PRELIMINARY STUDIES ON THE NITROGEN POTASSIUM BORON AND MOLYBDENUM REQUIREMENTS OF COWPEA (*V gna s nens s* SAVI) VARIETY NEW ERA

BY

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C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bona fide research work carried out by Shri N. Vijayakumar under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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C O N T E N T S

INTRODUCTION

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Pulses form an important part of Indian dietary. They supply vegetable proteins and essential adjuncts to predominantly starchy foods.

For vegetarians and as also those, who cannot afford the costly protein rich animal foods legumes are the most important source of protein in the dietary. Legume-protein provide certain essential amino-acids which cereal proteins are deficient and there by enhance the over all nutritive value of proteins in the mixed diet.

In economically advanced countries, the average intake of protein is generous and the protein of animal origin make up nearly half the total protein. Diet surveys carried out in India have shown that bulk of the food in Indian dietaries is formed by cereals, which supply about 80% of the total energy, are the major source of dietary proteins. Pulses have high protein content of 17 to 25 per cent and the corresponding figures for cereal being 6.14 per cent only. (Protein content of cowpea is 23.20 to 24.10 per cent).

Consumption of fruits, vegetables, pulses, eggs, fish and meat is thoroughly inadequate in India. The protein equivalent in India is 51 which compares poorly with the corresponding figures of 60 for under-developed countries and 90 for the developed countries. According to Aykroyd and Doughty (1964) the daily requirement of pulses of one adult is 3 ozs. to keep the diet a balanced one. Based on this standard about 14 million tons of pulses would be required in India per annum. But the present production is roughly 10 million tons, a fact which emphasise the necessity for increased production of pulses.

Cowpea, due to its adaptability to the agroclimatic conditions of Kerala, is extensively grown throughout the State. Total area under this crop is approximately 14600 hectares. The per hectare yield is comparitively low (250 kg. per hectare).

Trials conducted so far have revealed that the variety 'New-Era' is the most suited to local conditions.

Cowpea has been recognised as one of the most important crops in the rotational sequence of paddy.

Further its capacity to supply organic matter and nitrogen to the soil needs no emphasis.

Only very few studies have been conducted to determine the nutritional requirement of this crop under Kerala conditions. Judicial application of both major and traceelements have found to increase both yield and protein content of pulses elsewhere.

The present investigation was therefore undertaken to determine the requirement of nitrogen, potassium, boron and molybdenum of this crop under Vellayani conditions.

REVIEW OF LITERATURE

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Experiments conducted in India and outside have shown that legumes responds well to manuring.

Whyte, Nilsson-Leissner and Trumble (1953) have stated that apart from nitrogen, the nutrients required by legumes are phosphorus, potassium, calcium, magnesium, iron, sulphur, copper, zinc, manganese, boron and molybdenum.

NITROGEN

(i) Effect of nitrogen on yield

Since most of the leguminous plants are capable of obtaining their nitrogen supply through their symbiosis with nitrogen fixing bacteria it is considered that nitrogen application to legumes is generally unnecessary. But Younkin Hester and Hoadley (1950) have reported increased yields in peas by the nitrogen level of fertilizer 0 to 6 per cent. Proportion of small peas was also reduced.

Delver (1953) has shown that dwarf beans require considerable quantities of nitrogen and phosphorus but comparitively little potassium.

Martin (1960) has reported substantial increase in yields of dwarf beans when nitrogen was supplied at 40 kg per hectare.

Riepma, Vanhuisseling and Bom (1960) reported that the yield of haricot beans has increased at the rate of 5 Kilogram per kilogram of nitrogen applied.

Hester, Hoadly and Smith (1961) have obtained good response for both nitrogen and potassium in peas. They found out a nutrient ratio of 1:1:1 and that grain yield increased upto the point at which salt concentration injured germination.

Ezedinma (1964) observed that cowpea seedlings grown in sterile sand inoculated with Rhizobium strains responded well to light dressings of nitrogen. He is of opinion that light dressings of nitrogen were preferable to seed inoculation owing to the short growing period of the crop.

Shukla (1964) has reported that application of 20 lbs. of nitrogen per acre to gram (cicer arietinum) had produced maximum response to all plant characteristics.

Kataski and Panchatti (1965) has reported that nitrogen at the rate of 10 lbs. and 20 lbs. per acre has increased yields by 147 lbs. and 150 lbs. respectively in groundnut during 1956-57. However they did not get similar results during 1957-58.

Ebong (1965) reported that cowpea responds well to fertilizers including a small dosage of nitrogen at the seedling stage.

On the contrary many other workers have reported that nitrogen may exercise a depressing effect on yield in legumes. Singh and Sahasrabudhe (1957) reported slight decrease in yield in red gram when nitrogen was applied at 20 lbs. per acre. The decrease in yield was not satistically significant.

Trials by Sharma and Misra (1961) have given more or less similar results in peas under rainfed conditions. Nitrogen at 20 lbs. per acre depressed the yield.

Singh (1962) has stated that nitrogen at 15 lbs. per acre did not increase grain yield in '<u>moong</u>' even though there was increase in straw yield.

Klacan (1962) has reported that at very low concentrations of nitrogen canning peas produced fewer pods, and peas per pod.

Reviewing an extensive series of field trials in the eastern countries in England Gane (1963) concluded that application of nitrogenous fertilizer to peas was seldom worth while.

Moolani and Jana (1965) have reported that nitrogen at 25 kg. per hectacre caused 5 per cent reduction in the number of pods produced and the quantity of grain yield in gram.

Nair (1966) did not get any significant yield in cowpea by the application of nitrogen at 20 kg. per hectacre.

(ii) Effect of nitrogen on quality of legumes

Thornton (1956) and Martin (1959) have shown that there was increase in the protein content when red and sweet clover was manured with nitrogen fertilizer.

Dubey (1963) reported improvement in quality of pea in respect of its protein content when nitrogen was applied at the rate of 10 lbs. and 20 lbs. per acre.

Losek (1965) observed increased protein content in alfalfa when nitrogen was given as spray fertilizer.

(iii) Effect of nitrogen on nodulation

Lipman and Blair (1914 & 1915) have shown that application of nitrogenous fertilizers did not depress the nodulation in soya beans.

Richardson, Jordan and Garrard (1957) have shown that nitrogen at the rate of 0.5 and 12 ppm. increased nodulation in lucerne when given as ammonium ion but decreased nodulation when given as nitrate nitrogen. But in a pot culture study with cowpea Ezedinma (1964) observed increased nodulation with application of nitrate nitrogen. Number and weight of nodules decreased above 100 ppm. of nitrate nitrogen.

Jansson and Torstensson (1955) have reported that application of ammonium nitrate lowered nitrogen fixation in peas.

Samuels and Landrau (Jr.) (1953) observed reduction in number of nodules in tropical kudzu manured with Ammonium Sulphate.

Cartwright (1959) reported that higher levels of nitrogen depressed nodulation in several legumes grown in sand cultures.

Cowling (1961) found decrease of weight of root nodules in white clover manured with nitrogenous fertilizer.

Tewari (1965) has reported that increased levels of nitrogen depressed the formation of effective and ineffective nodules in cowpea.

Nair (1966) reported negative response to nodulation by addition of nitrogen to 4 varieties of cowpea.

POTASSIUM

(i) Effect of Potassium on yield in legumes

Comparitively very few studies seem to have been carried out on the effect of potassium on the yield of legumes.

Rossiter (1947) has reported that KCl at the rate of 1 cwt. per acre produced highly significant increase in yield of subteranean clover. Yield in lupines and other pasture species was depressed with addition of potassium.

Wade (1955) reported reduction in the incidence of *aphanomyces* root rot in pea plants with KCl at 4 cwts. per acre.

Yield of ranger alfalfa was increased with increasing potassium upto a content of 3 per cent in the plant in sand culture experiments by Wallace and Bear (1950). Boron deficiency was experienced in plants grown in solutions containing potassium.

Vargas (1957) observed significant increase in yields in beans by the application of potassium though the soil was moderately, rich in potassium. Highest yield was obtained with 60 kg. of potash per hectacre.

Wu (1963) observed increased yields in soya beans by the application of potassium, both in plot treated with phosphorus or inoculated.

Fedorov and Podjapoljasja (1960) reported that reducing potassium in sand culture mediums reduced yields and also reduced the weight of nodules formed in legumes.

Experiments conducted by Delver (1962) indicated that dwarf beans requires only comparitively little potassium than nitrogen and phosphorus.

Lin (1959) reported depressing effects with potassium on height of plants, weight of tops, roots, number of leaves and tillers per plant in yellow lupine. Potassium depressed the absorption of calcium also.

Kataski and Banahatti (1965) have revealed that application of potassium sulphate to ground nut to give 100 and 200 lbs. K_2O per acre had adverse effect on the yields.

(ii) Effect of potassium in nodulation

Tewari (1965) reported that addition of potassium had no effects on the formation of nodules in cowpea.

BORON

(i) Role of Boron in plants

Boron was found to be a constituent of plants by Willstein and Apoiger as early as 1857 (as stated by Moghe, Mathur and Talati 1966). Although Jay (1895) had suggested that boron might be found in all plants, little attention was paid until the research work of Aglhhon (1910) and Brenonley on the relation of the element to crop production. Warrington (1923) was the first to establish the essentiality of boron in plant growth.

Different functions have been attributed to boron in plants. Walla ce (1943) and Hass (1945) as quoted by Moghe, Mathur and Talati (1966) have stated that plants need relatively very small amount of boron and different species of plants vary as regards their boron requirement.

Brenchley and Thornton (1925) have suggested that effects of boron on legumes as regards nitrogen fixation is through its effect more on the host plant rather than on the bacteria or symbiotic system. Brenchley and Warrington (1927) have stated that boron does not replace any of the essential elements but is associated with the absorption and utilization of calcium.

Botoko, Matveeva and Syvorotkin (1933) have opined that boron is concerned with efficient assimilation of iron and utilization of nitrogen and mineral matter.

Reeve and Shive (1944) have stated that boron plays a part in the absorption of potassium.

Hass (1944) stressed the importance of boron in cell division of meristamatic tissues in plants.

Tisdale and Nelson (1956) have also suggested that a deficiency of boron may prevent the formation of vascular tissues necessary to supply the nodule organisms with carbohydrates necessary for their activity.

Russel (1961) is of opinion that boron effects cell division, nitrogen and carbohydrate metabolisom, pollen germination, flowering, fruiting, absorption of minerals and action of hormones and water relations in plants.

(ii) Effect of boron on yield.

Piland, Ireland and Reisnauer (1944) reported that addition of 25 lbs. of Borax per acre increased the yield of seeds by 120 lbs. in crimson clover. The increase in yield was attributed to the growth of a vigorous type of seed head and the growth of fully matured plump seed in the apical portions of the head.

Rogers (1947) obtained an increase of 58 per cent in lucerne and 104 per cent in bur-clover in the hay yields by the application of boron. Seed production was increased by 259 lbs. per acre. He concluded that boron may stimulate seed production in a number of legumes which show no vegetative response.

Reznikova (1950) reported that treatment of lupin seed with Borax before sowing and addition of 3 kg. of Borax per hectre to the soil increased the yield of lupin on a medium podzol soil by about 10%.

Higher green matters yield in sunhemp was obtained at Bangalore by the addition of boron in experiments conducted by Gopal Rao and Govindarajan (1951).

Anderson (1952) reported that in subteranean clover and lucerne the response for boron was more when molybdenum also was applied in molybdenum deficient soil.

Datta and Gurubasavaraj (1953) obtained significant response in fodder yield, seed yield, and nodulation in berseem when boron and molybdenum carrying fertilizers were applied. Their results indicated that effects of applied nutrients became more pronounced as the removal of major nutrients from the soil increased.

Shende and Sen (1958) got 31 per cent increase in green matter when boron and molybdenum were applied to guar along with phosphate.

Litynski and Kaczkowska (1960) in a three year trial with soya bean did get favourable effect with 5 kg. of Borax per hectare only in one year. Higher dozes of Borax restrained growth and reduced seed yields.

Ballal and Natu (1961) obtained 32 per cent increase in groundnut yields with 4 lbs. of Borax per acre singly or in combination with manganese.

Jaychandran (1966) has found that ground-nut responded markedly to the application of 20 kg. per hectare of boron under Vellayani - conditions.

Harris, Bledsoe and Clark (1954) did not obtain response for boron in cowpea.

Zimmermann (1961) reported that there was no response for boron in clover when Borax at the rate of 30 kg. per hectare was applied to the soil. When the same quantity of Borax was given as foliar spray the growth was depressed and yields reduced.

(iii) Effect of boron on quality in legumes

Fulkey (1943) has reported favourable effects of boron on protein content and slight increase in ash content in soya beans.

Wu and Hsing (1958) obtained increased protein content in soya beans treated with boron.

(iv) Effect of boron on nodulation

Moschini (1951) found that application of 'Fersin' a fertilizer containing mainly boron at the rate of 3 qtls. per hectare favourably affected nodulation and growth in broad beans.

Esterban Velasco and Lachicagarrido (1962) have reported that nodulation was increased only slightly by the application of boron in broad beans. Potash tended to decrease the number of nodules and potash boron inter action was significant Boron increased the number of flowers but the number of pods were markedly reduced.

MOLYBDENUM

(i) <u>Role of molybdenum in plants</u>

Biological importance of molybdenum was not realised until 1930 when Bortels (1930) showed that the element was highly beneficial in the fixation of gaseous nitrogen by *Azotobacter chroococum*.

The first evidence of the fact that the physiological role of molybdenum is not associated with nitrogen fixation alone was provided by the work of Steinberg initially reported in 1936.

Essentiality of molybdenum for higher plants was established by Arnon and Stout (1939).

Evans (1956) states that molybdenum is involved in the reduction of nitrates and in the process of nitrogen fixation in legumes. He states that the enzyme hydrogenase is ultimately associated with the nitrogen fixation in certain free living nitrogen fixing micro organisms. Molybdenum has been shown to be an essential constituent of this enzyme. He further states that a molybdoflavoprotein analogous to hydrogenase plays a prominent part in the nitrogen fixation by bacteria in leguminous plants. It is convincingly concluded that molybdenum functions as an electron carrier in the flavo protein nitrate reductases recently isolated from soya bean leaves and neurospora.

There is strong evidence that molybdenum may play a role in the inhibition of plant phosphotases, but the relation of the element to ascorbic acid accumulation and diminished capacity for dye reduction and to iron metabolism, all of which have been associated with deficiency of the element remains obscure.

From the fact that root nodule bacteria in molybdenum deficient soils are unable to fix nitrogen, though plants grow in such soils Russell (1961) concluded that molybdenum is primarily concerned with nitrogen fixation in legumes.

Research work with molybdenum on the yield, quality and nodulation in legumes though of recent origin is quite numerous.

(ii) <u>Effect of molybdenum on the yield of legumes</u>

Anderson (1948) obtained marked growth and development in subteranean clover by adding 2 ounces of molybdenum trioxide per acre. He is of opinion that probably one ounce per acre would have been sufficient. He further observed that response of legumes may be due to improved nitrogen fixation.

Neklyudove (1956) obtained increased yield in peas by the addition of molybdenum at one kilogram per hectare.

Jensen (1959) observed that yield of lucerne was doubled by the addition of sodium molybdate at the rate of 2 kg. per hectare. There was increase in the nitrogen content of the plants. Higher dozes of molybdenum produced further slight increase.

Aizupiete (1959) reported that molybdenum increased the hay yield of red clover by 32.5 per cent. Molybdenum and boron given together did not increase yield much more than molybdenum alone did. Molybdenum increased chlorophyll, carotene, and Vitamin 'C' content of the leaves.

Minina (1964) reported an increase of 9.3 h.kg. per hectare in forage and increased protein content in the seeds of forage beans to which molybdenum was applied.

Mehrotra and Gangwar (1965) obtained increased yields in berseem fodder to the extent of 7 and 9 per cent at Pusa and Buharifarms respectively by the addition of 0.56 kg. sodium molybdate per hectare. At 0.28 kg. per hectare level it failed to show beneficial effect at Pusa. At Kali however increased yields of the order of 8 per cent were obtained. A combination of molybdenum and boron has not shown any improvement over that of molybdenum alone.

Jayachandran (1966) observed favourable effects of molybdenum on the yield, height of plants, number of pods per plant and pods per hectare though the increase was not statistically significant.

Harris, Bledsoe and Clark (1954) did not get increase in yield in cowpeas by the addition of molybdenum though they noticed improved colour.

Vital Rao and Venkat Raju (1965) failed to get any variation in the yield of alfalfa by the application of boron and molybdenum individually or in combination. Both soil and foliar application had no response.

(iii) <u>Effect of molybdenum on quality of legumes</u>

Neklyudov (1956) obtained increased protein content of the seeds and vitamin 'C' content of plants, when molybdenum was added to peas. He also noticed increase in number of nodulebacteria particularly in limed soils.

Zurovska (1960) reported that molybdenum applied alone or in combination with boron increased enzyme activity, the contents of soluble sugars, protein and yield in peas.

Martynenko and Ivanova (1962) observed an increase of 4.5 to 6 per cent in the protein content of grain in peas. Seed treatment with molybdenum gave better results than soil or foliar application of the element.

(iv) Effect of molybdenum on nodulation

Mulder (1948) observed that root nodules on peas grown in water cultures with molybdenum in the absence of fixed nitrogen were pink in colour, while the molybdenum deficient ones were paler or yellow brown.

Blomefield (1954) reported that response to addition of molybdenum at the rate of two ounces per acre was observed in peas. Compared with the untreated plants, the treated plants had better colour, were slightly taller, and had pinkish nodules which were larger than the greyish nodules on the control plots. The treated plants were more resistant to collar rot and yielded thrice than the untreated plants.

Kliever and Kennedy (1960) revealed that legumes like birds foot, trefoil, lucerne, ladinoclover and red clover responded well to added sodium molybdate. The size of the individual nodules were increased. But there was a reduction in the number of nodules.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken to determine the effect of nitrogen, potassium and the trace-elements boron and molybdenum on the yield of cowpea, variety 'New-Era'.

1. Experimental site

The field experiment was laid out in the garden lands of the farm attached to the Agricultural College and Research Institute, Vellayani. The soil is red loam with medium fertility. The soil was analysed for its nutrient status and the data are given in Appendix I.

2. Season

The experiment was conducted during August to November 1966. Whether condition prevailed during the season is represented in the table given as Appendix II.

3. Seed material

The variety used was 'New-Era'. The seeds were obtained from the Agricultural College Farm, Vellayani.

'New-Era' is a North Rhodesian variety of approximately 70 days duration. It is a bushy plant with light green medium sized leaves. The flowers are with purple petals and green calyx. The pods are of medium size with purple tips seeds are chocolate coloured with mottlings.

4. <u>Manures and Fertilizers</u>

Uniform dose of cattle manure, lime and super-phosphate was given to all plots.

Nitrogen as Ammonium Sulphate, phosphorus as Super-phosphate, potassium as Muriate of potash, boron as Borax and molybdenum as Sodium molybdate was applied.

Cattle manure and fertilisers used analysed as follows:

Ammonium sulphate	-	20.5% N.
Super phosphate	-	16.00% P_2O_5
Muriate of potash	-	54.00% K_2O
Lime	-	54.30% CaO
<u>Cattle manure</u>	-	0.41% N
		0.30% P_2O_5
		0.20% K_2O

5. Layout and design

The trial was laid out as a split plot experiment with 3 replications. The whole plot treatments were combinations of nitrogen and potassium at 3 levels each. The interaction NK was confounded in replication II and NK^2 in replications I and III.

The sub-plot treatments were combinations of boron and molybdenum at 2 levels each.

Thus the three replications were laid out in 9 blocks, each block consisted of 3 whole plots and each whole plot containing 4 sub-plots.

6. Levels of treatments

Levels of nitrogen

1. n_0	-	No nitrogen
2. n_1	-	10 kg N/ha.
3. n_2	-	20 kg N/ha.

Levels of potassium

1. K_0	-	No potassium.
2. K_1	-	20 kg K_2O/ha.
3. K_2	-	40 kg K_2O/ha.

Levels of boron

1. B_0 - No boron
2. B_1 - 10 kg Borax/ha.

Levels of molybdenum

1. Mo_0 - No Molybdenum
2. Mo_1 - 1 kg Sodium molyb date/ha.

7. Size of plots

Whole plot	9.6 x 9.6 metres
Gross sub-plot	4.5 x 4.5 "
Net plot	3.9 x 3.9 "

8. Spacing

A spacing of 30 cm. either way as recommended by Krishnaswami *et al.* (1945) and Dungan and Ross (1957) was followed.

9. Number of plants in the sub-plot

Gross plot	-- 225 plants
Net plot	-- 169 "

10. Preparatory cultivation

The experimental site was ploughed thrice, clods broken and all the weeds and stubbles were removed. The field was then laid out.

11. Manuring

Well powdered calcium hydroxide at 1680 kg/ha. was applied before starting the preparatory cultivation. Cattle manure at the rate of 5600 kg per hectare was applied a fortnight after the lime was applied but before the completion of the preparatory cultivation. The doses of calcium hydroxide and cattle manure were fixed on the basis of recommendations made by Nair et al (1957) for leguminous crops under Kerala conditions.

The fertilizers were given as basal dose, a day prior to sowing. Ammonium sulphate, Muriate of potash, Borax and Sodium molybdate were mixed well and applied as broad cast. Super phosphate to supply 55 kg P_2O_5 was given in bands 30 cm. apart and 10 cm. deep.

12. Sowing

Seeds selected for sowing was tested for germination capacity and it was found to be 90 per cent. Healthy, well developed, plump seeds were selected for sowing. Two seeds per hole were dibbled in lines of

30 cm. botn ways on 28-8-66. Thinning was done a week after sowing, allowing only one seedling per hole.

13. <u>General condition of the crop</u>

Good rains were received on the previous day of sowing and the day after sowing. Germination was observed on the third day and completed within a week's time.

14. <u>After cultivation</u>

Plots were hand weeded twice on 12-9-66 and 3-10-66. Barring a mild attack of epilachna beetles the crop was free of insect pests. One spraying with Folidol E605 was given on 5-10-66.

15. <u>Harvest</u>

Because of the heavy rains during the growing period the vegetative phase of the crop was a little prolonged. Harvesting was completed on 23-11-66.

The border rows and plant selected for biometric observations were harvested separately. The grain yield of the net plots was recorded at 12 per cent moisture. The

<u>bhusa</u> were pulled out and dried under sun for 3 days and weight recorded.

16. <u>Observations made</u>

The following charactors were studied.

(i) <u>Height of plants at maturity</u>

Plants were selected at random in each sub-plot after leaving one border line on all the four sides. The height was taken from the cotyledonary node to the terminal node.

(ii) <u>Number of nodules</u>

All the nodules on the roots of the plants selected at random in each sub-plot were counted and average worked out.

(iii) <u>Number of pods per plant</u>

Number of pods on the selected plants were noted and average determined.

(iv) <u>Length of pods</u>

20 pods taken at random from pods collected from the selected plants were measured and average length worked out.

(v) Number of seeds per pod

Pods used for measuring the length were threshed separately and the number of seeds in each pod was counted and the average worked out.

(vi) Weight of dry seeds

Pods harvested from each sub-plot was dried, threshed and the weight recorded at 12 per cent moisture.

(vii) Weight of dried bhusa

Immediately after the completion of harvest of pods, the plants were pulled out dried uniformly and their weight recorded.

(viii) Weight of 100 seeds

100 seeds from each sub-plot were drawn at random, after thoroughly mixing the seeds and the weight was recorded using a physical balance.

RESULTS

RESULTS

The biometric observations, namely height of plants at maturity, number of root nodules, number of pods per plant, length of pods, number of seeds per pod, weight of dry seeds, weight of dried bhusa and weight of 100 seeds taken at preharvest and post-harvest stages of cowpea variety 'New Era' was analysed statistically. The analysis of variance tables are given as appendix III to X. Mean values of the different observations are given in Tables I to VIII.

1. Height of plants

The data on the height of plants at maturity was analysed statistically and is given in Appendix III.

Mean height of plants under various treatments are represented in Table I a, b and c.

It is observed that the height of plants increased significantly due to the addition of nitrogen. Effect of potassium also is significant, the influence being negative. Interaction between nitrogen and potassium is not significant. Addition of boron has also increased the mean height of plants. None of the other treatments were significant.

TABLE I(a)

Mean height of plants (in cm) at maturity

	N_o	N_1	N_2	Mean
K_0	33.95	41.31	44.67	39.97
K_1	34.04	35.34	42.63	37.34
K_2	34.19	35.53	41.89	37.60
Mean	34.06	37.39	43.06	

CD (0.05) for levels of N = 1.425

CD (0.05) for lovels of K = 1.425

CD (0.05) combinations of N and K = 3.1156

TABLE I(b)

	B_o	B_1	Mean
MO_o	37.62	38.42	38.02
MO_1	38.02	38.62	38.32
Mean	37.82	38.52	

CD (0.05) for levels of B = 0.6054

" MO = 0.6054

CD (0.05) for combinations of B and MO = 0.8516

TABLE I(c)

Mean height of plants (in cm) at maturity

	B_oMO_o	B_oMO_1	B_1MO_o	B_1MO_1	Mean
N_oK_o	33.82	34.12	33.15	34.69	33.95
N_oK_1	34.21	33.78	34.10	34.07	34.04
N_oK_2	33.23	33.95	34.75	34.82	34.19
N_1K_o	39.91	41.73	41.32	42.27	41.31
N_1K_1	34.61	35.18	36.28	35.35	35.34
N_1K_2	36.29	35.27	35.07	35.47	35.53
N_2K_o	43.44	44.31	45.58	45.34	44.67
N_2K_1	42.26	42.36	42.85	43.04	42.63
N_2K_2	40.88	41.48	42.66	42.55	41.89
Mean	37.62	38.02	38.42	38.62	

CD (0.05)	for whole plot treatment combinations	= 3.1156
CD (0.05)	for sub-plot treatment combinations	= 0.8516
CD (0.05)	for comparison between s b-plot treatments within the same wholo plot treatment	= 2.5722
CD (0.05)	for comparison between s b-plot treatments not within the same whole-plot treatment	= 4.4019

Maximum mean height of 44.67 cm. was recorded in the treatment combination N_2K_0 and the minimum of 33.82 cm. in the treatment combination of $N_0K_0B_0MO_0$.

2. Number of nodules

Analysis of variance for the number of nodules per plant is given in Appendix IV.

It is seen from the Tables II a, b and c, that nitrogen at all levels were significant, the influence being negative. Combinations of nitrogen and potassium has also significantly reduced the number of nodules per plant. Potassium did not show any significant response.

Application of boron and molybdenum has significantly increased the mean number of nodules per plant. The effect of combination of boron and molybdenum is significant and positive Highest number of nodules is noticed in the whole plot treatment combination N_0K_0 and the lowest in the combination N_2K_1.

3. Number of pods

Data on the number of pods per plant was analysed and the analysis of variance is given in Appendix V. It is seen that nitrogen, potassium, boron and molybdenum alone or

TABLE II(a)

Mean number of nodules produced

	N_o	N_1	N_2	Mean
K_o	24.71	19.54	15.83	20.02
K_1	24.38	20.42	15.72	20.17
K_2	23.98	21.35	16.11	20.48
Mean	24.35	20.43	15.88	

CD (0.05) for levels of N = 0.8969

" K = 0.8969

CD (0.05) for combinations of N and K = 1.5549

TABLE II(b)

	B_o	B_1	Mean
MO_o	18.26	21.67	19.96
MO_1	19.77	20.66	20.21
Mean	19.01	21.16	

CD (0.05) for levels of B = 0.2122

CD (0.05) for levels of MO = 0.2122

CD (0.05) for combination of B and MO = 0.2986.

TABLE II(c)

Number of nodules produced

	B_oMo_o	B_oMo_1	B_1Mo_o	B_1Mo_1	Mean
N_oK_o	22.11	23.81	27.18	25.74	24.71
N_oK_1	22.34	23.22	26.83	25.05	24.38
N_oK_2	22.18	22.81	25.93	24.11	23.98
N_1K_o	17.51	20.33	20.81	20.34	19.54
N_1K_1	18.38	20.03	22.60	20.67	20.42
N_1K_2	19.35	20.88	22.56	21.32	21.35
N_2K_o	13.31	15.83	16.31	15.98	15.83
N_2K_1	13.36	15.71	16.23	15.83	15.72
N_2K_2	15.80	15.33	16.58	16.78	16.11
Mean	18.26	19.77	21.67	20.66	

CD (0.05)	for whole plot treatment combinations	= 1.5549
CD (0.05)	for sub-plot treatment combination	= 0.2986
CD (0.05)	for comparison between sub-plot treatments within the same whole plot treatment	= 0.9859
CD (0.05)	for comparison between sub-plot treatments not within the same whole plot treatment	= 1.8711

in combination have not increased the mean number of pods per plant.

There is a trend towards increase in the mean number of pods for nitrogen at 10 kg. per hectare. Potassium at 20 kg. per hectare and combination of these two have shown the same trend.

The mean number of pods under various treatments are given in Table III a, b and c.

4. Length of pods

Data regarding the length of pods under various treatments were statistically analysed and the analysis of variance is given in Appendix VI.

Mean length of pods under various treatments is given in Table IV a, b and c.

It is seen from the tables that nitrogen and potassium alone or in combination have not significantly influenced the length of pods.

Addition of boron has influenced the length of pods significantly, the effect being positive. Interaction of boron and molybdenum is also significant and positive. Molybdenum has not shown any influence. The interactions NB, KB, N x K x MO, K x MO and N x B x MO were also significant.

TABLE III (a)

Mean number of pods per plant

	N_o	N_1	N_2	Mean
K_o	8.96	9.92	9.26	9.38
K_1	9.89	10.38	9.57	9.95
K_2	9.37	10.22	10.30	9.96
Mean	9.40	10.17	9.71	

CD (0.05) for levels of N = 0.8474

" K = 0.8474

CD (0.05) for combinations of N&K= 1.4682

TABLE III (b)

	B_o	B_1	Mean
MO_o	9.60	9.85	9.73
MO_1	9.69	9.91	9.80
Mean	9.65	9.88	

CD (0.05) for levels of B = 0.333

" MO = 0.333

CD (0.05) for combinations of B and MO = 0.4725

TABLE III (c)

Mean number of pods per plant

	B_oMO_o	B_oMO_1	B_1MO_o	B_1M_1	Mean
N_oK_o	8.62	8.83	9.41	9.00	8.96
N_oK_1	9.87	10.17	10.04	9.50	9.89
N_oK_2	9.46	8.58	10.29	9.16	9.37
N_1K_o	10.16	9.87	9.79	9.87	9.92
N_1K_1	10.54	10.08	9.33	11.54	10.38
N_1K_2	9.79	10.04	10.83	10.25	10.22
N_2K_o	8.62	9.70	9.16	9.54	9.26
N_2K_1	9.36	10.08	8.87	9.95	9.57
N_2K_2	10.00	9.91	10.91	10.37	10.30
Means	9.60	9.69	9.85	9.91	

CD (0.05)	for whole plot treatment combination	= 1.4682
CD (0.05)	for comparison between sub-plot treatments within the same whole plot treatment	= 1.4161
CD (0.05)	for sub-plot treatment combination	= 0.4725
CD (0.05)	for comparison between sub-plot treatments not within the same whole plot treatment	= 2.2134.

5. Number of seed per pod

Analysis of variance for the number of seeds per pod is presented in Appendix VII.

It is seen that none of the treatments influenced the number of seeds per pod.

Mean number of seeds under various treatments are given in Table V a, b and c.

6. Yield of seed

Data on the weight of seeds per net plot was statistically analysed and the analysis of variance is presented in Appendix VIII.

It is seen that application of both nitrogen and potassium singly or in combination has not significantly influenced the yield of seed. Among different levels, nitrogen at 10 kg. per hectare has given the highest yield of 930.30 kg. of seed. Similarly in the case of potassium highest yield of seed is obtained for the application of K_2O at 20 kg. per hectare. The treatment combination N_1K_1 has given the highest yield. The treatment combination N_2K_0 depressed the yield of seed.

Among the sub-plot treatments boron has significant effect in increasing the yield of seed. None of the other

TABLE IV (a)

Mean length of pod (in cm)

	N_0	N_1	N_2	Mean
K_0	15.62	15.49	15.40	15.50
K_1	15.48	15.42	15.34	15.41
K_2	15.78	15.48	15.40	15.55
Mean	15.62	15.46	15.38	

CD (0.05) for levels of N = 0.2166

" K = 0.2166

CD (0.05) for combination of N and K ==0.3757

TABLE IV (b)

	B_0	B_1	Mean
MO_0	15.44	15.51	15.47
MO_1	15.38	15.55	15.46
Mean	15.41	15.53	

CD (0.05) for levels of B = 0.082

" MO = 0.082

CD (0.05) for combined levels of B and MO = 0.0115

TABLE IV (c)

Mean length of pod (in cm)

	B_oMO_o	B_oMO_1	B_1MO_o	B_1MO_1	Mean
N_oK_o	15.60	15.79	15.38	15.72	15.62
N_oK_1	15.93	15.63	15.49	14.89	15.48
N_oK_2	15.73	16.02	15.75	15.61	15.78
N_1K_o	15.37	15.43	15.69	15.46	15.49
N_1K_1	15.41	15.57	15.67	15.14	15.42
N_1K_2	15.17	15.88	15.67	15.19	15.48
N_2K_o	15.19	15.46	15.36	15.58	15.40
N_2K_1	15.21	15.38	15.32	15.44	15.34
N_2K_2	15.39	15.46	15.39	15.39	15.40
Mean	15.44	15.38	15.51	15.53	

CD (0.05) for whole plot treatment combination = 0.3757

CD (0.05) for sub-plot treatment combination = 0.0115

CD (0.05) for comparison between sub-plot treatments within the same whole plot treatment = 0.0353

CD (0.05) for comparison between sub-plot treatments not within the same whole plot treatment = 7.9425.

effects produced significant results. The mean yield per plot under different treatments calculated as per hectare basis is given in Table VI a, b and c.

7. Yield of bhusa

Analysis of variance for the yield of bhusa per plot is presented in Appendix IX.

It is seen that nitrogen significantly increased the yield of bhusa. Potassium did not show any significant response. It is seen that nitrogen and potassium at the highest level produced the highest yield of 5624.45 kg. However the effect of combination of nitrogen and potassium was not significant.

Boron and molybdenum alone and in combination have significantly increased the yield of bhusa. The interaction N x B x MO has also influenced the yield of bhusa significantly.

The mean yield of bhusa per plot calculated as per hectare basis is given in Table VII a, b and c.

8. 100 seed weight

The analysis of variance of weight of 100 seed is presented in Appendix X.

TABLE V (a)

Mean number of seeds per pod

	N_0	N_1	N_2	Mean
K_0	15.13	15.41	15.53	15.35
K_1	15.42	15.08	15.00	15.23
K_2	15.38	15.54	15.09	15.33
Mean	15.33	15.34	15.21	

CD (0.05) for levels of N = 1.313

" K = 1.313

CD (0.05) for combination of N and K = 1.724.

TABLE V (b)

	B_0	B_1	Mean
MO_0	15.38	15.41	15.39
MO_1	15.09	15.62	15.36
Mean	15.23	15.51	

CD (0.05) for levels of B = 0.8321

" MO = 0.8321

CD (0.05) for combination of B and MO = 1.023.

TABLE V (c)

Mean number of seeds per pod

	B_0MO_0	B_0MO_1	B_1MO_0	B_1MO_1	Mean
N_0K_0	15.21	15.18	15.08	15.11	15.13
N_0K_1	15.41	15.50	15.38	15.42	15.42
N_0K_2	15.39	15.41	15.05	15.68	15.38
N_1K_0	15.35	15.52	15.38	15.41	15.41
N_1K_1	15.98	15.99	15.34	15.02	15.08
N_1K_2	15.40	15.55	15.64	15.56	15.54
N_2K_0	14.96	15.56	16.00	15.61	15.53
N_2K_1	14.83	15.01	15.00	15.01	15.00
N_2K_2	15.00	15.01	15.25	15.12	15.09
Mean	15.38	15.09	15.[illegible]1	15.62	

CD (0.05) for whole plot treatment combinations = 1.724

CD (0.05) for sub-plot treatment combinations = 1.023

CD (0.05) for comparison between sub-plot treatments within the same whole plot treatment = 2.983

CD (0.05) for comparison between sub-plot treatments not within the same whole plot treatment = 4.5313

Nitrogen and potassium alone or in combination did not influence significantly the 100 seed weight.

Boron and molybdenum alone or in combination did not significantly influence the 100 seed weight.

The interaction NB, KB and NMO, N x B x MO and K x B x MO were significant.

100 seed weight, under different treatments are given in Table VIII a, b and c.

TABLE VI (a)

Mean yield of seed in kg. per hectare

	N_o	N_1	N_2	Mean
K_o	650.06	743.20	612.34	668.53
K_1	735.26	930.30	727.04	797.53
K_2	654.17	824.32	845.05	774.51
Mean	679.83	832.62	728.14	

CD (0.05) for levels of N = 148.2

" K = 148.2

CD (0.05) for combination of N and K = 396.6

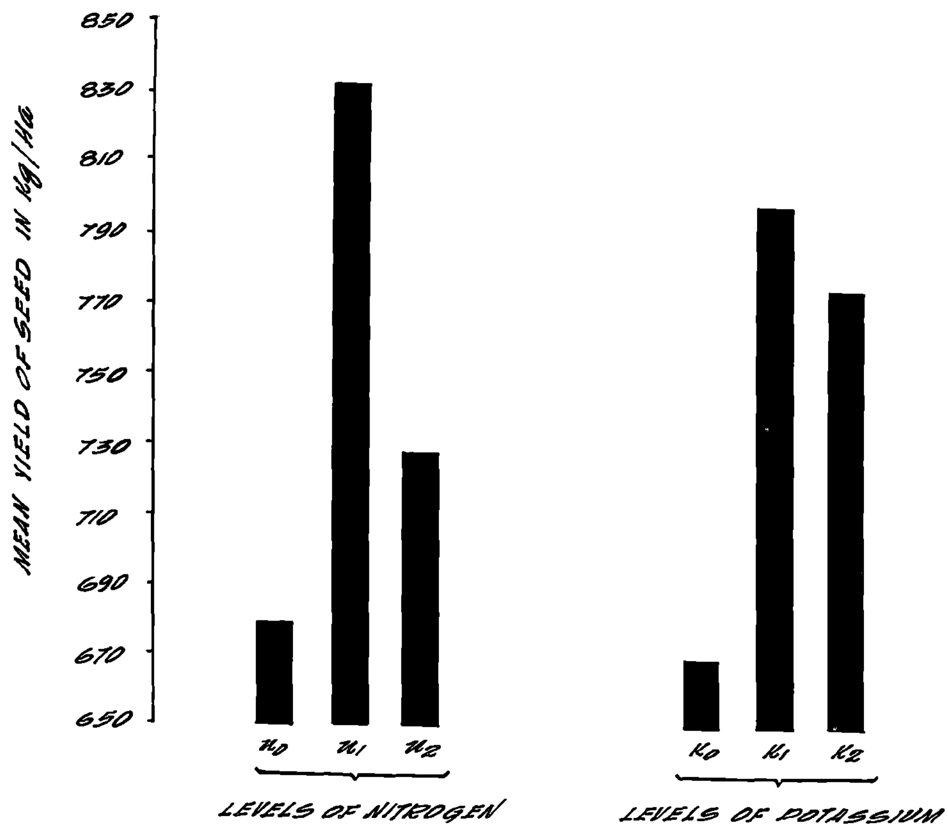
TABLE VI (b)

	B_o	B_1	Mean
MO_o	721.15	748.10	734.62
MO_1	729.78	786.88	758.33
Mean	725.46	767.49	

CD (0.05) for levels of B = 39.9

" MO = 39.9

CD (0.05) for combination of B and MO = 85.8



EFFECT OF NITROGEN AND POTASSIUM ON SEED YIELD

FIG 1

TABLE VI (c)

Mean yield of seed in kg. per hectare

	B_0MO_0	B_0MO_1	B_1MO_0	B_1MO_1	Mean
N_0K_0	659.65	681.13	557.74	695.81	650.06
N_0K_1	771.43	643.21	702.38	824.01	735.26
N_0K_2	642.11	644.31	659.65	670.61	654.17
N_1K_0	626.77	710.05	895.24	740.73	743.20
N_1K_1	806.48	1038.79	910.58	965.37	930.30
N_1K_2	797.71	768.13	771.40	9[illegible]9.89	824.32
N_2K_0	620.07	577.46	633.35	610.34	612.34
N_2K_1	746.21	714.43	741.83	705.67	727.04
N_2K_2	820.09	798.81	826.20	909.48	845.05
Mean	721.15	729.78	748.10	786.88	

CD (0.05)	for whole plot treatment combination	= 306.5
CD (0.05)	for sub-plot treatment combination	= 85.8
CD (0.05)	for comparison between sub-plot treatments within the same whole plot treatment	= 254.6
CD (0.05)	for comparison between sub-plot treatments not within the same whole plot treatment	= 614.00

TABLE VII (a)

Mean yield of bhusa in kg. per hectare

	N_0	N_1	N_2	Mean
K_0	3142.67	3740.96	5384.68	4089.43
K_1	3266.93	4122.29	5417.49	4268.90
K_2	3333.33	3734.32	5634.45	4234.05
Mean	3247.64	3865.88	5478.87	

CD (0.05) for levels of N = 501.60

" K = 501.60

CD (0.05) for combination of N and K = 872.80

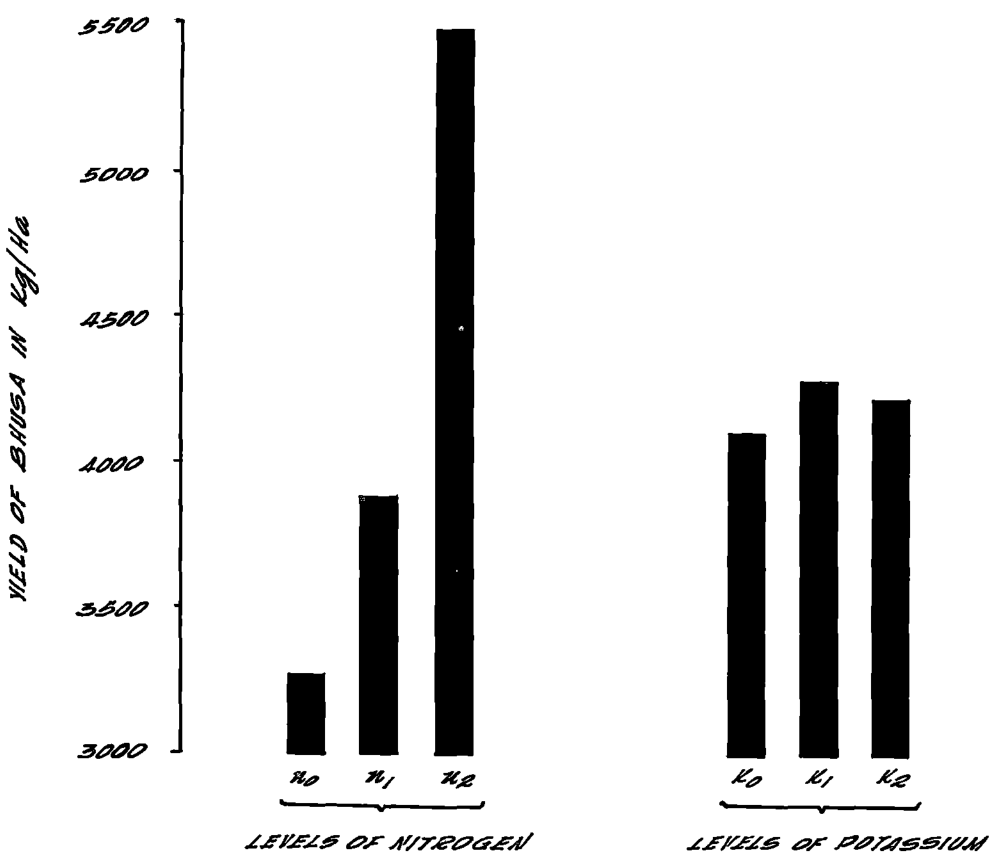
TABLE VII (b)

	B_0	B_1	Mean
MO_0	3800.13	4280.14	4040.13
MO_1	4332.67	4372.12	4352.39
Mean	4066.35	4326.13	

CD (0.03) for levels of B = 157.80

" MO = 157.80

CD (0.05) for combination of B and MO = 223.50



EFFECT OF NITROGEN AND POTASSIUM ON YIELD OF BHUSA

FIG 2

TABLE VII (c)

Mean yield of bhusa in kg. per hectare

	B_oMO_o	B_oMO_1	b_1MO_o	B_1MO_1	Mean
N_oK_o	2919.13	3241.28	3136.09	3287.31	3142.67
N_oK_1	2968.57	3418.80	3353.05	3333.33	3266.93
N_oK_2	3241.28	3195.26	3372.78	3504.27	3333.33
N_1K_o	3399.07	4123.01	3727.81	3727.81	3740.96
N_1K_1	3484.54	4123.01	4247.20	4490.46	4122.29
N_1K_2	3174.88	4049.96	3747.53	3964.49	3734.39
N_2K_o	4733.72	5542.40	5542.40	5719.91	5384.68
N_2K_1	4930.96	5642.40	5430.63	5735.94	5417.49
N_2K_2	5213.67	5786.32	5982.80	5568.70	5634.45
Mean	3800.13	4332.67	4280.14	4372.12	

CD (0.05)	for whole plot treatment combination	= 872.80
CD (0.05)	for sub-plot treatment combination	= 223.60
CD (0.05)	for comparison between sub-plot treatments within the same whole plot treatment.	= 670.5
CD (0.05)	for comparison between sub-plot treatments not within whole plot treatment.	= 507.5

TABLE VIII (a)

100 seed weight in gramme

	N_0	N_1	N_2	Mean
K_0	10.56	10.87	10.53	10.64
K_1	10.81	12.03	10.80	11.21
K_2	10.78	11.06	11.32	11.05
Mean	10.71	11.32	10.88	

CD (0.05) for levels of N = 0.6384

" K = 0.6384

CD (0.05) for combination of N and K = 1.2710

TABLE VIII (b)

	B_0	B_1	Mean
MO_0	10.88	11.01	10.95
MO_1	10.96	11.04	11.00
Mean	10.96	11.03	

CD (0.05) for levels of B = 0.1809

" = 0.1809

CD (0.05) for combination of B and MO = 0.2562

TABLE VIII (c)

100 seed weight in gramme

	B_oM_o	B_oMO_1	B_1MO_o	B_1MO_1	Mean
N_oK_o	11.20	10.53	10.47	10.03	10.56
N_oK_1	10.80	10.87	11.00	10.57	10.81
N_oK_2	10.97	10.13	10.80	11.20	10.78
N_1K_o	10.20	11.20	11.33	10.77	10.87
N_1K_1	11.60	11.90	12.30	12.57	12.03
N_1K_2	10.63	10.73	11.37	11.50	11.06
N_2K_o	9 .93	11.17	10.33	10.77	10.53
N_2K_1	11.03	11.17	10.23	10.77	10.80
N_2K_2	11.63	10.90	11.50	11.27	11.32
Mean	10.88	10.96	11.01	11.04	

CD (0.05) for whole plot treatment combination = 1.2710

CD (0.05) for sub-plot treatment combination = 0.2562

CD (0.05) for comparison between sub-plot treatments within the same whole plot treatments = 0.7687

CD (0.05) for comparison between sub-plot treatments not within the same whole plot treatments = 3.5110

DISCUSSION

DISCUSSION

An investigation was carried out at the Agricultural College and Research Institute, Vellayani, to study the effect of nitrogen, potassium, boron and molybdenum on cowpea variety 'New Era'.

The data recorded on the height of plants at maturity, number of root nodules produced, number of pods per plant, number of seeds per pod, yield of seed, and bhusa and 100 seed weight were statistically analysed. The results are discussed in the following pages.

1. Height of plant

As evident from Table I (a) nitrogen has significantly increased the height of plants at maturity. It is seen that nitrogen both at 10 kg. and 20 kg. per hectare has increased the height significantly. Role of nitrogen in the vegetative growth of plants is well known. Russel (1961) has stated that nitrogen increases the size of cells, promotes leaf growth and thus bring about enhanced photosynthesis which assist the growth process. Tisdale and Nelson (1956) associate nitrogen with vigorous growth in plants.

According to Russel (1961) small quantities of nitrogen are desirable for the early growth of legumes.

Results of the present investigation are in agreement with the findings of Shukla (1964) in gram, Ezedinma (1964) and Nair (1966) in cowpea.

Application of potassium at all levels has significantly reduced the mean height of plants.

Tisdale and Nelson (1956) opined that potassium is required chiefly for production and translocation of carbohydrates.

Russel (1961) states that potassium is important in photosynthetic activity in plants. He also states that with moderate dressings of nitrogen as Ammonium sulphate, potassium doubles the weight of roots but has only a very small effect on the yield of tops. Russel further observes that excess of potassium in the soil as brought about by too high a level of potassium manuring will reduce very considerably the amount of other cations the crop can take up, and this may lead to crop growth being badly upset by these induced deficiencies of other cations. The reason for potassium showing a depressing effect on the height of plants at maturity could be attributed to the above mentioned reasons.

Results of this investigation are in accordance with the findings of Lin (1959) who also observed a depressing effect on height by the application of potassium to yellow lupin.

Among the micro nutrients tried boron alone has shown significant response in increasing the height of plants at maturity (Table I (b)).

According to Russel (1961) boron is necessary for the meristems or actively dividing tissues and boron application will bring about increased meristamatic activity. Another function attributed to boron is that it helps in the uptake of calcium by the roots and efficient use in the plant. Calcium also is essential for the growth of meristems. Hass (1944) also has stressed the positive role of boron in cell division in meristamatic tissues of plants. Bobko Matveva and Syvorotkin (1933) have opined that boron is concerned with the efficient assimilation of iron and utilization of nitrogen and mineral matter. Lal and Rao (1954) has opined that influence of boron on growth of stem is more than that on leaves or roots.

Increase in height of plants at maturity by the application of boron along with calcium in the present investigation could be due to the aforesaid reason. Similar findings in legumes have been recorded by Piland, Ireland and Reisnauer (1944) Govindarajan (1951) Datta and Gurubasavaraj (1962), Shende and Sen (1958) and Jayachandran (1966).

2. Number of nodules

As seen from Table II nitrogen applied at the rate of 20 kg. per hectare produced the least number of nodules. Nitrogen at the lower level also reduced the mean number of nodules significantly.

Whyte, Nilsson-Leissner and Thrumble (1953) states that if combined nitrogen is applied to legumes as fertilizer the uptake of nitrogen by plant may sustain such a narrow carbon/nitrogen ratio that fixation is depressed and if this is continued for long, degeneration of nodule begins. The carbon nitrogen ratio also affects the development of nodules by the plant. A high level of combined nitrogen in the soil will prevent deformation of the roots and hence entry of the bacteria will be precluded and no nodules formed. According to Gibson (1951) one of the optimum conditions for nodulation is a restricted supply of nitrates in the soil. Russell (1961) has also expressed similar views. These might be the reasons for depression observed in the number of nodules caused by the application of nitrogen in the present investigation.

Similar results have been obtained by Jansson and Toostensson (1955) in peas, Samuels and Landru (jr) (1952) in tropical kudzu, Cartwright (1959) in several legumes, Cowling (1961) in white clover, Tewari (1965) and Nair (1966) in cowpea.

It is seen from the Table II that potassium had no effect on nodulation.

Andrew (1962) has opined that potassium alone does not affect nitrogen fixation. Russel (1961) stated that for active nitrogen fixation though potassium is required legumes differ considerably in the requirement of this nutrient. Landru and Samuels (1959) found no influence in nodulation derived from potassium application to <u>Cajanus cajan</u>. Tewari (1965) also has obtained similar results in cowpea.

Combined application of nitrogen and potassium also significantly reduced the number of nodules. The effect of combined application of nitrogen and potassium can be explained by the fact that since potassium is having no influence on the number of nodules, the general depressing effect of nitrogen on nodulation is showing its expression.

Effect of both boron and molybdenum singly and in combination is significant (Table II(b).

Brenchley and Thornton (1925) has suggested that adequate supply of boron is essential for the development of vascular system which is essential to supply the nodule bacteria with carbohydrate. The offect is more on the host plant than on the bacteria or the symbiotic system. Whittington (1958) stated that primary effects are cessation of growth and enlargement of the apical cells when boron was applied to field beans. Russel (1961) has opined that molybdenum is primarily concerned with nitrogen fixation.

Results of the present investigation are in conformity with the findings of Datta and Gurubasavaraj (1952) and Moschini (1951).

3. Number of pods

It is seen that none of the treatments had any significant effect on the mean number of pods per plant (Table III a, b and c).

Nitrogen at 20 kg. per hectare had a depressing effect on the mean number of pods when compared with nitrogen at 10 kg. per hectare.

Nitrogen is associated with vigorous vegetative growth and exeessive amount of this element may prolong vegetative phase and there by reduce the number of pods. (Tisdale and Nelson (1956)). Similar views in this regard is expressed by Russel (1961) also.

Lack of response to nitrogen in yield of pod could be due to the fact that applied nitrogen might have helped in increasing vegetative growth only. Similar results were obtained by Moolani and Jana (1965) and Nair (1966). These workers observed depressing effect of nitrogen at 25 kg. per hectare and 20 kg. per hectare in moong and cowpea respectively.

Potassium also has not influenced the mean number of pods significantly. However, there is a trend towards increase in the mean number of pods with increasing levels of potassium.

Rossiter (1947), and Vargas (1957) have reported increased yields in legumes by the application of potassium.

Russel (1961) has reported that excess application of potassic fertilizers to soil may bring about a decrease in the magnesium concentration in plants resulting in poor yields. This phenomena is especially important in acidic soils. Probably failure of added potassium to increase the number of pods significantly may be due to this reason. Another possibility may be that potassium being used up for the vegetative growth induced by excessive nitrogen.

Application of boron and molybdenum also had no significant effect on the mean number of pods per plant though there was a trend towards increase in the mean number of pods.

Datta and Gurubasavaraj (1952) Shende and Sen (1958), Ballal and Natu (1961) have obtained increased yields in different legumes by the application of boron, Neklyudove (1956) and Mehrotra and Gangwar (1965) by the application of molybdenum. Jayachandran (1966) obtained significant increase in the number of pods in groundnut by the application of boron when applied at the rate of 20 kg. borax per hectare, the increase for 10 kg. borax per hectare being not significant. The absence of response in the present study may be due to the low doze of borax tried.

In the case of molybdenum the lack of response can be attributed to its low availability under the acidic reaction of the soil in which the investigation was carried out.

4. Length of pods

Application of nitrogen and potassium has not significantly increased the mean length of pods. Combined effect of nitrogen and potassium also is not significant. Nair (1966) have reported that length of pods in cowpea was not significantly influenced by the application of nitrogen at 20 kg. per hectare. It should be assured that length of pod is more of a varietal charactor not influenced by fertilizer treatments. The results only indicate that this is a varietal charactor than anything else.

Boron singly and in combination has increased the mean length of pods significantly.

Lal and Rao (1954) have opined that boron may influence favourably the size of pods. Boron in general may aid in absorption and utilization of calcium more than others. Phosphorus transport also is improved in the presence of boron. Boron by virtue of its physiological role in cell division may increase the size of pods. (Lal and Rao (1954). Nair (1966) has recorded increase in mean length of pods in cowpea by the application of P_2O_5 at 55 kg. per hectare. Even though the length of pod is believed to be a varietal charactor the effect of boron in increasing the pod length can be explained by the fact that application of 55 kg. of P_2O_5 given as basal dressing along with boron influenced the utilization of phosphorus favourably bringing about an increase in the mean length of pod.

5. Number of seed

It is observed that none of the treatments were significant in increasing the number of seeds per pod. It is to be assumed that number of seeds per pod is a varietal charactor. Nair (1966) also did not get any significant difference in the mean number of seeds per pod by the application of nitrogen to cowpea.

6. Yield of seed

It is evident from the Table VI that none of the main plot treatments significantly influenced the yield of seed per hectare.

Tisdale and Nelson (1956) is of opinion that nitrogen is associated with virogous vegetative growth and excessive quantity of nitrogen may prolong the growing period and delay maturity. Gane (1963) while reviewing an extensive series of field trials for field beans has concluded that application of nitrogen for seed production is not worthwhile. From the Tables it is clear that nitrogen alone, at the highest level decreased the yield by 47.72 kg. per hectare. Contrary to this there was an increase of 92.14 kg. for the treatment of 10 kg. nitrogen per hectare. Russell(1961) has opined that small increments of nitrogen for legumes may promote early growth. Ebong (1966) also has reported favourable effect on yield for small dosage of nitrogen in cowpea. A reduction in yield is also noticed at 20 kg of nitrogen per hectare compared to 10 kg of nitrogen per hectare. This may be due to the excessive evegetative growth occuring at higher levels of nitrogen (Table VIII (a). This is in conformity with the findings of Singh and Sahasrabudhe (1957) Sharma and Misra (1961) Moolani and Jana (1965) and Nair (1966).

Application of potassium has shown a trend towards increase in yields with a slight depressing effect at the highest level. Too high a level of potassium may reduce the uptake of other cations and may unfavourably affect the crops. The depressing effect noted may be attributed to this. Depressing influence of higher levels of potassium has been recorded by Kataski and Banahatti (1965) in ground nut.

The treatment combination of N_1K_1 has given the maximum yield of 930.30 kg per hectare. Combinations of nitrogen and potassium other than N_0K_0 and N_2K_2 recorded increased yields though the differences were not significant. An increase to the tune of 194.99 kg is noticed for the treatment combination of N_2K_2 over that of N_0K_0. Same trend is noticed in the case of N_2K_1 also. This is in conformity with the statement of Russell (1961) that potassium acts as a corrective to the harmful effects of nitrogen when given at increased levels.

The lack of significant response of nitrogen and potassium in influencing yield may thus be attributed to the fact that nitrogen and potassium were utilized for promoting vegetative growth rather than for production of seed.

Of the sub-plot treatments boron alone has significantly increased the yield of seed per hectare. Boron is indispensible in the production of seed. Boron is concerned with carbohydrate transformation and utilization. Boron has favourable influence in the uptake and utilization of calcium and phosphorus (Lal and Rao 1954) Russell (1961) also has stressed, that primary functions of boron in the uptake and utilization of calcium in plants. Hence the increase in yield of seed noticed in the present investigation by the application of boron could be due to its influence on efficient uptake and utilisation of calcium and phosphorus, besides the physiological role of meristamatic activity and regulation of water relation of plants (Lal and Rao 1954). Increase in seed yield obtained due to the application of boron, by Piland, Ireland and Reisnauer (1944) in crimson clover was attributed to the growth of a vigorous type of seed head and the formation of matured plump seed. Results of the present investigations are in agreement with that of Ballal and Natu (1961) and Jayachandran (1966).

Mylybdenum, though failed to register a significant influence in the yield of seed has shown a trend towards increase in yield. The lack of significant influence may be attributed to the non availability of molybdenum particularly under soils of acidic reaction as reported by Tisdale and Nelson (1956).

7. Yield of Bhusa

Highly significant increase in yield bhusa has been recorded by the application of nitrogen at all levels (Table VIII (a)) Role of nitrogen in the promotion of vegetative growth is well known. The excessive vegetative growth even at the expense of seed production could have resulted in high yield of bhusa. This is in conformity with the findings of Nair (1966) in cowpea.

Potassium though not increased the yield of bhusa significantly has shown a distinctive trend towards increasing the yield of bhusa. Russell (1961) has opined that potassium has got only small effect on the yield of bhusa.

He states that initial effect of potassium on the growth of leaves disappears as the crop reaches maturity. Results of the present investigation is in conformity with this finding.

Interaction of nitrogen and potassium also is not significant. The reason for this may be that only nitrogen alone is significant in increasing the bhusa yield. However the treatment combinations have shown a trend towards increase in bhusa yield.

Application of boron and molybdenum singly and in combination have significantly increased the yield of bhusa. The favourable effects of boron may be due to its influence on the uptake and utilization of calcium and phosphorus and due to its physiological role in cell division and moristamatic tissues as suggested by Russell (1961) and Lal and Rao (1956). Results of the present investigation are in conformity with the findings of Gopal Rao and Govindarajan (1951) who obtained increased green matter yield in sunhemp, Datta and Gurubasavaraj (1952) in berseem and Shende and Sen (1958) in guar.

Though molybdenum is concerned primarily with nitrogen fixation in legumes (Russell1961), Evans (1956) has attributed the role of electron carrier in the nitrogen metabolism in plants as evidenced by the accumulation of nitrates in tissues of plants deficient in nitrogen. Plants receiving molybdenum show rich green colour, large size of leaves and marked rise in dry weight. (Arnon and Stout 1938). Anderson (1948) states that response to molybdenum by legumes may be due to improved nitrogen fixation. More over, molybdenum deficiency may lead to nitrogen deficiency also. Increase in the yield of bhusa in the present investigation may be attributed to these effects of molybdenum. Anderson (1948) Jensen (1959), Aizupete (1959) Minina (1964) and Mehrotra and Gangwar (1965) have obtained similar results.

Molybdenum in combination with boron improves size of plants. (Lal and Rao 1954). Anderson (1952) reported that in subterranean clover and lucerne the response was more when molybdenum was applied together with boron in molybdenum deficient soil. This is in conformity with the findings of the present investigation.

8. 100 seed weight

It is seen that none of the main plot treatments has any significant influence on the 100 seed weight (Table VIII). However the treatments have shown a trend towards increase in 100 seed weight. Probably the plumpiness of seeds might have contributed towards increase in per acre yields. However the excessive vegetative growth caused by nitrogen application might have resulted in masking the effect of the nutrients in 100 seed weight. Nair (1966) did not get significant influence for nitrogen in this factor.

In the sub-plot treatments boron and molybdenum singly and in combination has not shown any significant influence on the 100 seed weight. All the same these elements singly and in combination have shown a trend towards increasing the 100 seed weight. This tendency is evidenced in the per acre yield of seeds also (Table VI).

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

A field experiment was laid out in the farm attached to the Agricultural College and Research Institute, Vellayani during 1967 to study the effect of nitrogen, potassium, boron and molybdenum on cowpea variety, 'New Era'. The treatments comprised three levels of nitrogen, 0, 10 and 20 kg. per hectare, 3 levels of potassium, 0, 20 and 40 kg. per hectare, 2 levels of boron as 0 and 10 kg. Borax per hectare and two levels of molybdenum as 0 and 1 kg. Sodium molybdate per hectare. The main findings are summarised below.

I (a) Application of nitrogen significantly increased the mean height of plants. Nitrogen at 20 kg. per hectare recorded the maximum height.

(b) There was a reduction in the mean height of plants by the application of potassium.

(c) Boron has significantly increased the mean height of plants.

2 (a) Nitrogen application at 10 and 20 kg. per hectare had an adverse effect on nodulation.

(b) Potassium had no effect on nodulation.

(c) Boron and molybdenum alone and in combination has significantly increased the number of nodules.

3. Nitrogen, Potassium, boron and molybdenum did not exert any significant influence on the number of pods.

4. (a) Mean length of pods were not influenced by the application of nitrogen and potassium.

(b) Boron has significantly influenced the mean length of pods.

5. (a) The yield of seed was not affected by the application of nitrogen and potassium. 20 kg. of nitrogen per hectare tended to decrease the yield of seed.

(b) Boron as 10 kg. borax per hectare significantly increased the yield of seed.

6.(a) Effect of nitrogen was highly significant in increasing the yield of bhusa.

(b) Potash had no effect on the yield of bhusa.

(c) Boron and molybdenum alone and in combination significantly increased the bhusa yield.

Results of the oresent investigation indicate that there is no response, under Vellayani conditions, in yield in cowpea even at 10 kg. nitrogen and 20 kg. potassium per hectare. The study also revealed the necessity of application of boron to increase the yield of cowpea. Further studies are necessary to determine the trace element nutrition in legumes.

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APPENDICES

APPENDIX I

Chemical Charectoristics of the soil from the experimental field

Total nitrogen	0.067	per cent
Total P_2O_5	0.035	"
Available P_2O_5	0.0022	"
Total K_2O	0.0700	"
Available potash	0.00067	"
pH	5.1	

APPENDIX II

Meteriological data recorded at the Agricultural College Farm, Vellayani, during the period of crop growth

Month	Temperature °F		Relative humidity	Total rain-fall in mm
	Maximum	Minimum		
August	86	74	87.6	341
September	86	74	86.7	768
October	88	74	89.0	120
November	86	74	89.0	100

APPENDIX III

(Analysis of variance)

HEIGHT OF PLANTS

Source	S.S.	D.F.	Variance	F.
Total	1905.00	107		
Blocks	102.53	8	12.81	1.14
N	1283.38	2	641.69	57.34**
K	175.97	2	87.98	7.86**
NK	26.40	2	13.20	1.18
NK^2	39.85	2	19.92	1.78
Error (1)	111.90	10	11.19	
B	13.18	1	13.18	5.53*
MO	2.37	1	2.37	<1
B x MO	0.27	1	0.27	<1
NB	3.62	2	1.81	<1
KB	0.19	2	0.38	<1
N x K x B	8.36	4	2.09	<1
NMO	0.09	2	0.045	<1
KMO	4.62	2	2.31	<1
N x K x MO	2.72	4	0.68	<1
N x B x MO	0.93	2	0.46	<1
K x B x MO	0.14	2	0.07	<1
N x K x B x MO	0.18	4	0.08	<1
Error (2)	128.11	54	2.38	

** Significant at 1 per cent level.

APPENDIX IV

(Analysis of variance)

NUMBER OF NODULES

Source	S.S.	D.F.	Variance	F.
Total	161.59	107		
Blocks	3.25	8	0.40	<1
N	38.75	2	19.37	8.22**
K	19.74	2	9.37	3.97
NK	34.38	2	17.19	7.32**
NK^2	7.81	2	3.90	1.7
Error (1)	23.46	10	2.35	
B	3.50	1	3.50	12.06**
MO	2.83	1	2.83	9.75**
B x MO	1.31	1	1.31	4.51*
NB	1.28	2	0.64	1.9
KB	0.98	2	0.49	1.47
N x K x B	0.83	4	0.21	<1
NMO	1.11	2	0.56	1.93
KMO	1.03	2	0.52	1.79
N x K x MO	1.01	4	0.22	<1
N x B x MO	0.83	2	0.42	1.48
K x B x MO	0.91	2	0.45	1.49
N x K x B x MO	0.51	2	0.25	<1
Error (2)	18.08	54	0.33	

** Significant at 1 per cent level.

APPENDIX V

(Analysis of variance)

NUMBER OF PODS

Source	S.S.	D.F.	Variance	F.
Total	127.43	107		
Blocks	17.91	8	2.23	<1
N	10.77	2	5.38	2.16
K	7.91	2	3.95	1.59
NK	2.67	2	1.33	<1
NK^2	2.24	2	1.12	<1
Error (1)	24.83	10	2.48	
B	1.45	1	1.45	2.01
MO	0.15	1	0.15	<1
B x MO	0.01	1	0.01	<1
NB	0.09	2	0.04	<1
KB	3.06	2	1.53	2.12
N x K x B	0.74	4	0.18	<1
NMO	3.42	2	1.71	2.37
KMO	4.83	2	2.41	3.03
N x K x MO	1.07	4	0.54	<1
N x B x MO	2.05	2	1.02	1.4
K x B x MO	3.53	2	1.76	2.4
N x K x B x MO	1.90	4	0.47	<1
Error (2)	38.89	54	0.73	

APPENDIX VI

(Analysis of variance)

LENGTH OF POD

Source	S.S.	D.F.	Variance	F.
Total	11.65	107		
Blocks	1.72	8	0.21	1.3
N	1.18	2	0.59	3.6
K	0.40	2	0.20	1.2
NK	0.03	2	0.01	<1
NK^2	0.05	2	0.02	<1
Error (1)	1.61	10	0.16	
B	0.21	1	0.21	5.2*
MO	0.05	1	0.05	1.2
B x MO	0.65	1	0.65	16.1**
NB	0.64	2	0.32	8.0**
KB	0.31	2	0.15	3.7*
N x K x B	0.27	4	0.07	1.7
NMO	0.12	2	3.06	1.5
KMO	0.37	2	0.18	4.5*
N x K x MO	0.65	4	0.16	4.0*
N x B x MO	0.57	2	0.28	7.0**
K x B x MO	0.34	2	0.17	4.2*
N x K x B x MO	0.09	4	0.02	<1
Error (2)	2.39	54	0.04	

** Significant at 1 per cent level.

APPENDIX VII

(Analysis of variance)

NUMBER OF SEEDS PER POD

Source	S.S.	D.F.	Variance	F.
Total	158.53	107		
Blocks	25.81	8	3.22	<1
N	10.34	2	5.17	1.21
K	12.37	2	6.18	1.45
NK	6.63	2	3.31	<1
NK^2	4.11	2	2.06	<1
Error (1)	42.5	10	4.25	
B	0.81	1	0.81	<1
MO	0.53	1	0.53	<1
B x MO	0.51	1	0.51	<1
NB	1.01	2	0.50	<1
KB	0.83	2	0.41	<1
N x K x B	0.09	4	0.02	<1
NMO	0.66	2	0.33	<1
KMO	0.98	2	0.49	<1
N x K x MO	0.61	4	0.15	<1
N x B x MO	1.15	2	0.57	<1
K x B x MO	0.43	2	0.21	<1
N x K x B x MO	0.11	4	0.03	<1
Error (2)	49.10	54	0.91	

APPENDIX VIII

(Analysis of variance)

YIELD OF SEED PER NET PLOT

Source	S.S.	D.F.	Variance	F.
Total	9188677	107		
Blocks	2136052	8	267006.5	<1
N	1014897	2	507448.5	1.66
K	787340	2	393670	<1
NK	34640	2	17320	<1
NK^2	17837	2	8919.5	<1
Error (1)	3041548	10	30454.8	
B	103912	1	103912	4.44*
MO	38912	1	38912	1.80
B x MO	16397	1	16397	<1
NB	71940	2	35970	1.70
KB	10164	2	5082	<1
N x K x B	84026	4	21006.5	<1
NMO	64235	2	32117.5	1.5
KMO	16030	2	8015	<1
N x K x MO	126522	4	31630.5	1.6
N x B x MO	83216	2	41608	1.8
K x B x MO	56278	2	28139	1.2
N x K x B x MO	228584	4	57146	2.45
Error (2)	1256163	54	23262.27	

* Significant at 5 per cent level.

APPENDIX IX

(Analysis of variance)

YIELD OF BHUSA PER NET PLOT

Source	S.S.	D.F.	Variance	F.
Total	262.94	107		
Blocks	1.94	8	0.24	<1
N	221.49	2	110.74	128.76**
K	1.48	2	0.74	<1
NK	1.05	2	0.52	<1
NK2	0.84	2	0.42	<1
Error (1)	8.54	10	0.86	
B	4.24	1	4.24	26.5**
MO	6.16	1	6.16	38.5**
B x MO	3.14	1	3.14	19.61**
NB	0.49	2	0.24	1.50
KB	0.22	2	0.11	0.7
N x K x B	0.95	4	0.23	1.43
NMO	0.74	2	0.37	2.31
KMO	0.26	2	0.13	<1
N x K x MO	0.81	4	0.20	1.25
N x B x MO	1.64	2	0.82	5.12**
K x B x MO	0.01	2	0.04	<1
N x K x B x MO	0.01	4	0.002	<1
Error (2)	8.86	54	0.16	

** Significant at 1 per cent level.

APPENDIX X

(Analysis of variance)

100 SEED WEIGHT

Source	S.S.	D.F.	Variance	F.
Total	91.47	107		
Blocks	27.20	8	3.40	1.78
N	7.08	2	3.54	1.86
K	5.94	2	2.97	1.56
NK	5.03	2	2.51	1.32
NK^2	1.00	2	0.50	<1
Error (1)	19.01	10	1.901	
B	0.30	1	0.30	1.4
MO	0.07	1	0.07	<1
B x MO	0.01	1	0.01	<1
NB	1.88	2	0.94	4.47*
KB	1.49	2	0.74	3.52*
N x K x B	2.34	4	0.58	2.76
NMO	1.76	2	0.88	4.19*
KMO	0.77	2	0.38	1.80
N x K x MO	2.19	4	0.55	2.61
N x B x MO	1.42	2	0.71	3.38*
K x B x MO	1.88	2	0.94	4.47*
N x K x B x MO	0.63	4	0.31	1.47
Error (2)	11.57	54	0.21	

* Significant at 5 per cent level.