EFFECT OF SPACING AND FERTILIZERS ON YIELD AND QUALITY OF PIGEON PEA (Cajanus cajan (L.) Millsp).

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C E R T I F I C A T E

This is to certify that this thesis entitled "EFFECT OF SPACING AND FERTILIZERS ON YIELD AND QUALITY OF PIGEON PEA (Cajanus cajan (L.) Millsp) submitted by Shri Mathabhai Shivabhai Patel in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (Agriculture) in Agronomy is a record of bonafide research work carried out by him under my guidance and supervision.

The results of the investigations reported herein have not been presented anywhere for publication or for any other degree.

The assistance and help received during the course of investigation have been duly acknowledged by him.

(M.R.PATEL)
MAJOR PROFESSOR

Anand.
Date: 14th July, 1982.

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ABSTRACT

Effect of spacing and fertilisers on yield and quality of pigeon pea (Cajanus cajan (L.) Millsp).

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Pigeon pea (Cajanus cajan (L.) Millsp), locally known as tur, arhar or red gram, is an important pulse crop of India. With a view to find out a suitable spacing and nutrient requirement for the maximum and economical grain production of pigeon pea, this investigation was carried out.

A field experiment was laid out at Gujarat Agricultural University, Anand Campus, Anand during kharif season of 1981. Twenty seven treatments involving combinations of three spacings (150 x 30 cm, 150 x 60 cm, and 150 x 90 cm), three levels of nitrogen (0, 25 and 50 kg N/ha) and three levels of phosphorus (0, 50 and 100 kg P_2O_5/ha) were laid out in a 3^3 partial confounding factorial design with three replications.

The characters studied were yields of grain, stalks and bhusa per hectare, harvest index, yield per plant, number of pods per plant, number of branches per plant, test weight, plant height and protein content. Monetary return from the individual treatment was also computed.

From the findings of the investigation, it may be concluded that pigeon pea variety T.15-15 sown at 150 x 30 cm spacing with the application of 25 kg N and 100 kg P_2O_5 per hectare was found the best and secured the maximum grain yield per hectare. As regards to the effect of different interactions, the combination of 30 cm intra row spacing with an application of 25 kg N and 50 kg P_2O_5 per hectare gave the maximum net profit per hectare (Rs.4920/-) followed by the combination of $S_{30}N_{25}P_{100}$ (Rs.4851/- per hectare), while the lowest net profit of Rs.1969/- per hectare was obtained from the $S_{90}N_{50}P_{100}$ treatment combination.

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INTRODUCTION

Pigeon pea (Cajanus cajan (L.) Millsp) belon the order Leguminosae, suborder Papilionaceae and tribe Phaseoleae, commonly known as red gram, arhar or tur in different parts of India.

There prevails some controversy about the origin of pigeon pea (Tur) plant. However, according to P. de Sornay (1916), the botanical name "Cajanus cajan" now used for pigeon pea has been derived from the word "Catjany" which is of Indian origin. Therefore, pigeon pea is believed to have its origin in India.

Pigeon pea is largely grown in tropical and sub-tropical regions of the world. It is at present largely grown in India, Pakistan, West Indies, Nigeria, Uganda, Burma, Malaya and Viet-nam. It is one of the most important legume crops of India. The statewise acreage and production of pigeon pea is given in Table-1.

Gujarat stands sixth in acreage and fifth in production of pigeon pea. Therefore, this crop is of considerable important in the cropping patterns followed in Gujarat state. The cultivation of pigeon pea is mostly confined to the districts of middle and south Gujarat. The data on acreage and production of pigeon pea in different districts of the Gujarat State are given in Table-2.

Pigeon pea has very wide adaptability of climate and soil. The soils on which it is grown vary with the main

Table 1 Statewise acreage and production of pigeon pea during 1979-80

State	Area ('000 hectares)	Production ('000 tonnes)
Maharastra	662.6	411.3
Uttar Pradesh	542.8	353.0
Madhya Pradesh	477.3	205.4
Karnataka	308.4	217.4
Andhra Pradesh	193.0	48.7
Gujarat	153.0	87.7
Tamil Nadu	90.0	51.9
Bihar	84.8	75.2
Orissa	79.7	39.3
Rajasthan	28.1	4.9
West Bengal	18.7	25.4
Punjab	7.7	5.0
Haryana	6.6	6.1
Assam	6.0	4.2
Kerala	3.0	0.8
Dadra, Nagar Havelli	2.2	1.2
Meghalaya	0.7	0.5
Tripura	0.6	0.2
Himachal Pradesh	0.4	0.2
All India	2665.5	1738.6

Source: Estimate of Area and Production of crops in India 1979-80, Directorate of Economics and Statistics, Ministry of Agriculture and Rural Reconstruction, Government of India.

Table-2 Acreage and production of pigeon pea in various districts of Gujarat during 1979-80

Districts	Area '00 hectares	Production '00 tonnes
Bharuch	418	238
Vadodara	270	154
Surat	184	106
Panchmahals	144	81
Kheda	137	78
Valsad	94	54
Sabarkantha	91	52
Mehsana	63	36
Banaskantha	54	33
Ahmedabad	41	24
Dangs	33	19
Gandhinagar	4	2
Total	1530	877

Source : Districtwise area, production and yield per hectare of important food and nonfood crops in Gujarat State, from 1977-78 to 1979-80. Based on final forecast report. Department of Agriculture, Gujarat State Ahmedabad-380 006.

crops with which it is sown in mixture. It is grown successfully with jowar in loamy and medium black soils, with bajra in sandy loam soil and with kodra (Paspalum scrobiculatum) and drilled paddy in the 'basar' soil. Though it is successfully adapted on variety of soils, it grows very luxuriantly on sandy loam soil and gives comparatively high out-turn per hectare.

Pigeon pea is generally sown in June after the onset of monsoon and harvested in the month of February and March. It being a fairly drought resistant crop can be successfully grown even when the rainfall is low.

Pigeon pea grain is rich in protein. It provides balanced diet with cereals for human as well as animals, especially in developing countries where protein deficiency is predominantly noticed. The grains whole as well as split are boiled with water and liquid as well as semi solid preparations are made and used as food with cereals like wheat, rice, maize etc. in human diet. Green pods are used as vegetables in certain parts of the country especialy in Gujarat. The dry leaves, pod husks and 'ghuni' (broken pieces of tur grains) are fed to milch cattle as a source of rich proteinous food. Dry stalks are used as fuel in rural areas.

Over and above the food value of 'tur' grain, it is a good rotational crop. It is also grown in mixture with cereals. The crop has long and deep root system.

It forms root nodules with *Rhizobium* bacteria which add nitrogen to soil by fixing it from the atmosphere and making available to cereal crops with which it is grown either in mixed cropping or in rotation. Dry leaves fallen on the soil surface improve soil structure by adding organic matter. The results of the work carried out at Pusa (Anon. 1970) have revealed that a crop of pigeon pea add organic matter equivalent to about fifteen tonnes of cowdung per hectare.

The crop with such a high value in agriculture and of vast importance to human beings, has not been cared for exploiting its yielding potentialities as compared to that of cereals and other cash crops. Therefore, the need for increasing yield and improving quality of legumes including pigeon pea in India by research and full exploitation of genetic potential, cultural practices, use of chemical fertilizers, control of pests and diseases and evolving resistant varieties was emphasized by scientists. The sharp rise in prices of legumes now a days in India and the problem of protein malnutrition were also thought by Food and Agriculture Ministry of India and it was suggested to fill up the gap of protein deficit by increasing legume production by strengthening research on legume crops including pigeon pea.

It is almost an established fact that evolution of better varieties of crop plants for commercial planting and

boosting up their yields per hectare through spacing and appropriate applications of fertilizers are of primary consideration for effective progress in crop production.

In view of the facts and the considerations stated in the foregoing paragraphs, an experiment was planned and conducted at the College Farm of the B. A. College of Agriculture, Gujarat Agricultural University, Anand Campus, Anand during the year 1980-81, with the following objectives:

(1) To find out suitable spacing for pigeon pea for securing optimum yield and profit per hectare.

(2) To find out optimum level of requirements of nitrogen and phosphorus for increasing yield of pigeon pea under the agro-climatic conditions of Middle Gujarat.

(3) To study the effect of spacing, nitrogen and phosphorus on quality of grains.

(4) To study economics of pigeon pea under various spacing and levels of nitrogen and phosphorus.

REVIEW OF LITERATURE

Although pigeon pea is under cultivation since centuries, very limited information is available on its agronomical aspects. However, attempts have been made to review all available literature on pigeon pea with respect to its spacing and nutrient requirements for increased yield and quality of grains.

2.1 EFFECT OF SPACING:

De Menezes (1945) working on spacing experiments with pigeon pea in Germany, concluded that spacings of 200 x 100 cm and 100 x 100 cm could produce higher yields than that by the spacing of 200 x 200 cm.

In a spacing trial, conducted on the crop of pigeon pea at Berhampore, West Bengal (Anon. 1955), it was concluded that closer spacing of 60 x 60 cm was better for advancing yield than the wider spacing of 120 x 120 cm.

Cultural experiments conducted on pigeon pea at the Indian Agricultural Research Institute, New Delhi (Anon. 1955) showed that wider inter-row spacing of 300 cm gave significantly higher yield (1444 kg/ha) than that by the closer spacing of 180 cm (1027 kg/ha).

Trivedi (1960) conducted an experiment with six levels of spacing viz. 120 x 15 cm, 120 x 30 cm, 120 x 45 cm, 120 x 60 cm, 120 x 75 cm, and 120 x 90 cm. He observed that 120 x 90 cm spacing was conducive to increase number of

branches per plant giving optimum yield of pigeon pea grains (1645 kg/ha) with 19.97 per cent protein.

Mukherjee (1960) conducted an experiment on Cajanus cajan type-7 at Berhampore with the spacings of 60 x 60 cm, 60 x 90 cm, 60 x 120 cm, 90 x 90 cm, 90 x 120 cm, 120 x 120 cm and broadcast of seeds @ 13.5 kg/ha. He observed that closer spacing of 60 x 60 cm produced the highest grain yield per hectare (1422 kg/ha) but the maximum yield per plant was obtained from a wider spacing of 120 x 120 cm.

Derieux (1969) conducted a field trial in West Indies on dry calcareous soil with pigeon pea N.GI 54/3 from Trinidad (Semi dwarf, short photoperiod and determinate growth habit) and 218066 from Pakistan (dwarf, daylength neutral, indeterminate growth habit, continuous flowering) at spacing of 100 x 100 cm, 100 x 50 cm and 50 x 50 cm. He observed that increase in plant density tended to increase yields per hectare.

Sen et al. (1970) conducted field trials in 1959 to 1965 at Berhampore and in 1960 to 1963 at Kalyani on Cajanus cajan with rows 30 and 60 cm apart and with plants 30, 60, 90 and 120 cm apart in the rows. They observed that the highest average grain yields were obtained from a spacing of 30 x 30 cm at Berhampore and 30 x 90 cm at Kalyani.

Hammerton (1971) studied 14 plant densities in the range of 47900 to 4300 plants per hectare (0.21 to 2.32 $\cdot m^2$/plant) at the University Field Station, Trinidad and

reported that an increase in area per plant increased pod yield per plant but decreased pod yield per hectare. Plant heights at flowering and harvest time were increased by increase in plant density. He also observed that plant density had no effect on other yield components.

Singh et al. (1971) working at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur on pigeon pea with three plant populations, viz. 40,000, 50,000 and 60,000 plants per hectare and two row spacings viz. 75 and 100 cm, observed that the highest significant yield of 1,214 kg/ha was obtained with a plant population of 60,000 plants per hectare, but there was no significant difference in the grain yield at row spacings of 75 and 100 cm. The number of primary and secondary branches and number of pods per plant were higher with plant population of 40,000 than those with 50,000 and 60,000 plants per hectare. Protein content of grain was not effected by any of the treatments.

Choudhury and Bhatia (1971) reported that Cajanus cajan sown at a spacing of 20, 30 and 40 cm between plants in rows spaced at 50 cm apart gave avetage yields of 2.87, 2.37 and 2.01 t/ha, respectively.

Veeraswamy et al. (1972) conducted an experiment on Cajanus cajan CV. S.A. 1 with broadcast and in rows 90, 120 and 150 cm apart with spacings of 20, 30 and 40 cm within the row. They observed that mean seed yield was the

highest (1.03 t/ha) with a spacing of 90 x 30 cm. Such yields were higher with all spacings, except 120 x 30 cm than that with broadcasting (0.68 t/ha).

Manjhi et al. (1975) conducted an experiment in Todapur rainfed block of the Division of Agronomy, Indian Agricultural Research Institute, New Delhi with two rates of planting viz. 50,000 and 75,000 plants per hectare and two inter-row spacings viz. 50 cm and 75 cm. They observed that a row spacing of 50 cm gave significantly higher yields than a row spacing of 75 cm. Pods/plant and test weight (1000 grain-weight) were not affected by spacings.

Abrams and Julia (1975) reported that yields of fresh pods of Cajanus cajan CV. Kaki were higher at row spacing of 91.4 cm than those by 121.9 cm and 182.8 cm. It was also higher at plant population of 36,300 plants per hectare than those at 9075 and 18,150 plants per hectare. Plant height, number of days to flowering, number of seeds per pod, test weight and protein content of grains were not affected by plant population and row spacings. The number of pods per plant decreased with increase in plant population.

Rathi et al. (1974) conducted a field experiment at the farm of Regional Agricultural Research Station, Meerut in Kharif 1972 with three inter row spacings viz. 30, 75 and

100 cm. They observed that a spacing of 50 cm yielded higher grain than that by 75 and 100 cm inter row spacing$.

In an experiment conducted on the crop of pigeon pea at International Institute of Tropical Agriculture, Ibadan, Nigeria (Anon. 1974) showed that three dwarf pigeon pea cultivars yielded 70-90 per cent more seed under within row spacing of 20 cm than that under 40 cm spacing. They yielded 20-30 per cent less grains at row spacing of 120 cm than those at row spacing of 60 and 90 cm.

Akinola and Whiteman (1975) studied nine sowing densities ranging from 6727 to 215278 plants per hectare. They observed that maximum seed yield (2.77 t/ha) was obtained at a spacing of 91.4 x 61 cm (17940 plants/ha). With high densities, there was increase in stand mortality and decrease in number of pods per plant, resulting into severe reduction in yield. Decrease in pod number per plant was related to significant reduction in the number of pod producing branches and in the inflorescence bearing stem length, with little change in seed size and seeds per plant.

Studies were made by Ahlawat et al. (1975) for two years at Indian Agricultural Research Institute, New Delhi to find out the optimum row spacing for the new varieties of pigeon pea. They reported that grain yield increased under 50 cm spacing as compared to under 75 cm spacing by 25.25 and

23.65 per cent in 1972 and 1973, respectively. The plant height and test weight (100 grains weight) were not affected by row spacing in any of the years. The branches per plant were significant in 1972 only where wider spacing of 75 cm produced more branches than that by 50 cm row spacing. The pods per plant with wider row spacing were, however, significantly higher in both the years.

Singh et al. (1975) conducted an experiment to study the effect of three row spacings viz. 50, 75 and 100 cm on the growth and yield of four pigeon pea varieties viz. T-21, AS-3, AS-5 and P-4785 at Indian Agricultural Research Institute, New Delhi during kharif seasons of 1970 and 1971. They observed that the narrowest row spacing of 50 cm produced significantly more grain yield (21.1 q/ha) than those by the other two row spacings of 75 and 100 cm during both the years (18.7 and 17.2 q/ha respectively). Plants were taller with a inter row spacing of 100 cm than those under the two narrow inter row spacings of 50 and 75 cm. Inter row spacing have no significant influence on the number of branches per plant, number of pods per plant and 1000 grain weight.

Hammerton (1971) laid out an experiment on Caymanas clay loam at Lawrence Field in Jamaica with two spacings viz. 90 x 90 cm and 45 x 45 cm. He observed that close spacing (45 x 45 cm) gave more grain yield per hectare

than that by wide spacing (90 x 90 cm). The number of pods per plant was more in wide spacing as compared to that in close spacing.

Yadahalli et al. (1976) reported that increasing density from 50,000 to 75,000 plants per hectare increased seed yield from 1.88 to 2.08 t/ha in new Cajanus cajan CV. Hyd. 3C and from 0.95 to 1.04 t/ha in the standard CV. Co. 1.

Tiwari et al. (1977) conducted a field experiment on pigeon pea CV. Gwalior-3, 6826, 6800-27, 6842-9 and local variety at 45 x 15 cm, 90 x 30 cm and 180 x 60 cm spacing. They observed that the spreading types Gwalior-3 and local one yielded significantly more (1.33 and 1.22 t/ha respectively) than the semi-compact types (0.7-0.8 t/ha) at all the row spacings. They also produced the highest primary and secondary branches, pods per plant and seed yield per plant. All cultivars gave the highest yields at 45 x 15 cm except Gwalior-3 which gave the highest yield at 90 x 30 cm.

Rathi and Tripathi (1978) studied the effect of three intra-row spacings viz. 50, 75 and 100 cm keeping the common inter-row spacing of 30 cm on early maturing pigeon pea variety T-21. They observed that the maximum grain yield was obtained at 75 x 30 cm spacing. Increase in row distance to 100 cm resulted into significant reduction in plant stand per unit area which could not be compensated by higher yield per plant under wider spacing.

Subhramanium et al. (1978) conducted an experiment on cultivator's field in Coimbatore district of Tamil Nadu under rainfed condition with spacing of 20, 30 and 40 cm between the plants and 45 cm apart between two rows. They observed that 30 cm and 20 cm between plants in the row were at par and superior to the wider spacing of 40 cm which recorded only 710 kg of grain per hectare as against 801 and 794 kg of grain per hectare recorded by 30 and 20 cm spacings respectively.

Singh et al. (1978) conducted an experiment for two years during kharif seasons of 1974-75 and 1975-76 at the Research Farm, Department of Agronomy, Banaras Hindu University, to find out the optimum row spacing for pure as well as mixed culture of pigeon pea alongwith most remunerative inter crops. They observed that pure culture of pigeon pea yielded more grain yield at 50 cm row spacing than that by 75 cm row spacing.

Phogat (1981) conducted an experiment at the Agronomy Research Area of Haryana Agricultural University, Hissar during the kharif season with three plant densities viz. 66,666, 1,00,000, and 1,33,333 plants per hectare. He observed that population of 1,00,000 plants per hectare was significantly superior to 66,666 and 1,33,333 plants per hectare in respect of growth and yield attributes. However, all the plant populations were at par in case of 1000 seed weight. The three plant populations did not differ

significantly in seed yield per hectare and grain protein content, however, the difference was significant in stalk yield per hectare. The population with 1,00,000 plants per hectare gave the highest net return.

2.2 EFFECT OF NITROGEN:

Sardarsingh and Sahasrabuddhe (1957) in a manurial trial conducted over a period of four years, involving application of nitrogen @ 0 and 22.5 kg N per hectare in in the form of ammonium sulphate with and without a basal dressing of farm compost @ 45 kg N per hectare to the crop of pigeon pea. They concluded that there was depressing effect on grain yield when the crop was manured with ammonium sulphate but grain yield increased from 33 to 84 kg/ha when the crop was supplied with nitrogen in the form of farm compost.

Manjhi et al. (1973) carried out an investigation at Todapur rainfed block of the Division of Agronomy, Indian Agricultural Research Institute, New Delhi with two levels of nitrogen viz. 0 and 25 kg N per hectare. They observed that application of 25 kg N per hectare increased significantly grain yield per hectare, pods per plant and 1,000 grain weight over the control. Protein content of grains also increased from 19 per cent (control) to 22-23 per cent in case of the treatment involving application of 25 kg N per hectare.

Dalal (1974) conducted an experiment on a River Estate loam soil at the University Field Station, Trinidad with five levels of nitrogen viz. 0, 10, 20, 50 and 100 kg N per hectare. He observed that 20 kg N per hectare gave the maximum grain yield (3469 kg/ha) while 50 and 100 kg N per hectare showed depressing effect on grain yield (2093 and 1896 kg per hectare, respectively).

Lenka and Satpathy (1976) carried out an experiment with three levels of nitrogen viz. 0, 20 and 40 kg N per hectare at Bhubaneswar. They observed that application of 20 and 40 kg N per hectare increased vegetative growth, plant height, number of branches per plant, yield of sticks and bhusa significantly but did not increase the yield of grains. Application of 20 kg N per hectare only increased grain yield by 190 kg per hectare and 40 kg N per hectare had depressing effect on grain yield.

Singh et al. (1976) studied the effect of nitrogen on growth and yield of pigeon pea under rainfed condition at the Indian Agricultural Research Institute, New Delhi and reported that most of the growth characters showed a beneficial effect of 25 kg N per hectare over control (no nitrogen). However, effects were significant only in the case of plant height with the application of 25 kg N per hectare.

Dalal and Quilt (1977) conducted a field experiment at the University Field Station, Trinidad, with four levels of nitrogen viz. 0, 12, 20 and 30 kg N per hectare. They observed that there was no significant effect of nitrogen application on grain yield.

2.3 EFFECT OF PHOSPHORUS:

A field experiment was conducted with pigeon pea at Indore, (Anon. 1956) for six crop seasons to study the effect of two levels of phosphorus viz. 0 and 33.75 kg P_2O_5 per hectare. It was found that the higher level of phosphorus (33.75 kg P_2O_5/ha) increased the grain yield by 11.1 per cent.

Chowdhury and Bhatia (1971) conducted an experiment at the Indian Agricultural Research Institute, New Delhi with four levels of phosphorus viz. 0, 33, 67 and 100 kg P_2O_5 per hectare. They observed that with increasing levels of phosphorus the grain yield of pigeon pea also increased from 1.29 to 2.76 t/ha.

Veeraswamy et al. (1972) at Coimbatore, studied the effect of phosphoric acid and organic manure on yield of pigeon pea with no fertilizer, 5 tonnes compost/ha, 22.4 kg P_2O_5/ha and 5 tonnes compost + 22.4 kg P_2O_5/ha. They observed that the basal dressing of 22.4 kg P_2O_5/ha in the form of superphosphate and 5 tonnes compost/ha gave significantly higher yield (765 kg/ha) than those by the other treatments.

Manjhi et al. (1973) conducted an experiment at Indian Agricultural Research Institute, New Delhi with three levels of phosphorus viz. 0, 21.83 and 43.67 kg P_2O_5 per hectare. They observed that higher dose of phosphorus significantly increased grain yield over the control.

Rathi et al. (1974) conducted a field experiment at the Regional Agricultural Research Station, Meerut with three levels of phosphorus viz. 0, 40 and 80 kg P_2O_5 per hectare. They observed that 80 kg P_2O_5 per hectare gave significantly higher yield of grain (30.8 q/ha) than that by 40 kg P_2O_5 per hectare (19.1 q/ha), whereas 40 kg P_2O_5 per hectare proved superior to control (15.7 q/ha).

Kaul and Sekhon (1975) conducted an experiment during the kharif season of the year 1972 in order to study response of pigeon pea variety T-21 to four rates of phosphorus viz. 0, 20, 40 and 60 kg P_2O_5 per hectare. They observed that grain yield increased significantly upto 40 kg P_2O_5 per hectare (18.7 q/ha) and declined thereafter. However, application of 60 kg P_2O_5 per hectare proved significantly superior to 0 and 20 kg P_2O_5 per hectare in respect of grain yield. Number of pods per plant and plant height were at the top with of 40 kg P_2O_5 per hectare, though they failed to attain the level of significance. The dry matter production increased significantly with phosphorus application. The trends were similar to those observed for grain yield.

A slight improvement in harvest index was recorded with application of phosphorus.

Singh et al. (1976) conducted an experiment with a view to evaluate yield potential of pigeon pea varieties at different levels of phosphorus viz. 0, 25, 50, 75 and 100 kg P_2O_5 per hectare at Indian Agricultural Research Institute, New Delhi. They observed that grain yield increased significantly with increase in the levels of phosphorus and the highest grain yield (22.2 q/ha) was obtained with an application of 100 kg P_2O_5 per hectare. However, considering the higher cost of phosphate, an application of only 25 kg P_2O_5 per hectare was economical. They recorded significant increase in number of branches per plant and number of pods per plant over control when 100 kg P_2O_5 per hectare was applied. Harvest index also showed increase with increase in the level of phosphorus.

Lenka and Satpathy (1976) studied response of pigeon pea varieties to phosphorus @ 0, 40, 80 and 120 kg P_2O_5 per hectare in laterite soil at Bhubaneswar. They observed the significant response to levels of phosphorus and grain yield showed linear increase from 0.83 to 1.17 t/ha. Pod length and number of grains per pod were significantly affected by phosphorus application, while other yield attributes were not affected by phosphorus application.

Dalal and Quilt (1977) conducted an experiment at the University Field Station, Trinidad with four levels of phosphorus viz. 0, 50, 100 and 250 kg P_2O_5 per hectare. They observed that grain yield of pigeon pea increased (1,716 to 3,102 kg/ha) with the increase in the level of phosphorus.

Rao (1977) conducted an experiment at the College of Agriculture, Rewa with three varieties of pigeon pea viz. BS-1, T-21 and Prabhat and four levels of phosphorus viz. 0, 30, 60 and 90 kg P_2O_5 per hectare. He observed that phosphorus application increased grain yield by 37.2 per cent (4.44 q/ha) over that of the control. The variety T-21 gave 0.89 and 6.61 q/ha more yield of grain than those by BS-1 and Prabhat respectively. BS-1 variety gave higher protein content than those by T-21 and Prabhat. They also observed increase in protein contents of grain with increase in the level of phosphorus application.

Ramanathan et al. (1977) while working at Coimbatore with CO.2 red gram to determine its response to application of different levels of phosphorus viz. 0, 12.7, 25.4 and 76.2 kg P_2O_5 per hectare over common dosage of N, P and K, found that the crop responded markedly to phosphorus over uniform basal dressing of N and farm yard manure. Of the different levels of phosphorus tested the maximum level at 76.2 kg P_2O_5 per hectare gave significantly higher number of pods per plant and grain yield than other treatments.

Rathi and Tripathi (1978) studied the effect of three levels of phosphorus involving 0, 40 and 80 kg P_2O_5 per hectare on early maturing pigeon pea variety T-21 in Central U. P. and revealed a significant positive effect of phosphorus application on grain yield. The application of 40 kg P_2O_5 per hectare gave more grain yield (18.1 q/ha) than those by 0 and 80 kg P_2O_5 per hectare (14.5 and 16.6 q/ha, respectively).

Devarajan et al. (1980) studied the effect of phosphorus @ 0, 25 and 50 kg P_2O_5 per hectare on pigeon pea Co. 1 at Tamil Nadu Agricultural University, Coimbatore. They observed that the highest grain yield was obtained with the application of 25 kg P_2O_5 per hectare.

Singh et al. (1980) while working at Banarus Hindu University, Varanasi reported that increasing the rate of applied phosphorus upto 60 kg per hectare increased significantly yield of pigeon pea from 1.67 to 2.05 t/ha.

2.4 EFFECT OF SPACING X PHOSPHORUS:

Rathi et al. (1974) conducted a field experiment at the farm of Regional Agricultural Research Station, Meerut in kharif with three inter row spacings viz. 50, 75 and 100 cm and three levels of phosphorus viz. 0, 40 and 80 kg P_2O_5 per hectare. They observed that in early sowing, the highest yield was obtained by sowing in rows of 75 cm apart with 80 kg P_2O_5 per hectare, while in late sown crops, the

best row spacing was found to be 50 cm and the dose of phosphorus was 80 kg P_2O_5 per hectare.

Subramanium et al. (1978) conducted the experiments on cultivators' fields at Devarayapuram in Thondamutur block, Coimbatore district under rainfed condition with spacings of 20, 30 and 40 cm between plants within a row and 45 cm apart between two rows and five levels of fertiliser viz. Control (no manurial treatment), 25 kg P_2O_5/ha, 12.5 kg N + 25 kg P_2O_5/ha, 25 kg N + 25 kg P_2O_5/ha and 25 kg N + 50 kg P_2O_5/ha. They indicated that adoption of 45 x 30 cm spacing and 25 kg P_2O_5/ha alone were quite effective for erect and bushy type Co. 3 pigeon pea for securing increased yield of grain under rainfed condition.

Rathi and Tripathi (1978) studied effect of three inter-row spacings viz. 50, 75 and 100 cm, keeping the common intra-row spacing of 30 cm and three levels of phosphorus viz. 0, 40 and 80 kg P_2O_5 per hectare on early maturing pigeon pea variety T. 21. They reported that the maximum grain yield (19.6 q/ha) was obtained when sowing was done at 75 x 30 cm and fertilized with 40 kg P_2O_5 per hectare.

2.5 EFFECT OF NITROGEN X PHOSPHORUS:

An experiment was conducted at Indore (Anon. 1955) with a view to study effect of the single as well as combined application of nitrogen in the form of groundnut

ogen and phosphorus in the form of superphosphate, both at 22.5 and 45 kg per hectare on the crop of pigeon pea. It was revealed that yield of pigeon pea appreciably increased with single application of lower dose of nitrogen (22.5 kg N/ha) and phosphorus (22.5 kg P_2O_5/ha), while higher dose of nitrogen (45 kg N/ha) as well as phosphorus (45 kg P_2O_5/ha) did not prove so effective as lower dose of the same. But it was noticed that combined application of nitrogen and phosphorus gave higher yields of pigeon pea grain than that by the single application of the same.

Sen (1958) in an investigation carried over a period of three years at the Indian Agricultural Research Institute, New Delhi, to study nitrogen economy of soil under pigeon pea in relation to nodulation, concluded that pigeon pea greatly benefitted by single as well as combined application of 45 kg N per hectare in the form of ammonium sulphate and 137.50 kg P_2O_5 per hectare in the form of superphosphate.

Phogat (1981) conducted an experiment at Haryana Agricultural University, Hissar with five fertility levels viz. Control, 40 kg P_2O_5/ha, 25 kg N + 40 kg P_2O_5/ha, 40 kg P_2O_5/ha + inoculation and 25 kg N + 40 kg P_2O_5/ha + inoculation. He observed that 25 kg N + 40 kg P_2O_5/ha + inoculation had a significant effect on increasing plant height, number of branches and dry matter accumulation per plant. Yield attributes and grain as well as stalk yield were also increased significantly due to increase in fertility levels over control.

MATERIALS AND METHODS

Materials used and techniques adopted during the course of this investigation are described as under:

3.1 LOCATION

The field investigation reported in this manuscript was conducted at the College Farm of the B.A.College of Agriculture, Gujarat Agricultural University, Anand Campus, Anand during the Kharif season of 1980-81. The aim was to investigate effect of spacing and fertilizers on yield and quality of pigeon pea.

3.2 CLIMATOLOGICAL DATA

The Anand Campus of Gujarat Agricultural University, where this investigation was carried out, is situated at 22^0 - 35' North latitude, 70^0 - 55' East longitude with an elevation of 45.1 metres above the mean sea level.

The climate of this area is sub-tropical. In general, monsoons are warm and moderately humid, winters are fairly cold and dry, while summers are largely hot and dry. Monsoon commences by the middle of June and retreats by the middle of September with an average annual rainfall of about 865 mm realised entirely from South-West monsoon currents. The monsoon in this area is not assured as in the south Gujarat. Partial failure of monsoon once in three to four years is very common in this area. July and August are the months of high rainfall.

The regular winter season starts by the end of October and continues till the end of February. The coldest months of winter season are December and January. The summer season commences in the beginning of March and ends by the end of June. May is the hottest month of the year.

The meteorological data for the period from June 1980 to February 1981 recorded at Meteorological Observatory of B.A. College of Agriculture, Anand are presented in Table 3. The data clearly indicate that the weather conditions were fairly favourable for growth and development of pigeon pea during the crop season, except that the months of November, December and Janu[illegible]d unusual cloudy weather accom[illegible]d by precipitation amounting to 1.2, 16.5 and 9.2 mm respectively. Such conditions during that period favoured infestation of Tur pod fly. Precautionary measures were taken by timely spraying of appropriate pesticides to control tur pod fly.

3.3 SOIL CHARAC[illegible]ICS:

The soil of the experimental field was sandy loam type, locally known as "Goradu". This soil is alluvial in origin and very deep, well drained and medium in fertility. It responds very well to irrigation and fertilisers. It is quite suitable for a variety of tropical and sub-tropical crops. The water table is usually at more than 10 metres below the surface.

Table 3: Weekwise rainfall, rainy days, maximum and minimum temperatures and Relative Humidity

Period No.	Week No.	Dates	Rain fall mm	No. of Rainy days	Mean daily temp. °C Max.	Mini.	Ave.	R.H. at 7.[illegible] a.m.
1	2	3	4	5	6	7	8	9
1980								
VI	23	4-10 June	34.0	2	35.0	26.9	31.0	88
	24	11-17 "	1.5	0	36.5	27.3	31.9	86
	25	18-24 "	28.2	1	34.9	26.1	30.5	91
	26	25-1 July	65.0	5	30.6	25.6	28.1	96
			128.7	8	34.2	26.4	30.4	90
VII	27	2-8 July	118.4	6	30.5	25.1	27.8	98
	28	9-15 "	6.8	1	32.4	26.1	29.3	90
	29	16-22 "	0.2	0	34.7	26.6	30.7	88
	30	23-29 "	45.5	2	32.3	25.7	29.0	89
	31	30-5 Aug.	240.4	5	30.1	24.9	27.5	97
			411.3	14	32.0	25.7	28.8	91
VIII	32	6-12 Aug.	33.0	3	29.9	25.0	27.5	95
	33	13-19 "	25.4	1	33.1	25.4	29.3	92
	34	20-26 "	70.0	3	31.4	24.2	27.8	97
	35	27-2 Sept.	50.9	2	30.7	24.6	27.7	95
			179.3	9	31.3	25.3	28.3	90

(Contd.)

1	2	3		4	5	6	7	8	9
IX	36	3-9	"	0.0	0	32.7	24.2	28.5	90
	37	10-16	"	7.0	1	32.4	24.0	28.2	93
	38	17-23	"	0.0	0	33.9	24.1	29.0	89
	39	24-30	"	0.0	0	36.3	24.9	30.6	88
				7.0	1	33.8	24.3	29.1	80
X	40	1-7	Oct.	0.0	0	35.9	22.4	29.2	85
	41	8-14	"	0.0	0	36.8	20.6	28.7	84
	42	15-21	"	0.0	0	37.0	20.4	28.7	75
	43	22-28	"	0.0	0	34.5	18.3	26.4	81
	44	29-4	Nov.	0.0	0	34.8	16.7	25.8	78
				0.0	0	35.8	19.7	27.8	80
XI	45	5-11	Nov.	0.0	0	33.1	15.1	24.1	54
	46	12-18	"	1.2	0	33.1	20.6	26.9	67
	47	19-25	"	0.0	0	32.9	18.6	25.8	64
	48	26-2	Dec.	0.0	0	31.7	16.4	24.1	78
				1.2	0	32.7	17.7	25.2	66
XII	49	3-9	Dec.	0.0	0	31.1	14.1	22.6	64
	50	10-16	"	0.0	0	30.3	10.6	20.5	69
	51	17-23	"	16.5	2	30.0	10.1	20.1	86
	52	24-31	"	0.0	0	24.5	13.5	19.0	93
				16.5	2	29.0	12.1	20.5	78

(Contd.)

1	2	3	4	5	6	7	8	9
1981								
I	1	1-7 Jan.	0.0	0	28.4	12.3	20.4	95
	2	8-14 "	0.0	0	24.3	8.3	16.3	62
	3	15-21 "	9.2	1	27.1	11.4	19.3	84
	4	22-28 "	0.0	0	28.1	12.0	20.1	89
	5	29-4 Feb.	0.0	0	29.2	11.0	20.1	71
			9.2	1	27.4	11.0	19.2	80
II	6	5-11 Feb.	0.0	0	28.8	9.5	19.1	67
	7	12-18 "	0.0	0	30.1	12.5	21.3	79
	8	18-25 "	0.0	0	34.7	16.0	25.4	60
	9	26-4 March	0.0	0	34.4	15.8	25.1	65
			0.0	0	32.0	13.4	22.7	68

The composite soil sample representing the field used for this investigation was drawn before laying out the experiment. The mechanical and chemical analysis of the sample were carried out. Their results are presented in Table-4.

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD:

The cropping history of the experimental field for the last three years is given in Table-5.

Table 4 Mechanical and Chemical composition of soil

Sr. No.	Name of soil constituents	Content	Methods of analysis followed
1	Course sand (%)	0.50	Bauyoucos Hydrometer (Piper, 1950)
2	Fine sand (%)	85.60	-do-
3	Silt (%)	8.50	-do-
4	Clay (%)	2.50	-do-
5	Organic matter (%)	0.52	Colorimetric method (Shah chta, 1950)
6	Total nitrogen (kg/ha)	560.00	Modified kjeldahl (A.O.A.C., 1960)
7	Available P_2O_5 (kg/ha)	42.90	0.5 M $NaHCO_3$ extractable (Olsen et al., 1954)
8	Available K_2O (kg/ha)	336.00	Volumetric cobaltnitrite (Jakson, 1967)
9	Soil pH (Soil : Water, 1 : 2.5)	8.20	Backman's pH meter (Jakson, 1967)

Table 5 Cropping history of the experimental field

Year	Season	Crop	Fertilizers applied
1978-79	Kharif	Tobacco	180 kg N + 0 kg P_2O_5 + 0 kg K_2O/ha
	Rabi	-do-	
	Summer	Fallow	
1979-80	Kharif	Bajra	90 kg N + 45 kg P_2O_5 + 0 kg K_2O/ha
	Rabi	Fallow	---
	Summer	Gaur experiment	25 kg N + 50 kg P_2O_5 0 kg K_2O/ha
1980-81	Kharif	Pigeon pea experiment	As per treatment
	Rabi	-do-	

3.5 THE EXPERIMENTAL DETAILS

In order to study effect of various levels of spacing and fertilizers on growth and yield of pigeon pea, a field experiment was planned. The factors of study and their levels were as given on next page.

Factors	No. of levels	Particulars of levels
Spacing (S)	3	S_{30} = 150 cm x 30 cm
		S_{60} = 150 cm x 60 cm
		S_{90} = 150 cm x 90 cm
Nitrogen (N)	3	N_0 = 0 kg N/ha
		N_{25} = 25 kg N/ha
		N_{50} = 50 kg N/ha
Phosphorus (P)	3	P_0 = 0 kg P_2O_5/ha
		P_{50} = 50 kg P_2O_5/ha
		P_{100} = 100 kg P_2O_5/ha

3.5.1 TREATMENT COMBINATIONS

Twenty seven treatment combinations involving three levels of spacing, three levels of nitrogen and three levels of phosphorus were included in the experiment, for which the details are as on next page.

Sr. No.	Treatment combinations			Treatment symbols
	Spacing (cm)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	
1	2	3	4	5
1	150 x 30	0	0	$S_{30}N_0P_0$
2	150 x 30	0	50	$S_{30}N_0P_{50}$
3	150 x 30	0	100	$S_{30}N_0P_{100}$
4	150 x 30	25	0	$S_{30}N_{25}P_0$
5	150 x 30	25	50	$S_{30}N_{25}P_{50}$
6	150 x 30	25	100	$S_{30}N_{25}P_{100}$
7	150 x 30	50	0	$S_{30}N_{50}P_0$
8	150 x 30	50	50	$S_{30}N_{50}P_{50}$
9	150 x 30	50	100	$S_{30}N_{50}P_{100}$
10	150 x 60	0	0	$S_{60}N_0P_0$
11	150 x 60	0	50	$S_{60}N_0P_{50}$
12	150 x 60	0	100	$S_{60}N_0P_{100}$
13	150 x 60	25	0	$S_{60}N_{25}P_0$
14	150 x 60	25	50	$S_{60}N_{25}P_{50}$
15	150 x 60	25	100	$S_{60}N_{25}P_{100}$
16	150 x 60	50	0	$S_{60}N_{50}P_0$
17	150 x 60	50	50	$S_{60}N_{50}P_{50}$
18	150 x 60	50	100	$S_{60}N_{50}P_{100}$

(Contd.)

1	2	3	4	5
19	150 x 90	0	0	$S_{90}N_0P_0$
20	150 x 90	0	50	$S_{90}N_0P_{50}$
21	150 x 90	0	100	$S_{90}N_0P_{100}$
22	150 x 90	25	0	$S_{90}N_{25}P_0$
23	150 x 90	25	50	$S_{90}N_{25}P_{50}$
24	150 x 90	25	100	$S_{90}N_{25}P_{100}$
25	150 x 90	50	0	$S_{90}N_{50}P_0$
26	150 x 90	50	50	$S_{90}N_{50}P_{50}$
27	150 x 90	50	100	$S_{90}N_{50}P_{100}$

3.5.2 DESIGN OF THE EXPERIMENT:

A 3^3 partial confounded factorial design was employed in this study. The treatments were assigned at random to each replication. The plan of layout is depicted in Figure 1.

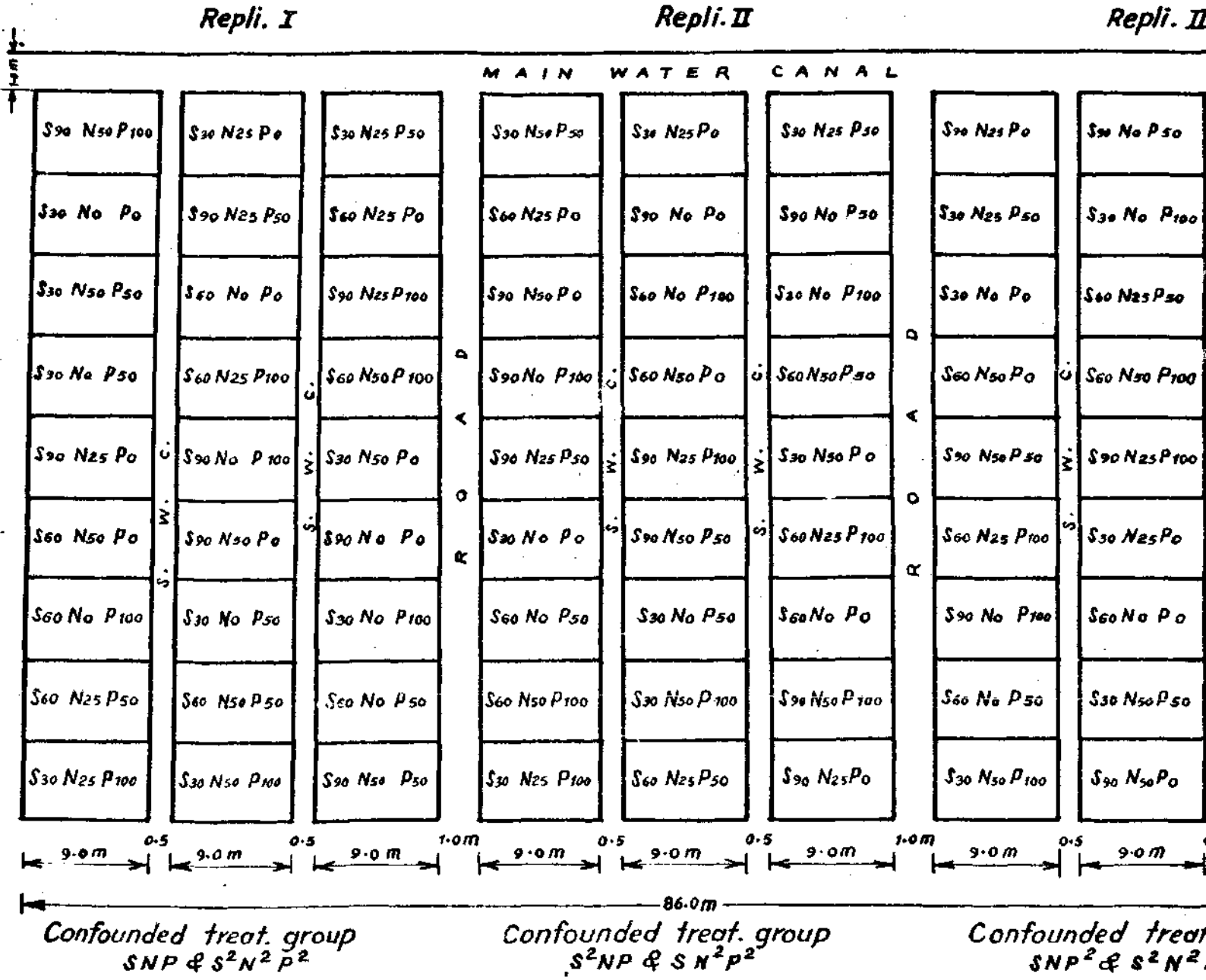
3.5.3 NUMBER OF REPLICATIONS: Three.

3.5.4 OTHER DETAILS:

(1) Plot size:

Spacing	Gross plot size	Net plot size
150 x 30 cm	9.00 x 6.00 m	7.2 x 3.0 m
150 x 60 cm	9.00 x 6.00 m	7.2 x 3.0 m
150 x 90 cm	9.00 x 6.00 m	7.2 x 3.0 m

Fig.1 Plan of layout



Confounded treat. group
SNP & $S^2N^2P^2$

Confounded treat. group
S^2NP & SN^2P^2

Confounded treat
SNP^2 & S^2N^2

(2) Total area of experiment: 4730.00 m^2
(including channels)

(3) Area of one replication : 1512.00 m^2

(4) Net area sown: 4374.00 m^2

(5) Total number of plots : 81

(6) Direction of sowing: North-South

(7) Variety : T-15-15

(8) Seed rate : 5 kg/ha

(9) Method of fertilisers application:

Fertilisers were applied in furrows.

(10) Date of sowing: 23-6-80

(11) Date of harvesting : 29-1-81.

3.6 CULTURAL OPERATIONS:

The calender of cultural operations is given in Table-6.

Table-6: Calender of cultural operations carried out during the course of study

Sr. No.	Operation	Frequency	Date
1	2	3	4
1	Preparatory tillage		
(i)	Tractor ploughing	One	19-6-80
(ii)	Harrowing and planking	Two	20-6-80
2	Lay out		
(i)	Preparation of beds	One	20-6-80
(ii)	Marking as per spacing treatment	One	21-6-80
(iii)	Opening of furrows by country plough	One	21-6-80

(Contd.)

(Contd.)

1	2	3	4
3	Fertiliser application		
	(i) Before sowing as per treatments in the opened furrows	One	23-6-80
4	Dibbling	One	23-6-80
5	Gap filling	One	1-7-80
6	Thinning	One	14-7-70
7	After care		
	(i) Intercultivation		
	a. By hand hoe	One	18-7-80
	b. By bullocks	Three	1st 26-7-80
			2nd 14-8-80
			3rd 28-8-80
	(ii) Hand weeding	Three	1st 12-7-80
			2nd 29-7-80
			3rd 21-8-80
8	Irrigation	Four	1st 22-9-80
			2nd 29-10-80
			3rd 14-11-80
			4th 5-12-80
9	Plant protection measures		
	(i) Dusting of DDT 10 %	One	12-7-80
	(ii) Spraying of Ecalux (25 E. C.)	One	23-7-80
	(iii) Spraying of Rogar (30 E.C.)	One	27-10-80
	(iv) Spraying of Nuvacron (40 E.C.)	One	12-11-80
10	Harvesting	One	29-1-81
11	Threshing and cleaning	One	11-2-81 to 15-2-81

3.6.1 PREPARATORY TILLAGE:

After removal of stubbles of the previous crops, the field was ploughed once by a tractor drawn plough and harrowed twice by Gandhi Allen hoe. The land was planked thoroughly for laying out the experiment.

3.6.2 MANURING:

The fertilizers were applied as per treatments i.e. 0, 25 and 50 kg N/ha and 0, 50 and 100 kg P_2O_5/ha in the form of Ammonium Sulphate and Single superphosphate respectively, before sowing in the furrows opened 150 cm apart.

3.6.3 SOWING:

After preparing the land, marking was done according to spacings included in the experiment. Three seeds were dibbled on every cross made by marker.

3.6.4 IRRIGATION:

Four irrigations were given according to the requirement of the crop.

3.6.5 AFTER CARE:

Gap filling was done 10 days after sowing in order to secure uniform plant stand. The crop was thinned out by keeping only one plant per hill after about three weeks from the time of sowing. Hand weedings as well as

interculturings were done three times, while hand-hoeing was done once during the season of the study.

3.6.6 PLANT PROTECTION MEASURES:

In the initial stage, the crop was attacked by hairy caterpiller and aphids. Dusting with D.D.T. 10 per cent @ 25 kg/ha and the insecticidal spray of Ecalux (25 E.C.) @ 1 C.C./L were attended in time to check these pests. Rogor (30 E.C.) @ 1 C.C./L was sprayed as a preventive measure against attack of Tur pod fly in the fourth week of October. Tur pod fly attack was observed in the second week of November. It was checked by the spraying of Nuvacron (40 E.C.) @ 2 ml/L.

3.6.7 HARVESTING AND THRESHING:

Harvesting was done when all the pods on the plants were matured. The plants in the ring area were harvested first and they were removed from the experimental field and spread for drying. Then plants in the net area were harvested and left in their respective plots for sun drying. After about ten days from the date of harvest, threshing was done by beating pods and stems with wooden sticks. Then grains were separated by hand winnowing and the weight of cleaned grains was recorded separately for each of the plots. The stalks were left in the respective plots for further

drying. They were weighed after about six days when they were completely dry. Weight of dry stalks was recorded only when two consecutive weights were found constant.

3.7 PLANT CHARACTERS STUDIED:

The details of the different plant characters studied during the course of the investigation are narrated as under.

Five plants were randomly selected and tagged from net plot area of each experimental plot for studying individual plant characters.

3.7.1 GRAIN YIELD PER HECTARE:

Yield of grains of each net plot was recorded separately. Subsequently yield of grains in kg per hectare was worked out on the basis of the data on yield of grains per net plot and recorded accordingly.

3.7. 2 STALK YIELD PER HECTARE:

After threshing of the grains, the stalks were allowed to dry for six days in open place and weight was recorded. Yield of stalks per hectare was then worked out and recorded accordingly.

3.7.3 YIELD OF BHUSA (GOTAR) PER HECTARE:

The mixture of broken pieces of stems, pod husks and dry leaves which were left out in the process of

winnowing was weighed and recorded as bhusa for each of the plots. Then yield of bhusa in kg per hectare was worked out and recorded.

3.7.4 HARVEST INDEX:

The harvest index was calculated by the following formula.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

The biological yield refers to total dry matter (Stalk + Bhusa) and economic yield refers to the economically useful part (grain) of biological yield. As it is very difficult to get correct weight of all the roots at harvest stage, the roots were not included into the biological yield.

3.7.5 WEIGHT OF GRAINS PER PLANT:

Dry pods were harvested from the five randomly selected plants and threshed by beating the pods with wooden sticks. The grains were separated by hand winnowing and then weight of cleaned grains was recorded in grams for each of the treatments. Mean yield of grains per plant for all the plots was recorded separately.

3.7.6 NUMBER OF PODS PER PLANT:

Total number of matured pods on each of the five randomly selected plants were counted and recorded separately

for each of the plots. Average number of matured pods per plant was worked out and recorded separately.

3.7.7 N. BRANCHES PER PLANT:

Only those branches that had matured pods were counted and recorded separately for each of the plots. Average number of branches per plant was worked out and recorded separately.

3.7.8 TEST WEIGHT:

In order to know the treatment effects on development of grains, two samples of seeds were drawn from the produce of each of the experimental plots and the weight of one thousand grains was determined for each of the samples, and recorded separately the average weight for the respective plots.

3.7.9 PLANT HEIGHT:

The height of the randomly selected individual plant was recorded initially at one month period of growth of the crop and then after every fifteen days interval. The plant height was measured in cm from the base of the plant to the apex of the main stem. The final height was measured prior to harvest. Average height of five plants was worked out and recorded accordingly.

3.7.10 PROTEIN CONTENT OF SEEDS:

A representative sample from the produce (grain) of each of the experimental plots was drawn. The samples were analysed to find out nitrogen content by Kjeldahl's method (Jackson, 1967). Protein content was obtained by multiplying nitrogen per cent by 6.25.

3.7.11 MONETARY RETURNS:

The gross realization on hectare basis was worked out taking into consideration the yield of grain, stalks and bhusa from each of the treatments. The market price of these materials prevailing in the month of February 1981 was considered. The cost of cultivation involving all items of expenses from preparatory tillage to harvest viz. seeds, fertilizers, pesticides, irrigation, threshing, cleaning etc. was worked out. The cultivation cost was then deducted from the gross realization to obtained the figures of net realization per hectare for each of the treamtnets and recorded accordingly.

3.8. STATISTICAL METHOD EMPLOYED:

The data obtained on various characters under study were statistically analysed and 'F' value was worked out and compared with Table value of 'F' at 5 per cent level of probability. Wherever, the treatment differences were significant, C.D. values were worked out (Nigam and Gupta, 1979) to test treatment differences.

EXPERIMENTAL RESULTS

The present investigation was undertaken with a view to study the effects of various levels of spacing, nitrogen and phosphorus on the yield and quality of pigeon pea (*Cajanus cajan* (L.) Millsp) in the year 1988-89. The data on grain and dry matter yields, protein content and different plant characters as affected by various treatments are presented and discussed here.

4.1 Grain yield

The mean data on grain yield in kg/ha of pigeon pea as influenced by spacings, nitrogen and phosphorus levels are presented in Table 7 and graphically in Figure 2.

The data revealed that the grain yield was significantly increased due to spacing. The inter-row spacing of 30 cm secured the top position in grain yield (1888 kg/ha) followed by 60 cm (1458 kg/ha) and 90 cm (1149 kg/ha).

Differences in grain yield were significant due to nitrogen levels. The plots which received 25 kg N per hectare gave significantly more grain yield (1592 kg/ha) than those received 50 kg/ha and no nitrogen. The latter two treatments gave 1539 and 1446 kg grains per hectare, respectively.

As to the effect of phosphorus doses on grain yield, it was observed that all the three levels of phosphorus significantly differed from each other. An increasing trend was observed with increase in levels of phosphorus. The doses of 0, 50 and 100 kg P_2O_5 per hectare gave the mean grain yield of 1406 , 1535 and 1597 kg per hectare, respectively.

Table 7. Mean grain yield of pigeon pea (kg/ha) as influenced by spacing, nitrogen and phosphorus.

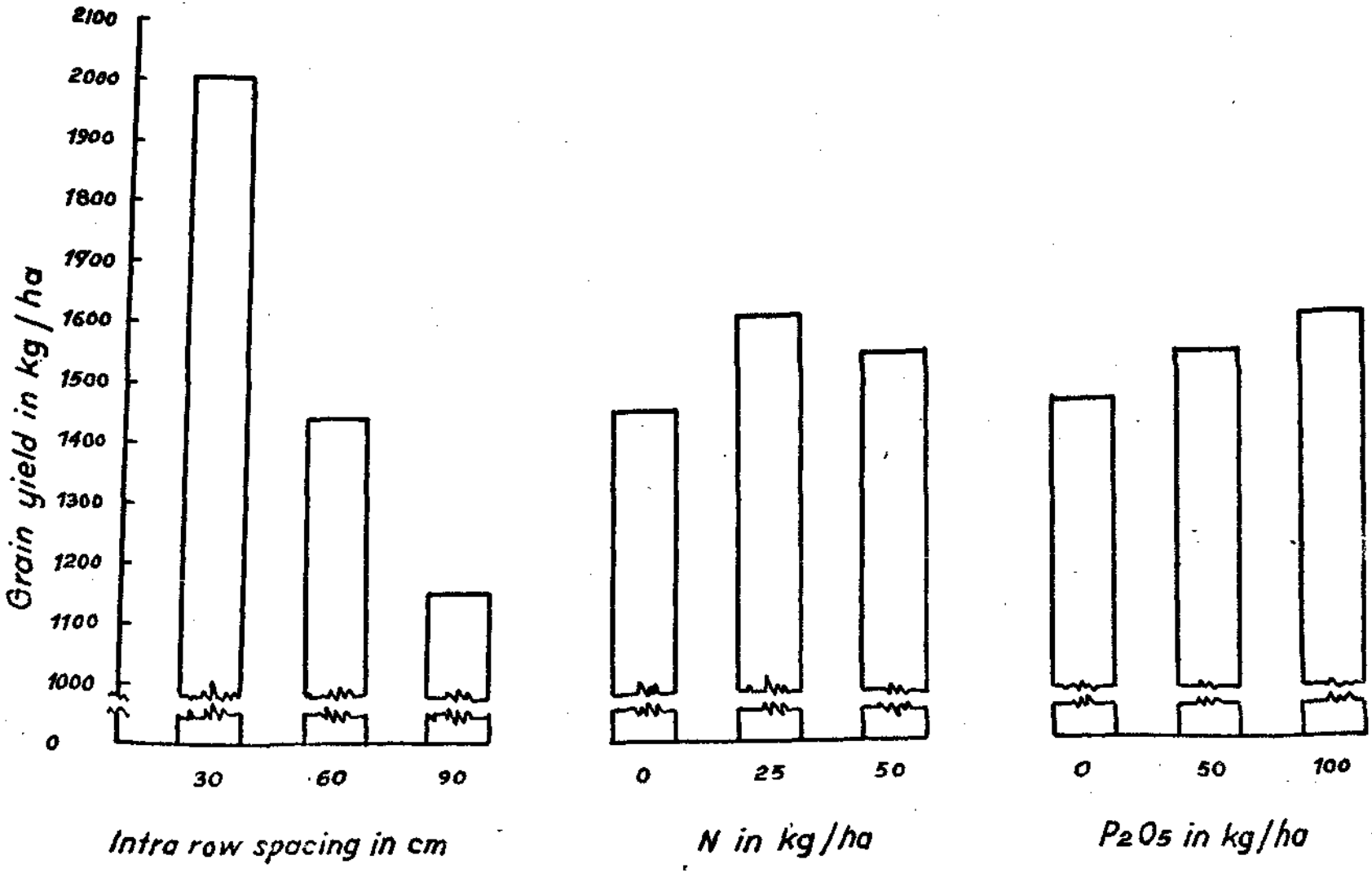
Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm)			Mean N×P
		S_{30}	S_{60}	S_{90}	
N_0	P_0	1826	1335	963	1375
	P_{50}	1894	1384	1953	1444
	P_{100}	2002	1436	1125	1521
	Mean	1907	1385	1047	1446
N_{25}	P_0	1972	1420	1175	1522
	P_{50}	2104	1488	1252	1614
	P_{100}	2190	1556	1271	1672
	Mean	2087	1487	1232	1602
N_{50}	P_0	1908	1392	1114	1471
	P_{50}	2049	1419	1175	1548
	P_{100}	2082	1517	1214	1578
	Mean	2006	1443	1168	1579
Mean	P_0	1902	1382	1084	1456
	P_{50}	2016	1430	1160	1535
	P_{100}	2085	1503	1203	1597
	Mean	2001	1438	1149	1529

Statistical values

Source	S.Em.±	C.D. at 5%	C.V.%
Spacing (S)	6.55	11.65	2.22
Nitrogen (N)	6.55	11.65	
Phosphorus(P)	6.55	11.65	
S x N	11.34	32.30	
S x P	11.34	32.30	
N x P	11.34	32.30	
S x N x P*	24.06	68.53	
S x N x P	19.63	55.92	

*Confounded treatment group

Fig.2 Grain yield in kg/ha as influenced by different intra row spacings, nitrogen and phosphorus.



The results revealed that all the interactions viz. S x N, S x P, N x P and S x N x P produced significant effects on grain yield. In S x N interaction, the combination of $S_{30}N_{25}$ showed the highest grain yield (2087 kg/ha), while it varied from 1047 to 2006 kg per hectare in the rest of the combinations. In case of interaction S x P, the combination $S_{30}P_{100}$ showed the highest grain yield (2085 kg/ha), while it ranged from 1084 to 2016 kg per hectare in the rest of the combinations. In N x p interaction, the combination $N_{25}P_{100}$ recorded the highest grain yield (1672 kg/ha), while it varied from 1375 to 1614 per hectare in the rest of the combinations.

The combinations of $S_{30}N_{25}P_{100}$ of S x N x P showed the highest grain yield (2190 kg/ha) as against the lowest grain yield (963 kg/ha) in $S_{90}N_0N_0$ among all the combinations.

4.2 Stalk yield

The data on mean yield of stalk per hectare as influenced by various treatments are presented in Table 8 and illustrated graphically in Figure 3.

Significant differences were observed in stalk yield due to different intra-row spacings. Increase in intra-row spacings showed decreasing trend in stalk yield. The intra-row spacings of 30, 60 and 90 cm gave an average 5044, 4101 and 3291 kg stalks per hectare respectively.

Table 8, Mean stalk yield of pigeon pea (kg/ha) as affected by spacing, nitrogen and phosphorus

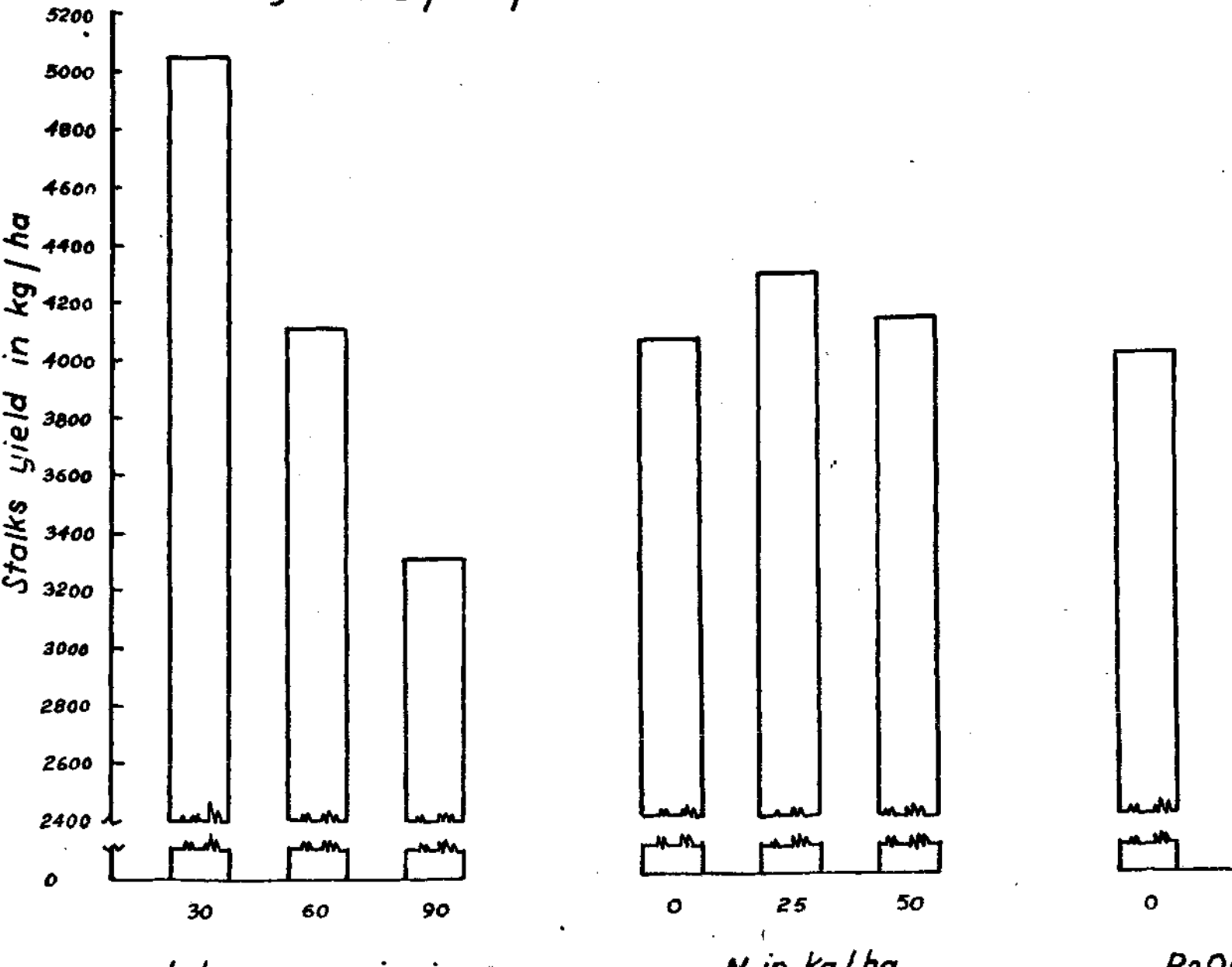
Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm) S_{30}	S_{60}	S_{90}	Mean N x P
N_0	P_0	4841	3825	3031	3902
	P_{50}	4985	4120	3120	4075
	P_{100}	5162	4228	3201	4197
	Mean	4996	4061	3117	4058
N_{25}	P_0	4900	3904	3366	4057
	P_{50}	5324	4213	3417	4318
	P_{100}	5432	4398	3472	4434
	Mean	5219	4172	3418	4270
N_{50}	P_0	4753	3943	3272	3989
	P_{50}	4985	4066	3360	4137
	P_{100}	5012	4198	3380	4198
	Mean	4918	4069	3337	4108
Mean	P_0	4831	3894	3223	3983
	P_{50}	5098	4133	3299	4177
	P_{100}	5203	4275	3351	4276
	Mean	5044	4101	3291	4145

Statistical values

Source	S.Em.±	C.D.at 5%	C.V.%
Spacing (S)	6.99	1991	8.78
Nitrogen (N)	6.99	1991	
Phosphorus (P)	6.99	19.91	
S x N	12.08	34.40	
S x P	12.08	34.40	
N x P	12.08	34.40	
S x N x P *	25.69	73.19	
S x N x P	20.97	N.S.	

* Confounded treatment group

Fig.3 Stalks yield in kg/ha as influenced by different intra row nitrogen and phosphorus levels.



The results revealed that the differences in stalk yield due to various levels of nitrogen were significantly different from each other. The yields of plants per stalks in descending order were 4278, 4108 and 4059 kg per hectare with 25, 50 and 0 kg N per hectare respectively.

The effect of phosphorous levels were found to be significant on stalk yield. There was increase in stalk yield with increase in dose of phosphorus. The phosphorous dose of 100 kg per hectare produced significantly higher stalk yield (4276 kg/ha) than that by 50 kg P_2O_5 (4177 kg/ha) and control (3983 kg/ha).

All the interactions except S x N x P (not confounded treatment group) produced significant differences in stalk yield. In S x N interaction, the combination $S_{50}N_{25}$ showed significantly higher stalk yield (5219 kg/ha) than that by the rest of the combinations. In S x P interaction, the combination $S_{50}P_{100}$ showed significant increase in stalk yield (5203 kg/ha) over the rest of the combinations. In N x P interaction, the combination $N_{25}P_{100}$ showed significant superiority in stalk yield (4434 kg/ha) to the rest of the combinations.

In higher order interaction S x N x P (confounded treatment group) the combination $S_{50}N_{25}P_{100}$ gave 5432 kg/ha stalk yield and that was significantly more than that by the rest of the combinations.

4.3 Bhum yield

The data on mean yield of pigeon pea bhums per hectare as affected by various treatments are presented in Table 9 along with the statistical data. The same are illustrated graphically in Figure 4.

It was observed that there were significant differences in bhusk yield due to different intra-row spacings. Increase in intra-row spacing showed decreasing trend in bhusk yield. The intra-row spacing of 30, 60 and 90 cm gave 2307, 1865 and 1476 kg bhusk per hectare respectively.

Differences in bhusk yield were significant due to nitrogen levels. The plots which received 25 kg N per hectare gave significantly more bhusk yield (2152 kg/ha) than those receiving 50 kg and no nitrogen per hectare (1925 and 1839 kg/ha) respectively.

As to the effect of phosphorus on bhusk yield, it was observed that all the three levels of phosphorus significantly differed from each other. There was significant increase in bhusk yield per hectare with successive increase in level of phosphorus. The phosphorus doses of 0, 50 and 100 kg per hectare gave an average bhusk yields of 1920, 2042 and 2146 kg per hectare respectively.

As regards the effect of interaction, all the interactions produced significant differences in bhusk yield except S x N x P (confounded treatment group).

Table 9. Mean bhusa yield of pigeon pea (kg/ha) as affected by spacing, nitrogen and phosphorus

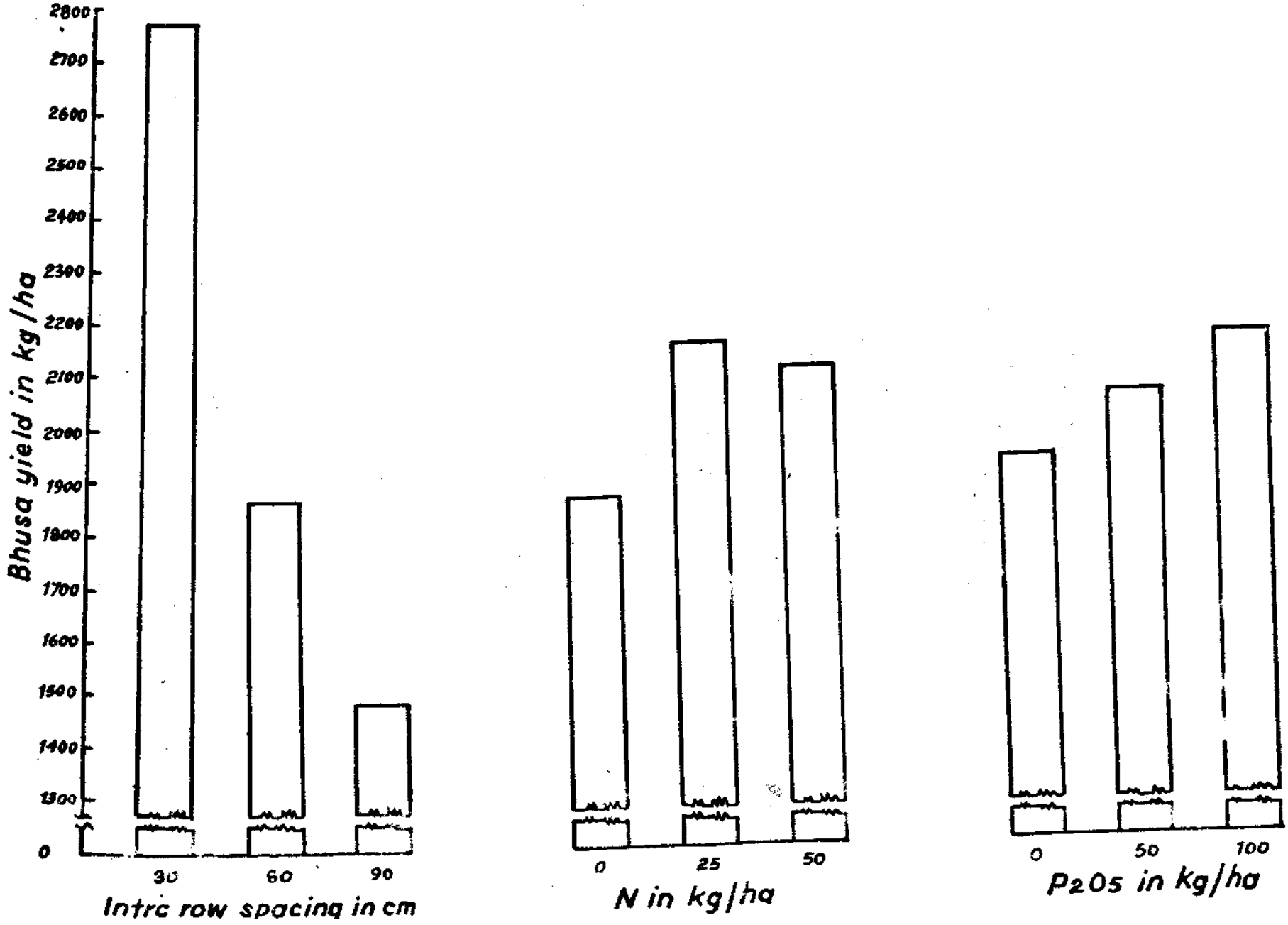
Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm) S_{30}	S_{60}	S_{90}	Mean N x P
N_0	P_0	2446	1508	1307	1754
	P_{50}	2568	1620	1360	1849
	P_{100}	2742	1719	1452	1971
	Mean	2585	1616	1373	1858
N_{25}	P_0	2741	1801	1497	2013
	P_{50}	2917	2048	1520	2162
	P_{100}	3042	2174	1631	2282
	Mean	2900	2008	1549	2152
N_{50}	P_0	2718	1829	1435	1994
	P_{50}	2847	1991	1512	2117
	P_{100}	2887	2097	1568	2184
	Mean	2817	1972	1505	2098
Mean	P_0	2635	1713	1413	1920
	P_{50}	2777	1886	1464	2042
	P_{100}	2890	1997	1550	2146
	Mean	2767	1865	1476	2036

Statistical values

Source	S.Em.±	C.D. at 5%	C.V.%
Spacing (S)	5.19	14.77	13.25
Nitrogen (N)	5.19	14.77	
Phosphorus (P)	5.19	14.77	
S x N	8.98	25.60	
S x P	8.98	25.60	
N x P	8.98	25.60	
S x N x P *	19.07	N.S.	
S x N x P	15.60	44.44	

* Confounded treatment group

Fig.4 Bhusa yield in kg/ha as influenced by different intra row spacings, nitrogen and phosphorus levels.



In S x P interaction, the combination of $S_{30}N_{25}$ showed significantly higher bhusa yield (2900 kg/ha) than that by the rest of the combinations. In S x P interaction, $S_{30}P_{100}$ showed significant increase in bhusa yield (2890 kg/ha) over the rest of the combinations. In N x P interaction, the combination $N_{25}P_{100}$ gave significantly higher bhusa yield (2282 kg/ha) than that by the rest of the combinations.

As regards effect of higher order interaction S x N x P (not confounded treatment group), the combination $S_{30}N_{25}P_{100}$ gave the highest bhusa yield (3042 kg/ha) as against the lowest bhusa yield (1307 kg/ha) by $S_{90}N_0P_0$.

4.4 Harvest index

The data pertaining to harvest index as influenced by various treatments are presented in Table 10 alongwith statistical values.

It was observed that there were significant differences in harvest index due to different intra-row spacings. The intra-row spacing of 30 cm gave significantly higher harvest index (0.256) than those by 60 (0.241) and 90 cm (0.241). The intra-row spacings of 60 and 90 cm were at par in their effects on this character.

It was observed that the effect of different doses of nitrogen on harvest index was significant. Application of 25 kg N per hectare recorded the highest harvest index (0.249) and was significantly superior to that of the control. However, it did not show such superiority to the application of 50 kg N per hectare.

Table 10. Mean harvest index of pigeon pea as influenced by various spacings nitrogen and phosphorus levels

Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm) S_{30}	S_{60}	S_{90}	Mean N x P
N_0	P_0	0.251	0.250	0.222	0.241
	P_{50}	0.251	0.241	0.235	0.242
	P_{100}	0.253	0.241	0.242	0.245
	Mean	0.252	0.244	0.233	0.243
N_{25}	P_0	0.258	0.249	0.242	0.250
	P_{50}	0.256	0.237	0.254	0.249
	P_{100}	0.259	0.237	0.249	0.248
	Mean	0.258	0.241	0.248	0.249
N_{50}	P_0	0.255	0.243	0.237	0.245
	P_{50}	0.262	0.234	0.241	0.246
	P_{100}	0.261	0.241	0.245	0.249
	Mean	0.259	0.239	0.241	0.246
Mean	P_0	0.255	0.247	0.234	0.245
	P_{50}	0.256	0.237	0.243	0.245
	P_{100}	0.258	0.240	0.245	0.248
	Mean	0.256	0.241	0.241	0.246

Statistical Values

Source	S.Em. ±	C.D. at 5%	C.V.
Spacing (S)	0.0011	0.0031	2.36
Nitrogen (N)	0.0011	0.0031	
Phosphorus (P)	0.0011	N.S.	
S x N	0.0019	0.0054	
S x P	0.0019	0.0054	
N x P	0.0019	N.S.	
S x N x P *	0.0041	N.S.	
S x N x P	0.0033	N.S.	

* Confounded treatment group.

Application of phosphorus did not show significant differences in harvest index. However, application of 100 kg P_2O_5 per hectare was slightly higher than the rest of the phosphorus levels. Application of 0, 50 and 100 kg P_2O_5 per hectare gave 0.205, 0.245 and 0.240 harvest index respectively.

The interactions S x N and S x P were significant in their effects on harvest index. In S x N interaction, the combination of $S_{90}N_{50}$ showed the highest harvest index (0.330), while it varied from 0.235 to 0.290 in the rest of the combinations. In case of interaction S x P, the combination of $S_{90}P_{100}$ showed the highest harvest index (0.290), while it ranged from 0.234 to 0.285 in the rest of the combinations.

4.5 Grain yield per plant

The mean data on grain yield per plant of pigeon pea as affected by spacing, nitrogen and phosphorus levels are presented in Table 11 alongwith the statistical values.

The data revealed that there were significant differences in grain yield per plant due to different intra-row spacings. The intra-row spacing of 90 cm produced the highest grain yield per plant (149.7 gm). The treatments involving 60 cm and 30 cm intra-row spacing gave an average grain yield of 129.2 and 86.3 gm respectively.

Significant differences in grain yield per plant were observed due to application of various doses of nitrogen. The plots that received 25 kg N per hectare

Table 11. Mean grain yield per plant of pigeon pea in gm as affected by various spacing, nitrogen and phosphorus levels

Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm)			Mean
		S_{30}	S_{60}	S_{90}	N x P
N_0	P_0	80.2	119.6	143.2	114.3
	P_{50}	82.4	122.4	145.3	116.7
	P_{100}	85.4	126.5	148.3	120.1
	Mean	82.7	122.8	145.6	117.0
N_{25}	P_0	84.7	130.2	150.6	121.8
	P_{50}	88.7	134.7	153.3	125.6
	P_{100}	95.5	138.8	155.2	129.8
	Mean	89.7	134.6	153.0	125.7
N_{50}	P_0	83.2	128.1	148.9	120.1
	P_{50}	86.5	129.9	150.2	122.2
	P_{100}	90.3	132.8	152.3	125.1
	Mean	86.7	130.3	150.5	122.5
Mean	P_0	82.7	126.0	147.6	118.8
	P_{50}	85.9	129.0	149.6	121.5
	P_{100}	90.4	132.7	151.9	125.0
	Mean	86.3	129.2	149.7	121.7

Statistical values

Source	S.Em.±	C.D. at 5%	C.V.%
Spacing (S)	0.05	0.15	2.2
Nitrogen (N)	0.05	0.15	
Phosphorus (P)	0.05	0.15	
S x N	0.08	0.25	
S x P	0.08	0.25	
N x P	0.08	0.25	
S x N x P *	0.19	0.54	
S x N+P	0.15	0.44	

* Confounded treatment group

gave significantly more grain yield per plant than those received 50 kg N and no nitrogen per hectare. Applications of nitrogen at the rate of 0, 25 and 50 kg N per hectare produced 127.0, 135.7 and 128.5 gm grains per plant respectively.

It was observed that all the levels of phosphorus differed significantly among themselves in their effects on grain yield per plant. Each successive dose of P_2O_5 showed significant increase to the preceding lower one. The levels of 0, 50 and 100 kg P_2O_5 per hectare produced on average 118.8, 121.5 and 125.0 gm grain yield per plant respectively.

As to the effect of various interactions, all of them viz. S x N, S x P, N x P and S x N x P were found significant on grain yield per plant. In S x N interaction, the combination $S_{90}N_{25}$ showed the highest grain yield per plant (135.0 gm) among all, while it varied from 82.7 to 130.9 in the rest of the combinations. In case of interaction S x P, the combination $S_{90}P_{100}$ showed the highest grain yield per plant (131.9 gm), while it ranged from 90.7 to 140.6 gm in the rest of the combinations. In N x P interaction, the combination $N_{25}P_{100}$ recorded the highest grain yield per plant (129.8 gm), while it varied from 112.5 to 125.6 in the rest of the combinations.

As to the effect of higher order interaction of S x N x P, the combination $S_{90}N_{25}P_{100}$ showed the highest

grain yield per plant (155.2 gm) as against the lowest grain yield per plant (80.2 gm) in case of $S_{30}N_0P_0$ among all combinations.

4.6 Number of pods per plant

The mean data on number of pods per plant of pigeon pea as influenced by spacing, nitrogen and phosphorus levels are presented in Table 12 alongwith the statistical values.

It was observed that the effect of different intra-row spacings on number of pods per plant was found to be significant. The intra-row spacing of 90 cm produced significantly more pods per plant (355.5) than those by 60 cm (293.8) and 30 cm (216.9) spacings.

The number of pods per plant was significantly different due to varying applications of nitrogen. The treatment involving 25 kg N per hectare recorded the highest number of pods per plant (290.8) as compared to those of 50 kg N (288.3) and no N (287.1) per hectare.

As to the effect of phosphorus levels on pods per plant, it was observed that each successive dose of phosphorus produced significantly more pods per plant than that by the preceeding ones. The applications of phosphorus at the rate of 0, 50 and 100 kg per hectare produced 285.0, 289.0 and 292.2 pods per plant respectively.

As regards effects of interactions, all the interactions viz. S x N, S x P, N x P and S x N x P were significant. In S x N interaction, the combination $S_{90}N_{25}$

Table 12. Mean number of pods per plant of pigeon pea as affected by the various spacing, nitrogen and phosphorus levels.

Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm) S_{30}	S_{60}	S_{90}	Mean N x P
N_0	P_0	210.3	290.4	350.1	283.6
	P_{50}	215.0	293.5	253.2	287.2
	P_{100}	218.6	296.2	356.3	290.4
	Mean	214.6	293.4	353.2	287.1
N_{25}	P_0	214.1	292.4	352.2	286.2
	P_{50}	220.6	294.2	358.2	291.0
	P_{100}	225.1	298.8	361.3	295.1
	Mean	220.0	295.1	357.2	290.8
N_{50}	P_0	212.2	291.4	351.7	285.1
	P_{50}	216.6	292.4	357.2	288.7
	P_{100}	219.3	295.1	359.3	291.2
	Mean	216.0	293.0	356.1	288.3
Mean	P_0	212.2	291.4	351.3	285.0
	P_{50}	217.4	293.4	356.2	289.0
	P_{100}	221.0	296.7	359.0	292.2
	Mean	216.9	293.8	355.5	288.7

Statistical values

Source	S.Em.±	C.D. at 5 %	C.V.%
Spacing (S)	0.04	0.12	
Nitrogen (N)	0.04	0.12	0.78
Phosphorus (P)	0.04	0.12	
S x N	0.13	0.37	
S x P	0.13	0.37	
N x P	0.13	0.37	
S x N x P *	0.16	0.46	
S x N x P	0.13	0.37	

*Confounded treatment group

showed significantly higher thum number of pods per plant (357.2) than that by the rest of the combinations. In S x P interaction, the combination $S_{90}P_{100}$ produced significantly more pods per plant (359.0) than that by the rest of the combinations. In N x P interaction, the combination $N_{25}P_{100}$ showed significant superiority in number of pods per plant (295.1) to the rest of the combinations.

As regards effect of higher order interaction S x N x P, the combination $S_{90}N_{25}P_{100}$ showed 361.3 pods per plant and that was significantly more than that by the rest of the combinations.

4.7 Number of branches per plant

The mean data on number of branches of pigeon pea as influenced by spacing, nitrogen and phosphorus levels are presented in Table 13 alongwith the statistical values.

The results indicated that there were significant differences in numberof branches per plant due to dfferent intra-row spacings. The wider spacing of 90 cm produced significantly more branches per plant (26.55) than those by 60 cm (21.73) and 30 cm (18.17) intra-row spacings.

As regards effect of the levels of nitrogen treatments, it was observed that application of nitrogen, caused significant difference in number of branches per plant. Application of 25 kg N per hectare produced the highest number of branches per plant (22.87). The other two levels viz. 50 kg N 21. and no nitrogen gave 21.91 and 21.46 branches per plant respectively.

Table 13. Mean number of branches per plant of pigeon pea as influenced by various spacings, nitrogen and phosphorus levels

Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm)			Mean N x P
		S_{30}	S_{60}	S_{90}	
N_0	P_0	16.4	20.8	24.3	20.5
	P_{50}	17.5	21.5	25.2	21.4
	P_{100}	18.5	22.6	26.3	22.5
	Mean	17.5	21.6	25.3	21.46
N_{25}	P_0	17.3	21.0	26.3	21.5
	P_{50}	19.5	22.5	27.3	23.1
	P_{100}	20.3	25.3	28.3	24.0
	Mean	19.0	22.3	27.3	22.87
N_{50}	P_0	16.5	20.2	25.8	20.8
	P_{50}	18.3	21.6	26.4	22.1
	P_{100}	19.3	22.0	27.1	22.8
	Mean	18.0	21.3	26.4	21.91
Mean	P_0	16.7	20.7	25.5	20.96
	P_{50}	18.4	21.9	26.3	22.20
	P_{100}	19.4	22.6	27.2	23.08
	Mean	18.17	21.73	26.33	22.08

Statistical values

Source	S.Em.±	C.D. at 5%	C.V.%
Spacing (S)	0.05	0.15	1.19
Nitrogen (N)	0.05	0.15	
Phosphorus (P)	0.05	0.15	
S x N	0.09	0.25	
S x P	0.09	0.25	
N x P	0.09	0.25	
S x N x P *	0.15	0.43	
X x N x P	0.18	N.S.	

* Confounded treatment group

Application of phosphorus showed significant differences in number of branches per plant. Increase in number of branches per plant was observed with increase in the dose of phosphorus. The plots which received 100 kg P_2O_5 per hectare gave the highest number of branches per plant (23.08). The other two levels viz. 50 kg P_2O_5 and no P_2O_5 per hectare gave an average 22.20 and 20.96 branches per plant respectively.

The results revealed that all the interactions except S x N x P (confounded treatment group) produced significant effects on number of branches per plant. In S x N interaction, the combination $S_{90}N_{25}$ showed significantly higher number of branches per plant (27.3) than that by the rest of the treatment combinations. In S x P interaction, the combination $S_{90}P_{100}$ showed significant increase in number of branches per plant (27.2) when compared to the rest of the combinations. In N x P interaction, the combination $N_{25}P_{100}$ showed the highest number of branches per plant (24.0).

As regards effect of higher order interaction S x N x P (not confounded treatment group), the combination $S_{90}N_{25}P_{100}$ produced the highest number of branches per plant (28.3).

4.8 Plant height

The data on plant height at harvest as influenced by different treatments are reported in Table 14 alongwith the statistical values.

Table 14. Mean height of pigeon pea plants in [illegible] as influenced by spacing, nitrogen and phosphorus

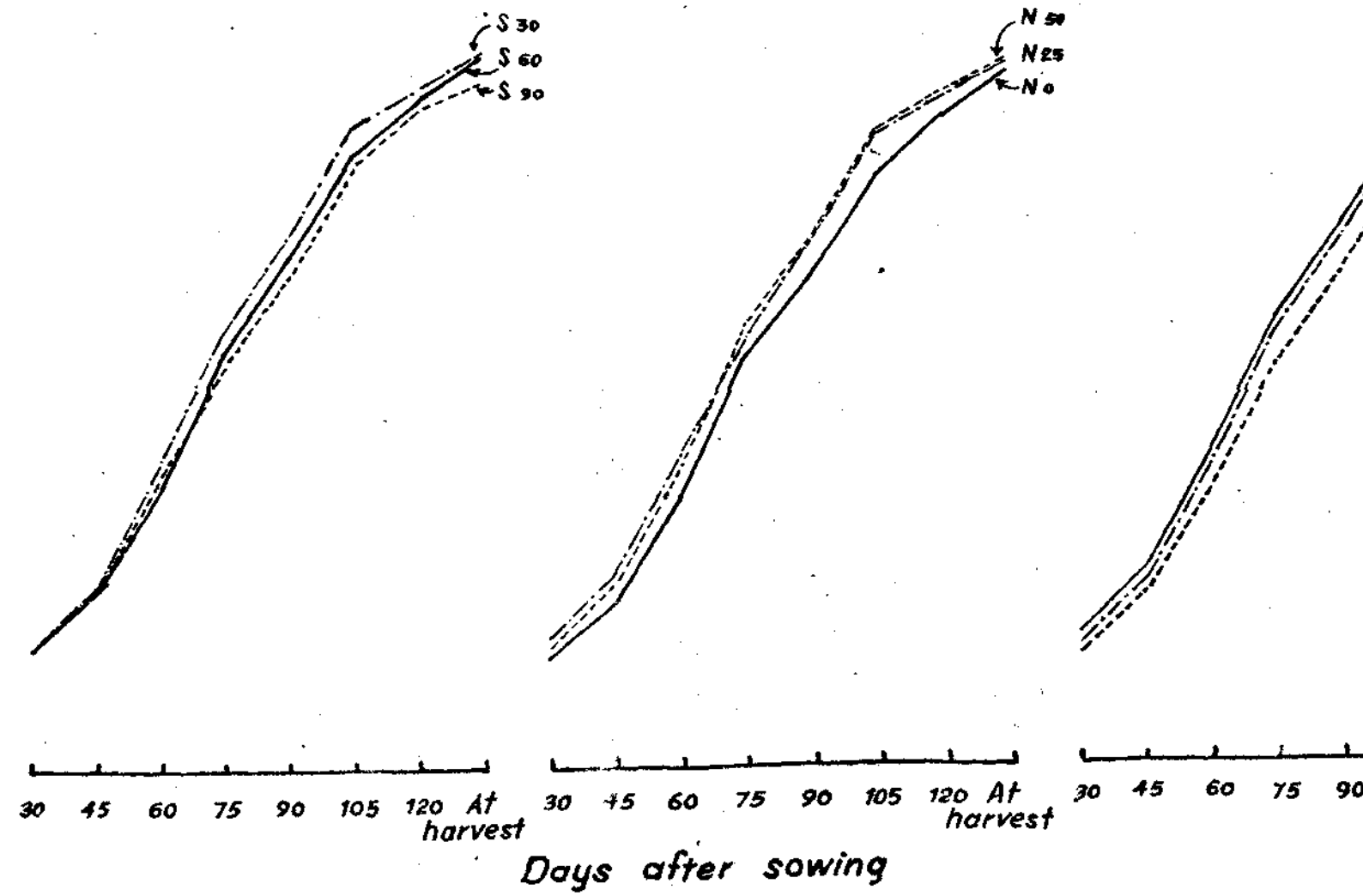
Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm) S_{30}	S_{60}	S_{90}	Mean N x P
-	P_0	[illegible]	[illegible]	212.80	[illegible]
N_0	P_{50}	[illegible]	[illegible]	195.00	219.69
	P_{100}	[illegible]	223.87	206.33	214.73
	Mean	[illegible]	[illegible]	204.71	[illegible]
	P_0	216.33	[illegible]	[illegible]	218.59
N_{25}	P_{50}	222.86	[illegible]	229.07	224.17
	P_{100}	[illegible]	196.33	223.27	221.82
	Mean	227.49	214.33	221.86	221.33
	P_0	225.50	[illegible]	212.13	[illegible]
N_{50}	P_{50}	221.13	[illegible]	220.07	[illegible]
	P_{100}	[illegible]	[illegible]	[illegible]	[illegible]
	Mean	227.10	226.82	219.64	224.19
	P_0	[illegible]	229.03	[illegible]	219.77
Mean	P_{50}	[illegible]	229.93	214.71	[illegible]
	P_{100}	[illegible]	251.60	[illegible]	[illegible]
	Mean	224.44	224.18	215.03	[illegible]

Statistical values

Sources	S.Em.±	C.D at 5%	C.V.%
Spacing (S)	[illegible]	[illegible]	[illegible]
Nitrogen (N)	[illegible]	[illegible]	
Phosphorus (P)	[illegible]	[illegible]	
S x N	[illegible]	2.66	
S x P	[illegible]	[illegible]	
N x P	[illegible]	[illegible]	
S x N x P *	[illegible]	[illegible]	
S x N x P	1.62	[illegible]	

* Confounded treatment group

Fig.5 Mean periodical height as influenced by intra row spacings, n
and phosphorus levels.



Close examination of data reported in Table 14 revealed that differences in plant height were significant due to intra-row spacings. The intra-row spacing of 30 and 60 cm produced significantly taller plants than that by 90 cm intra-row spacing. The former two were at par in this respect. The intra-row spacings of 30, 60 and 90 cm gave an average 224.44, 224.18 and 213.06 cm height respectively.

It was observed that significant increase in plant height corresponded with increase in levels of nitrogen. Application of 50 kg N per hectare gave significantly taller plants (224.39 cm) than those produced by 25 kg N (221.33 cm) and no nitrogen (218.16 cm) per hectare.

As regards effects of phosphorus, it was observed that there were significant differences in plant height due to different doses of phosphorus. The maximum height of 223.14 cm was recorded in the plots that received 50 kg P_2O_5 per hectare. However, the other two levels viz.100 kg P_2O_5/ha and no phosphorus were at par in this respect.

As regards effects of interactions, it was observed that all the interactions were found to be significant in their effects on this character. In S x N interaction, the maximum plant height of 227.40 cm was noticed in $S_{30}N_{50}$ combination, while the lowest plant height of 204.71 cm was observed in the plots receiving $S_{90}N_0$. In S x P interaction, the best response was obtained by the maximum treatment combination $S_{30}P_{100}$ which had the highest plant height of 230.91 cm, whereas the lowest plant height (212.67 cm) was

observed for the combination $S_{90}P_0$. In N x P interaction, the maximum plant height (226.33 cm) was obtained from the combination $N_{50}P_{100}$ whereas the lowest was (218.59 cm) obtained in the plots receiving treatment $N_{25}P_0$ combination.

In case of the higher order cinteraction S x N x P, the highest plant height of 244.07 cm was recorded in $S_{30}N_{25}P_{100}$ combination, while the minimum plant height of 211.00 cm was recorded under $S_{30}N_0P_0$ combination.

4.9 Test weight (Weight of 1000 grains)

Data pertaining to the weight of 1000 grains of pigeon pea as influenced by various treatments are presented in Table 15 alongwith the statistical values.

It was evident from the results that the intra-row spacings had significant effect on the weight of 1000 grains of pigeon pea. The maximum weight (114.22 gm) was recorded under the wider intra-row spacing of 90 cm. This was significantly higher than those of 112.40 gm and 108.09 gm obtained from the plots under 60 and 30 cm intra-row spacings respectively.

The effect of nitrogen levels was significant on 1000 grain weight of pigeon pea. In this case, application of 50 and 25 kg N per hectare produced significantly more test weight than that by no nitrogen treatment. The former two were at par in this regard. The nitrogen levels of 0, 25 and 50 kg per hectare showed weight of 110.80, 111.91 and 112.00 gm per 1000 seeds respectively.

Table 15. Mean weight of thousand seeds of pigeon pea in gms as influenced by spacing, nitrogen and phosphorus

Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm)			Mean N x P
		S_{30}	S_{60}	S_{90}	
N_0	P_0	106.53	110.51	113.53	110.19
	P_{50}	107.07	111.20	113.74	110.67
	P_{100}	108.70	111.84	114.06	111.53
	Mean	107.43	111.18	113.78	110.80
N_{25}	P_0	107.45	112.33	114.24	111.34
	P_{50}	108.00	113.03	114.58	111.87
	P_{100}	109.27	113.43	114.85	112.52
	Mean	108.24	112.93	114.56	111.91
N_{50}	P_0	108.15	112.92	114.15	111.74
	P_{50}	108.09	113.03	114.30	111.81
	P_{100}	109.52	113.32	114.54	112.46
	Mean	108.59	113.09	114.33	112.00
Mean	P_0	107.38	111.92	113.97	111.09
	P_{50}	107.72	112.42	114.21	112.45
	P_{100}	109.16	112.86	114.48	112.17
	Mean	108.09	112.40	114.22	112.57

Statistical values

Source	S.Em.±	C.D. at 4%	C.V. %
Spacing (S)	0.07	0.19	3.14
Nitrogen (N)	0.07	0.19	
Phosphorus (P)	0.07	0.19	
S x N	0.12	0.33	
S x P	0.12	0.33	
N x P	0.12	N.S.	
S x N x P *	0.25	N.S.	
S x N x P	0.20	N.S.	

* Confounded treatment group

It was observed that all the levels of phosphorus differed significantly among themselves in their effects on weight of 1000 seeds. Each successive higher dose of P_2O_5 showed significantly superiority to the preceding lower one. The phosphorus levels of 0, 50 and 100 kg per hectare produced 111.09, 111.49 and 112.37 gm weight per 1000 grains respectively.

As regards effects of various interactions, S x N and S x P were significant in their effects on weight of 1000 seeds. In S x N interaction, the combinations of $S_{90}N_{25}$ was found to be better than the rest of the combinations by producing 114.56 gm test weight. The combination of $S_{90}N_0$ produced the lowest 107.43 gm test weight. In S x P interaction, the top ranking combination was $S_{90}P_{100}$. It was significantly superior to the rest of the combinations. The weight of 1000 grains in this combination was 114.48 gm. The lowest value of 107.38 gm was noticed under the combination $S_{90}P_0$.

The effect of the interaction N x P was not significant. However, the maximum test weight (112.52 gm) was obtained from the combination $N_{25}P_{100}$ whereas the lowest was (110.19 gm) obtained under N_0P_0 combinations.

The effect of three factor interaction S x N x P was not significant. However, the maximum test weight of 114.85 gm was obtained under the treatment combination $S_{90}N_{25}P_{100}$. The lowest test weight of 105.53 gm was obtained under the $S_{90}P_0$ combination.

4.10 Protein content of grain (%)

The results on protein content of pigeon pea grains are given in Table 16 alongwith statistical data and the same are presented graphically in Figure 5.

Significant differences in protein content were observed due to intra-row spacings. All the three levels of intra-row spacings differed significantly among themselves in this respect. The intra-row spacing of 90 cm secured the top position in protein content (25.71 per cent) and it was followed by 60 cm (24.82 per cent) and 30 cm (24.21 per cent) intra-row spacings.

Significant influence of nitrogen was noticed on the protein content of grains of pigeon pea. Application of 50 kg N per hectare ranked the top position (25.62 per cent) and it was followed by application of 25 kg N (24.71 per cent) and no nitrogen (24.43 per cent) per hectare.

As regards effect of phosphorus on protein content, it was observed that all the three levels of phosphorus were significantly differed from each other in their effects on this character. There was significant increase in protein content with successive increase in level of phosphorus. The phosphorus doses of 0, 50 and 100 kg per hectare showed the protein content of 24.55, 24.83 and 25.37 per cent respectively.

The results revealed that all the interactions viz. S x N, S x P, N x P and S x N x P produced significant

Fig 6 Protein content of seed in per cent as influenced by differe
row spacings, nitrogen and phosphorus levels.

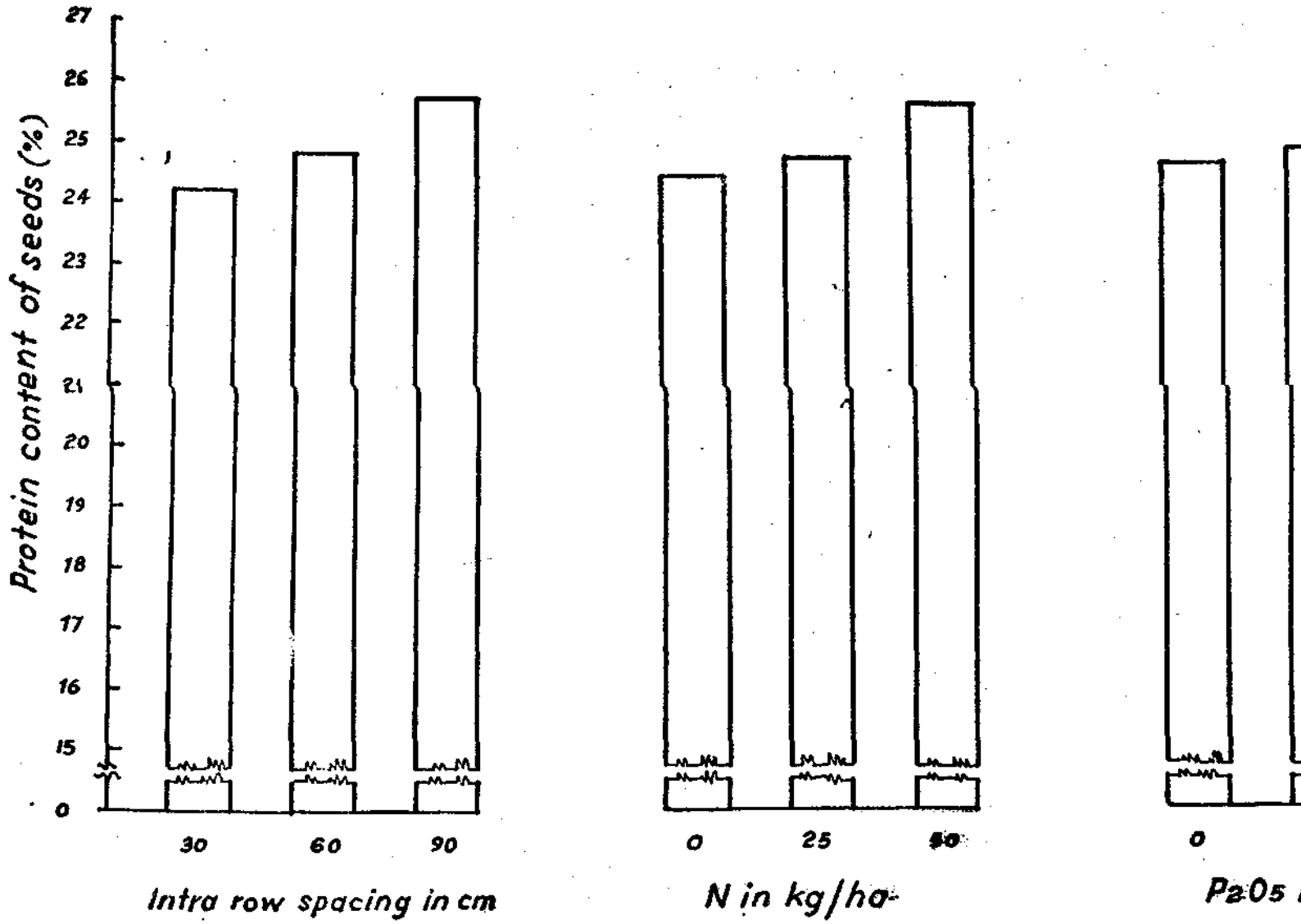


Table 16. Mean percentage of protein in grai of pigeon pea as affected by spacing, nitrogen and phosphorus

Nitrogen (kg/ha)	Phosphorus (kg/ha)	Spacing (cm)			Mean
		S_{30}	S_{60}	S_{90}	N x P
N_0	P_0	22.37	23.53	25.33	23.94
	P_{50}	23.44	23.15	25.41	24.00
	P_{100}	24.29	25.28	26.46	25.34
	Mean	23.57	23.99	25.73	24.43
N_{25}	P_0	22.19	25.10	25.70	24.33
	P_{50}	24.53	25.38	25.28	25.06
	P_{100}	24.34	24.04	25.78	24.72
	Mean	23.69	24.84	25.59	24.71
N_{50}	P_0	25.86	24.76	25.51	25.38
	P_{50}	24.87	26.36	25.09	25.44
	P_{100}	25.40	25.82	26.86	26.03
	Mean	25.38	25.65	25.82	25.62
Mean	P_0	23.67	24.46	25.51	24.55
	P_{50}	24.28	24.96	25.26	24.83
	P_{100}	24.08	25.05	26.37	25.37
	Mean	24.21	24.82	25.71	24.92

Statistical values

Source	S.Em.±	C.D. at 5%	C.V.%
Spacing (S)	0.02	0.07	5.20
Nitrogen (N)	0.02	0.07	
Phosphorus (P)	0.02	0.07	
S x N	0.04	0.12	
S x P	0.04	0.12	
N x P	0.04	0.12	
S x N x P *	0.09	0.26	
S x N x P	0.07	0.21	

*Confounded treatment group

effects on protein content. Under S x N interaction, the combination $S_{90}N_{50}$ showed the highest protein content (25.82 per cent), while the minimum (23.57 per cent) was found under the combination of $S_{30}N_{0}$. Under S x P interaction, the combination $S_{90}P_{100}$ showed significantly higher protein content (26.37 per cent) than the rest of the combinations. In case of N x P interaction, the combination $N_{50}P_{100}$ recorded the highest protein content in grains (26.03 per cent), while it varied from 23.94 to 25.44 per cent in the rest of the treatment combinations.

As regards the interaction of three factors S x N x P the combination $S_{90}N_{50}P_{100}$ showed the highest protein content in grains (26.86 per cent) as against the lowest protein content of seeds (22.37 per cent) in case of $S_{30}N_{0}P_{0}$.

4.11. Monetary return

The gross realisation, cost of cultivation and net profit per hectare for different treatment combinations were worked out. They are presented in Table 17. The data revealed that the treatment combination $S_{30}N_{25}P_{50}$ gave the highest net profit of Rs.4926/- per hectare, while $S_{30}N_{50}P_{100}$ gave the lowest net profit of Rs.1369/-per hectare.

The data further indicated that the highest net profit per hectare was obtained from the produce of 30 cm intra-row spacing. The intra-row spacings of 30, 60 and 90 cm showed average net profit of Rs.4574, 2752 and 1769/- per hectare respectively.

Table 17. Mean grain, stalk and bhusa yields in kg per hectare, gross realization, cost of cultivation and net profit in rupees per hectare as influenced by various treatments

Treatment No.	Treatment combination	Yield (kg/ha)			Gross realization (Rs/ha)	Cost of cultivation (Rs/ha)	Net profit
		Grain	Stalk	Bhusa			
1	2	3	4	5	6	7	8
1	$S_{30}N_0P_0$	1826	4841	2446	6055	1588	4467
2	$S_{30}N_0P_{50}$	1894	4985	2568	6282	1865	4417
3	$S_{30}N_0P_{100}$	2002	5162	2742	6633	2115	4518
4	$S_{30}N_{25}P_0$	1972	4900	2741	6521	1790	4731
5	$S_{30}N_{25}P_{50}$	2104	5324	2917	6966	2040	4926
6	$S_{30}N_{25}P_{100}$	2190	5432	3042	7241	2290	4851
7	$S_{30}N_{50}P_0$	1908	4753	2718	6321	1964	4357
8	$S_{30}N_{50}P_{50}$	2049	4985	2847	6766	2214	4552
9	$S_{30}N_{50}P_{100}$	2062	5015	2887	6812	2464	4348
10	$S_{60}N_0P_0$	1335	3835	1508	4415	1588	2827
11	$S_{60}N_0P_{50}$	1384	4120	1620	4599	1865	2734
12	$S_{60}N_0P_{100}$	1436	4228	1719	4774	2115	2659
13	$S_{60}N_{25}P_0$	1420	3904	1801	4707	1790	2917
14	$S_{60}N_{25}P_0$	1486	4213	2048	4963	2040	2923
15	$S_{60}N_{25}P_{100}$	1556	4398	2174	5201	2290	2911
16	$S_{60}N_{50}P_0$	1392	3943	1829	4635	1964	2671
17	$S_{60}N_{50}P_{50}$	1478	4066	1991	4750	2214	2536
18	$S_{60}N_{50}P_{100}$	1517	4198	2097	5058	2464	2594

Contd...

1	2	3	4	5	6	7	8
19	$^{S}50^{X}0^{Z}0$	963	3071	1307	3046	1500	1635
20	$^{S}50^{X}0^{Z}50$	1075	3120	1360	3367	[illegible]	1632
21	$^{S}50^{X}0^{Z}100$	1125	[illegible]	[illegible]	3744	2120	[illegible]
22	$^{S}50^{X}25^{Z}0$	1275	3356	1407	3811	1790	22.21
23	$^{S}50^{X}25^{Z}50$	1232	3427	1500	4135	2040	[illegible]
24	$^{S}50^{X}25^{Z}100$	1271	3472	1631	4214	[illegible]	1986
25	$^{S}50^{X}50^{Z}0$	1114	3272	1435	3717	1964	1795
26	$^{S}50^{X}50^{Z}50$	1175	3300	1512	3822	2214	[illegible]
27	$^{S}50^{X}50^{Z}100$	1214	3700	1565	4075	2454	1909

Mean values for net profit

Levels	Net profit in Rs/ha
S_{30}	4574
S_{60}	2752
S_{90}	1789
S_0	2951
N_{25}	3267
N_{50}	2998
P_0	3056
P_{50}	3160
P_{100}	3111

1.	Cost of nitrogen from ammonium sulphate	Rs.6.98/kg N
2.	Cost of phosphoric acid from single super phosphate	Rs.5.00/kg P_2O_5
3.	Cost of seed	Rs.6.00/kg
4.	Bullock charges (pair)	Rs.12.00/day
5.	Cost of plowing with tractor	Rs.22.00/hr.
6.	Cost of harrowing	Rs.22.00/hr.
7.	Irrigation charges	Rs.6.00/hr.
8.	Cost of rogor (30 E.C.)	Rs.65.00/L.
9.	Cost of nuvacron (40 E.C.)	Rs.180.00/L.
10.	Cost of D.D.T. 10% dust	Rs.3.20/kg.
11.	Cost of ecnlux (25 E.C.)	Rs.108.00/L.

12.	Selling price of grains	Rs.2.85/kg.
13.	Selling price of stalk	Rs.0.10/kg.
14.	Selling price of bhusa	Rs.0.15/kg.

Among the three levels of nitrogen, 25 kg N per hectare gave the highest net profit of Rs.3267/- per hectare. The lowest net profit of Rs.2951/-per hectare was obtained from control.

The variation in net profit was observed due to levels of phosphorus. The maximum net profit of Rs.3160/- per hectare was secured from the plots receiving 50 kg P_2O_5 per hectare. The phosphorus levels of 0,50 and 100 kg per hectare showed the net profit of Rs.3056, 3160 and 3111/- per hectare respectively.

Among the various treatment combinations, it was observed that the sowing at 30 cm intra-row spacing with application of 25 kg N per hectare and 50 kg P_2O_5 per hectare gave the highest net profit of Rs.4926/-per hectare followed by the treatment combination of $S_{30}N_{25}P_{100}$ (Rs.4851/-per hectare), while the lowest net profit of Rs.1569/- per hectare was obtained from the $S_{90}N_{50}P_{100}$ treatment combination.

DISCUSSION

The results of the investigation carried out to study effects of various levels of spacing, nitrogen and phosphorus on yield and quality as well as various yield and yield parameters of pigeon pea are discussed below

1.1 Grain yield

The data (Table 7) on effect of intra-row spacings on pigeon pea yield revealed that 30 cm intra-row spacing gave the highest grain yield of 2001 kg/ha. It showed 39.23 and 74.15 per cent increase in grain yield over 60 and 90 cm intra-row spacing respectively. This kind of response may be due to higher plant population per hectare in narrow spacing. The results are in agreement with the results of Mahalingam (1966), Derieux (1969), Sen et al.(1970), Emmerton (1971), Chaudhary and Martin (1971), Veeranna et al.(1972), Ahuwan and Sahib (1973), Mehta et al. (1974), Krinsin and Whitney (1974), Emmerton (1976), Tabbalii et al.(1976), Shroff et al.(1977), Mehta and Rajpathi (1978), Subramani et al.(1978) and Singh et al.(1978). They observed that increase in row spacing resulted in significant reduction in plant stand per unit area which could not be compensated for by higher yield per plant under wider spacing and thus yield per hectare was reduced.

The results of seed yield presented in table 7 revealed that the effect of nitrogen levels was significant on seed yield of pigeon pea. Application of 25 kg N per

hectare increased the grain yield by 4.09 and 10.79 per cent over 50 kg and no nitrogen per hectare respectively. These results have clearly indicated that aplication of nitrogen beyond 25 Kg per hectare did not increase the seed yield of pigeon pea. The results are in conformity with those reported by Dalal (1974) Dalal and Gulit (1977) and Lenka and Satpathy (1976).

The data on seed yield showed that pigeon pea responded well to application of phosphorus and a significant increase in seed yield was noticed with each successive higher dose of phosphorus from 0 to 100 kg P_2O_5 per hectare. Application of 100 kg P_2O_5 per hectare showed increase in grain yield by 9088 and 4.04 per cent over 0 kg and 50 kg P_2O_5 per hectare respectively. Thus seed yield of pigeon pea showed linear response to phosphorus. The results are in close conformity with those reported by Anam (1976), Chaudhary and Bhatia (1971), Mangla et al.(1973), Rathi et al.(1974), Singh et al. (1976); Lenka and Satpathy (1976), Dalal and Gulit (1977), Rao (1977) and Ramanathan et al.(1977).

All the interactions were significant in their effects on grain yield of pigeon pea. In case of spacing x nitrogen interaction, the maximum grain yield was obtained from the treatment combination $S_{90}N_{25}$ (2067 kg/ha), while the minimum grain yield was obtained from the combination of $S_{90}N_0$ (963 kg/ha). Thus it was observed that in respect of grain yield, wider spacing in combination with the lowest dose of

nitrogen was unaffective as the closer spacing combined with medium dose of nitrogen as observed in the present study. In spacing x phosphorus interaction, the combination of $S_{30}P_{100}$ showed significantly more grain yield (2085 kg/ha) than rest of the combinations. Similar results were reported by Sethi et al.(1974). As regards effect of nitrogen x phosphorus, the treatment combination $N_{25}P_{100}$ was significantly superior to the rest of the treatment combinations. The mean value of grain yield per hectare for the above combination was [illegible] kg/ha. In case of higher order interaction spacing x nitrogen x phosphorus, the combination of $S_{30}N_{25}P_{100}$ was superior to the rest of the combinations. It produced the highest grain yield of 2062 kg/ha as against the minimum of 989 kg/ha at $S_{90}N_{0}P_{0}$ combination.

5.2 Stalk yield

It was seen from the data (Table [illegible]) that the dry matter (stalk) yield trend was also similar to that of grain yield. Out of the three intra-row spacings studied, the stalk production was found maximum with closer spacing. Intra-row spacing of 30 cm resulted in increased stalk yield by [illegible] and [illegible] per cent over 60 and 90 cm respectively. This was due to greater plant population in 30 cm intra-row spacing than those under 60 and 90 cm intra-row spacings. The increase in stalk yield under narrow row spacing was reported by Akinola and Whiteman (1975) and Singh et al.([illegible]).

Stalk yield was significantly affected by graded doses of nitrogen. Application of 25 kg N per hectare gave the highest stalk yield of 4370 kg/ha which was 5.22 and 3.94 per cent higher than those of 0 and 50 kg N per hectare respectively. Such increase in stalk yield involving application of 25 kg N per hectare appear to be due to increased number of branches as compared to that under the rest of the nitrogen levels (Table 13). The findings are in agreement with the results reported by Singh et al.(1976) and Lenka and Satpathy (1976).

As regards effect of phosphorus, all the three levels differed significantly among themselves in respect of stalk yield per hectare. There was a linear increase in stalk yield with increase in the dose of the phosphorus application. The highest stalk yield was seen in the high phosphorus dose of 100 kg P_2O_5 per hectare. The increases in yield were by 7.29 and 2.97 per cent over 0 kg and 50 kg P_2O_5 per hectare respectively. Increase in stalk yield with increase in phosphorus levels might be due to corresponding increase in plant height and number of branches per plant (Table 14 and 15). These findings are supported by Akinola and Whiteman (1975); Lenka and Satpathy (1976) and Singh et al. (1976).

Among the effective combination of applying N nitrogen, the combination of $S_{90}N_{25}$ gave the highest stalk yield of 5282 kg/ha. It was 42.97 per cent higher than that of $S_{90}N_0$. As regard the effect of interaction of applying N phosphorus, the combination $S_{90}P_{100}$ gave the highest stalk yield of 5203 kg/ha but it was significantly superior to the rest of the combinations.

In case of nitrogen x phosphorus interaction, the application of 25 kg N and 100 kg P_2O_5 per hectare helped in producing higher stalk yield of 4198 kg/ha. It was 7.04 per cent higher than that of N_0P_0. In three factor interaction (spacing x nitrogen x phosphorus), the combination $S_{30}N_{25}P_{100}$ was superior to the rest of the combinations. It produced the highest stalk yield of 5432 kg/ha as against the minimum of 3031 kg/ha under $S_{90}N_0P_0$ combination.

5.3 Yield of bhusa (gorat)

The data on yield of bhusa presented in Table 9, indicated that the narrow intra-row spacing of 30 cm produced significantly more bhusa than those by 60 and 90 cm. The intra-row spacing of 30 cm gave 48.36 and 87.47 per cent more bhusa than those of 60 and 90 cm respectively. The reason that can be attributed to the significant response in favour of 30 cm intra-row spacing seems to be increased number of plants per plot.

Significant effect of nitrogen levels was observed bhusa yield. Application of 25 kg N per hectare gave 2.57 and 18.52 per cent more bhusa yield than those of 50 kg N and 0 kg N per hectare respectively. The probable reason for comparatively high yield of bhusa in the plots receiving 25kg N per hectare seems to be the increased number of pods per plant and subsequently increased yield of grains per plant as well as per hectare which could be evindenced from the data given in Table 12, 11 and 7 respectively. These results are in conformity with th reported by Lenka and Satpathy (1976).

Yield of bhusa significantly affected by graded doses of phosphorus. Application of 100 kg P_2O_5 per hectare showed significant superiority over 50 kg P_2O_5 and no application of P_2O_5 per hectare. Application of 100 kg P_2O_5 per hectare produced 11.77 and 5.04 per cent more yield of bhusa than those by 0 kg and 50 kg P_2O_5 per hectare respectively. Increase in yield of bhusa with increase in phosphorus level might be due to corresponding increase in plant height and number of pods per plant (Table 14 and 12). The findings are in agreement with the results reported by Lenka and Satpathy (1976).

All the interactions were significant in their effects on yield of bhusa per hectare. In case of spacing x nitrogen interaction, the combination of $S_{30}N_{25}$ produced significantly more yield of bhusa than that by the rest of the combi tions. The combination $S_{30}N_{25}$ increased the yield of bhusa per hectare by 12.19, 2.95, 179.46, 44.42, 47.06, 111.22, 87.22 and 92.68 per cent over that by $S_{30}N_0$, $S_{30}N_{50}$, $S_{60}N_0$, $S_{60}N_{25}$, $S_{60}N_{50}$, $S_{90}N_0$, $S_{90}N_{25}$ and $S_{90}N_{50}$ respectively. In case of spacing x phosphorus interaction, the combination $S_{30}P_{100}$ showed significantly more yield of bhusa per hectare than that by the rest of the combinations. It was 9.68, 4.07, 68.71, 53.23, 44.72, 104.53, 97.40 and 86.45 per cent more than those by $S_{30}P_0$, $S_{30}P_{50}$, $S_{60}P_0$, $S_{60}P_{50}$, $S_{60}P_{100}$, $S_{90}P_0$, $S_{90}P_{50}$ and $S_{90}P_{100}$ respectively. As regards effects of nitrogen x phosphorus interaction, the combination $N_{25}P_{100}$ was superior in yield of bhusa per hectare to the rest of the combinations. The combination of $N_{25}P_{100}$ produced 30.10, 23.42, 15.79, 13.36, 5.55,

14.44, 7.79 and 4.49 per cent more yield of bhusa over N_0P_0, N_0P_{50}, N_0P_{100}, $N_{25}P_0$, $N_{25}P_{50}$, $N_{50}P_0$, $N_{50}P_{50}$ and $N_{50}P_{100}$ respectively. In case of higher order interaction spacing x nitrogen x phosphorus, the combination of $S_{30}N_{25}P_{100}$ was superior to rest of the combinations. It produced the maximum yield of bhusa 2900 kg/ha as against the minimum of 1307 kg/ha at $S_{90}N_0P_0$ combination as observed in the present investigation.

5.4 Harvest index

Differences in harvest index due to spacings were significant. The intra-row spacing of 30 cm showed significantly higher harvest index than those observed in 60 and 90 cm intra-row spacings. The later two did not differ in their effect on this character. The intra-row spacing of 30 cm showed 6.22 and 6.22 per cent more harvest index than those of 60 and 90 cm intra-row spacings respectively.

Significant differences in harvest index were observed due to nitrogen levels. Application of 25 kg N per hectare produced 0.249 harvest index and was significantly superior to 0 kg N per hectare. However, it did not show such superiority over 50 kg N per hectare. Application of 25 kg N per hectare gave 2.47 and 1.22 per cent higher harvest index than that of 0 and 50 kg N per hectare respectively.

Differences in harvest index due to different phosphorus levels were not significant. However, the application of 100 kg P_2O_5 per hectare tended to show slight superiority in harvest index to rest of the phosphorus levels. These findings are in agreement with the results reported by Kaul and Sekhon (1975), and Singh et al.(1976).

In case of spacing x nitrogen interaction, the combination $S_{30}N_{50}$ was found superior to the rest of the combination by giving 0.259 harvest index. The minimum harvest index of 0.233 was observed under $S_{90}N_0$ combination. Under spacing x phosphorus interaction, the combination $S_{30}P_{100}$ showed significantly higher harvest index (0.259) than that by the rest of the combinations. The interaction of nitrogen x phosphorus and spacing x nitrogen x phosphorus were not significant.

5.5 Grain yield per plant

The results obtained in respect of grain yield per plant as affected by different spacing treatments (Table 11) revealed that there was significant difference with respect to spacings. The widest spacing of 90 cm proved to be effective in maximizing seed yield per plant as compared to other two spacings of 30 and 60 cm. The intra-row spacing of 90 cm showed 15.87 and 73.46 per cent more seed yield per plant than those of 60 and 30 cm respectively. The increase in yield per plant with wider spacing was due to the favourable effects of moisture, light, air, nutrients etc. and large number of brahches and increased number of pods per plant (Table 13 and 13) as compared to thoseunder narrow intra-row spacings.

The findings are in agreement with those reported by Mukherjee (1969), Trivedi (1969), Emmerton (1971), Emmerton (1975) and Singh gill. (1976).

The data on weight of seeds per plant reported in Table XI showed that the effect due to application of 0, 25 and 50 kg N per hectare was significant and they differed significantly among themselves. Application of 25 kg N per hectare produced 17.34 and 2.61 per cent more yield per plant than that by no nitrogen and 50 kg N per hectare respectively. Maximum seed yield per plant was secured by 25 kg N per hectare.

Significant differences were observed in grain yield per plant due to phosphorus levels. There was increase from 118.8 to 125.0 g in grain yield per plant with increase in dose of phosphorus from 0 to 100 kg P_2O_5 per hectare. The dose of 100 kg P_2O_5 per hectare gave the highest grain yield per plant (125.0 g) and was significantly superior to rest of the doses, while the dose of 50 kg P_2O_5 per hectare ranked the second position (123.5 g) and was significantly superior to no P_2O_5 (118.8 g). The plots receiving 100 kg P_2O_5 per hectare gave 5.12 and 2.00 per cent more yield than those of receiving 50 kg P_2O_5 and no P_2O_5 per hectare respectively.

All the interactions were significant in their effects on grain yield per plant. In case of cropping x nitrogen interaction, the combination of $S_{90}N_{25}$ was superior to the rest

of the combinations. by producing 153.0 gm grain yield per plant. The percentage increased in yield of grain per plant under $S_{90}N_{25}$ treatment combination over $S_{30}N_0$, $S_{30}N_{25}$, $S_{30}N_{50}$, $S_{60}N_0$, $S_{60}N_{25}$, $S_{60}N_{50}$, $S_{90}N_0$ and $S_{90}N_{50}$ were 85.0, 70.57, 76.47, 24.59, 13.67, 17.42, 5.08 and 1.66 respectively. Under spacing x phosphorus interaction, the combination $S_{90}P_{100}$ gave significantly more grain yield per plant than that by the rest of the combinations. It was 83.43, 76.83, 68.03, 20.56, 17.75, 14.47, 2.91 and 1.54 per cent more than that of $S_{30}P_0$, $S_{30}P_{50}$, $S_{30}P_{100}$, $S_{60}P_0$, $S_{60}P_{50}$, $S_{60}P_{100}$ $S_{90}P_0$, and $S_{90}P_{50}$ respectively. As regards effects of nitrogen x phosphorus, the combination $N_{25}P_{100}$ was superior to the rest of the combinations. The combination $N_{25}P_{100}$ showed 13.56, 11.23, 8.08, 6.57, 3.34, 8.08, 6.22, and 3.77 per cent more grain yield than that by N_0P_0, N_0P_{50}, N_0P_{100}, $N_{25}P_0$, $N_{25}P_{50}$, $N_{50}P_0$, [illegible], $N_{50}P_{50}$ and $N_{50}P_{100}$ respectively. In case of higher order interaction spacing x nitrogen x phosphrus, the combination $S_{90}N_{25}P_{100}$ was superior to the rest of the combinations. It produced the highest grain yield per plant (155.2 gm) as against the minimum of 80.2 gm per plant under $S_{30}N_0P_0$ combination, which showed 93.52 per cent increase over that of $S_{30}N_0P_0$.

5.6 Number of pods per plant

Significant differences were observed in the number of pods per plant due to various intra-row spacing treatments.

Among the three intra row spacings (30,60 and 90), the intra-row spacing of 90 cm yielded the highest number of pods per plant. Accordingly 90 cm gave 63.90 and 21.00 per cent increase in number of pods per plant over that of 30 and 60 cm intra-row spacings, respectively. The increase in number of pods per plant in favour of wider intra-row spacing apparently seems to be due to large area available per plant than that with narrow intra-row spacing resulting in reduced competition for nutrients, moisture, air, light etc. and subsequently providing better conditions for plant development and increased number of branches per plant (Table 13). This is in conformity with the observations of Trivedi (1960), Emmerton (1971), Abreme and Julia (1973) Emmerton (1976) and Singh et al. (1978).

There were significant differences in number of pods per plant due to nitrogen application. The highest number of pods per plant was secured with application of 25 kg N per hectare. The increase over 0 and 50 kg N per hectare was 1.29 and 0.87 per cent respectively. The findings are supported by Manjhi et al.(1975).

As to the effect of phosphorus levels on number of pods per plant, significant increase in number of pods per plant was observed with successive increase in dose of phosphorus. The phosphorus dose of 100 kg per hectare produced the highest number of pods per plant and no phosphorus per hectare

produced the lowest number of pods per plant. The application of 100 kg P_2O_5 per hectare gave 2.53 and 1.11 per cent more number of pods per plant than those of 0 and 50 kg P_2O_5 per hectare respectively. These results are in concurrence with those reported by Manjhi et al.(1975), Singh et al.(1976), and Ramanathan et al.(1977).

As regards effects of spacing x nitrogen interaction, the combination $S_{90}N_{25}$ produced the highest number of pods per plant. It gave 66.45, 62.36, 65.37, 21.75, 21.04, 21.91, 1.13 and 0.31 per cent increase in number of pods per plant over those of $S_{30}N_0$, $S_{30}N_{25}$, $S_{30}N_{50}$, $S_{60}N_0$, $S_{60}N_{25}$, $S_{60}N_{50}$, $S_{90}N_0$ and $S_{90}N_{50}$ respectively. Under spacing x phosphorus interaction, the combination $S_{90}P_{100}$ showed significant increase in number of pods per plant (359.0) over that by the rest of the combinations. The minimum number of 214.6 pods per plant was observed under $S_{30}P_0$ combination. The combination $S_{90}P_{100}$ gave 69.18, 65.13, 62.44, 25.20, 22.36, 21.00, 2.13 and 0.79 per cent increase in number of pods per plant over that by $S_{30}P_0$, $S_{30}P_{50}$, $S_{30}P_{100}$, $S_{60}P_0$, $S_{60}P_{50}$, $S_{60}P_{100}$ $S_{90}P_0$ and $S_{90}P_{50}$ respectively. In case of nitrogen x phosphorus interaction, the treatment combination $N_{25}P_{100}$ produced significantly more pods per plant that that by the rest of the treatments. The percentage increases in number of pods per plant in $N_{25}P_{100}$ treatment over N_0P_0, N_0P_{50}, N_0P_{100},

$N_{25}P_0$, $N_{25}P_{50}$, $N_{50}P_0$, $N_{50}P_{50}$ and $N_{50}P_{100}$ were 4.06, 2.75, 1.62, 3.11, 1.41, 3.51, 2.22 and 1.34 respectively. As regards the higher order interaction (Spacing x nitrogen x phosphorus) the combination $S_{90}N_{25}P_{100}$ was superior to rest of the combinations. It produced the highest number of pods per plant (361.3) as against the minimum (210.3) under $S_{30}N_0P_0$ combination.

5.7 Number of branches per plant:

Differences in number of branches per plant due to various spacing treatments were significant. The intra-row spacing of 90 cm produced significantly more number of branches per plant than those by 30 and 60 cm intra-row spacings. The intra-row spacing of 90 cm showed 44.31 and 21.77 per cent higher number of branches per plant than those of 30 and 60 cm respectively. Such increase in branches per plant due to wider intra-row spacing especially 90 cm seems to be due to the larger area available per plant, with co paratively increased supply of moisture and nutrients when compared with that under narrow intra-row spacings. These findings are in confirmity with the findings of Trivedi (1960), Akinola and Whiteman (1975) and Singh et al.(1978).

The number of branches per plant due to nitrogen levels differed significantly. The highest number of branches per plant was recorded when nitrogen was applied at the rate of 25 kg per hectare. Application of 25 kg N per hectare showed 6.57 and 4.38 per cent more branches per plant than those of 0 and 50 kg N per hectare.

There were significant differences in number of branches per plant due to various doses of phosphorus. Number of branches per plant increased with increase in level of phosphorus. Application of 100 kg P_2O_5 per hectare produced the maximum number of branches per plant and it was significantly superior to the rest of the P_2O_5 levels. The effect of phosphorus on this character was linear in nature. Application of 100 kg P_2O_5 per hectare produced 10.11 and 3.96 per cent more branches per plant than that of 0 and 50 kg P_2O_5 per hectare respectively. These results are similar to those reported by Singh et al. (1978).

As regards the effect of spacing x nitrogen interaction, the combination of $S_{90}N_{25}$ produced the highest number of branches per plant. It was 56.00, 43.68, 51.67, 28.17, 22.42, 26.39, 7.91 and 3.41 per cent more than that by $S_{30}N_0$, $S_{30}N_{25}$, $S_{30}N_{50}$, $S_{60}N_0$, $S_{60}N_{25}$, $S_{60}N_{50}$, $S_{90}N_0$ and $S_{90}N_{50}$ respectively. In spacing x phosphorus interaction, the combination of $S_{90}P_{100}$ showed significantly more number of branches per plant (27.2) than the rest of the combinations. The minimum number of 16.7 branches per plant was observed at $S_{30}P_0$ combination. The combination $S_{90}P_{100}$ gave 68.87, 47.83, 40.21, 31.40, 24.20, 20.35, 6.67, and 3.42 per cent increase in number of branches per plant over that by $S_{30}P_0$, $S_{30}P_{50}$, $S_{30}P_{100}$, $S_{60}P_0$, $S_{60}P_{50}$, $S_{60}P_{100}$, $S_{90}P_0$ and $S_{90}P_{50}$ respectively. In case of nitrogen x phosphorus

interaction, the treatment combination $N_{25}P_{100}$ produced significantly more number of branches per plant than the rest of the treatments. The percentage increase in number of branches per plant in $N_{25}P_{100}$ treatment combination over N_0P_0, N_0P_{50}, N_0P_{100}, $N_{25}P_0$, $N_{25}P_{50}$, $N_{50}P_0$, $N_{50}P_{50}$ and $N_{50}P_{100}$ was 17.07, 12.15, 6.67, 11.63, 3.90, 15.38, 8.60 and 5.26 per cent respectively. As regards to the higher order interaction spacing x nitrogen x phosphorus, the combination of $S_{30}N_{25}P_{100}$ was superior to rest of the combinations. It produced the maximum number of branches per plant (28.3) as against the minimum of 16.4 in $S_{30}N_0P_0$ combination.

5.5 Plant height

As to the effect of different intra-row spacings on plant height, it was observed that there was significant difference in plant height due to intra-row spacings. The intra-row spacings of 30 and 60 cm were at par and produced significantly taller plants than that of 90 cm intra-row spacing. The 30 cm intra-row spacing showed 0.12 and 3.37 per cent more highest height than those of 60 and 90 cm intra-row spacings respectively. The results are supported by Ramamurthy (1971) and Akinola and Whiteman (1975).

It was observed that there was significant increase in plant height with successive increase in level of nitrogen. The maximum plant height of 224.19 cm was obtained by application of 50 kg N per hectare. The plots treated with 50 kg N per hectare produced 2.76 and 1.29 per cent more plant height than those of 0 and 25 kg N per hectare respectively. The results are in agreement with those reported by Singh et al.(1976).

Differences in plant height due to phosphorus application were significant. Application of 50 kg P_2O_5 per hectare produced significantly taller plants than those observed in 0 and 100 kg P_2O_5 per hectare. The later two did not differ in their effects on this character. Application of 50 kg P_2O_5 per hectare showed 1.53 and 1.09 per cent more plant height than those of 0 and 100 kg P_2O_5 per hectare. The findings are in concurrence with the findings reported by Singh et al.(1976).

All the interactions were found to be significant in their effects on plant height. As to the effect of spacing x nitrogen interaction, the combination of $S_{60}N_0$ produced the tallest plants (231.05 cm), while $S_{90}N_0$ produced the shortest plants. The combination $S_{30}N_{25}$, $S_{30}N_{50}$ and $S_{60}N_{50}$ did not differ in their effects on this character. The combination $S_{60}N_0$ produced 15.36, 1.56, 1.74, 1.86, 12.87, 4.17 and 5.68 per cent more height than those by $S_{30}N_0$, $S_{30}N_{25}$, $S_{30}N_{50}$, $S_{60}N_{25}$, $S_{60}N_{50}$, $S_{90}N_0$ and $S_{90}N_{50}$ and $S_{90}N_{25}$ respectively. As regards the effect of spacing x phosphorus interaction, the combination $S_{30}P_{100}$ was superior in plant height to rest of the combinations except $S_{60}P_{50}$ and $S_{60}P_0$. The combination of $S_{30}P_{100}$ showed 15.70, 2.32, 0.43, 0.04, 7.68, 8.15, 7.13 and 5.62 per cent increase in plant height over $S_{30}P_0$, $S_{30}P_{50}$ $S_{60}P_0$, $S_{60}P_{50}$, $S_{60}P_{100}$, $S_{90}P_0$, $S_{90}P_{50}$ and $S_{90}P_{100}$ respectively. In nitrogen x phosphorus interaction, the combination of $N_{50}P_{100}$ produced taller plants than that by the rest of the

combinations. The combinations $N_{50}P_{100}$, $N_{50}P_{50}$ and $N_{25}P_{50}$ did not differ significantly in their effects on plant height. Likewise $N_{25}P_{100}$, $N_{50}P_{0}$, $N_{0}P_{0}$, $N_{0}P_{50}$ and $N_{25}P_{0}$ were also at par in this respect. The combination $N_{50}P_{100}$ produced 2.84, 3.02, 3.54, 0.96, 2.31, 2.57 and 0.33 per cent more plant height than those by $N_{0}P_{0}$, $N_{0}P_{50}$, $N_{0}P_{100}$, $N_{25}P_{0}$, $N_{25}P_{50}$, $N_{25}P_{100}$, $N_{50}P_{0}$ and $N_{50}P_{50}$ respectively. As regards three factor interaction, the combination $S_{30}N_{25}P_{100}$ was superior to the rest of the combinations. It produced the maximum plant height of 244.07 cm as against the minimum of 211.00 cm at $S_{30}N_{0}P_{0}$ combination.

5.9 Test weight (100 seeds weight)

As to the effect of different intra-row spacings on seed development, it was observed that there was significant difference in test weight due to intra-row spacings. The intra-row spacing of 90 cm secured the highest test weight of 114.22 gm, while it was the minimum in case of 30 cm intra-row spacing (108.09 gm). The intra-row spacing of 90 cm showed 5.67 and 1.62 per cent more test weight than those by 30 and 60 cm. The increase in test weight with increase in intra-row spacing might be due to increased availability of moisture, light, nutrients, air etc. which effect favourably.

Significant differences in test weight were observed due to nitrogen levels. Applications of 25 and 50 kg N per hectare were at par and produced significantly more test weight than that by 0 kg N per hectare. Application of 50 kg N per hectare showed 0.68 and 1.08 per cent more test weight than those by 0 and 25 kg N per hectare. The results are similar to those reported by Manjhi et al. (1973).

There was significant increase in test weight with successive increase in dose of phosphorus. The highest test weight of 112.17 gm was observed by application of 100 kg P_2O_5 per hectare. The minimum test weight was found by application of 0 kg P_2O_5 per hectare. Application of 100 kg P_2O_5 per hectare showed 0.97 and 0.65 per cent more test weight than those of plots receiving no P_2O_5 and 50 kg P_2O_5 per hectare. The results are in agreement with those observed by Manjhi et al.(1973).

As regards the effect of spacing x nitrogen interaction, the combination of $S_{90}N_{25}$ was found superior to the rest of the combination. It showed 114.58 gm test weight while the lowest test weight of 107.45 gm was observed at $S_{90}N_0$ combination. The combination $S_{30}N_{25}$ produced 6.60, 5.84, 5.38, 3.08, 1.44, 1.30, 0.69 and $^{0.23}_{\wedge}$ per cent more test weight than those by $S_{30}N_0$, $S_{30}N_{25}$, $S_{90}N_{50}$, $S_{60}N_{25}$, $S_{60}N_{50}$, $S_{90}N_0$ and $S_{90}N_{50}$ respectively. In case of interaction spacing x phosphorus, the combination of $S_{90}P_{100}$ showed significantly more test weight (114.40 gm) than that

by the rest of the combinations except $S_{90}P_{50}$. The combination $S_{90}P_{100}$ produced 6.61, 6.28, 4.87, 2.29, 1.83, 1.44, 0.45 and 0.24 per cent more test weight than those of $S_{30}P_{0}$, $S_{30}P_{50}$, $S_{30}P_{100}$, $S_{60}P_{0}$, $S_{60}P_{50}$, $S_{60}P_{100}$, $S_{90}P_{0}$, and $S_{90}P_{50}$ respectively. The interactions of nitrogen x phosphorus and spacing x nitrogen x phosphorus were not significant in this character.

5.10 Protein content

Differences in protein content of pigeon pea were significant due to different intra-row spacings. All the intra-row spacings were significantly differed among themselves in this respect. The intra-row spacing of 90 cm produced the maximum protein content (25.71 per cent) while 30 cm produced the minimum protein content (24.21 per cent). The intra-row spacing of 90 cm showed increase in protein content by 6.20 and 3.59 per cent over 30 and 60 cm intra-row spacings respectively. The results are in agreement with those reported by Trivedi (1960), and Lenka and Satpathy (1976).

The data on protein content indicated that application of nitrogen showed significant effect on protein content. Application of 50 kg N per hectare produced maximum protein content (25.62 per cent), while application of 0 kg N per hectare produced the minimum protein content (24.43 per cent). The plots receiving 50 kg N per hectare showed increase in protein content by 4.87 and 3.68 per cent protein content over 0 and 25 kg N per hectare respectively. These results are in conformity with those reported by Manjhi et al. (1973).

There were significant differences in protein content due to phosphorus levels. The protein content was found to be increased with increase in phosphorus level. The highest dose of phosphorus (100 kg P_2O_5 per hectare) showed the maximum protein content of 25.37 per cent and minimum was found in the plots receiving 0 kg P_2O_5 per hectare. Application of 100 kg P_2O_5 per hectare showed increase in protein content by 3.34 and 2.17 per cent over those of 0 and 50 kg P_2O_5 per hectare respectively. The results are in agreement with those reported by Manjhi et al. (1973), Singh et al and Prasad (1976) and Rao (1977).

In case of interactions, all the interactions were found to have significant effect on protein content of pigeon pea. In case of interaction of spacing x nitrogen, the combination $S_{90}P_{50}$ showed significantly more protein content (25.82 per cent) than those of rest of the combinations. The lowest protein content of 23.57 per cent was found in $S_{30}N_0$ combination. The combination $S_{90}N_{50}$ produced 9.55, 8.99, 11.17, 7.63, 3.95, 0.66, 0.35 and 0.90 per cent more protein content than those by $S_{30}N_0$, $S_{30}N_{25}$, $S_{30}N_{50}$, $S_{60}N_0$, $S_{60}N_{25}$, $S_{60}N_{50}$, $S_{90}N_0$ and $S_{90}N_{25}$ respectively. As to the interaction of spacing x phosphorus, the combination $S_{90}P_{100}$ showed significantly more protein content (26.37 per cent) than that by the rest of the combinations. The increase was 11.41, 8.61, 6.85, 7.81. 5.65, 5.27, 3.37 and 4.39 per cent protein content over $S_{30}P_0$, $S_{30}P_{50}$, $S_{30}P_{100}$, $S_{60}P_0$, $S_{60}P_{50}$, $S_{60}P_{100}$, $S_{90}P_0$ and $S_{90}P_{50}$ respectively. In respect of the interaction of nitrogenxphosphorus, the combination $N_{50}P_{100}$ showed significantly ore protein content (.03 per cent) than that observed in the rest of the c binations. The lowest protein content of 23.94 per cent

was found in the combination N_2P_2. The combination $N_{50}P_{100}$ showed increase by 8.7%, 8.4%, 2.7%, 6.8%, 3.8%, 5.3%, 2.5% and 2.3% per cent over that of N_0P_0, N_0P_{50}, N_0P_{100}, $N_{25}P_0$, $N_{25}P_{50}$, $N_{25}P_{100}$, $N_{50}P_0$ and $N_{50}P_{50}$ respectively. As regards effect of interaction of spacing x nitrogen x phosphorus, the combination $S_{30}N_{25}P_{100}$ showed 23.8% per cent protein content and it was significantly more than that by the rest of the combinations. The lowest protein content of 22.19 per cent was observed in case of $S_{30}N_{25}P_0$ combination.

5.11 Economic return.

Data reported in Table 37 revealed that spacing at 30 cm intra-row spacing gave more net profit per hectare (Rs.4974/-) than those by 60 cm (Rs.3795/-per hectare) and 90 cm (Rs.3703/- per hectare). The intra-row spacing of 30 cm resulted into increase in net profit by 31.03 and 34.27 per cent over 60 and 90 cm intra-row spacings respectively. The increase in net profit at 30 cm intra-row spacing was mainly due to higher yield of grain, which was more than those by 60 and 90 cm intra-row spacings as observed in the present investigation. The results are substantiated with findings obtain by Singh et al.(1978).

The three levels of nitrogen viz. 0, 25 and 50 kg per hectare gave Rs.3934, 4007/- and 3990/-per hectare respectively. Application of 25 kg N per hectare gave higher net profit than that by the rest of the combinations. Application of 25 kg N per hectare resulted into increase in

net profit by 10.71 and 8.97 per cent over 0 and 50 kg N per hectare respectively. The net profits at 25 kg N and 50 kg N were more than that by 0 kg N per hectare. But the increased rate of application of nitrogen under 50 kg N per hectare did not compensate the increased cost of nitrogen as compared to that under 25 kg N per hectare giving corresponding increase in yields of grain, stalk and bhusa. Thus, application of 25 kg N per hectare proved to be the most effective and economical.

As regards phosphorus levels, application of 50 kg P_2O_5 per hectare gave the maximum net profit of Rs.3164/- per hectare followed by application of 100 kg and 0 kg P_2O_5 per hectare. The later two levels gave Rs.3111/- and Rs.3056/- net profit per hectare respectively. Application of 50 kg P_2O_5 per hectare gave 3.40 and 1.58 per cent higher net profit than that by the application of 0 and 100 kg P_2O_5 per hectare respectively. Application of 100 kg P_2O_5 per hectare gave lower net profit than that by the application of 50 kg P_2O_5 per hectare because of high cost of phosphorus (5 Rs/kg P_2O_5). The results are in agreement with those reported by Chowdhury and Bhatia (1971) and Singh et al. (1976).

As to the effect of treatment combinations, $S_{30}N_{25}P_{50}$ gave the maximum net profit of Rs.4926/- per hectare, while the lowest net profit of Rs.1569/- was realised in case of $S_{90}N_{50}P_{100}$.

The results as a whole, lead to the findings that optimum and economical yield of pigeon pea grain could be obtained by adopting the spacing of 150 cm x 30 cm with fertilizer application of 25 kg N and 50 kg P_2O_5 per hectare.

Practical application:

The results obtained in this investigation brought out the following findings for practical considerations for cultivation of pigeon pea.

(i) Spacing of 150 cm x 30 cm should be adopted for maximum production of pigeon pea.

(ii) Nitrogen @ 25 kg and phosphorus @ 50 kg per hectare should be applied for securing the highest yield of pigeon pea.

SUMMARY AND CONCLUSIONS

With a view to find out suitable spacing, nitrogen and phosphorus levels for maximum and economical grain production of pigeon pea per unit area, the present investigation was carried out at the Agronomy Farm, B.A. College of Agriculture, Gujarat Agricultural University, Agricultural Campus, Anand, during the kharif season of 1980-81. The soil of this area is sandy loam in nature.

In all, twentyseven treatment combinations comprising three levels of spacing (150 x 30 cm, 150 x 60 cm and 150 x 90 cm), three levels of nitrogen(0, 25 and 50 kg and N per hectare) and three levels of phosphorus (0, 50and 100 kg P_2O_5 per hectare) were included in the study. A 3^3 partial confounding factorial design was employed with three replications in this investigation.

During the course of investigation, treatment effects were studied on grain yield, stalk yield, straw yield,harvest index, grain yield per plant, number of pods per plant,number of branches per plant, plant height, test weight and protein content of seeds. The economics for each of the treatments was also worked out. The results obtained with respect to treatment effects on the aforesaid characters are summarised as follows:

I EFFECT OF SPACING

(1) There was significant effect of spacing on grain yield per hectare. The maximum grain yield (2001 kg/ha) was secured by 30 cm intra-row spacing. It was 29.15 and

74.15 per cent more than those of 60 and 90 cm intra-row spacings respectively.

(2) The intra-row spacing of 30 cm gave significantly more stalk yield (5044 kg/ha) than that by the other two intra-row spacings. It showed increase by 22.99 and 55.27 per cent over 60 and 90 cm intra-row spacings respectively.

(3) Significant increase in bhusa yield was obtained with narrow intra-row spacing of 30 cm (2767 kg/ha). It was 48.36 and 87.47 per cent more than that by 60 and 90 intra-row spacings respectively.

(4) As regards harvest index, the intra-row spacing of 30 gave significantly higher harvest index (0.256) than that by 60 and 90 cm intra-row spacings. Effects of 60 and 90 cm intra-row spacings on harvest index were at par.

(5) The highest grain yield of 149.7 gm per plant was secured by wider intra-row spacing of 90 cm. It was 73.46 and 15.87 per cent more than that by 30 and 60 cm intra-row spacings respectively.

(6) The maximum number of pods per plant (355.9) was recorded under the intra-row spacing of 90 cm. It was 63.90 and 21.00 per cent more than that by 30 and 60 cm intra-row spacings respectively.

(7) The maximum number of branches per plant (28.55) was obtained by wider intra-row spacing of 90 cm. It was 44.31 and 21.77 per cent more than that by 30 and 60 cm intra-row spacings respectively.

(8) The intra-row spacing of 30 cm produced significantly taller plants than that by 60 and 90 cm intra-row spacings.

(9) The maximum test weight (11.4 g) was secured under the intra-row spacing of 90 cm. It was 5.07 and 1.62 per cent more than that by 30 and 60 cm intra-row spacings respectively.

(10) The highest protein content of 23.71 per cent was secured under the intra-row spacing of 90 cm. It was 6.30 and 3.99 per cent more than that by 30 and 60 cm intra-row spacings respectively.

(11) The maximum net profit of Rs.4974/- was obtained at 90 cm intra-row spacing. It was Rs.1822/- and Rs.2785/- more than that by 60 and 90 cm intra-row spacings respectively.

II EFFECT OF NITROGEN

(1) Application of 25 kg N per hectare showed the highest grain yield of 1602 kg per hectare, which was 16.79 and 4.09 per cent more than that by 0 and 50 kg N per hectare respectively.

(2) Application of 25 kg N per hectare produced 4270 kg stalk per hectare. It was 5.22 and 3.04 per cent more than that by 0 and 50 kg N per hectare respectively.

(3) The maximum bhusa yield of 2152 kg per hectare was secured by 25 kg N per hectare. It was 18.52 and 2.57 per cent higher than that by 0 and 50 kg N per hectare respectively.

(4) Application of 25 kg N per hectare showed the highest harvest index (0.249). The increase was 2.47 and 1.22 per cent over 0 and 50 kg N per hectare respectively.

(5) The maximum grain yield per plant (125.7 gm) was secured by 25 kg N per hectare. It was17.44 and 2.61 per cent higher than that by 0 and 50 kg N per hectare respectively.

(6) Application of 25 kg N per hectare showed 290.8 pods per plant. It was 1.29 and 0.87 per cent more than that by 0 and 50 kg N per hectare respectively.

(7) The maximum number of branches per plant (22.87) was secured at 25 kg N per hectare, which was 6.57 and 4.38 per cent more than that by 0 and 50 kg N per hectare respectively.

(8) The maximum plant height of 224.19 cm was secured by 50 kg N per hectare, which was 2.76 and 1.29 per cent higher than that by 0 and 25 kg N per hectare respectively.

(9) The highest test weight (112.00 gm) was secured by 50 kg N per hectare. It was at par with that under 25 kg N per hectare.

(10) The highest dose of nitrogen (50 kg N Per hectare) showed the maximum protein content of 25.62 per cent

in pigeon pea. It was higher by 4.87 and 3.68 per cent than that by 0 and 25 kg N per hectare respectively.

(11) Application of 25 kg N per hectare showed the highest net profit of Rs.3267/- among all the treatments. It showed increase of Rs.316/- and Rs.269/- over 0 and 50 kg per hectare respectively.

4.12 EFFECT OF PHOSPHORUS

(1) Grain yield increased with increase in the levels of phosphorus. Application of 100 kg P_2O_5 per hectare showed the highest grain yield of 1597 kg per hectare. It was 9.88 and 4.04 per cent more than that by 0 and 50 kg P_2O_5 per hectare respectively.

(2) Application of 100 kg P_2O_5 per hectare produced the highest stalk yield of 4276 kg per hectare. It was 7.19 and 2.37 per cent higher than that by 0 and 50 kg P_2O_5 per hectare respectively.

(3) The maximum bhusa yield of 2146 kg per hectare was obtained under application of 100 kg P_2O_5 per hectare. It was 11.77 and 5.04 per cent more than that by 0 and 50 kg P_2O_5 per hectare respectively.

(4) There was no significant effect on harvest index due to phosphorus.

(5) Application of 100 kg P_2O_5 per hectare produced significantly increased grain yield per plant (125.0 gm).

It was 5.28 and 2.88 per cent higher than that by 0 and 50 kg P_2O_5 per hectare respectively.

(6) The maximum number of pods per plant (292.2) was secured at 100 kg P_2O_5 per hectare. It was 8.33 and 3.31 per cent more than that by 0 and 50 kg P_2O_5 per hectare respectively.

(7) Application of 100 kg P_2O_5 per hectare showed 23.08 branches per plant. It was 10.11 and 3.96 per cent higher than that by 0 and 50 kg P_2O_5 per hectare respectively.

(8) The maximum plant height of 225.14 cm was secured by 50 kg P_2O_5 per hectare. It was 1.93 and 1.09 per cent higherthan that by 0 and 100 kg P_2O_5 per hectare respectively.

(9) The highest test weight mt (112.17 gm) was observed by application of 100 kg P_2O_5 per hectare.

(10) Application of 100 kg P_2O_5 per hectare showed the highest protein content of 25.37 per cent in seed. It was 3.34 and 2.17 per cent higher than that by 0 and 50 kg P_2O_5 per hectare respectively.

(11) Application of 50 kg P_2O_5 per hectare showed higher net profit of Rs.3160/-. It was higher by Rs.104/- and Rs.49/- than that by 0 and 100 kg/per hectare respectively.

P_2O_5

IV EFFECT OF INTERACTION

(1) All the interactions were found to be significant in their effects on grain, stalk and bhusa yields per hectare. As to the effect of different interactions, as of S x N, S x P, and N x P, the combinations $S_{30}N_{25}$, $S_{30}P_{100}$ and $N_{25}P_{100}$ were found to be top ranking in producing grain, stalk and bhusa per hectare in their respective groups of combinations. In second order interaction, the combination $S_{30}N_{25}P_{100}$ secured the top position among all, by producing 2190, 5432 and 3242 kg grain, stalk and bhusa per hectare respectively.

(2) The interaction S x N and S x P produced significant differences in harvest index. The combination of $S_{30}N_{50}$ and $S_{30}P_{100}$ gave the highest harvest index of 0.29 and 0.28 and 0.238 respectively among all the combinations.

(3) All the interactions were found to be significant in their effects on grain yield per plant, number of pods per plant and number of branches per plant. As to the effect of different interactions of S x N, S x P, N x P and S x N x P, the combinations of $S_{90}N_{25}$, $S_{90}P_{100}$ and $S_{90}N_{25}P_{100}$ were found to be top ranking in producing grain yield per plant, number of pods per plant and number of branches per plant in their respective groups of combinations.

(4) The tallest plants of 244.07 cm were observed at S $_{90}N_{25}P_{100}$.

(5) The interactions of S x N and S x P were found significant in test weight seeds. The combinations of $S_{90}N_{25}$ and $S_{90}P_{100}$ gave the highest test weight (214.5% and 124.0% as respectively) among all the combinations.

(6) All the interactions were found to be significant in their effects on protein content of grain. The maximum protein content of [illegible] per cent was observed in $S_{90}N_{50}P_{100}$.

(7) The combination of $S_{30}N_{25}P_{50}$ gave maximum net profit of Rs.4826/- per hectare followed by $S_{90}N_{25}P_{100}$ (Rs.4851/- per hectare) and $S_{90}N_{25}P_{0}$ (Rs.4751/- per hectare).

CONCLUSION

The findings of the present investigation as a whole, led to the following conclusion.

Among the various treatment combinations studied in the present investigation, it was found that-

(i) Niger pea variety T-15-15 sown at 150 x 30 cm with the fertilizer application of 25 kg N and 100 kg P_2O_5 per hectare secured the maximum grain yield as well as dry matter per hectare.

(ii) The treatment combination $S_{90}N_{50}P_{100}$ produced the highest protein content in grain followed by $S_{90}N_{0}P_{100}$.

(iii) The treatment combination of $S_{30}N_{25}P_{50}$ gave the maximum net profit per hectare followed by $S_{30}N_{25}P_{100}$ and $S_{30}N_{25}P_{0}$.

Future scope of research:

(i) The spacing requirement of pigeon pea crop under investigation may be tested for two more seasons.

(ii) To test the various spacings with different sowing times.

(iii) To determine optimal dose of macronutrients viz. nitrogen, phosphorus, and potash in conjuction with proper bacterial inoculation.

(iv) To workout the requirement of micronutrients viz. molybdenum, copper, zinc and manganese for quantitative improvement of pigeon pea crop under the soil conditions as prevailing in the middle Gujarat.

(v) To try pigeon pea as a mixed crop in varying proportions with cereals like sorghum, bajra, maize etc.

(vi) To evolve multiple cropping systems and suitable crop rotation by involving pigeon pea as one of the crops for maximisation of returns per unit area per year.

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