influence on the yield attributing characters such as number of pods per plant, length of pod, number of seeds per pod, seed yield per plant and 100 seed weight. In the case of potash there was a linear and significant increase with increase in the level of potash in the number of pods per plants, length of pod, number of seeds per pod seed yield per plant and 100 seed weight.

7. Nitrogen and phosphorus had no significant influence in increasing the grain yield per ha while potash at 30 kg per ha recorded the maximum grain yield of 1757 kg per ha which was significantly higher when compared to the lower levels.

8. Neither the individual effect of nitrogen, phosphorus and potash nor their interactions were significant in increasing the bhusa yield per ha.

9. Harvest index was not affected by the levels of nitrogen, phosphorus and potash.

10. Total dry matter production increased significantly with increase in the level of potash, while nitrogen and phosphorus had no significant effect with respect to this character.

11. Effect of potash alone was significant in increasing the nitrogen uptake by the crop. Potash at 30 kg per ha recorded the maximum uptake of 125.77 kg nitrogen per ha.

12. Uptake of phosphorus was significantly influenced by the levels of nitrogen only. The maximum uptake of 6.94 kg/ha was recorded at the nitrogen level of 40 kg per ha.

13. The effect of potash alone was significant in increasing the potash uptake by the crop. The maximum uptake of 27.09 kg per ha was recorded at the potash level of 30 kg per ha.

14. Protein content of the grain was not influenced significantly by none of the levels of N, P and K tried.

15. The effect of potash alone was significant to increase the grain protein yield and the maximum grain protein yield of 410.66 kg/ha was recorded at the potash level of 30 kg per ha.

16. Protein content of bhusa followed the very same pattern as that of the grain.

17. Though the levels of nitrogen, phosphorus and potash and potash had no influence in significantly affecting the fodder protein yield. The highest yield of 396.22 kg per ha was obtained with 45 kg $P_2O_5$ per ha.

18. Total nitrogen content of the soil after the experiment was found to be significantly influenced by the P x K interaction.

19. There was no significant effect in the available phosphorus and potassium content of the soil after the experiment with different levels of nitrogen, phosphorus and potash and their interactions.

20. Grain yield was significantly and positively correlated with the yield attributes, nitrogen uptake, phosphorus uptake and potash uptake.

Dry matter production was positively and significantly correlated with nitrogen uptake and potash uptake.

21. The maximum net profit of Rs.3696.30 was obtained with 30 kg $K_2O$ per ha.

The present investigation indicates that black gram requires a fertilizer dose of 20 kg N, 30 kg $P_2O_5$ and 30 kg $K_2O$ per ha, for giving higher yield in rice fallows under Kerala condition.

<u>Future line of work</u>

From the investigation it is seen that black gram, can respond to even higher levels of potash beyond 30 kg tried, in rice fallows. Hence further trials with higher doses of potash have to be conducted to fix the optimum dose of potash for this crop.

# REFERENCES

# REFERENCES


*Addy, H.S.N. (1975). The effect of nitrogen and phosphorus fertilisation on yields and nodulation of cowpea. Miscellaneous paper, Soil Research Institute: 209.

Agarwal, S.K., Behl, N.K. and Moolani, M.K. (1976). Response of summer mung to levels of phosphorus and irrigation under different dates of planting. Indian J. Agron. 21(3): 290-291.

*Almeida, D.L. DE., Pessanha, G.G. and Penteado, A. DE.F. (1973). Effect of liming and of phosphorus and nitrogen fertilizer on nodulation and yield of beans (Phaseolus vulgaris). Pesquisa Agropecuaria Brasileira, Agronomia. 8(7): 127-130.

*Anand Prakash (1969). Soil and foliar application of phosphate. Proc. Third Annual Workshop Conference on Pulse Crop IARI, New Delhi.

*Anonymous. (1974). Wet land pulses, ways and means of maximising production. Technical Bulletin Director of Agriculture, Madras: pp. 60-61.

Anonymous. (1977). Response to N, inoculation and P in red gram. Report of Research work done on Pulses. AICIP, Main Centre, Bangalore (1977-78): 53.

Arora, S.K. and Luthra, Y.P. (1972). Improvement in the quality of Phaseolus aureus Linn. by the application of sulphur phosphorus and nitrogen. Indian J. agric. Chem. 5(2): 77-85.

Aykroyd, W.R. and Doughty Joyce. (1964). Legumes in human nutrition, F.A.O., Rome 1964.

*Badanur, V.P., Satyanarayana, T. and Havanagi, G.V. (1976). Influence of lime and phosphorus in the yield of black gram and uptake of N and P. Curr. Res. 5(2): 29-30.

*Bala, V. (1970). The effect of mineral nutrients on the growth of soybean. Lucrari stiintifice, Institutul Agronomic Timisora, Agronomia. 13: 181-188.

Bains, K.S. (1967). Effect of applied nutrients on soil fertility, chemical composition and yield of field beans. Indian J. Agron. 12(2): 200-206.

Bains, K.S. (1969). Relationship between applied nutrients, plant composition and yield of beans (Phaseolus vulgaris L.) Indian J. Agron. 14(1): 60-62.

Banerjee, M., Das, N. and Bhattacharjee, T.K. (1967). Nutrition of laterite zone groundnut in West Bengal. Fert. News. 12(9): 41-42.

*Barrios, A., Rodriguez, D.A., Ortega, S. and Perez, C.H. (1970). Results of fertilizer trials with beans (Phaseolus vulgaris). Agronomia Tropical. 20(5): 355-369.

*Bebin, S.I. and Ignatenko, Yu, E. (1969). Effect of plant density and mineral fertilizers on soybean yield in the Central Chernozem zone. Izv timiryazev sel'khoz. Akad. 3: 34-45.

*Behl, N.K., Sawhney, J.S. and Moolani, M.K. (1969). Response of urd (Phaseolus mungo Roxb.) to phosphatic fertilization. J. Res. Punjab agric. Univ. 6(3): 608-613.

Bhangoo, M.S. and Albritton, D.J. (1972). Effect of fertilizer nitrogen, phosphorus and potassium on yield and nutrient content of Lee soybean. Agron. J. 64(6): 743-746.

Bhatia, P.C. and Chowdhury, S.L. (1972). Effect of phosphate and irrigation levels on grain yield of summer mung. Fert. News. 17(4): 37-38.

Bhattacharya, B. (1971). Effects of fertilizers on growth and yield of horse gram (Dolichos biflorus) in laterite uplands. Indian Agric. 15(1/2): 161-168.

Bhuiya, Z.H. and Chowdhury, S.U. (1974). Effects of N, P, K and S on the protein and oil content of groundnut grown in Brahmaputra flood-plain soil. Indian J. agric. Sci. 44(11): 751-754.

Black, C.A. (1968). Soil Plant Relationships. Published by John Wiley and Sons, Inc, New York, 2nd Ed. 1968: 1-792.

*Borcean, I., Cojocaru, O., Sirbescu, L. and Anton, I. (1977). Effect of increasing rate of nitrogen applied with a constant base rate of P to peas grown for seed on medium leached chernozems of Timisoara. Lucrari Stiintifice, Institutul Agronomic Timisoara, Agronomia. 14: 85-88.

Bricen, S.J.M. and Sanchez, C. (1975). Yield of cowpea (Vigna sinensis = (Vigna unguiculata) with the application of lime and P on savanna soils. Boletin Informativo Instituto de Investigaciones Agropecuarias Universidad de Oriente, Agronomia 3: 6.

Chatterjee, B.N., Roquib, A. and Maiti, S. (1972). Phosphate manuring of soybean and its effect on wheat yield. J. Indian Soc. Soil Sci. 20(4): 375-378.

*Cheeney, H.A.D. (1974). Performance of cowpea cv. 'Black eye' in Guyana as affected by phosphorus and potassium. Turrialba. 24(2): 195-199.

*Chevalier, H. (1976). Response to potassium fertilizers. Absorption pattern of nutrients of soyabean on Altona. Informations Techniques. 53: 7-15.

*Chevalier, H. (1978). The response of soyabean to potassium fertiliser. In Fertilizer use and production of carbohydrate and lipids. Worblaufen-Bern, Switzerland; International Potash Institute: 329-334.

Chowdhury, S.L. and Bhatia, L.C. (1971). Prudent fertilizer use boosts yield of summer mung. Indian Fmg. 11(1): 18.

Chowdhury, S.L., Ram, S. and Giri, G. (1975). Effect of P, N and inoculum on root nodulation and yield of gram. Indian J. Agron. 20(3): 290-291.

Chundawat, G.S., Sharma, R.G. and Shekhawat, G.S. (1976). Effect of nitrogen, phosphorus and bacterial fertilization on growth and yield of gram in Rajasthan. Indian J. Agron. 21(2): 127-130.

Cochran, W.G. and Cox, G.M. (1965). Experimental Designs. Asia Publication House.

*Costache, D. and Nica, O.C. (1960). Protein and oil content of soyabeans as affected by variety fertilizers and nutritive environment. Lucr. stunt Inst. agron Nicolae Balcescu (A). 11: 133-147.

*Costache, D. (1970). The effect of mineral fertilizers on soyabean yield and quality on medium alluvial soil from the flood plain of the Danube. Lucrari Stiintific Institul Agronomic 'N.Balcescu', Bucuresti, A. (Agronomia) 13: 275-287.

Dalal, R.C. and Quilt, P.C. (1977). Effect of N, P liming and Mo on nutrition and grain yield of pigeon pea. Agron. J. 69(5): 854-857.

*Dart, P.J. and Mercer, F.V. (1965). The effect of growth temperature, level of ammonium nitrate and light intensity on the growth and nodulation of cowpea. Australian J. agri. Res. 16(1): 321-345.

Deshpande, A.M. and Bathkal, B.G. (1965). Effect of phosphorus on mung (Phaseolus aureus Roxb.). Indian J. Agron. 10(3): 271-278.

*Demooy, C.J. and Pesek, J. (1971). Response in yield and leaf composition of soybean varieties to phosphorus, potassium and calcium carbonate materials. Research Bulletin, Agriculture and Home Economics, Experiment Station, Iowa, State University (572): 512-537.

*Eira, P.A. DA., Fessanha, C.G., Britto, D.P.P. DES. and Carbajal, A.R. (1974). Application of mineral fertiliser with P and K to beans and its residual effect. Pesquisa Agropecuaria Brasileira, Agronomia. 9(10): 121-124.

*Enedigma, P.O.C. (1965). The influence of seed size and fertiliser on the development and yield of cowpea (Vigna sinensis Endl). Niger agric. Jnl. 2(2): 75-79.

*Feucomnier, D. (1976). An experiment with application of potash fertilizers. Revista de Agricultura, Piracicaba, Brazil. 51(1): 17-21.

Fogeria, N.K. (1977). Effect of phosphatic fertilization on growth and mineral composition of pea plants (Pisum sativum L.). Agrochimia. 21(1/2): 75-78.

Garg, K.P., Sharma, A.K. and Thakur, B.S. (1970). Manuring of cowpea, studies on the effect of different rates of P and Mo on the growth, yield of cowpea fodder and residual effect on wheat. Indian J. Agron. 15(2): 112-118.

Garg, K.P., Chauhan, Y.S. and Sharma, N. (1971). Response of pea varieties to nitrogen and phosphorus application. Indian J. Agron. 16(2): 213-215.

*Georgiev, S. (1977). Effect of N and P application on the intensity of N, P and K accumulation in groundnuts. Pochvoznanie i Agrokhimiya. 12(1): 81-92.

Gill, A.S., Pandey, R.K., Mukhtar Singh and Abichandani, C.T. (1971). Effect of soil and foliar application of phosphorus on seed yield of cowpeas (Vigna sinensis). Indian J. agron. 16(3): 303-304.

Gill, J.S. and Cheema, S.S. (1976). Response of summer mung (*Phaseolus aureus*) to irrigation at different potential evaporation values, planting method and P levels. *J. Res. Punjab agric. Univ.* *13*: 52-56.

*Graves, C.R., McCutchen, T. and Freeland, R. (1978). Soybean varieties response to potassium. Tennessee Farm and Home Science (105): 6-7.

*Groneman, A.F. (1974). Effect of deep placement of nitrogen, phosphorus and potassium fertilizers on dry matter production, nodulation, chemical composition and yield of soybean. *Dissertation Abstr. International* B: *34*(10): 4787

Grunes, D.L. (1959). Effect of N on the availability of soil and fertilizer P to plants. *Advan. Agron.* *11*: 369-393.

*Gutstein, Y. (1978). Response of groundnuts to K fertilization and its absorption pattern from the soil profiles. *Hassadeh.* *58*(10): 1967-1972.

*Habib, M.M., Koraiem, Y.S. and El-Sebaie, F.A. (1971). The influence of N and P levels on seed yield and quality of soybean varieties. *Alexandria J. agric. Res.* *19*(2): 217-222.

*Haghparast, M.R., Mengel, K. (1973). The effect of increased K application on the yield and on the content of soluble amino acids and protein in *Vicia faba*. *Zeitschrift fur Pflanzenernahrung and Bodenkunde.* *135*(2): 150-155.

Harishankar and Kushwaha, R.P.S. (1971). Chemical composition of urd plants (*Phaseolus mungo*) at various stages of growth. *Indian J. agric. Res.* *5*(2): 79-82.

Hathcock (1975). Effects of applied nitrogen on juvenile growth and nodulation of soybeans. Tennessee farm and Home Science Progress Report. 96: 32-33.

*Hoera, C., Sutcu, C., Triboi, E., Mihaila, V., Bologa, M., Burlacu, G. and Stancin, A. (1972). Investigation of methods of fertilizer application for soyabeans using the isotopes $^{15}N$ and $^{32}P$. *Analele Institutuluiide Cercetari Pentru Cereale Si Plante Technice, Fundulea B.* 38: 309-314.

Horner, G.M., Mojtehedi, M. (1970). Yield of grain legumes as affected by irrigation and fertilizer regime. *Agron. J.* *62*(4): 449-450.

Jadhate, P.N. (1965). A package programme for groundnut. *Fert. News.* *8*(8): 13-15.

Jackson, M.L. (1967). Soil Chemical analysis. Prentice Hall of India Private Ltd., New Delhi, 2nd Ed. 1-498.

Janneja Sharma (1977). Effect of spacing, nitrogen and phosphorus on the yield of cowpea. All India Co-ordinated Pulses Research Project report. Kharif 1977: 2-4.

Jayadevan, R. and Sreedharan, C. (1975). Effect of nitrogen and phosphorus on Asiriya Mwitunde groundnut in Kerala. Agri. Res. J. Kerala. 13(2): 123-127.

Jethmalani, S.C., Tiwari, K.L. and Motiramani, D.P. (1969). Soybean fertilization and inoculation. Indian Fmg. 19(4): 17-18.

Johnson, W.A. and Evans, C.E. (1975). Nitrogen, phosphorus and potassium fertilization of southern peas for one time harvest on a sandy soil. J. Amer. Soc. Hort. Sci. 100(3): 261-265.

Kadwe, R.S. and Badhe, N.N. (1973). Effect of Mo and Phosphate on the growth, uptake of nutrients and nitrogen fixation by urd (Phaseolus mungo). Indian J. agric. Res. 7(1): 43-46.

Kalyan Singh and Rajendra Prasad (1975). It pays to fertilize arhar under rainfed conditions. Fert. News. 20(2): 28

Kalyan Singh and Prasad, R. (1976). Effect of N, P and rhizobium inoculation on protein content and nutrient uptake of pigeon pea. Indian J. Agron. 21(3): 266-270.

*Kapoor, A.C. and Gupta, Y.P. (1977). Effect of maturity and phosphorus nutrition on nitrogen fraction and free amino acids in soybean. Forage Res. 2(1): 77-81.

*Katti, C.P., Krishnamurthy, K.N., Patil, R.B. and Rangaswami, G. (1970). Studies on rhizobium treatment and phosphate application to soybean and their residual effect on cereals. Mysore J. agric. Sci. 4(1): 88-95.

Kaul, J.N. and Sekhon, N.S. (1976). Effect of phosphate and row spacing on mung. Indian J. Agron. 21(1): 63.

Kesavan, G. and Morachan, Y.B. (1975). Response of soybean varieties to graded doses of nitrogen and phosphorus. Madras agric. J. 60(1): 23-26.

*Koinov, G. and Petkov, P.S. (1975). The effect of fertiliser on some biological characteristics of Phaseolus vulgaris. Rasteniev'dni Nauki. 12(1): 65-73.

*Kranz, W.M., Musilli, O., Pompeu, A.S. and Raij, B. VAN. (1976). Response of beans to N, P and K on the principal soils of Parana State. In Anais do decimo quinto congresso Brassileiro de ciencia do solo, campinas sp, Brazil 14 a 20 de Julho de 1975. Campinas, Sao Paulo Brazil, Sociedade Brasi leira de Ciencia do solo: 235-238.

Kurdikeri, C.B., Patil, R.V. and Krishnamurthy, K. (1973). Response of cowpea (Vigna catjang) to varying fertiliser levels. Mysore J. agric. Sci. 7(2): 170-174.

Lenka, D. and Satpathy, R.K. (1976). Response of pigeon pea varieties to levels of nitrogen and phosphate in laterite soils. Indian J. Agron. 21(3): 217-220.

Mahatanya, E.T. (1976). The effect of phosphorus and copper on the bean plant (Phaseolus vulgaris L.). Mysore J. agric. Sci. 10(2): 214-225.

*Malik, B.S., Arora, N.D.C. and Lodhi, G.P. (1972). Response of cowpea grain to varying levels of nitrogen and phosphorus. Haryana agric. Univ. J. Res. 2(2): 114-118.

*Maples, R. and Keogh, J.L. (1969). Soybean fertilization experiments. Rep. Ser. 178. Arkans agric. Exp. Stn. pp.20.

Marappan, P.V. (1970). Achievements in Agricultural Research 1969-70. Madras agric. J. 57: 8-12.

*Marchuk, P.N. and Saichuk, E.I. (1971). Effect of fertilizers on peas grown on dernopodzolic soil in the forest zone of the ukraine. Agrokhimiya. 5: 74-79.

*Markus, S. (1976). Effect of fertilizers on the yield of soybean on brown forest soil at Tirgu Mures Research Station. Analele Institutul de cercetari Pentru Cereale si Plante Tehnice, Fundulea. 41: 295-300.

*Mascarenhas, H.A.A., Miyasaka, S., Igue, T. and Freire, E.S. (1968). Fertilizing soybeans, 7 effects of increasing doses of lime, phosphorus and potassium on a latosol soil with cerrado vegetation. Bragantia. 27(2): 279-289.

Mishra, M.N. and Singh, A.N. (1968). Root development in relation to plant population and fertility levels in soybean. Ann. arid zone. 7(1): 121-126.

*Mitkees, A. (1974). Response of snap bean plants to fertilization with P, K and Mn. Agric. Res. Review. 52(5): 149-159.

Mocanita, V. (1974). Effect of various rates and combinations of chemical fertilizer on the protein content of seed of Vicia faba var minor Lucrari Stiintifice, Institutul Agronomic 'Dr. Petru Groza', Agriculture. 28: 157-161.

Mohammed Yaseen. (1977). Fertility cum inoculation trial on arhar under rainfed condition. Results on coordinated trials conducted during Kharif 1977: 10.

Moolani, M.K. and Jana, M.K. (1965). A note on response of green gram (Phaseolus aureus L.) to fertilizers in laterite soil. Indian J. Agron. 10(1): 43-44.

Mustafa, S.P., Sukumar, N., Jayachandran, V., Natarajan, A. and Jagadeesan, P. (1970). Effect of NPK fertilizers on the yield of irrigated groundnut. The Farm Science. 4(2).

Muthuswamy, S. (1973). Effect of application of N, P and K on nodulation of groundnut plants. Fert. News. 18(2): 45-47.

Nair, K.S., Ramaswamy, P.P. and Perumal, R. (1970). Nutritional factors affecting N fixation in Arachis hypogea L. Madras agric. J. 57(6): 307-310.

Nair, N. Purushothaman. (1978). Studies on the performance of two groundnut varieties, T.MV-2 and TMV-1 under graded doses of phosphorus and potassium. M.Sc.(Ag.) Thesis, Kerala Agricultural University.

*Nakagawa, J., Gooton, L.C., Almeida, T. DLS. and Neptune, A.M.L. (1966). NPK manuring, liming and foliar diagnosis of groundnuts. Anais ESC. Sup. Agric. Luiz Queiroz. 23: 369-377.

*Nattribhop, S. and Ferraris, R. (1970). The effect of ridge spacing, nitrogen application and number of rows planted per ridge on the yield of mung bean. In Thai Australian Chao Phya Research Project, Second report to the Ministry of Agriculture of the Kingdom of Thailand. Part B. Canberra, Australia, Department of Foreign Affairs. 101-104.

*Nemeth, K. and Forster, H. (1976). Relationship between yield and K uptake in field beans (Vicia faba) and a study of various soil K fraction. Bodenkultur. 27(2): 111-119.

*Niklyaev, V.S. (1975). Effect of sowing and fertiliser rates on growth, development and yield of grain legumes. Vest. Sel'-khoz Nauki Moscow, USSR. 11: 29-35.

*Odurukwe, O. (1973). Differential responses in growth, rate of net photosynthesis, chemical composition and yield of seed among soybean lines from applied N, P, K fertilisers. Dissertation Abstracts International, B. 33(10): 4621.

*Omueti, J.O. and Oyenuga, V.A. (1970). Effect of phosphorus fertiliser on the protein and the essential components of the ash of groundnuts and cowpeas. W. Afr. J. Biol. appl. Chem. 13(17): 14-19.

Panda, D., Misra, S.N. and Padhi, S.C. (1971). Response of groundnut varieties to varying levels of fertility. Indian J. Agron. 16(2): 249-250.

Panda, S.C. (1972). Effect of different levels of nitrogen and phosphorus on the growth and yield of Pusa Baisakhi mung. Indian J. Agron. 17(3): 239-241.

Panwar, R.S. and Kanwar Singh. (1975). Effect of different spacings and phosphorus level on the growth, yield and chemical composition of moong (Phaseolus aureus Roxb.) Variety Pusa Baisakhi under early summer conditions. Haryana agric. Univ. J. Res. 5(1): 91-93.

Panwar, K.S., Singh, V.V. and Misra, A.S. (1976). Response of mung (Phaseolus aureus L.) to different levels of N and P in Central Uttar Pradesh. Indian J. agric. Res. 10(1): 53-56.

Panwar, K.S., Misra, A.S. and Singh, V.V.(1977). Response of black gram to nitrogen and phosphorus. Indian J. Agron. 22(3): 149-152.

*Papanicolaou, E.P., Skarlou, V.D. and Apostolakis, C.G. (1977). A study of rate and time of application of nitrogen fertiliser labelled with $N^{15}$ in the cultivation of beans. Agrochimica. 21(5): 390-407.

*Peck, N.H. and MacDonald, G.E. (1969). Plant response to concentrated superphosphate and potassium chloride fertilisers (1) Pea (Pisum sativum L.). Bull. 825 New York State agric. Exp. Stn: 30.

*Petkov, P.S. (1974). Effect of fertilisers on the development and productivity of Phaseolus vulgaris under the conditions of S.E. Bulgaria. Rasteniev"dni Nauki. 11(4): 56-59.

Prabhanjan Rao, S.B., Ramnath, B. and Sen, M.J. (1973). Response of gram to fertiliser application in the Black cotton soils of Bellary under dry land farming. Mysore J. agric. Sci. 7: 360-365.

Prasad, R., Bhendia, M.L. and Raina, S.S. (1968). Response of grain legume to levels and sources of phosphorus on different soils. Indian J. Agron. 13(4): 305-309.

Pusmoose, K.I. and George, C.M. (1974). Studies on the effect of nitrogen and phosphorus on the yield and quality of groundnut (Arachis hypogea L.) in the red loam soils of Kerala. Agri. Res. J. Kerala. 12(2): 151-157.

Pusmoose, K.I. and George, C.M. (1975). Effect of applied nitrogen and phosphorus on the nodulation in groundnut (Arachis hypogea). Agri. Res. J. Kerala. 13(2): 169-174.

Puntamkar, S.S. and Bathkal, B.G. (1967). Influence of N, P and K fertilisers on composition growth and yield of groundnut. Indian J. Agron. 12(4): 344-350.

Rajagopalan, C.K., Venugopal, K. and Mohammed Shariff, N. (1970). An economic manurial schedule for dry land black gram. Madras agric. J. 57(5): 271-275.

Rajendran, K., Sivappah, A.N. and Krishnamoorthy, K.K. (1973). Radiotracer studies on phosphorus nutrition of black gram (Phaseolus mungo L.). Madras agric. J. 60(8): 1006-1033.

Rajendran, K., Sivappah, A.N. and Krishnamoorthy, K.K. (1974). Effect of fertilization on yield and nutrient concentration of black gram (Phaseolus mungo L.). Madras agric. J. 61(8): 447-450.

Rajendran, K. and Krishnamoorthy, K.K. (1975). Uptake of nutrients by black gram. Madras agric. J. 62(6): 376-379.

Rammohana Rao, M. and Mader, E.L. (1975). Nodulation pattern in soybeans as affected by rates of N and P. Indian J. Agron. 20(1): 67.

*Ratner, E.I. (1977). Nitrogen nutrition of legumes and some means of improving it. Special publication Division of Scientific Publications, Bet Dagan. 80: 110.

Ravankar, H.N., Badhe, N.N. and Kadue, R.B. (1972). Effect of different levels of phosphate on growth, nodulation and nitrogen fixation by urid (Phaseolus mungo Roxb.) and mung (Phaseolus aureus L.). Nagpur College of Agriculture Magazine. 45: 50-55.

Ravankar, H.N. and Badhe, N.N. (1975). Effect of phosphate on yield, uptake of nitrogen and phosphate and quality of urd, mung and soybean. The Punjabrao Krishi Vidyapeeth Research Journal. 3(2): 145-146.

Reiss, W.D. and Sherwood, L.V. (1965). Effect of row spacing, seed rate and potassium and calcium hydroxide addition on soybean yields on soils of Southern Illinois. Agron. J. 57(5): 431-433.

Rollin Bhaskar, P. (1979). Studies on the response of green gram (Vigna radiata (L) Wilczek) to methods and levels of phosphorus application. M.Sc.(Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Roheja, P.C. (1966). Soil productivity and crop growth. Published by P.S. Jaya Singhe, Asia Publishing House, Bombay: 1-442.

*Rubes, L. and Neuberg, J. (1973). Investigation of the utilization of mineral nitrogen in the case of combined fertilization with NO of peas (Pisum sativum L.). Rostlinna' vyroba. 19(1): 15-31.

Sahu, S.K. and Behera, B. (1972). Note on effect of rhizobium inoculation on cowpea, groundnut and green gram. Indian J. Agron. 17(4): 359-360.

Sahu, S.K. (1973). Effect of Rhizobium inoculation and phosphate application on black gram (Phaseolus mungo) and horsegram (Dolichos biflorus). Madras agric. J. 60(8): 989-994.

Sankara Reddi, G.H., Goyeswara Rai, Y., Krishna Reddi, C. and Subbiah, S.V. (1976). Response of soybean varieties to potassium under rainfed conditions. Ann. arid zone. 15(4): 323-325.

*Saraf, C.S., Kapoor, S.K. and Davis, R.J. (1968). Report of the result of co-ordinated agronomic trials. Proc. Sec. Annual Workshop Conference on pulse crop. IARI., New Delhi.

Sasidhar, V.K. and George, C.M. (1972). Studies on the role of applied phosphorus and potash on the uptake of nutrients by a legume crop (CO-1 lab lab) planted at different spacings. Agri. Res. J. Kerala. 10(2): 75-79.

Sawhney, J.S., Sandhu, K.S. and Moolani, M.K. (1975). Effect of NPK application on the yield of black gram on light soils. Indian J. Agron. 20(4): 372-373.

*Scheffer, F. and others. (1960). Chromatographic investigation of the effect of potassium and phosphate manuring on the content of some amino acids in peas. Qual Plant et Material Veg. 7(4): 329-340.

*Sedov, A.I. (1972). Uptake of nitrogen, phosphorus and potassium by haricot bean plants under field conditions. Nauchnye Trudy Vsesoyuznogo Instuta Zernobobovykh Kul'tur 4: 329-336.

Sewa Ram and Gajendra Giri. (1975). Response of black gram varieties to fertility levels. Indian J. Agron. 20(1): 68-69.

*Sharma, A.K. and Garg, K.P. (1973). Effect of phosphorus and molybdenum fertilization on the nodulation of cowpea. Agriculture and Agro Industries Journal. 6(2): 23-24.

Sharma, C.B., Shukla, V., Subramanian, T.R. and Srinivasa Moorthy, H.K. (1974). Effect of phosphate fertilization on growth and P uptake in cowpea for green manuring. Indian J. Hort. 31: 82-85.

Sharma, D.N. and Yadav, J.S.P. (1976). Availability of P to gram as influenced by phosphate fertilization and irrigation regime. Indian J. agric. Sci. 46(5): 205-210.

Sharma, K.N., Bran, J.J., Kapur, M.L., Meelu, O.P. and Rana, D.S. (1978). Potassium soil test values and responses of wheat, bajra and gram to fertilizer K. Indian J. Agron. 23(1): 10-15.

Shekhawat, G.S., Chundawat, G.S. and Samar Singh. (1972). Response of moth (Phaseolus aconitifolius) to N and P under rainfed conditions of arid Rajasthan. Indian J. Agron. 17(2): 65-68.

*Shcapol, V.I. and Kulmesh, N.P. (1967). N, P and K content in leguminous crops under different nutrition conditions. Agrokhimiya. 12: 47-50.

*Shevelova, L.K. (1974). Effect of rates and forms of K fertilizers on yield and quality of peas and Phaseolus vulgaris grown on different sub-types of grey forest soil. Trudy, Vsesoyuznyi Institut Udobrenii i Agropochvovedeniya (25): 115-117.

Shivashankar, K., Veeranna, V.S. and Krishnamurthy, K. (1974). Response of soybeans to phosphate and zinc application. Mysore J. Agric. Sci. 8(3): 370-375.

Shukla, S.C. (1964). Response of gram (Cicer arietinum Linn.) to nitrogen and phosphate fertilization. Indian J. Agron. 9(2): 104-112.

Simpson, J.E., Adair, C.R., Kohler, G.O., Dawson, E.H., Debald, H.A., Kester, E.B. and Klick, J.T. (1965). Quality evaluation studies of foreign and domestic rices. Tech. Bull. No. 1331. Service, U.S.D.A. 1-186.

Singh, R.M. and Jain, T.C. (1968). Effect of phosphate and molybdate on the uptake of N and P by Russian giant cowpea. Ann. arid zone. 7(1): 142-146.

Singh, V. and Singh, J.P. (1968). Effect of spacing, nitrogen and phosphorus levels on yield and protein content of soybean. Madras agric. J. 55(3): 129-133.

Singh, R.P., Dubey, S.K., Mahabirparshad and Khokhar, N.S. (1969). Studies on the effect of nitrogen, phosphorus, potash and farm yard manure on the yield of peas under irrigated conditions. Indian J. Agron. 14(2): 112-117.

Singh, R.S. (1970). Effect of number of cultivation and increasing level of N and P on yield and quality of gram. Madras agric. J. 57(2): 267-270.

Singh, J.N., Negi, P.S. and Tripathy, S.K. (1971). Response of inoculated soyabean varieties to levels of nitrogen and phosphorus in Tarai region of U.P. Indian J. Agron. 16(3): 303-308.

Singh, N.P. and Saxena, M.C. (1972). Field study on nitrogen fertilisation of soyabean (Glycine max (L) Merr). Indian J. agric. Sci. 42(11): 1028-1031.

Singh, K.K., Hasan, U., Singh, S.P. and Prasad, R. (1975). Response of moong to graded levels of nitrogen and phosphorus. Indian J. Agron. 20(2): 187-188.

*Singh, O.P., Swarnkar, K.C. and Verma, M.M. (1975). Interaction of N, P and S on nodulation, protein and S-containing amino acids content in Cicer arietinum. Proceedings of the National Academy of Sciences India. 45(4): 303-308.

Singh, A.K. (1976a). To study the effect of phosphate manuring with and without rhizobium culture on the yield of different moong varieties. Report of Agronomic experiments on kharif pulses in Rajasthan during 1976-77. University of Udaipur, Durgapura, Jaipur: 3-4.

Singh, A.K. (1976b). Effect of phosphate manuring with and without rhizobium culture on different cowpea varieties under unirrigated conditions. Report of Agronomic experiments on kharif pulses in Rajasthan during 1976-77. University of Udaipur, Durgapura, Jaipur: 4-6.

Sinha, M.N. (1970). Studies on the uptake of P in peas using radiotracer technique as affected by doses and placement. Indian J. Agron. 15(1).

Sinha, M.N. (1971). Effect of doses and methods of P placement on growth, yield and uptake of P by gram (Cicer arietinum L.) under irrigated conditions. Indian J. Agron. 16(1): 60-63.

*Sistachs, E. (1970). Effect of nitrogen fertilization and inoculation on yield and nitrogen content of black beans (Phaseolus vulgaris). Rev. Cubana Ciencia Agricola 4(3): 227-230.

*Slobko, YU. I. (1970). Development of root system and nodules in relation to nitrogen nutrition of soyabean. Sbornik Nauchnykh Trudov Primorskogo Sels'kokhozyaistvennogo Instituto. 19: 32-40.

*Smith, R.L., Hutton, C.E. and Robertson, W.K. (1968). The effect of nitrogen on the yield of soybeans. Proc. Soil Crop Sci. Soc. Fla. 28: 16-23.

*Son, S.H., Lee, E.S. and Lee, E.W. (1974). The effects of calcium and potassium on the growth and yield of groundnut (Arachis hypogea L.) Research Reports of the Office of Rural Development, Crop. 16: 25-31.

Srivastava, S.P. and Singh, A.P. (1975). Phosphorus fertilization in gram under dry land conditions. Science and Culture. 41(11): 583.

Stewart, F.B and Reed, M. (1969). The effect of fertilization on yield, growth and mineral composition of southern peas. J. Amer. Soc. hort. Sci. 94(3): 250-260.

Subramaniyan, A., Balasubramaniyan, A. and Venkatachalam, C. (1977). Effects of varying levels of fertiliser and spacing on the yield of cowpea. Madras agric. J. 64(9): 614-615.

Sundaram, P., Thangamuthu, G.S. and Kandasamy, P. (1974). Performance of cowpea varieties under different levels of phosphorus and potash manuring. Madras agric. J. 61(9): 776-779.

*Sutton, P., Albregts, E.E. and Howard, C.M. (1973). Influence of N and K on pole beans (Phaseolus vulgaris L.) response and soil and plant analysis. Proc. Soil Crop Sci. Soc. Fla. 32: 136-137.

Tarila, A.G.I., Ormrod, D.P. and Adedipe, N.O. (1977). Effects of phosphorus, inoculation and light intensity on growth and development of the cowpea (Vigna unguiculata L.) Annals of Botany. 41(171): 75-83.

*Tej Singh, Agarwal, S.K. and Singh, K.P. (1975). Effect of P and N levels on the grain yield and protein content of moong (Phaseolus aureus Roxb.) varieties. Haryana agric. Univ. J. Res. 5(3): 231-235.

Terman, G.L. (1977). Yield and nutrient accumulation by determinate soy beans, as affected by applied nutrients. Agron. J. 69(2): 234-238.

*Tewari, G.P. (1965). Effect of nitrogen, phosphorus and potassium on flowering and yield of soybeans in Nigeria. Expl. Agric. 1(3): 185-188.

Thimma Gowda and Krishna Gowda, K.T. (1978). Influence of fertilizers on yield and its components of green gram. Indian J. Agron. 23(4): 374.

Tisdale Samuel, L. and Nelson Werner, L. (1975). Soil Fertility and fertilizers. MacMillan Publishing Co., Inc. New York. 3rd Ed. 1-694.

*Toan, T.D. (1970). The effect of fertilizers with trace elements on soyabeans. Lucrari Stiintifice Institutul Agronomic "N.Balcescu, Bucuresti, A. (Agronomia) 13: 355-364.

Venugopal, K. and Morachan, Y.B. (1974). Response of green gram to season and graded doses of N and P fertilizers. *Madras agric. J.* 61(8): 457-460.

Viswanathan, T.V., Viswambaran, K. and Chandrika, P. (1978). Response of cowpea (*Vigna sinensis* ENDL) to different levels of N, P and K. *Agri. Res. J. Kerala.* 16(2): 129-132.

*Williamson, A.J.P. and Diatloff, A. (1975). Effects of supplementary nitrogen fertiliser on nodulation, yield and seed characteristics of soybean (*Glycine max*) on the Darling Downs. Australian Journal of experimental Agriculture and Animal Husbandry. 15(76): 694-699.

*Originals not seen

# APPENDICES

## APPENDIX I

Weather data during the crop period and its variation from the past five years

| Weeks | Period | Temperature °C | | | | Rainfall (mm) | | Relative humidity (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Maximum | | Minimum | | | | | |
| | | 1976-79 | Variation | 1976-79 | Variation | 1978-79 | Variation | 1978-79 | Variation |
| 1. | Jan.15 - Jan.21 | 31.32 | +0.27 | 21.83 | +0.01 | — | -1.14 | 94.57 | +24.62 |
| 2. | ,, 22 - ,, 28 | 31.82 | +0.66 | 22.20 | +0.47 | — | -0.71 | 92.45 | +21.14 |
| 3. | ,, 29 - Feb. 4 | 31.60 | +0.75 | 22.90 | +0.93 | — | -0.29 | 90.70 | +14.65 |
| 4. | Feb. 5 - Feb.11 | 32.00 | +0.99 | 22.20 | +0.90 | — | -0.46 | 86.90 | + 7.28 |
| 5. | ,, 12 - ,, 18 | 30.85 | -0.12 | 23.10 | +1.23 | 12.40 | +10.54 | 92.65 | +12.47 |
| 6. | ,, 19 - ,, 25 | 31.82 | +0.33 | 23.78 | +1.38 | — | -1.00 | 92.28 | +11.92 |
| 7. | ,, 26 - March 4 | 31.71 | -0.13 | 23.17 | ±0.50 | — | -5.58 | 90.57 | + 9.67 |
| 8. | March 5- ,, 11 | 31.43 | -0.66 | 23.27 | +0.64 | 4.00 | +3.25 | 83.42 | +.9.42 |
| 9. | ,, 12 - ,, 18 | 31.75 | -1.05 | 23.18 | -0.29 | 1.28 | +1.28 | 91.71 | +10.76 |
| 10. | ,, 19 - ,, 25 | 32.14 | -0.75 | 23.60 | -0.12 | 2.14 | +2.14 | 91.20 | +10.18 |
| 11. | ,, 26 - April 1 | 32.61 | -0.30 | 24.10 | -0.27 | — | — | 90.14 | +9. 09 |
| 12 | April 2 - ,, 8 | 32.68 | +0.39 | 24.88 | +0.64 | — | -1.03 | 91.28 | + 9.37 |
| 13. | ,, 8 - ,, 15 | 33.68 | +0.87 | 25.06 | -0.04 | 1.57 | -1.08 | 87.57 | + 7.14 |

Positive sign (+) shows increase over the average data and negative sign (-) the decrease

## APPENDIX II

Abstract of analysis of variance table for height of the plant at 5 stages

| Source | df | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Height (cm) 15 day after sowing | Height (cm) at flowering | Height (cm) 45th day after sowing | Height (cm) 60th day after sowing | Height (cm) at harvest |
| Block | 5 | 10.632** | 62.498** | 84.564** | 73.028* | 73.277* |
| N | 2 | 3.265 | 0.036 | 12.011 | 11.974 | 6.455 |
| P | 2 | 7.472 | 14.858 | 37.472 | 53.402 | 34.605 |
| N x P | 4 | 2.437 | 11.219 | 13.266 | 15.776 | 13.072 |
| K | 2 | 0.7546 | 17.300 | 35.474 | 42.607 | 65.124 |
| N x K | 4 | 3.193 | 2.113 | 8.009 | 14.256 | 14.696 |
| P x K | 4 | 12.476** | 54.200** | 77.360** | 107.311** | 101.012** |
| NPK T | 2 | 0.1240 | 9.910 | 20.567 | 2[illegible].121 | 21.556 |
| $NP^2K$ | 2 | 0.1335 | 15.421 | 16.062 | 26.784 | 24.607 |
| $NPK^2$ T | 2 | 1.121 | 10.899 | 15.269 | 7.918 | 7.064 |
| $NP^2K^2$ | 2 | 2.634 | 1.458 | 3.582 | 11.611 | 11.621 |
| Error | 22 | 2.397 | 12.525 | 16.534 | 20.516 | 19.936 |

T Partially estimable

**Significant at 0.01 level
*Significant at 0.05 level

## APPENDIX III

Abstract of analysis of variance table for number of leaves per plant at 5 stages

| Source | df | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Number of leaves per plant 15th day after sowing | Number of leaves per plant at flowering | Number of leaves per plant 45th day after sowing | Number of leaves per plant 60th day after sowing | Number of leaves per plant at harvest |
| Block | 5 | 0.0504* | 0.5763 | 1.8830* | 2.3990** | 2.1020** |
| N | 2 | 0.0207 | 0.3069 | 3.5740** | 2.685** | 0.6469 |
| P | 2 | 0.0474 | 0.0746 | 0.6106 | 0.2902 | 0.1535 |
| N x P | 4 | 0.0241 | 0.6674 | 0.1078 | 0.4960 | 0.6013 |
| K | 2 | 0.0246 | 0.6319 | 0.9867 | 1.0060 | 1.2200 |
| N x K | 4 | 0.0163 | 0.0138 | 0.9197 | 2.1160** | 1.6420** |
| P x K | 4 | 0.1095** | 0.2457 | 1.1860 | 0.5165 | 1.1390* |
| NPK Ŧ | 2 | 0.0357 | 0.1226 | 0.1225 | 0.1435 | 0.4226 |
| $NP^2K$ | 2 | 0.1335** | 0.4100 | 0.0172 | 0.6257 | 1.5390* |
| $NPK^2$ Ŧ | 2 | 0.0235 | 0.8237 | 1.5450 | 0.0095 | 0.0015 |
| $NP^2K^2$ | 2 | 0.0333 | 0.0146 | 0.5206 | 0.0791 | 0.1096 |
| Error | 22 | 0.0149 | 0.5196 | 0.5806 | 0.3830 | 0.3840 |

Ŧ Partially estimable

**Significant at 0.01 level

*Significant at 0.05 level

## APPENDIX IV

Abstract of analysis of variance table for number of branches per plant, number of nodules per plant and 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 | 0.5279** | 783.042 | 317.616 |
| N | 2 | 0.0274 | 364.542 | 722.358 |
| P | 2 | 0.2674 | 3813.347** | 2675.810 |
| N x P | 4 | 0.0641 | 281.097 | 410.706 |
| K | 2 | 2.259** | 72.181 | 24.074 |
| N x K | 4 | 0.0219 | 167.097 | 104.282 |
| P x K | 4 | 0.1719 | 161.486 | 599.942 |
| NPK ‡ | 2 | 0.3077 | 177.009 | 96.528 |
| $NP^2K$ | 2 | 0.1207 | 68.347 | 168.866 |
| $NPK^2$ ‡ | 2 | 0.2948 | 193.676 | 301.620 |
| $NP^2K^2$ | 2 | 0.1919 | 45.792 | 77.894 |
| Error | 22 | 0.1266 | 530.007 | 1021.675 |

‡ Partially estimable

**Significant at 0.01 level

*Significant at 0.05 level

## APPENDIX V

Abstract of analysis of variance table for number of pods per plant, length of pod, number of seeds per pod, seed yield per plant and 100 grain weight

| Source | df | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Number of pods per plant | Length of pod (cm) | Number of seeds per pod | Seed yield per plant (g) | 100 seed weight (g) |
| Block | 5 | 1.7560 | 0.0208 | 0.0606 | 0.0988 | 0.1462 |
| N | 2 | 0.2274 | 0.0297 | 0.0246 | 0.0111 | 0.0143 |
| P | 2 | 1.0820 | 0.0023 | 0.0024 | 0.0685 | 0.0164 |
| N x P | 4 | 0.2023 | 0.0165 | 0.0199 | 0.0121 | 0.0019 |
| K | 2 | 16.805** | 0.3629** | 0.4169** | 0.9659** | 0.1444* |
| N x K | 4 | 0.5166 | 0.0258 | 0.0427 | 0.0293 | 0.0367 |
| P x K | 4 | 0.9713 | 0.0155 | 0.0330 | 0.0553 | 0.0354 |
| NPK T | 2 | 2.1570 | 0.0307 | 0.0715 | 0.1252 | 0.0335 |
| $NP^2K$ | 2 | 0.7679 | 0.0184 | 0.0000 | 0.0439 | 0.0224 |
| $NPK^2$ T | 2 | 0.4867 | 0.0379 | 0.0159 | 0.0277 | 0.0331 |
| $NP^2K^2$ | 2 | 1.2400 | 0.00946 | 0.0113 | 0.0745 | 0.0402 |
| Error | 22 | 0.6011 | 0.0181 | 0.0295 | 0.0308 | 0.0276 |

T Partially estimable

**Significant at 0.01 level

*Significant at 0.05 level

## APPENDIX VI

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

| Source | df | Mean square | | | |
|---|---|---|---|---|---|
| | | Grain yield (kg/ha) | Bhusa yield (kg/ha) | Harvest index (kg/ha) | Total dry matter production (kg/ha) |
| Block | 5 | 109562.344 | 60377.403 | 10.656 | 146901.350 |
| N | 2 | 17493. 701 | 110525.936 | 0.638 | 252836.810 |
| P | 2 | 18485.050 | 226362.041 | 6.949 | 87811.165 |
| N x P | 4 | 13375.294 | 46878.596 | 1.792 | 128716.212 |
| K | 2 | 740623.178** | 23.930 | 46.268 | 1167214.650** |
| N x K | 4 | 48242.141 | 41448.402 | 3.295 | 119214.352 |
| P x K | 4 | 38359.989 | 95171.699 | 5.435 | 112674.015 |
| NPK † | 2 | 162159.517* | 34293.629 | 12.479 | 200528.145 |
| $NP^2K$ | 2 | 42371.083 | 69589.285 | 10.162 | 5784.200 |
| $NPK^2$ | 2 | 27078.180 | 650.702 | 1.438 | 37406.385 |
| $NP^2K^2$ | 2 | 116697.756 | 176820.455 | 1.490 | 605402.755* |
| Error | 22 | 45392.799 | 67728.032 | 26.017 | 139958.704 |

† Partially estimable

**Significant at 0.01 level

*Significant at 0.05 level

## APPENDIX VII

Abstract of analysis of variance table for uptake of nitrogen, uptake of phosphorus and uptake of potash

| Source | df | Mean square | | |
|---|---|---|---|---|
| | | Uptake of nitrogen by the plant (kg/ha) | Uptake of phosphorus by the plant (kg/ha) | Uptake of potash by the plant (kg/ha) |
| Block | 5 | 340.968* | 0.7902* | 21.730 |
| N | 2 | 357.961 | 2.123** | 1.212 |
| P | 2 | 67.098 | 0.2599 | 10.940 |
| N x P | 4 | 22.392 | 0.1082 | 1.417 |
| K | 2 | 732.056** | 0.8338 | 297.906** |
| N x K | 4 | 52.561 | 0.3052 | 8.262 |
| P x K | 4 | 65.295 | 0.2526 | 30.061 |
| NPK Ŧ | 2 | 140.288 | 0.3263 | 20.733 |
| $NP^2K$ | 2 | 1.665 | 0.3771 | 10.682 |
| $NPK^2$ Ŧ | 2 | 138.131 | 0.6573 | 10.736 |
| $NP^2K^2$ | 2 | 396.315* | 1.9230** | 15.142 |
| Error | 22 | 123.780 | 0.2704 | 15.028 |

Ŧ Partially estimable

**Significant at 0.01 level
*Significant at 0.05 level

## APPENDIX VIII

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

| Source | df | Mean square | | | |
|---|---|---|---|---|---|
| | | Protein content of grain (per cent) | Grain protein yield (kg/ha) | Protein content of bhusa (per cent) | Fodder protein yield (kg/ha) |
| Block | 5 | 3.6938 | 7267.464* | 1.109 | 3699.566 |
| N | 2 | 0.8831 | 1626.250 | 1.718 | 6070.576 |
| P | 2 | 0.8345 | 519.830 | 0.1533 | 5277.509 |
| N x P | 4 | 0.6036 | 289.590 | 1.214 | 509.246 |
| K | 2 | 0.9178 | 37388.275** | 1.186 | 713.155 |
| N x K | 4 | 2.6660 | 1237.298 | 1.031 | 1270.912 |
| P x K | 4 | 0.5810 | 1913.888 | 0.314 | 2631.271 |
| NPK Ŧ | 2 | 0.2523 | 9034.670* | 3.054 | 696.782 |
| $NP^2K$ | 2 | 0.5914 | 3001.423 | 0.038 | 1398.358 |
| $NPK^2$Ŧ | 2 | 0.9004 | 2292.850 | 1.414 | 5632.293 |
| $NP^2K^2$ | 2 | 0.3137 | 6259.010 | 1.458 | 2590.699 |
| Error | 22 | 1.4850 | 2015.462 | 1.260 | 2519.395 |

Ŧ Partially estimable

**Significant at 0.01 level
*Significant at 0.05 level

## APPENDIX IX

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

| Source | df | Mean square: Total nitrogen content of soil (kg/ha) | Available phosphorus content of soil (kg/ha) | Available potassium content of soil (kg/ha) |
|---|---|---|---|---|
| Block | 5 | 97185.185 | 3233.001** | 1161.930 |
| N | 2 | 38518.519 | 238.376 | 228.130 |
| P | 2 | 31851.852 | 951.255 | 1368.130 |
| N x P | 4 | 115185.185 | 453.509 | 1042.130 |
| K | 2 | 38518.519 | 253.368 | 732.741 |
| N x K | 4 | 11851.852 | 216.094 | 72.324 |
| P x K | 4 | 178518.518* | 444.415 | 1897.574 |
| NPK ♀ | 2 | 1481.482 | 157.466 | 1058.259 |
| $NP^2K$ | 2 | 145105.185 | 14.139 | 853.907 |
| $NPK^2$ ♀ | 2 | 77037.038 | 61.866 | 1754.926 |
| $NP^2K^2$ | 2 | 56296.297 | 215.704 | 269.241 |
| Error | 22 | 45252.525 | 452.307 | 1116.975 |

♀ Partially estimable

**Significant at 0.01 level

*Significant at 0.05 level

# NUTRITIONAL REQUIREMENT OF BLACK GRAM [*Vigna mungo* (L.) Hepper]


By

**ANNAMMA GEORGE**


ABSTRACT OF A THESIS

submitted in partial fulfilment of the
requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University


Department of Agronomy
COLLEGE OF AGRICULTURE
Vellayani - Trivandrum


1980

ABSTRACT

An experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani during 1979 to study the effect of three levels each of nitrogen (20, 30 and 40 kg/ha), phosphorus (30, 45 and 60 kg/ha) and potash (10, 20 and 30 kg/ha) on growth, yield and quality of black gram grown in rice fallows.

The experiment was laid out as $3^3$ partially confounded factorial experiment with two replications, confounding NPK in replication I and $NPK^2$ in replication II.

The study revealed that height of the plant was significantly influenced by P x K interaction. Nitrogen showed significant negative influence with increasing doses on the number of leaves per plant during the later stages of plant growth. Number of branches per plant was significantly influenced only by potash levels. Highest level of phosphorus alone had significant effect in increasing the number of nodules per plant.

The yield and yield attributes showed linear and significant increase with increase in the level of potash. The maximum grain yield of 1757 kg per ha was recorded at the potash level of 30 kg per ha. Potash also had significant effect on the total dry matter production.

Uptake studies showed that nitrogen uptake was significantly increased with increase in the level of potash. Nitrogen had significant effect on phosphorus uptake while potash application significantly increased potash uptake by the crop.

Protein content of the grain and bhusa and fodder yield were not affected by the levels of nitrogen, phosphorus and potash, while grain protein yield showed significant increase with increase in the level of potash.

Positive and significant correlations between grain yield and yield contributing factors such as number of pods per plant, number of seeds per pod, length of pod, seed yield per plant and 100 seed weight and between grain yield and $K_2O$ uptake were noted.