EFFECT OF LEVELS OF POTASSIUM AND RHIZOBIAL CULTURE INOCULATION ON THE GROWTH AND YIELD OF SOYBEAN [*Glycine max* (L.) Merrill]

BY

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled "Effect of levels of potassium and rhizobial culture inoculation on the growth and yield of soybean (Glycine max (L.) Merrill)" is a bonafide record of research work done by me during the cource of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

7/8/81

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Vellanikkara,

10th July 1981.

CERTIFICATE

Certified that this thesis entitled "Effect of levels of potassium and rhizobial culture inoculation on the growth and yield of soybean (*Glycine max* (L.) Merrill)" is a record of research work done independently by Kumari. REENA GRITTLE PINHERO under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned, members of the Advisory Committee of Kumari Reena Grittle Pinhero, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Effect of levels of potassium and rhizobial culture inoculation on the growth and yield of soybean (Glycine max (L.) Merrill) may be submitted by Kumari Reena Grittle Pinhero, in partial fulfilment of the requirements for the degree.

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DEDICATED

TO

MY MOTHER

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INTRODUCTION

INTRODUCTION

Soybean, a potential source of plant protein and vegetable oil has gained importance in India from 1960. Since then efforts are being made to popularise soybean among the farmers. In India, soybean is familiar to many and is now grown on a commercial scale as a source of oil and protein in quite a few parts of the country. On an average, soybean seeds contain 40 per cent protein and 20 per cent good quality edible oil.

The current shortage of vegetable oil in the country caused by increasing population, improved standard of living and higher demand from consuming industries and the poor yield of oil seed crops, is being met by importing soybean and sunflower oils. The need to build up the oil and protein economy of the country on a self supporting basis necessitates identification of various sources for augmenting the vegetable oil and protein supplies in the country.

A review of the trend in production of oil seeds in the world over a decade reveals that soybean has become very popular in many countries. As attempts for improving the yield potential of the conventional oil seeds like groundnut, gingelly and castor did not yield spectacular results, new oil seeds like sunflower and soybean have been introduced. Among the newly introduced crops, soybean is found to be more suitable to a wide range of agro-climatic conditions and so the cultivation of soybean was one of the resources decided to be exploited to bridge the gap between production and demand of vegetable oils and proteins.

In Kerala, soybean being a new crop, knowledge on its crop husbandry is rather limited. Identification of most suitable varieties and evaluation of optimum package of practices are essential to launch on a grand scale development programme. A varietal trial involving 25 varieties conducted in red loam soils of Trichur, identified the variety EC 39821 to be the most promising. A nutritional trial on this crop was conducted during 1977 to study the nitrogen requirement and response to rhizobial culture inoculation (Nair, 1978). Kurien (1979) studied the effect of phosphorus nutrition, liming and rhizobial inoculation on soybean. With a view to standardise the nutritional requirement of this crop, it was considered necessary to continue the experimental work on the response of soybean to potassium too.

Legumes have the property of symbiotic nitrogen fixation by which they can meet most of their nitrogen requirement. For efficient symbiotic nitrogen fixation by soybean, presence of appropriate strains of the required symbiotic bacteria Rhizobium japonicum is a must. Soybean, being a newly introduced crop in India, the most effective strains of this bacteria may not be available originally in our soils. In such a case, an increase in crop yield is to be normally expected because of culture inoculation. The experiments conducted during 1977 and 1978 indicated a decrease in yield, nodulation and nitrogen uptake of soybean consequent to culture inoculation. As these results were quite contrary to the expectation, it was felt necessary to check the results by repeating the treatments again.

The present study was undertaken with the following broad objectives:

1) To study the effect of graded levels of fertilizer potassium and to arrive at its requirement for soybean.

2) To evaluate the advantage due to rhizobial culture inoculation.

3) To study the interaction between potassium nutrition and culture inoculation.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Experimental results on the influence of potassium and rhizobial inoculation on soybean yield show both positive and no responses. In certain cases, even negative responses have also been reported. A brief review of the work done on these aspects is presented below.

A. Effect of potassium on soybean

A1. Growth characters

Height of plants

Camper and Lutz (1977) reported that application of potassium increased plant height and hastened maturity.

Maguire et al. (1976) in a pot culture experiment noted that potassium did not affect soybean growth.

Whigham et al. (1978) observed a negative correlation between plant height and applied potassic fertilisers.

Nodulation

Jones et al. (1977) observed that applied potassium increased the number of nodules per plant, total and individual weight of nodules more than phosphorus, but increases were largest when both phosphorus and potassium were applied.

Dry matter production

Chevalier (1976) in a field trial found that at seed formation stage dry matter yields were 4.8 t ha^{-1} without potassium and 5.7 t ha^{-1} with 200 kg K_2O ha^{-1}. He concluded from his work that during active growth period dry matter increased with increasing rates of potassium application but the reverse was true at seed formation. At maturity seed and stem dry matter increased with higher levels of potassium showing a favourable effect of potassium on ripening. Terman (1977) in a two year experiment observed that maximum dry matter yield occurred during the early pod filling stage of growth. Dry matter yield then declined as a result of greater loss of leaf and petiole than that of increase in seed weight.

A2. Yield and yield attributes

Maples and Keogh (1969) carried out field trials at 17 locations on silt loam and sandy loam soils and found that potassium increased seed yield significantly at seven locations. Most of the increase was produced by 60 lb K_2O ac^{-1} or less. They also observed a highly significant correlation between potassium as measured by soil test and crop response to potassium. In a six-year trial on a silt loam soil with pH 5.9 to 6.6, Caviness and Hardy (1970) observed a significant increase in seed yield due to the application of 93 kg K_2O ha^{-1}. However, doubling the rate of potassium did not lead to any further significant increase in yields.

Bhangoo et al. (1972) reported marked increase in seed yield due to the application of 90 kg K_2O ha^{-1} and yield increase ranged from 9 to 19 per cent. They also observed that soybean yield showed a positive correlation with the potassium content of seed and leaf tissue. Cheaney (1973) reported significant increase in seed yields with potassium application only during the period of heavy rainfall and the effect was greater at higher levels of nitrogen.

Braga et al. (1976) observed a significant positive correlation between available potassium and seed yield. Fauconnier (1976) reported that application of 100 kg and 200 kg K_2O ha^{-1} increased yield to 1.98 and 2.03 t ha^{-1} respectively compared to the yield of 1.58 t ha^{-1} in the control with no potassium. Ferrari et al. (1976) in their field trials at 14 sites with soybean variety 'Santa Rosa' found that without potassium the yield varied from 0.69 to 1.49 t ha^{-1} while with 100 kg K_2O ha^{-1} the range was 0.81 to 1.61 t ha^{-1}.

Keogh et al. (1976) reported that potassium fertilization consistently increased the yield at all sites studied but no yield advantage was obtained from higher applications of potassium in the first two years. They also observed that leaf potassium content increased with applied potassium and was strongly correlated with yield.

Markus (1976) noted increased yield upto 1.81 t ha^{-1} with 150 kg K_2O ha^{-1}, compared to 1.71 t ha^{-1} without potassium. Graves et al. (1978) found that applied potassium increased yield of all cultivars tried at all locations in both years.

In field trials under rainfed condition with two soybean cultivars, application of 20 to 40 kg K_2O ha^{-1} gave no significant effect on seed yield (Reddi et al., 1976).

Svec et al. (1976) in their two-year studies at two locations observed an average seed yield of 1.43 t ha^{-1} with no potassium and 0.56 t ha^{-1} with 223 kg K_2O ha^{-1} in one location but had no significant effect in the second year at the other location.

A3. Quality of seed

Protein content

Davidescen et al. (1975) reported that balanced NPK application enhanced seed protein content more than the seed oil content. Lixandro et al. (1975) observed that seed protein contents were greatly increased by nitrogen than by phosphorus or potassium. Markus (1976) noted increased protein yield due to application of potassium. Park et al. (1976) observed positive correlation between protein and potassium content of seed and negative correlation between protein and oil content.

According to Chesney (1973), protein content of the seed was not influenced by potassium.

Chevalier (1976) found that protein content of ripe seed decreased from 43.24 to 40.25 and then to 39.34 per cent with 0, 100 and 200 kg K_2O ha^{-1}.

Oil content

Chevalier (1976) observed that oil content of seed increased from 17.94 to 18.61 and then to 19.01 per cent with 0, 100 and 200 kg K_2O ha^{-1}. The same author in 1978 noted increased oil yield from 294 kg ha^{-1} without potassium to 482 kg ha^{-1} with 200 kg K_2O ha^{-1}.

According to Cheaney (1973), oil content of the seed was not influenced by potassium.

A4. Content and uptake of nutrients

Bhangoo et al. (1972) reported that application of potassium increased the potassium content of leaves and seeds. They also found that soybean yield showed a positive correlation with potassium content of seeds and leaf tissues. Lutz et al. (1975) in a trial on clay loam soil noted that leaf potassium content was increased with increase in applied potassium. Chevalier (1976) observed that application of potassium increased the total potassium content of the plant during the early stages of growth but decreased with age. At ripening, the potassium content of the seed remained unaffected while that of stem was increased. He also found that when the level of potassium was increased from 0 to 200 kg K_2O ha^{-1}, the uptake of nitrogen at seed ripening stage was increased from 110.7 kg ha^{-1} to 173.8 kg ha^{-1}.

Mascarenhas et al. (1976) noted that application of potassic fertilizers increased the potassium concentration in the leaves but seed yield was not significantly increased. Jones et al. (1977) reported that potassium concentration in leaves decreased throughout the season and was much enhanced by application of potassium and its content in seeds ranged from 1.57 to 1.85 per cent. According to Terman (1977), concentration of potassium in leaves and seeds increased with increased levels of applied potassium.

B. Effect of rhizobial inoculation on soybean

B1. Growth characters

Height of plants

Rosas (1969) reported that nodulation increased plant height on fertile or moderately fertile soil. Prokopenko and Vashchenko (1974) in pot culture studies with soybeans found that seed inoculation with rhizobium increased plant height.

Kurien (1979) observed that inoculation did not exert any significant influence on height of plants.

Number of branches

Nair (1978) reported that inoculation had no effect on number of branches. Similar result was observed by Kurien (1979).

Nodulation

According to Chatterjee *et al.* (1972) seed inoculation increases nodulation. Hamdi *et al.* (1974) reported that nodulation frequency and fresh weight of nodules increased with inoculation and the inoculated plants were found to be better than uninoculated plants in the field where it had not been cultivated before. Patil *et al.* (1974) observed that inoculation with 'Nitragin' significantly increased nodule numbers. Similar increase in nodulation due to inoculation was observed by Pal and Saxena (1975) and Saxena and Tilak (1975). Janssanvian *et al.* (1976) noted that *Rhizobium japonicum* increased nodulation and nodule weight.

Kumar *et al.* (1976) in their trials with five soybean cultivars found that seed inoculation with an efficient *Rhizobium* strain increased nodulation. Kaul and Sekhon (1977) noted that the numbers of nodules per plant at 60 days after sowing were 20.1 and 34.7 for inoculation and inoculation plus mulching respectively. Lee *et al.* (1977) observed that the total numbers of root nodules and effective root nodules were increased by *Rhizobium* inoculation. Rao and Patil (1977) found that inoculation of soybean seed with five commercial inoculants of Rhizobium japonicum increased the number and dry weight of the nodules. Similar increase in nodule number was observed by Sachansky (1977).

Tramminhtien and Hinson (1977) compared inoculation with uninoculated control on fine sand in soybean and noted no significant difference in nodule number in 14-day old plants. Boonkerd et al. (1978) found that nodulation and plant growth were not affected by inoculation with Rhizobium japonicum strains. Nelson et al. (1978) found no significant difference in nodule weight between plants grown without inoculation and those receiving seed or soil inoculation with commercial Rhizobium strains. Kurien (1979) observed that inoculation did not influence the number and weight of root nodules.

A reduction in nodule number due to inoculation was reported by Nair (1978).

Dry matter production

Rewari et al. (1973) observed significant increases in dry matter yield due to inoculation. Prokopenko and Vashchenko (1974) in pot culture experiments with soybeans found that seed inoculation increased plant dry matter and hastened maturity. Similar result was observed by Rao and Patil (1977). Ruiz-Argueso et al. (1977) noted that inoculated plants produced 380 to 461 per cent more dry matter as compared to uninoculated plants.

Ruschel and Ruschel (1975) found no difference in dry weight at 45 days of age due to inoculation. Kurien (1979) observed no significant difference in dry weight of plant due to inoculation.

Leaf area index

Nair (1978) reported that inoculation had no influence on leaf area index. A similar result was observed by Kurien (1979).

Net assimilation rate

Nair (1978) found no difference in net assimilation rate due to inoculation. Similar result was observed by Kurien (1979).

B2. Yield and yield attributes

Number of pods, number of seeds and weight of seeds

Kang (1975) observed increase in pod number and seed weight of soybean by the application of higher levels of nitrogen along with inoculation. Ruschel et al. (1975) reported that inoculation increased the number of pods without increasing seed number. Increase in 1000 seed weight due to inoculation was observed by Konova et al. (1976), Rois et al. (1977), and Sable and Khuspe (1977).

According to Kurien (1979) number of pods, number of seeds and 1000 seed weight were not influenced by inoculation.

Yield

Freire *et al.* (1968) found that inoculation with a *Rhizobium* strain increased yield of two soybean varieties by 45 per cent and a multi-strain inoculant increased yield by 145 per cent. Jethmalani *et al.* (1969) observed that seed yield of soybean varieties "Bragg" and "Clark 63" with inoculation was significantly superior to the uninoculated ones. Saxena and Tilak (1975) reported that the yield increased by about 73 to 94 per cent over control due to inoculation. Babich (1976) observed that seed inoculation with *Rhizobium* sp. increased yields by 7.3, 11.5 and 18.4 per cent in three soybean cultivars, Dneprovskaya 12, Kirovgradskaya 3 and VH11SK-1 respectively. Lee (1976) found that in soybean cultivar Chippewa-64, inoculation with *Rhizobium japonicum* gave 1.48 to 1.65 t seed ha^{-1} compared with 1.21 t without inoculation. He also concluded that yields with or without nitrogen were increased by inoculation with *Rhizobium japonicum*. Kumar *et al.* (1976) observed that on an average in five varieties of soybean, the influence of inoculation on yield was rather small. However, two of the varieties individually showed better yield responses to inoculation. Kaul and Sekhon (1977) found that inoculation increased the yield to 1.42 t ha^{-1} while the uninoculated plots recorded only 0.84 t ha^{-1}.

Increased yield due to inoculation was reported by Chesney et al. (1973), Rewari et al. (1973), Bajpai et al. (1974), Patil et al. (1974), Prokopenko and Vashchenko (1974), Rao and Viswanatha (1974), Ruschel et al. (1975), Blinkov and Prokopenko (1976), Ciafardini (1976), Konova et al. (1976), Varma and Tiwari (1976), Zhgenti et al. (1976), Lee et al. (1977), Rois et al. (1977), Sable and Khuspe (1977), Sobol'Nikova et al. (1977), Boonchee and Schiller (1978) and Bagyaraj et al. (1979).

According to Kang (1975) higher levels of nitrogen combined with inoculation increases yield of soybean. Kozlov (1977) observed that seed inoculation with an effective Rhizobium strain increased yields from 1.03 to 1.32 t ha^{-1} without applied nitrogen and with the application of nitrogen at the rate of 20 and 40 kg ha^{-1}, the increases in yield were 1.22 to 1.62 t ha^{-1} respectively.

Cardwell and Johnson (1971) found that soybean yields were not significantly increased by inoculating the seeds with Rhizobium japonicum. Miller (1972) also noted that inoculation did not influence the yield of soybean significantly. Similar results were observed by Basistaya and Shil'Nikova (1977), Bhattarai (1977), Tran Minh Tien and Hinson (1977) and Kurien (1979). Nelson et al. (1978)

from their field trials at two sites on which soybeans had not been grown at least for 15 years, reported that seed yield in three soybean cultivars did not differ significantly between plants grown without inoculation and those with seed or soil inoculation with commercial Rhizobium strains.

Nair (1978) found a significant depression in yield due to culture inoculation.

Kurien (1979) observed that inoculation had no significant effect on stover yield and harvest index.

B3. Quality of seed

Protein content

Prokopenko and Vashchenko (1974) noted that seed inoculation increased protein accumulation by 2.34 per cent. Ruschel et al. (1975) in a glass house trial observed that in cultivar 'Mineira' inoculation increased protein content to the same extent as in the treatments which received nitrogen and inoculation. Blinkov and Prokopenko (1976) observed that inoculation increased protein yield by 95 kg ha^{-1} over control. Sable and Khuspe (1977) also found that seed inoculation increased seed crude protein content.

Cardwell and Johnson (1971) reported that seed protein percentage was not significantly increased by inoculating soybean seeds with Rhizobium japonicum. Singh et al. (1971) observed that inoculation along with 20 to 40 kg N and 40 to 60 kg P_2O_5 ha^{-1} gave little effect on protein content.

Oil content

Singh et al. (1971) noted that inoculation along with 20 to 40 kg N and 40 to 60 kg P_2O_5 ha^{-1} had little effect on oil content of seed.

Ruschel et al. (1975) in a glass house trial found that in cultivar 'Mineira', inoculation decreased the oil percentage. Varma and Tiwari (1976) observed that the oil content of seed in nine soybean cultivars decreased with increases in seed yields due to seed inoculation with Rhizobium japonicum. Sable and Khuspe (1977) also found that seed inoculation decreased oil content of seed.

B4. Content and uptake of nutrients

According to Sokorenko (1971) inoculation of soybean seeds markedly increased the total nitrogen content of plants when no fertilisers were given and when supplied with phosphorus and potassium, but not when given nitrogen, phosphorus and potassium in combination. Chatterjee et al. (1972) reported that seed inoculation had resulted in an increased nitrogen content of plants. Similar increase in nitrogen content of plants due to seed inoculation was reported by Rewari and Jain (1973), Prokopenko and

Vashchenko (1974), Konova *et al.* (1976), Boonchee and Schiller (1978) and Bagyaraj *et al.* (1979).

Higher levels of nitrogen application combined with inoculation of soybean increased nitrogen uptake and nitrogen content of seed (Kang, 1975).

Nelson *et al.* (1978) found no significant difference in leaf nitrogen content in three soybean cultivars grown with and without inoculation with commercial *Rhizobium* strains. Small but inconsistent differences were noticed in phosphorus content of seed. Kurien (1979) observed no significant difference in nitrogen content of leaves, shells and seeds due to inoculation. He also found that the nitrogen uptake by leaves, stem, shells and seeds was also not affected by inoculation.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken to study the effect of graded levels of potassium and rhizobial inoculation on growth, yield and quality of soybean.

The experiment was conducted in the Instructional Farm attached to the College of Horticulture, Vellanikkara. The College of Horticulture is situated at 10° 32' N latitude and, 76° 10' E longitude at an altitude of 22.25 metres above mean sea level.

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

The area had been left fallow during the immediately preceeding two years, before which green manure crops had been raised in it.

Soil

The soil of the experimental area is deep, well drained, sandy clay loam.

Data on physical and chemical characteristics of the soil are given in Table 1.

Table 1

A. Mechanical composition

Clay	-	29.75%
Silt	-	21.20%

Fine sand	-	22.10%
Coarse sand	-	26.00%

B. Chemical properties

Constituent	Content in soil	Rating	Method used for estimation
Total nitrogen	0.078%	Medium	Microkjeldahl
Available phosphorus	2.15 ppm	Low	In Bray-1 extract, Chlorostannous reduced molybdophosphoric blue colour method
Available potassium	157.5 ppm	High	In neutral normal ammonium acetate extract-Flame photometric
pH	4.6		1:2.5 soil:water suspension using a pH meter

Season and climate

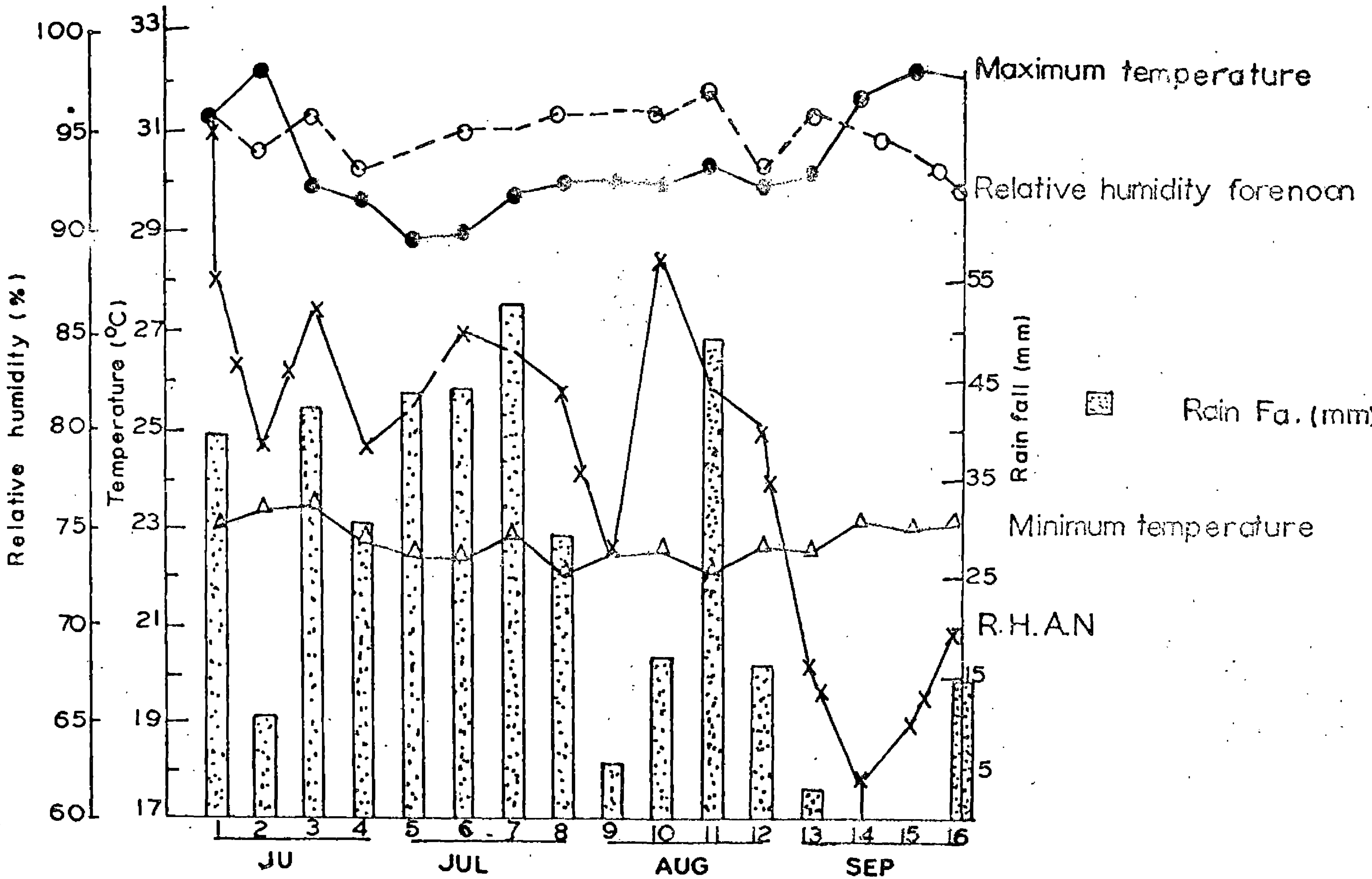
The experiment was conducted during the period from June to September 1980. The crop was sown on 10-6-1980 and harvested on 25-9-1980. The meteorological data for the above period are presented in Table 2 and Fig. 1.

The area enjoys a humid tropical climate. The weekly average of daily maximum temperature during the cropping period ranged from 28.77°C to 32.3°C and the minimum temperature from 21.97°C to 23.37°C. The maximum

Table 2. Meteorological data during the crop period (Weekly averages)

Month	Week	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	Forenoon	Afternoon	
June 1980	1st	31.32	22.97	96.25	88.20	37.26
	2nd	32.30	23.32	93.75	78.60	10.86
	3rd	29.97	23.37	95.80	85.75	42.11
	4th	29.70	22.74	93.33	79.00	29.94
July 1980	1st	28.77	22.29	94.00	81.00	43.54
	2nd	28.89	22.53	95.00	85.33	43.83
	3rd	29.67	22.86	95.43	84.33	52.69
	4th	29.93	22.04	95.71	82.14	28.97
August 1980	1st	29.97	22.37	95.71	72.57	5.77
	2nd	29.86	22.50	95.71	88.86	16.71
	3rd	30.29	21.97	97.00	82.33	49.23
	4th	29.93	22.59	92.57	80.43	15.65
September 1980	1st	30.11	22.50	95.71	67.86	3.34
	2nd	31.69	23.07	95.29	61.71	Nil
	3rd	32.24	22.93	93.57	65.00	0.03
	4th	32.23	22.97	92.14	69.71	14.09

FIG.1 WEATHER DATA FOR THE PERIOD FROM JUNE TO SEPTEMBER 1980



The maximum and minimum relative humidity ranged from 92.14 to 97 per cent and 61.71 to 88.85 per cent respectively. The total rainfall received during the crop season in 94 rainy days amounted to 2843.57 mm. Even though the distribution of rainfall during the cropping period was satisfactory, a good portion of the rain was received during the first ten weeks after sowing and for the remaining period, rainfall was low.

Materials

Seeds

Soybean variety, EC 39821 was used for the trial. This was originally an introduction from Thailand. The crop usually matures in 3 to 3½ months under tropical conditions. The seeds were tested for viability and were found to give over 70 per cent germination.

Fertilisers

Fertilisers with the following analysis were used for the experiment.

Ammonium sulphate analysing	20% N
Superphosphate analysing	16% P_2O_5
Muriate of potash analysing	60% K_2O

Details of treatments

The treatments consisted of factorial combinations of 5 levels of potassium and 2 levels of rhizobial inoculation.

a) Levels of potassium

i)	K_0	-	Control (no potassium)
ii)	K_1	-	30 kg K_2O ha^{-1}
iii)	K_2	-	60 kg ,,
iv)	K_3	-	90 kg ,,
v)	K_4	-	120 kg ,,

b) Levels of rhizobial inoculation

i)	I_0	-	Control (without inoculation)
ii)	I_1	-	Inoculated

Treatment combinations

i)	K_0I_0	vi)	K_2I_1
ii)	K_0I_1	vii)	K_3I_0
iii)	K_1I_0	viii)	K_3I_1
iv)	K_1I_1	ix)	K_4I_0
v)	K_2I_0	x)	K_4I_1

In addition to the above, all the plots received a uniform dose of 20 kg N, 80 kg P_2O_5 and 500 kg calcium hydroxide per hectare

Design and lay out

The trial was laid out in randomised block design with four replications. The procedure followed for the allocation of treatments to different plots was in accordance with random number tables (Fisher and Yates, 1963).

The details of the lay out are as follows:

Number of blocks	-	4
Number of plots per block	-	10
Number of beds per plot	-	2
Gross plot size	-	5 m x 4 m
Bed size	-	4.5 m x 1.5 m
Spacing	-	45 cm x 5 cm

The lay out plan is shown in Fig. 2.

Field culture

The experimental plot was ploughed with tractor, stubbles were removed, clods were broken and the land was levelled properly. The field was then laid out into blocks and plots as per the experimental design. Beds of size 4.5 m x 1.5 m were laid out in the plots with channels of 30 cm width in between. Provision for proper drainage was also made in the plots.

Liming and fertilizer application

Lime was broadcast on each bed and raked in 12 days prior to sowing. The entire quantities of nitrogen, phosphorus and potassium were applied as basal dressing one day prior to sowing.

FIG. 2

LAY OUT PLAN

FACTORIAL EXPERIMENT IN RANDOMISED BLOCK DESIGN

K_0 No POTASSIUM K_1 30 Kg K_2O . ha^{-1}
K_2 60 Kg K_2O . ha^{-1} K_3 90 Kg K_2O . ha^{-1}
K_4 120 Kg K_2O . ha^{-1}

S

REPLICATION I

$K_2 I_1$	$K_0 I_1$	$K_4 I_1$	$K_3 I_0$	$K_1 I_0$
$K_1 I_1$	$K_0 I_0$	$K_2 I_0$	$K_3 I_1$	$K_4 I_0$

REPLICATION II

$K_3 I_0$	$K_4 I_1$	$K_1 I_1$	$K_2 I_1$	$K_2 I_0$
$K_0 I_0$	$K_0 I_1$	$K_4 I_0$	$K_1 I_0$	$K_3 I_1$

REPLICATION III

$K_4 I_0$	$K_2 I_1$	$K_0 I_1$	$K_0 I_0$	$K_1 I_0$
$K_3 I_1$	$K_2 I_0$	$K_4 I_1$	$K_3 I_0$	$K_1 I_1$

REPLICATION IV

$K_2 I_1$	$K_1 I_0$	$K_3 I_0$	$K_4 I_0$	$K_1 I_1$
$K_3 I_1$	$K_0 I_1$	$K_4 I_1$	$K_0 I_0$	$K_2 I_0$

I_0 UNINOCULATED I_1 INOCULATED

Seed inoculation and sowing

For treating the seed with the inoculum, the procedure recommended by the Tamil Nadu Agricultural University was followed. Jaggery syrup was prepared first by mixing 125 g of jaggery in 500 ml of water. It was boiled for 30 minutes and then cooled. To this, rhizobium culture was added and mixed throughly. The required amount of seeds was then mixed with this culture and the seeds were subsequently dried in shade.

Sixty seeds were dibbled in each row of 1.5 metre length, maintaining a distance of 45 cm between rows. Seedlings were thinned out a week after sowing to retain a population of 30 plants per row, thus giving an average spacing of 5 cm between plants. The total number of plants in a bed was fixed as 300.

After cultivation

Hand weeding and earthing up were done one month after sowing.

General condition of the crop

The stand of the crop was satisfactory throughout the period.

Plant protection

A mild attack of leaf eating caterpillars and aphids was noticed during the preflowering period which was effectively controlled by spraying 0.2 per cent sevin and 0.03 per cent phosphamidon (Dimecron) respectively.

Harvesting

Maturity of the crop was decided by complete shedding of leaves. Harvesting was done 107 days after sowing by cutting the plants at the base using sickles.

Observations recorded

I. Growth characters

Eight plants were selected at random after eliminating the border rows and all the biometric observations were recorded from these plants at various growth stages. A separate sampling area was marked for destructive sampling to record the number and weight of root nodules and for growth analysis. From the sample plants collected from this area the different plant parts such as stem, leaves, shells and seeds were separated and used for chemical analysis subsequently.

a) Height of plants

From the observation plants marked for biometric observations the height of plants was measured from the base to the terminal bud and the average height worked out. This observation was taken five times at intervals of 15 days commencing from 30th day after sowing.

b) Number of branches

Number of branches was counted on the observation plants on 45th day, 60th day and 75th day after sowing and the averages were calculated.

c) Number of nodules per plant

This observation was taken at four stages at regular intervals of 15 days starting from 45th day after sowing. Plants were pulled out carefully after loosening the soil around them with the help of a hand fork. The total number of root nodules was counted and the average worked out.

d) Weight of nodules per plant

Fresh weight of the nodules was taken and from this the average weight calculated.

e) Dry matter production

After eliminating the border rows, five plants each were collected on 30th, 45th, 60th, 75th and 90th days after sowing and at harvest, from the area marked for destructive sampling. During the first four stages, the leaves and stems of the plants were separated and their dry weights recorded separately. During the last two stages, the plant was separated into leaves, stems, shells and seeds and the individual dry weights recorded. The total dry weight in each stage was worked out by adding the dry weights of the individual components.

f) Growth analysis

i) Specific leaf area

Specific leaf area (SLA) was worked out as follows:

$$SLA = \frac{(LA_1/LW_1) + (LA_2/LW_2)}{2}$$

where,

LA_1 - Total leaf area at 1st stage

LA_2 - Total leaf area at 2nd stage

LW_1 - Total leaf dry weight at 1st stage

LW_2 - Total leaf dry weight at 2nd stage

ii) Leaf weight ratio (LWR)

Leaf weight ratio was calculated as follows:

$$LWR = \frac{(Lw_1/W_1) + (Lw_2/W_2)}{2}$$

where,

Lw_1 - Total leaf dry weight at 1st stage

Lw_2 - Total leaf dry weight at 2nd stage

W_1 - Total dry weight of plant at 1st stage

W_2 - Total dry weight of plant at 2nd stage

iii) Leaf area index (L A I)

Leaf area index was worked out by following the 'weight of paper method'. Five plants were uprooted and their leaves were separated. Ten leaves were selected at random and their outlines were traced accurately with pencil on quality bond paper of known area per unit weight. The trace was then cut out carefully and weighed. From this, the actual area of the sample leaf was calculated.

The leaves were then dried in a hot air oven at 70 to 80°C to constant weights and the dry weights of ten leaves and the remaining leaves were recorded separately. Leaf area was then calculated using the area weight relationship and total dry weight of leaves.

LAI was calculated at five stages as follows.

$$LAI = \frac{\text{Total leaf area of five plants}}{\text{Land area occupied by five plants}}$$

iv) Absolute growth rate (AGR)

Absolute growth rate was worked as follows:

$$AGR = \frac{W_2 - W_1}{T_2 - T_1}$$

where,

W_2 - Total dry weight of plant at time T_2

W_1 - Total dry weight of plant at time T_1

v) Crop growth rate (CGR)

Crop growth rate was worked out as follows:

$$CGR = \frac{1}{P} \quad \frac{W_2 - W_1}{T_2 - T_1}$$

where,

P - Ground area

W_2 - Total dry weight of plant at time T_2

W_1 - Total dry weight of plant at time T_1

vi) Net assimilation rate (NAR)

The procedure given by Watson (1958) as modified by Buttery (1970) was followed for calculating NAR. The following formula was used to arrive at the net assimilation rate.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1 \frac{(A_1 + A_2)}{2}}$$

where,

W_2 - Total dry weight of plants m^{-2} at time t_2

W_1 - Total dry weight of plants m^{-2} at time t_1

$t_2 - t_1$ - Time interval in days

A_2 - Leaf area m^{-2} at time t_2

A_1 - Leaf area m^{-2} at time t_1

II. Post-harvest observations

a) Number of pods per plant

Average number of pods per plant was worked out by counting the total number of pods from the observation plants.

b) Weight of pods per plant

Average weight of pods per plant was calculated by recording the weight of total number of pods from the observation plants.

c) Number of seeds per pod

Twenty pods were selected at random from the observation plants, the total number of seeds counted and average worked out.

d) 1000 seed weight

From each plot, 100 dry seeds were taken at random, and their weight recorded. From this, 1000 seed weight was calculated.

e) Shelling percentage

Shelling percentage was calculated on 90th day after sowing and at harvest using the following formula.

$$\text{Shelling percentage} = \frac{\text{Dry weight of seeds}}{\text{Dry weight of pods}} \times 100$$

f) Moisture percentage of seeds

The cleaned seeds were sun dried for three days, samples were drawn from each treatment and the initial weights recorded. The seeds were then oven dried to constant weights and moisture percentage worked out as follows.

$$\text{Moisture percentage} = \frac{\text{Weight of moisture}}{\text{Weight of seeds after oven drying}} \times 100$$

g) Yield of seeds

The pods harvested from the net area were sun dried for three days, threshed, winnowed, cleaned and the weight of clean seeds recorded. Yield was expressed in kg ha^{-1}.

h) Yield of stover

Stover obtained from each net plot was sun dried for three days and total weight was recorded. Yield was expressed in kg ha^{-1}.

i) Harvest index

Harvest index was calculated as follows:

$$\text{Harvest index} = \frac{Y\ econ}{Y\ biol}$$

where,

Y econ - Dry weight of seeds

Y biol - Total dry weight of plants

III. Chemical studies

A. Nitrogen, phosphorus and potassium content of plants

Plant samples collected for recording dry weight were used for chemical analysis. The nitrogen, phosphorus and potassium contents of stem, leaves, shells and seeds at different stages of growth were determined by using Auto analyser and EEL Flame Photometer (Jackson, 1958). From the nutrient contents and dry weights of the plant components, the nutrient content of the whole plant was also worked out.

B. Uptake of nutrients

The total uptake of nitrogen, phosphorus and potassium by the plant and individual plant parts was calculated at different stages of growth from the nutrient content and dry weights of plant parts.

C. Harvest indices of nutrients

Harvest indices of nitrogen, phosphorus and potassium were worked out as follows:-

$$\text{Harvest index of nitrogen} = \frac{\text{Amount of nitrogen in seeds}}{\text{Total amount of nitrogen in plants}}$$

$$\text{Harvest index of phosphorus} = \frac{\text{Amount of phosphorus in seeds}}{\text{Total amount of phosphorus in plants}}$$

$$\text{Harvest index of potassium} = \frac{\text{Amount of potassium in seeds}}{\text{Total amount of potassium in plants}}$$

D. Utilization of potassium

a) Response

Response of yield per unit of applied potash was calculated by using the following formula.

$$\text{Response} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Quantity of potash applied}}$$

b) Productive efficiency

Productive efficiency (Yield per unit of recovered potassium) was calculated as shown below.

$$\text{Productive efficiency} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\left\{\begin{array}{l}\text{Potassium uptake}\\ \text{in treatment}\end{array}\right\} - \left\{\begin{array}{l}\text{Potassium uptake}\\ \text{in control}\end{array}\right\}}$$

IV. Quality characters

a) Protein content of seeds

The protein content of seeds was calculated by multiplying the nitrogen content of seeds with the factor 6.25 (A.O.A.C., 1950).

b) Protein yield

The protein yield was calculated from the protein content of seeds and total seed yield and expressed in kg ha^{-1}.

c) Oil content of seeds

The oil content of oven dried seeds was estimated by using Soxhlet apparatus (A.O.C.S., 1971) and expressed as percentage.

d) Oil yield

The oil yield was estimated from the oil content of seeds and total yield of seeds and expressed as kg ha^{-1}.

V. Soil analysis

Soil samples were taken replication-wise before the experiment and plotwise after the experiment and the total nitrogen, available phosphorus and available potassium contents were estimated.

Statistical analysis

The data on different characters were analysed statistically by applying the technique of analysis of variance for 5x2 factorial experiment in RBD and significance of the effects were tested by F test (Cochran and Cox, 1965).

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results of the experiment on the growth, yield and quality of soybean as influenced by different treatments are presented and discussed below.

A. Growth characters

a) Height of plants

The mean height of plants as on the 30th, 45th, 60th, 75th and 90th days after sowing are presented in Table 3. The analysis of variance and mean tables for two factor combinations are given in Appendices 1 and 22 to 24 respectively.

There was no significant difference in plant height due to levels of potassium at any of the stages of growth. Mugwira *et al.* (1976) also recorded similar results in soybean. However, Camper and Lutz (1977) reported that application of potassium increased plant height in soybean. The lack of significant increase in height in the present investigation indicates that the native potassium is adequate for the growth of plants in terms of plant height.

Table 3. Effect of potassium and inoculation in height of plants and number of branches at various growth stages.

Treatments	Height of plant (cm)					Number of branches		
	30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing
Levels of potassium (K_2O kg ha^{-1})								
0	23.78	47.55	77.02	78.40	78.87	1.71 (1.308)	2.80 (1.674)	2.80 (1.674)
30	21.66	42.80	72.48	73.05	73.16	1.78 (1.336)	3.14 (1.771)	3.14 (1.771)
60	23.09	46.71	75.72	77.12	77.13	2.04 (1.429)	3.10 (1.761)	3.10 (1.761)
90	22.75	47.20	81.50	82.73	82.96	1.34 (1.156)	3.19 (1.784)	3.19 (1.784)
120	23.13	47.08	76.44	79.06	79.42	1.22 (1.105)	2.92 (1.708)	2.99 (1.728)
SEm ±	0.924	2.016	2.703	2.803	2.734	0.124	0.097	0.084
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Rhizobial inoculation								
Uninoculated	22.21	44.99	74.92	76.52	76.83	1.34 (1.159)	2.93 (1.710)	2.93 (1.710)
Inoculated	23.56	47.64	78.34	79.62	79.75	1.89 (1.375)	3.13 (1.769)	3.13 (1.769)
SEm ±	0.584	1.275	1.709	1.772	1.729	0.079	0.062	0.053
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Figures in parenthesis indicate x transformed values

Rhizobial inoculation of seeds also did not significantly influence the height of plants at any of the growth stages. The inoculated treatment was on par with the uninoculated one. Kurien (1979) also observed similar results in soybean on sandy clay loam soils of Trichur.

The interaction effects between potassium and inoculation were significant on 60th, 75th and 90th days after sowing. The treatment 60 kg K_2O ha^{-1} along with inoculation recorded the highest mean heights of 86.80 cm, 88.23 cm and 88.51 cm respectively in the above stages.

It was also noted that irrespective of the treatments the growth rate was low upto 30th day, rapid from 30th to 60th day and more or less steady after that.

b) Number of branches

The data for the number of branches during the various stages of plant growth are presented in Table 5 and the analysis of variance in Appendix 1.

The data revealed that neither the application nof potassium nor the inoculation had any significant effect on this character at any of the growth stages. Interaction effects were also not significant at any of the growth stages.

As in the case of plant height, there was no significant effect of potassium application and inoculation on number of branches also. The reasons attributed to the lack of significant effect in plant height are attributable here also.

c) Number of root nodules per plant

The data on the number of root nodules per plant during various stages of plant growth are presented in Table 4 and the analysis of variance in Appendix 2.

Applied potassium have not influenced the number of root nodules per plant in any of the stages of growth. It was also observed that the maximum number of nodules were recorded on the 75th day after sowing. Jones et al. (1977) observed an increase in number of root nodules per plant due to applied potassium. The lack of influence on number of nodules in this experiment again points to the fact that the quantity of native potassium present in the soil was adequate to produce the maximum number of nodules.

Significant increase in the number of root nodules per plant due to inoculation was observed on 45th day after sowing. The interaction effect due to various combinations were also not significant.

Table 4. Effect of potassium and inoculation on number of root nodules and fresh weight of root nodules at various growth stages.

Treatments	Number of root nodules per plant				Fresh weight of nodules per plant (g)			
	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})								
0	2.210 (1.792)	3.68 (2.163)	3.12 (2.029)	5.81 (2.610)	0.081	0.062	0.048	0.111
30	1.77 (1.665)	1.67 (1.636)	5.14 (2.479)	5.69 (2.587)	0.119	0.089	0.192	0.135
60	2.15 (1.775)	3.42 (2.102)	7.29 (2.879)	6.73 (2.780)	0.109	0.063	0.146	0.182
90	2.12 (1.767)	1.59 (1.611)	6.40 (2.721)	4.39 (2.096)	0.102	0.079	0.184	0.057
120	1.87 (1.693)	3.22 (2.055)	9.55 (3.248)	9.12 (3.181)	0.076	0.052	0.159	0.156
SEm ±	0.184	0.298	0.562	0.606	0.031	0.022	0.079	0.058
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Rhizobial inoculation								
Uninoculated	1.35 (1.534)	1.93 (1.711)	5.42 (2.533)	4.82 (2.412)	0.086	0.058	0.147	0.108
Inoculated	2.77 (1.942)	3.48 (2.116)	6.89 (2.809)	7.35 (1.889)	0.109	0.080	0.189	0.148
SEm ±	0.116	0.189	0.355	0.383	0.020	0.014	0.050	0.036
C.D. at 5%	(0.339)	NS	NS	NS	NS	NS	NS	NS

Figures in paranthesis indicate $\sqrt{x+1}$ transformed values

A review of literature on the effect of inoculation on nodulation generally shows an increase in the number of nodules per plant (Chatterjee et al., 1972; Hamdi et al., 1974; Patil et al., 1974; Pal and Saxena, 1975; Saxena and Tilak, 1975; Jansenvian et al., 1976; Kumar et al., 1976; Sekhon, 1977; Lee et al., 1977; Rao and Patil, 1977 and Sachansky, 1977). But non-significant effect of inoculation on nodule number was also reported by Tramminhtien and Hinson (1977), Boonkerd et al. (1978) and Nelson et al. (1978).

The lack of response of rhizobial inoculation on 60th, 75th and 90th days after sowing indicates that effective strains of Rhizobium japonicum were available in the soil originally. Nair (1978) and Kurien (1979) reported a decrease in nodulation due to inoculation in the sandy clay loam soils of Trichur, indicating the effectiveness of the native strain of Rhizobium japonicum over the introduced one.

d) Weight of root nodules per plant

Results on the weight of root nodules per plant under the various treatments are given in Table 4 and the analysis of variance in Appendix 2.

Neither the effects of levels of potassium and inoculation nor their interactions were significant on this character at any stages of plant growth. A more or less similar trend noticed in the number of nodules per plant with levels of potassium and inoculation was noticed here also. As in the case of nodule number per plant, the highest nodule weight was also obtained on the 75th day after sowing both under the levels of potassium and inoculation.

The results reported on the effect of potassium and inoculation generally indicate a positive response on nodulation. In the present study the treatments had no significant effect on this character. The reasons for such an observation were discussed already while dealing with the observation on nodule number.

c) Dry matter production

i) Dry weight of stem per plant

The results on the dry weight of stem per plant during the various stages of plant growth are presented in Table 5 and Fig. 3 and the analysis of variance in Appendix 3.

The data revealed that the effect of potassium was significant only on 75th day after sowing and the highest value of 9.262 g $plant^{-1}$ was recorded in the treatment 120 kg K_2O ha^{-1}. In all other stages namely

Table 5. Effect of potassium and inoculation dry weight of stem at various growth stages.

Treatments	Dry weight of stem per plant (g)					
	30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing	Harvest
Levels of potassium (K_2O kh ha^{-1})						
0	0.225	1.688	3.869	6.538	4.163	2.538
30	0.231	1.531	4.581	6.194	5.569	3.338
60	0.238	1.244	5.075	8.369	5.188	4.026
90	0.213	1.750	5.181	6.226	5.788	3.794
120	0.269	1.713	4.331	9.262	5.408	4.594
SEm ±	0.028	0.166	0.495	0.762	0.625	0.489
C.D. at 5%	NS	NS	NS	2.211	NS	NS
Rhizobial inoculation						
Uninoculated	0.225	1.553	4.970	7.290	4.485	3.287
Inoculated	0.245	1.618	4.245	7.345	6.000	4.028
SEm ±	0.018	0.105	0.315	0.482	0.395	0.309
C.D. at 5%	NS	NS	NS	NS	1.149	NS

30th, 45th, 60th and 90th days after sowing and at harvest, potassium did not make any significant difference.

Increase in dry weight of stem due to inoculation was found to be significant only on 90th day after sowing and the inoculated treatment recorded a stem weight of 6.0 g $plant^{-1}$ while the uninoculated plot gave 4.483 g $plant^{-1}$. The interaction effect of potassium and inoculation was not significant. It was also observed that the maximum stem dry weight was recorded on the 75th day after sowing.

Discussion on this aspect will be covered while dealing with total phytomass production per plant.

ii) Dry weight of leaves per plant

The data on the dry weight of leaves per plant at different stages of growth are presented in Table 6 and Fig. 4. The analysis of variance and mean table for two factor combinations are given in Appendices 3 and 25 respectively.

Dry weight of leaves was not influenced by the levels of potassium on the 30th, 45th, 60th and 90th days after sowing. But on the 75th day there was a significant increase with increasing levels of potassium. At this stage, the highest leaf dry weight of 5.129 g $plant^{-1}$ was recorded by 120 kg K_2O ha^{-1}.

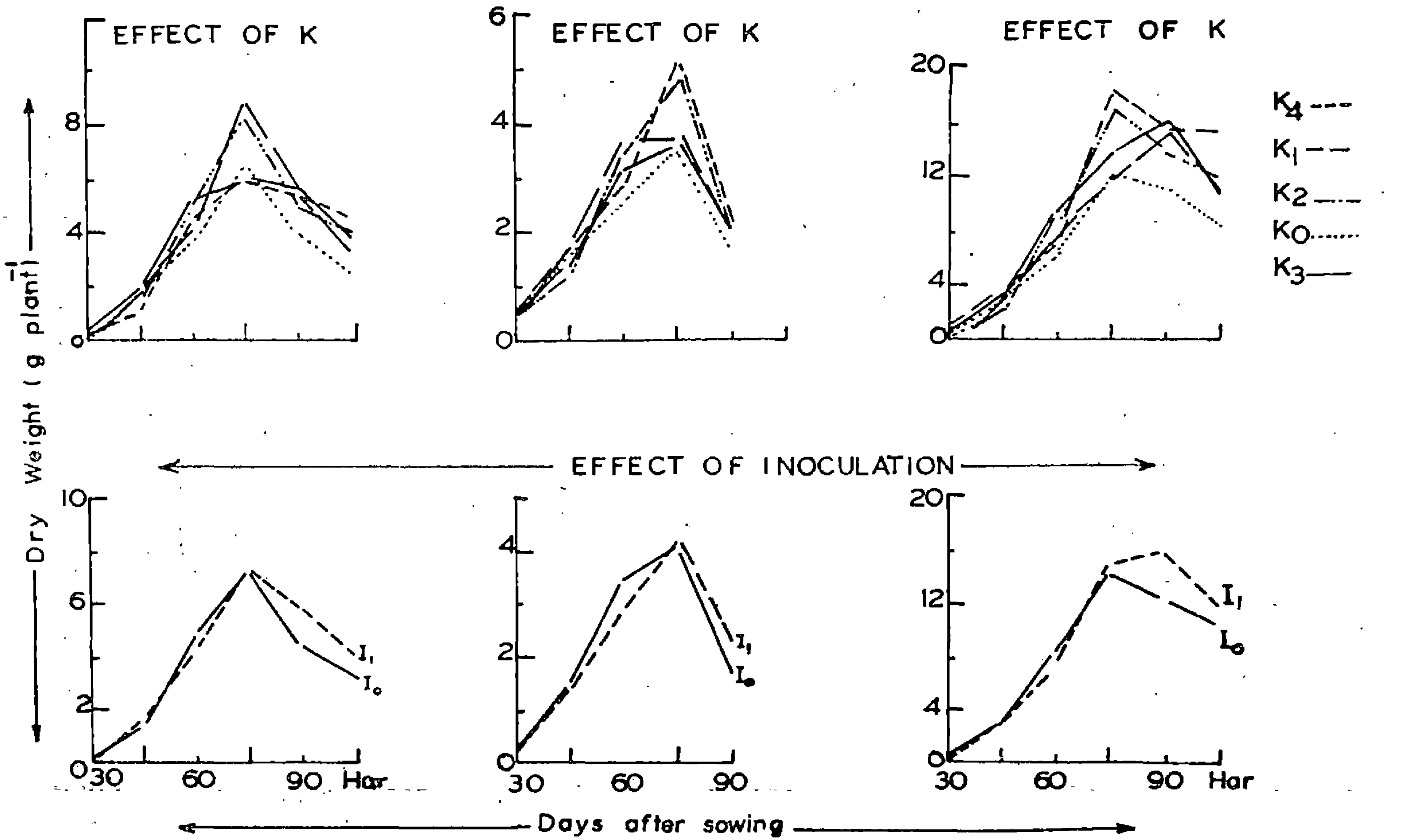
Table 6. Effect of potassium and inoculation on dry weight of leaves at various growth stages.

Treatments	Dry weight of leaves per plant (g)				
	30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})					
0	0.276	1.526	2.543	3.495	1.727
30	0.287	1.346	3.103	3.559	2.046
60	0.293	1.155	3.375	4.752	1.821
90	0.240	1.633	3.669	3.702	1.614
120	0.333	1.578	2.941	5.129	2.164
SEm ±	0.035	0.140	0.303	0.432	0.246
C.D. at 5%	NS	NS	NS	1.255	NS
Rhizobial inoculation					
Uninoculated	0.271	1.453	3.364	4.061	1.666
Inoculated	0.301	1.442	2.888	4.194	2.163
SEm ±	0.022	0.088	0.191	0.273	0.156
C.D. at 5%	NS	NS	NS	NS	0.452

FIG.3 DRY WEIGHT OF STEM AT DIFFERENT GROWTH STAGES

FIG.4 DRY WEIGHT OF LEAVES AT DIFFERENT GROWTH STAGES

FIG.5 TOTAL PHYTOMASS AT DIFFERENT GROWTH STAGES



Inoculation increased the dry weight of leaves significantly only on 90th day after sowing. A dry weight of 2.163 g $plant^{-1}$ was recorded in the inoculated plot as against 1.666 g $plant^{-1}$ in the uninoculated one.

Interaction between potassium and inoculation was significant only on 45th day after sowing and 120 kg K_2O ha^{-1} besides the inoculation treatment recording the maximum leaf dry weight of 1.93 g $plant^{-1}$ at this stage.

It was also observed that the dry weight of leaves increased at a faster rate from 30th day after sowing and the maximum values were recorded on 75th day after sowing. Thereafter, there was a reduction in leaf dry weight.

Discussion on this aspect will be covered while dealing with total phytomass production per plant.

iii) Dry weight of shells per plant

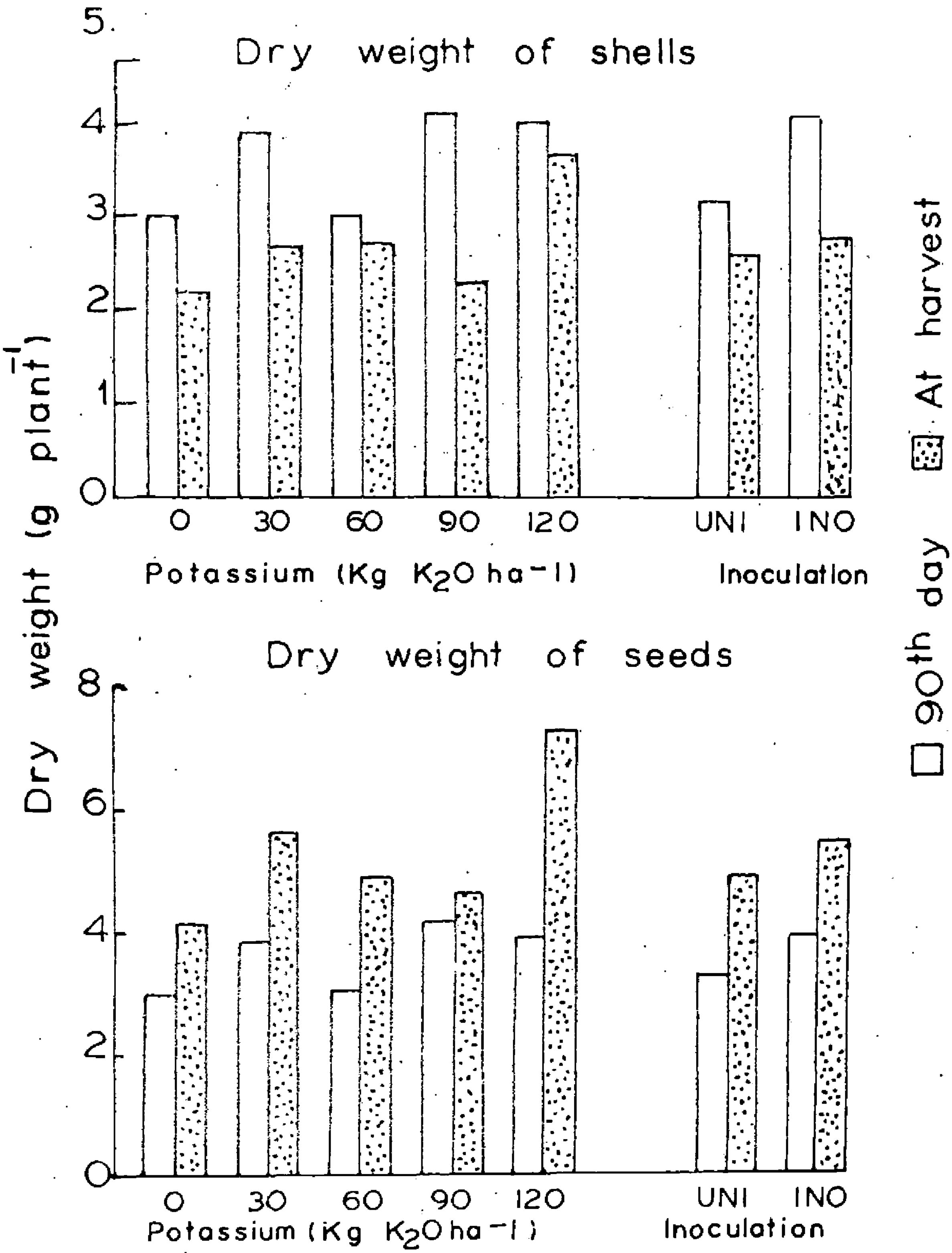
The data on dry weight of shells per plant are presented in Table 7 and Fig.6 and the analysis of variance in Appendix 4.

Increasing levels of potassium had no significant effect on the dry weight of shells on 90th day after sowing and at harvest. However, there was an increase in dry weight upto 30 kg K_2O ha^{-1} at both the stages.

Table 7. Effect of potassium and inoculation on dry weight of shells and seeds at various growth stages.

Treatments	Dry weight of shells per plant (g)		Dry weight of seeds per plant (g)	
	90th day after sowing	Harvest	90th day after sowing	Harvest
Levels of potassium (K_2O kg ha^{-1})				
0	3.031	2.181	2.969	4.100
30	3.988	2.713	3.888	5.656
60	3.081	2.731	3.075	4.881
90	4.150	2.356	4.169	4.606
120	4.113	3.700	3.950	7.288
SEm ±	0.464	0.417	0.559	0.740
C.D. at 5%	NS	NS	NS	1.148
Rhizobial inoculation				
Uninoculated	3.210	2.630	3.290	4.928
Inoculated	4.135	2.842	3.930	5.445
SEm ±	0.294	0.255	0.354	0.468
C.D. at 5%	0.852	NS	NS	NS

FIG.6 EFFECT OF POTASSIUM AND INOCULATION ON DRY WEIGHT OF SHELLS AND SEEDS



The highest mean dry weight of 4.15 g $plant^{-1}$ was recorded on 90th day after sowing when 90 kg K_2O ha^{-1} was applied.

Inoculation increased the dry weight of shells significantly on 90th day after sowing but not at harvest. The highest dry weight of 4.135 g $plant^{-1}$ was recorded in the inoculated plot as against 3.21 g $plant^{-1}$ in the uninoculated control. Interaction effect was not significant.

It was also observed that there was a decline in the dry weight of shells at harvest as compared to that on the 90th day after sowing.

These results will be discussed while dealing with total phytomass production per plant.

iv) Dry weight of seeds per plant

Data on the dry weight of seeds are presented in Table 7 and Fig. 6 and the analysis of variance in Appendix 4.

Potassium levels did not influence the dry weight of seeds on 90th day after sowing, but at harvest the effect was significant. The maximum dry weight of 7.288 g $plant^{-1}$ was recorded in 120 kg K_2O ha^{-1} at harvest which was superior to all other levels. Though the overall trend was in favour of increasing the dry weight of seeds, with increasing levels of potassium, it was neither steady nor consistent.

No significant difference was noted with inoculation on 90th day after sowing and at harvest. But an increasing trend was observed with inoculation over control. Interaction also had no significant effect. It was also noted that the dry weight of seeds increased from 90th day to harvest.

The discussion on this will be covered subsequently.

v) Total phytomass production per plant

The data on total phytomass produced per plant during various growth stages are presented in Table 8 and Fig. 5. The analysis of variance and mean table for interactions are given in Appendices 4 and 26 respectively.

At none of the stages except 75th day after sowing potassium exerted any influence on the total phytomass production. On the 75th day after sowing 120 kg K_2O ha^{-1} recorded the highest value of 18.623 g $plant^{-1}$ which was on a par with 60 kg K_2O ha^{-1} but superior to all the other levels. The effect of potassium was not significant

Table 8. Effect of potassium and inoculation on total phytomass production at various growth stages.

Treatments	Total phytomass production per plant (g)					
	30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing	Harvest
Levels of potassium (K_2O kg ha^{-1})						
0	0.509	3.214	6.518	12.751	11.891	8.319
30	0.519	2.878	7.814	12.641	15.490	11.106
60	0.530	2.399	8.583	17.214	13.071	11.638
90	0.453	3.383	9.020	13.089	15.920	10.756
120	0.601	3.290	7.434	18.625	15.714	15.569
SEm ±	0.060	0.298	0.800	1.500	1.736	1.570
C.D. at 5%	NS	NS	NS	4.353	NS	NS
Rhizobial inoculation						
Uninoculated	0.499	3.006	8.475	14.723	12.611	10.840
Inoculated	0.546	3.060	7.273	15.004	16.223	12.315
SEm ±	0.038	0.189	0.506	0.948	1.098	0.993
C.D. at 5%	NS	NS	NS	NS	3.186	NS

at all other stages. However, there was an increase in phytomass production upto 30 kg K_2O ha^{-1} in all the stages except on the 45th and 75th days after sowing.

It can be seen from Tables 5, 6 and 7 that there was no significant increase in dry matter accumulation in stem, leaves, shells and seeds at any of the stages by application of potassium. These results also support the conclusion that the native potassium status of the soil is adequate for the growth of soybean.

Effect of inoculation on total phytomass production was significant only on 90th day after sowing and the highest value of 16.223 g $plant^{-1}$ was recorded in the inoculated plot as against 12.611 g $plant^{-1}$ in the uninoculated plot.

The non-significant effect of inoculation on phytomass production in almost all the stages may be due to its inability to influence the dry matter accumulation in the various plant parts as evidenced from Tables 5, 6 and 7.

Interaction between potassium and inoculation was found to be significant only on the 45th day after sowing. The treatment 120 kg K_2O ha^{-1} along with inoculation recorded the highest value of 3.923 g $plant^{-1}$.

Many of the reported experimental results indicate significant increase of dry weight, consequent to application of potassium (Chevalier, 1976; Terman, 1977) and inoculation (Rewari *et al*., 1973; Prokopenko and Vashchenko, 1974; Rao and Patil, 1977; Ruiz-Argueso *et al*., 1977).

There was a steady increase in the dry weight of stem and leaf upto the 75th day after sowing, after which it showed a conspicuous reduction. Hence the total phytomass production per plant also showed a similar trend. The highest dry weight recorded on the 75th day and a decrease in total dry weight noticed between 90th day and harvest may be attributed to the leaf fall that occurred at the advanced stage of maturity. A decrease in dry weight of shells noticed between the above stages also substantiates the above results.

f. Growth analysis

1) Specific leaf area

The results on specific leaf area during the various stages of plant growth are presented in Table 9 and the analysis of variance in Appendix 5.

Specific leaf area was not influenced by the levels of potassium at any stages of plant growth.

The effect of inoculation on specific leaf area was significant only between the 60th and 75th day after sowing.

The interaction effect due to various combinations was also not significant.

The maximum specific leaf area was recorded between 30th and 45th day after sowing. It can be seen from Table 10 that the leaf area was increasing sharply during this stage indicating a rapid leaf expansion which might have resulted in higher specific leaf area.

Comparison between stages indicated a decline in specific leaf area with age, which might perhaps be due to the accumulation of minerals in the leaves in the advanced stages of growth.

ii) Leaf weight ratio

The data on the leaf weight ratio between different stages of plant growth are presented in Table 9 and the analysis of variance in Appendix 5.

The data revealed that the effect of potassium on leaf weight ratio was not significant at any stage of growth. Similarly, inoculation also did not significantly influence this character at any of the growth stages.

Table 9. Effect of potassium and inoculation on specific leaf area and leaf weight ratio between various growth stages.

Treatments	Specific leaf area ($cm^2 g^{-1}$)				Leaf weight ratio			
	Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing	Between 75th and 90th day after sowing	Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing	Between 75th and 90th day after sowing
Levels of potassium (K_2O kg ha^{-1})								
0	408.85	412.64	358.68	330.22	0.536	0.435	0.332	0.205
30	392.10	402.30	348.33	324.11	0.509	0.436	0.341	0.209
60	413.26	380.51	361.05	335.81	0.515	0.440	0.335	0.205
90	426.96	389.85	364.63	355.82	0.513	0.445	0.344	0.196
120	429.36	424.14	350.21	320.72	0.520	0.440	0.339	0.205
SEm ±	19.21	19.94	15.25	15.88	0.009	0.008	0.005	0.007
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Rhizobial inoculation								
Uninoculated	427.19	399.04	342.18	332.68	0.552	0.441	0.338	0.206
Inoculated	401.02	408.74	370.98	341.87	0.515	0.437	0.339	0.202
SEm ±	12.15	12.61	9.65	10.05	0.006	0.005	0.003	0.004
C.D. at 5%	NS	NS	28.00	NS	NS	NS	NS	NS

The inoculated treatment was on a par with the uninoculated one.

The interaction effects between potassium and inoculation were also not significant.

It was also observed that the leaf weight ratio decreased over stages and the decreasing trend was more or less uniform for the various treatments. The decline in leaf weight ratio noticed with age of plants, may be due to the reduction in leaf weight consequent to abscission of leaves, translocation of carbohydrates to reproductive organs and increase in dry weight of plant parts other than leaves.

iii) Leaf area index (LAI)

The data on leaf area index during the various stages of plant growth are presented in Table 10 and the analysis of variance in Appendix 6.

Neither the effects of levels of potassium and inoculation nor their interactions were significant on this character at any stages of plant growth. The effect of potassium on leaf area index was erratic and no uniform trend could be noticed with levels of potassium at any of the growth stages.

Nair (1978) and Kurien (1979) also reported that inoculation had no influence on LAI.

It was also observed that LAI increased from 30th day to 75th day and the highest values were recorded at this stage and after that there was a sharp decline. The reduction in LAI after this stage was due to leaf shedding.

iv) Absolute growth rate (AGR)

The data on absolute growth rate are presented in Table 11 and Fig. 7. The analysis of variance and mean table for interaction are given in Appendices 7 and 27 respectively.

Increasing levels of potassium had significant effect only between 60th and 75th day after sowing and the highest value of 0.746 g day^{-1} was recorded in the treatment 120 kg K_2O ha^{-1} which was on par with 60 kg K_2O ha^{-1}. In all other stages, potassium did not make any significant difference.

Inoculation failed to produce any significant influence on AGR at any stage of observation. However, there was an increase in AGR, though marginal, due to inoculation in all the stages except between 45th and 60th day after sowing.

Table 10. Effect of potassium and inoculation on leaf area index at various growth stages.

Treatments	Leaf area index				
	30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})					
0	0.461	3.071	4.066	5.538	2.400
30	0.421	2.755	5.081	5.238	2.874
60	0.579	2.024	5.356	6.890	2.640
90	0.455	3.050	6.039	5.174	2.316
120	0.580	3.235	4.946	7.444	2.926
SEm ±	0.064	0.083	0.597	0.605	0.364
C.D. at 5%	NS	NS	NS	NS	NS
Rhizobial inoculation					
Uninoculated	0.491	2.902	5.284	5.968	2.318
Inoculated	0.508	2.752	5.112	5.281	2.945
SEm ±	0.040	0.052	0.377	0.383	0.230
C.D. at 5%	NS	NS	NS	NS	NS

Interaction effect was significant only between 30th and 45th day after sowing and 120 kg K_2O ha^{-1} along with inoculation recorded the highest AGR of 0.23 g day^{-1} at this stage.

There was a steady increase in AGR upto the 75th day in all the treatments except in 90 kg K_2O ha^{-1}. It can be seen from Table 8 that there was a steady increase in total phytomass production upto 75th day and hence a more or less similar trend was noticed in AGR also.

v) Crop growth rate (CGR)

The data on crop growth rate at different stages of growth are presented in Table 11 and Fig.8. The analysis of variance and mean table for two factor combinations are given in Appendices7 and 28 respectively.

As in the case of AGR, potassium had significant effect on CGR only between 60th and 75th day after sowing and the treatment 120 kg K_2O ha^{-1} recorded the highest value of 33.146 g m^{-2} day^{-1} which was on par with 60 kg K_2O ha^{-1}.

No significant difference was noted with inoculation at any stage of growth.

Interaction effect was significant only between 30th and 45 day after sowing and 120 kg K_2O ha^{-1} along

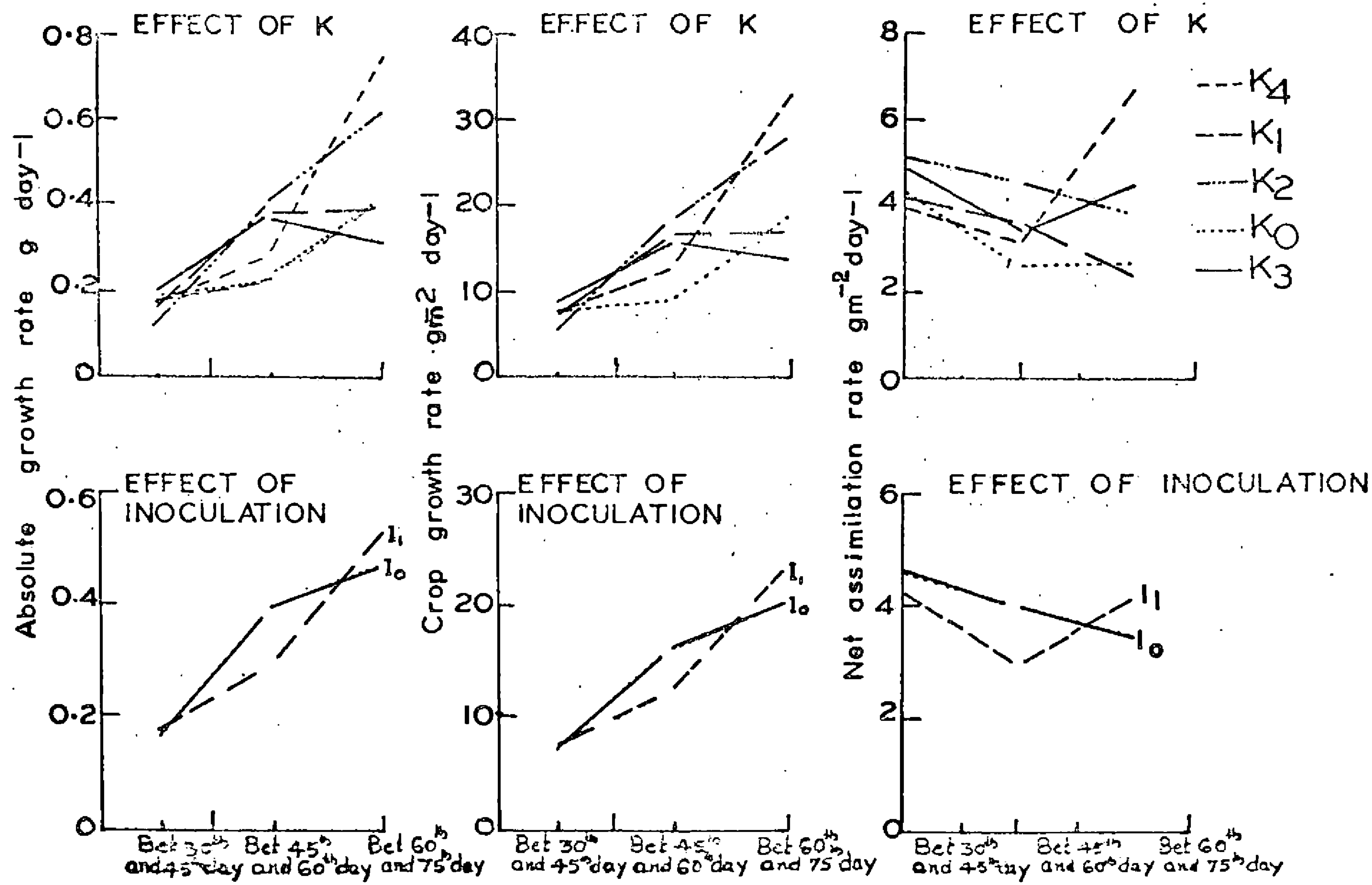
Table 11. Effect of potassium and inoculation on absolute growth rate, crop growth rate and net assimilation rate between various growth stages.

Treatments	Absolute growth rate (g day^{-1})			Crop growth rate (g m^{-2} day^{-1})			Net assimilation rate (g m^{-2} day^{-1})		
	Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing	Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing	Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing
Levels of potassium (K_2O kg ha^{-1})									
0	0.181	0.220	0.416	8.021	9.794	18.491	4.435	2.619	2.660
30	0.157	0.308	0.395	6.988	17.217	17.531	4.355	3.710	2.405
60	0.124	0.413	0.635	5.527	18.331	28.128	5.210	4.628	3.915
90	0.195	0.376	0.313	8.677	16.704	13.915	5.164	3.686	4.456
120	0.179	0.290	0.746	7.971	12.871	33.146	4.126	3.178	6.886
SEm ±	0.018	0.057	0.096	0.815	2.530	4.277	0.554	0.524	0.821
C.D. at 5%	NS	NS	0.279	NS	NS	12.413	NS	NS	2.384
Rhizobial inoculation									
Uninoculated	0.167	0.388	0.469	7.413	17.241	20.828	4.577	4.045	3.494
Inoculated	0.168	0.286	0.532	7.462	12.726	23.656	4.274	3.004	4.156
SEm ±	0.011	0.036	0.061	0.515	1.600	2.705	0.350	0.332	0.519
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	0.963	NS

FIG. 7 ABSOLUTE GROWTH RATE BETWEEN STAGES

FIG. 8 CROP GROWTH RATE BETWEEN STAGES

FIG. 9 NET ASSIMILATION RATE BETWEEN STAGES



with inoculation recorded the highest value of 10.063 g m^{-2} day^{-1}.

It was also noted that CGR increased from 30th day upto 75th day following the same trend observed in AGR.

CGR is defined as the increase of plant material per unit of time and is a function of NAR and LAI. In the present study, LAI increased upto 75th day but NAR decreased upto 60th day and then remained nearly constant. The increase in CGR upto 60th day was because of a larger increase in LAI than the decrease in NAR.

The reasons discussed under AGR are applicable here also.

vi) Net assimilation rate (NAR)

The data on net assimilation rate during various growth stages are presented in Table 11 and Fig. 9 and the analysis of variance in Appendix 7.

Potassium levels influenced NAR significantly only between 60th and 75th day after sowing and the treatment 120 kg K_2O ha^{-1} recorded the highest value of 6.886 g $m^{-2}day^{-1}$ which was superior to all other levels. In the other stages of growth, the effect of potassium was not significant.

Increase in NAR due to inoculation was found to be significant only between 45th and 60th day after sowing. The uninoculated plot recorded the highest value of 4.045 g $m^{-2}day^{-1}$ against 3.004 g $m^{-2}day^{-1}$ in the inoculated treatment.

Interaction effect was not significant in all the stages.

It was also observed that the NAR decreased from 30th day to 60th day and after that there was an increase except in 60 kg K_2O ha^{-1} and 30 kg K_2O ha^{-1}. It can be seen from Table 10 that the LAI increased sharply from 30th day upto 75th day after which there was a decline. It is generally expected that NAR will decrease with increase in LAI especially at higher LAI values. In the present study also a more or less similar relationship was noticed indicating thereby that LAI was high enough to exert mutal shading.

II. Post-harvest observations

a) Number of pods per plant

The data on number of pods per plant at harvest are presented in Table 12 and the analysis of variance in Appendix 8.

Number of pods per plant was not influenced by levels of potassium. But an increasing trend in number

Table 12. Effect of potassium and inoculation on number of pods per plant, weight of pods per plant, number of seeds per pod, 1000 seed weight and shelling percentage.

Treatments	Number of pods per plant	Weight of pods per plant (g)	Number of seeds per pod	1000 seed weight (g)	Shelling percentage 90th day after sowing	Shelling percentage Harvest
Levels of potassium (K_2O kg ha^{-1})						
0	29.62 (5.443)	3.93	2.03 (1.425)	97.16	49.75	65.71
30	30.94 (5.562)	4.86	2.10 (1.450)	96.09	48.10	64.97
60	33.90 (5.822)	4.76	1.86 (1.363)	94.12	47.89	64.42
90	40.03 (6.327)	4.35	2.00 (1.416)	98.08	48.28	64.06
120	23.30 (4.827)	6.87	1.913 (1.382)	99.47	46.51	65.76
SEm ±	0.343	0.709	0.021	2.260	2.881	1.242
C.D. at 5%	NS	NS	(0.062)	NS	NS	NS
Rhizobial inoculation						
Uninoculated	29.96 (5.474)	4.724	1.980 (1.409)	96.88	48.36	65.03
Inoculated	32.70 (5.719)	5.181	1.980 (1.409)	97.09	47.86	64.92
SEm ±	0.216	0.448	0.013	1.429	1.822	0.785
C.D. at 5%	NS	NS	NS	NS	NS	NS

Figures in parenthesis indicate $\sqrt{x}$ transformed values of pods per plant was noticed with increasing levels of potassium upto 90 kg K_2O ha^{-1}.

Inoculationalso failed to influence this character. The interaction effect was also not significant.

The absence of a significant increase in the number of pods per plant in this study indicates that the level of native potassium in the soil was adequate to produce maximum number of pods. It may also be noted that in this experiment there was no significant increase in final yield also, due to potassium application.

Ruschel et al. (1975) reported an increase in number of pods per plant when culture inoculation was resorted to, presumably through the increased nitrogen supply by enhanced symbiotic nitrogen fixation. But in this study, there was no response to culture inoculation. Similar results were obtained by Kurien (1979) .

b) Weight of pods per plant

The data on the weight of pods per plant are presented in Table 12 and the analysis of variance in Appendix 8.

It is seen that the effect of potassium was not significant on weight of pods per plant. However, an increasing trend was noticed upto 30 kg K_2O ha^{-1}.

Inoculation failed to produce any significant effect on this character. Interaction effect was also not significant.

The total weight of the pods per plant is a function of the number of pods per plant and the test weight. It may be noted that these characters were not significantly affected by the various treatments under study. Hence the weight of pods per plant also remained unaffected.

c) Number of seeds per pod

The mean values on number of seeds per pod are presented in Table 12 and the analysis of variance in Appendix 8.

The results revealed that the effect of potassium was significant and 30 kg K_2O ha^{-1} registered the highest value of 2.1 seeds per pod. When the level of potassium was further increased, the number of seeds per pod decreased.

The reduction in number of seeds may be due to the nutritional imbalance at higher levels of potassium (Russell, 1975) for instance due to luxury consumption.

It can be concluded that 30 kg K_2O ha^{-1} at the existing soil fertility level was optimum for obtaining higher number of seeds per pod.

Inoculation and interaction effects were not significant.

The lack of response noted due to culture inoculation was in agreement with the findings of Kurien (1979).

d) 1000 seed weight

The data on 1000 seed weight for various treatments are presented in Table 12 and the analysis of variance in Appendix 8.

All the levels of potassium and rhizobial inoculation were on a par statistically. Interaction effects were also not significant.

The lack of response of potassium on test weight in this study again indicates that the level of native potassium in the soil was adequate.

The ineffectiveness of inoculation on test weight observed in this study is in agreement with the findings of Kurien (1979).

e) Shelling percentage

The data on shelling percentage on 90th day after sowing and at harvest are presented in Table 12 and the analysis of variance in Appendix 8.

The effects of potassium, inoculation and their interactions were not significant on both the stages.

There was a marked increase in shelling percentage from 90th day to harvest. Most of the increase must be attributed to the increase in seed weight and the reduction in shell weight (Table 7) with maturity.

The reasons attributed to the lack of significant increase in the other yield components consequent to application of potassium and culture inoculation are applicable in this case also.

f) Moisture percentage of seeds

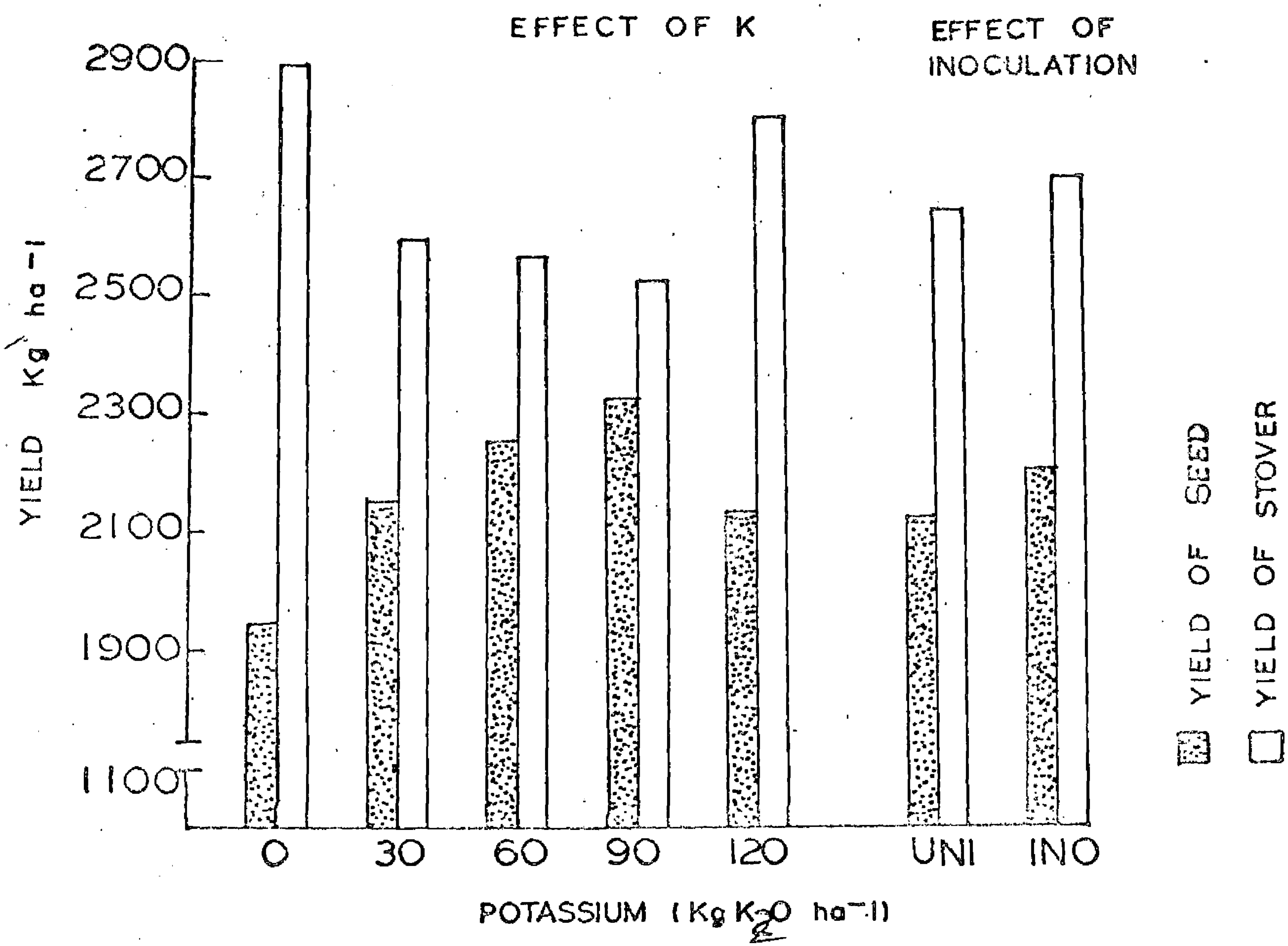
Data on moisture percentage of seeds are presented in Table 13. The analysis of variance and mean table for two factor combinations are given in Appendices 8 and 29 respectively.

None of the treatments could influence moisture percentage of seeds significantly. But the interaction effects were significant.

Table 13. Effect of potassium and inoculation on moisture percentage of seeds, seed yield, stover yield and harvest index.

Treatments	Moisture percentage of seeds	Yield (kg ha^{-1})		Harvest index
		Seed	Stover	
Levels of potassium (K_2O kg ha^{-1})				
0	7.49	1941.10	2888.50	0.416
30	7.11	2147.75	2594.20	0.453
60	7.30	2251.93	2557.90	0.423
90	6.79	2318.04	2523.10	0.478
120	7.45	2127.93	2796.00	0.463
SEm ±	0.347	100.264	135.787	0.013
C.D. at 5%	NS	NS	NS	0.036
Rhizobial inoculation				
Uninoculated	6.95	2116.33	2640.90	0.456
Inoculated	7.50	2198.38	2703.00	0.433
SEm ±	0.219	63.413	85.880	0.008
C.D. at 5%	NS	NS	NS	NS

FIG. 10 YIELD OF SEED AND STOVER



Moisture content of seed is usually considered to be a character indicative of difference in the degree of maturity. The study indicated that this component was not altered by the different treatments. One of the objectives of recording the moisture content of seeds was to adjust the seed yield of the net plot to a uniform moisture content. As the data showed no difference in moisture percentage, such an adjustment was not done.

There was a significant variation in moisture percentage due to interaction and the highest value was recorded in 0 kg K_2O ha^{-1} along with inoculation. Though such a significant variation was noticed, the results were inconsistent and difficult to explain.

g) Yield of seeds

Data on Table 13 and Fig. 10 show the mean values on yield of seeds. The analysis of variance is given in Appendix 8.

The results revealed that the effect of potassium on seed yield was not significant. But there was an increase in seed yield from control upto 90 kg K_2O ha^{-1} after which there was a decline.

Increase in seed yield due to inoculation was found to be not significant. However, there was an increase in seed yield, though marginal, due to inoculation.

The interaction effect of potassium and inoculation was also not significant.

The results of a non-significant effect of graded levels of potassium on seed yield is in agreement with the trend noticed in the case of yield components. There was also no consistent improvement in the growth of the plant as indicated by the results on the growth characters like plant height, number of branches and by the data on dry weights of the plant components. Similarly, potassium application could not influence nodule weight also. In almost all stages, the content and uptake of nitrogen by soybean were also not increased by application of potassium(Tables 15 and 16). All these point to the fact that the availability of potassium in the soil on which the experiment was conducted was adequate enough, both in terms of requirement for the growth of crop and for effective nodulation and nitrogen fixation. It can be seen from Table 1 that the soil initially contained 157.5 ppm of available potassium which was quite high.

A number of reports are available in literature showing increased yield of soybean consequent to application of potassium (Maples and Keogh, 1969; Cavinoss and Hardy, 1970; Bhangoo et al., 1972; Chesney, 1973; Fauconnier, 1976; Ferrari et al., 1976; Keogh et al., 1976; Markus, 1976 and Graves et al., 1978).

There are also a few reported results in which there was no increase in yield because of application of potassium (Reddi et al., 1976). Negative response due to potassium application was also reported by Svec et al. (1976).

Culture inoculation did not result in a significant increase in yield. However, the mean yield of the inoculated plot was slightly higher than the uninoculated one. The average yield of seeds obtained was fairly high and comparable to the yield figure observed in literature. Such a result points to the fact that the crop did not suffer for want of nitrogen symbiotically fixed. There was also no visual symptom of nitrogen deficiency in the crop. The data on nodule weight and nodule number also substantiate the fact that inoculation was not beneficial. All these results point to the fact that the soil originally had adequate number of strains of Rhizobium japonicum, effective on soybean. In a similar experiment conducted earlier in the same type of soil, there was a significant decrease in yield, nodulation and nitrogen uptake of soybean when culture inoculation was done (Nair, 1978). It was then concluded from the results that there was not only adequate number of effective strains of Rhizobium but also that the strains introduced through the culture were less effective on soybean. Kurien (1979) has also observed a decrease in yield, though not significant in the same type of soil consequent to culture inoculation. However, literature on this subject in general indicates an improvement in the performance of the crop due to inoculation.

h) Yield of stover

The mean values on stover yield are presented in Table 13 and Fig.10. The analysis of variance and mean table for two factor combinations are given in Appendices 8 and 30 respectively.

Yield of stover was not influenced significantly by levels of potassium. Moreover, a decreasing trend in stover yield was noticed from control upto 90 kg K_2O ha^{-1}.

Inoculation also failed to influence stover yield, though a marginal increase was noted with the inoculated plots over the uninoculated ones.

Interaction effect was significant and 60 kg K_2O ha^{-1} along with inoculation recorded the highest stover yield of 2972.9 kg ha^{-1}.

It can be seen from Table 3 that the growth characters such as height of plants and number of branches were not significantly influenced due to potassium application at any stage of plant growth. Similarly the total dry weight of plants was also not affected significantly in any of the stages except on 75th day. The nonsignificant effect of potash on stover yield is due to the inability of this nutrient to influence the growth characters.

Inoculation also failed to influence the stover yield significantly and this again can be attributed to the non-significant influence of this treatment on growth characters at almost all stages of plant growth. Similar non-significant influence of inoculation on stover yield was reported by Kurien (1979).

Though interaction effect between potassium and inoculation was significant, the results were inconsistent and difficult to explain.

i) Harvest index

The data on harvest index are presented in Table 13 and the analysis of variance in Appendix 8.

Harvest index was influenced by the levels of potassium significantly and 90 kg K_2O ha^{-1} recorded the highest value of 0.468, which was on par with 120 kg K_2O ha^{-1}

and 30 kg K_2O ha^{-1}. No significant difference was noted due to inoculation. Interaction effect was also not significant.

The failure of inoculation to affect harvest index may be due to its inability to influence seed yield and stover yield. Similar results were obtained by Kurien (1979), in the same type of soil.

III. Chemical studies

A.1. Nitrogen content

a) Nitrogen content of stem

The data on nitrogen content of stem during the various stages of plant growth are presented in Table 14 and Fig. 11. The analysis of variance and the mean tables for two factor combinations are given in Appendices 9 and 31 to 33 respectively.

The data revealed that the effect of potassium on nitrogen content of stem was significant on 30th and 60th days and at harvest. On 30th day, the control plot recorded the highest content of 1.144 per cent which was superior to all other levels. But on 60th day, 90 kg K_2O ha^{-1} recorded the highest content of 1.049 per cent which was on par with 120 kg K_2O ha^{-1}. At harvest also the control plot recorded the highest value of 0.555 per cent and was superior to all other levels. Though there was significant variation in nitrogen content of stem, the results were

Table 14. Effect of potassium and inoculation on nitrogen content of stem and leaves at various growth stages.

Treatments	Nitrogen content (%)						
	Stem				Leaves		
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})							
0	1.144	0.930	0.673	0.555	2.727	3.427	1.841
30	1.044	0.860	0.674	0.491	3.050	3.272	2.496
60	1.032	0.973	0.780	0.367	3.135	3.493	2.498
90	1.049	1.049	0.705	0.334	3.000	2.811	2.094
120	1.015	1.024	0.743	0.330	3.321	3.440	2.457
SEm ±	0.003	0.010	0.029	0.003	0.035	0.168	0.037
C.D. at 5%	0.008	0.041	NS	0.009	0.101	0.687	0.107
Rhizobial inoculation							
Uninoculated	1.095	0.974	0.716	0.431	3.025	3.272	2.184
Inoculated	1.078	0.961	0.714	0.402	3.069	3.305	2.369
SEm ±	0.001	0.009	0.018	0.001	0.022	0.106	0.023
C.D. at 5%	0.006	NS	NS	0.006	NS	NS	0.067

FIG. 11 NITROGEN CONTENT OF STEM AT DIFFERENT STAGES

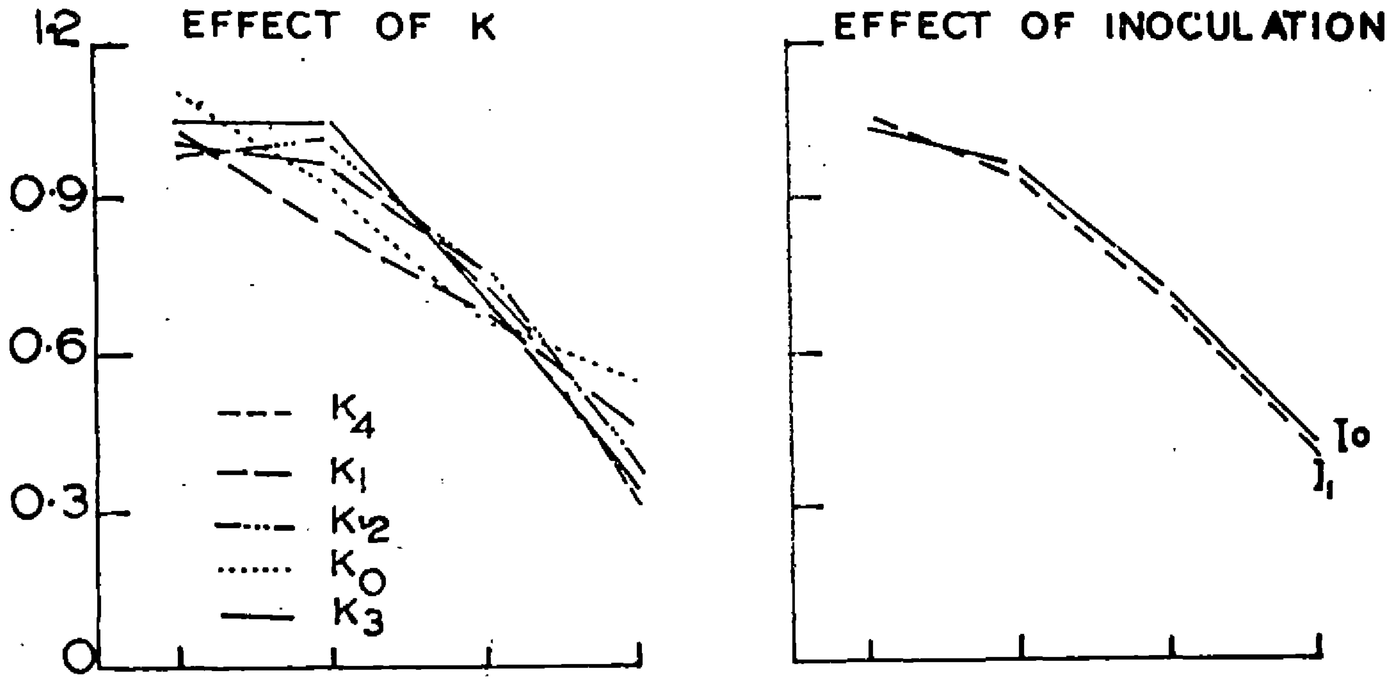
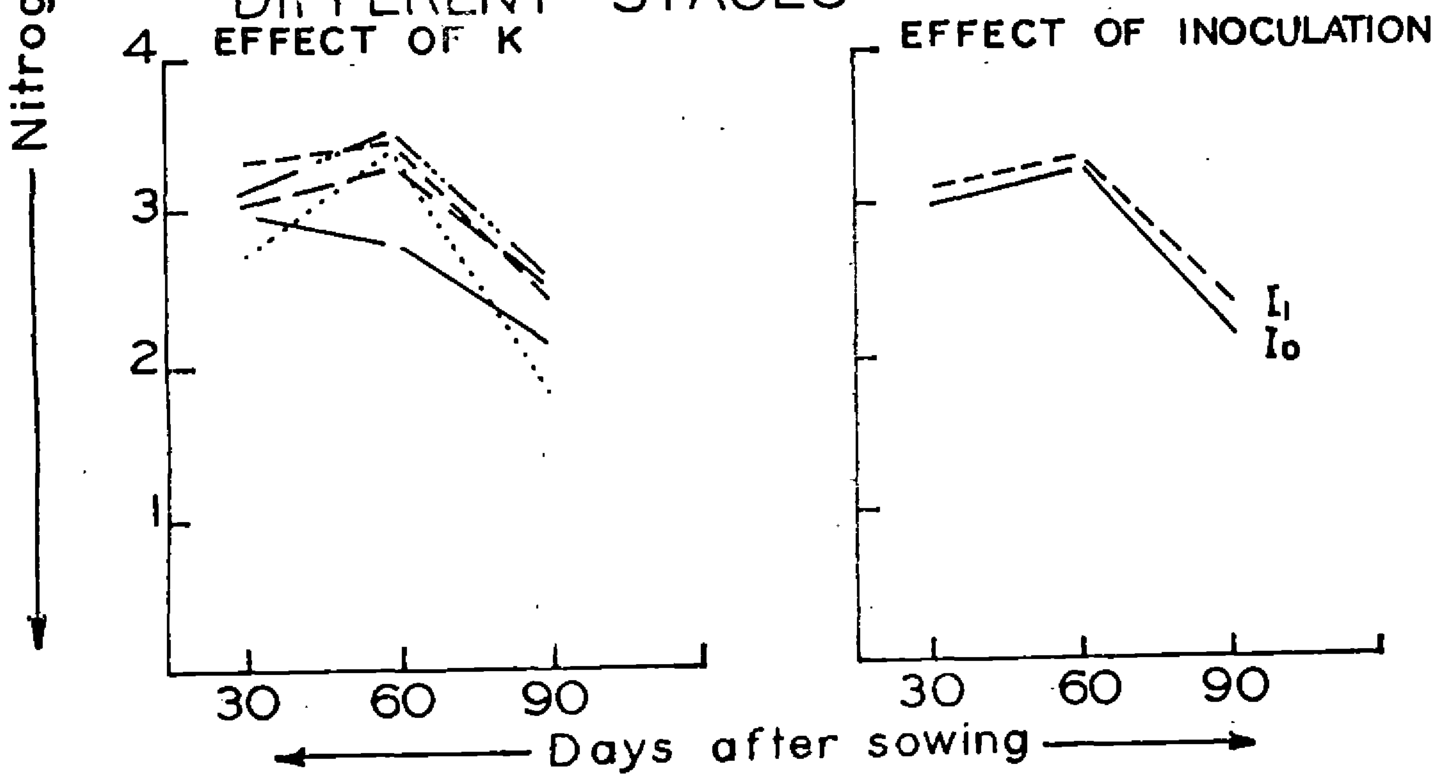


FIG. 12 NITROGEN CONTENT OF LEAVES AT DIFFERENT STAGES



not consistent.

Inoculation influenced the nitrogen content of stem on 30th day and at harvest. On 30th day, the inoculated plot recorded the highest percentage of nitrogen while at harvest the reverse was true. The effects of inoculation on 60th and 90th days were not significant.

Interaction effect was also significant on 30th and 60th days and at harvest. On 30th day, 0 kg K_2O ha^{-1} along with inoculation recorded the highest per cent while on 60th day, 90 kg K_2O ha^{-1} without inoculation recorded the highest value. But at harvest, 30 kg K_2O ha^{-1} without inoculation recorded the highest per cent.

The nitrogen content of stem was highest in the initial stages which decreased markedly with advancement of crop growth.

The non-significant difference noticed in the nitrogen content of stem in some stages, is in agreement with the findings of Kurien (1979).

One of the reasons for the marked decline in nitrogen content of stem over stages may be due to the dilution of nitrogen in larger bulk of the dry matter as the plants develop. The translocation of this nutrient from stem to the sink might have also contributed to this.

b) Nitrogen content of leaves

The data on nitrogen content of leaves on different stages are presented in Table 14 and Fig. 12. The analysis of variance and the mean tables for two factor combinations are given in Appendices 9 and 34 to 35 respectively.

There was significant difference in the nitrogen content of leaves due to potassium application on all the stages studied. On 30th day, 120 kg K_2O ha^{-1} recorded the highest content, which was superior to all other levels, while on 60th day and 90th days, 60 kg K_2O ha^{-1} recorded the highest values.

The effect of inoculation on nitrogen content of leaves was significant only on 90th day and the inoculated treatment recorded a nitrogen content of 2.369 per cent while the uninoculated plot gave 2.184 per cent. In all the other stages, the effect of inoculation remained non-significant.

The interaction effect was significant on 30th and 90th days and 120 kg K_2O ha^{-1} along with inoculation recorded the highest content of nitrogen in both the above stages.

It was also observed that there was a slight increase in nitrogen content of leaves from 30th day upto 60th day in all the treatments, except in 90 kg K_2O ha^{-1}, after which there was a sharp decline.

The increase in nitrogen content of leaves in the early stage indicates accumulation of absorbed nitrogen in the leaves. The reduction in the content of this nutrient in the leaves during advanced stages of growth may be due to the dilution effect of nitrogen in the bulk of dry matter and its translocation to the developing seeds. The "self destructive phenomenon" of this crop is well known.

c) Nitrogen content of shells

Table 15 and Fig. 13 show the data on the nitrogen content of shells on 90th day after sowing and at harvest. The analysis of variance and the mean tables for two factor combinations are given in Appendices 10 and 36 to 37 respectively.

Potassium had significant effect on nitrogen content of shells on both the above stages. On 90th day, 120 kg K_2O ha^{-1} recorded the highest content of 1.632 per cent which was on par with 30 kg K_2O ha^{-1} and superior to all other levels. At harvest, 30 kg K_2O ha^{-1} recorded the highest per cent of 0.695 and was superior to all other levels.

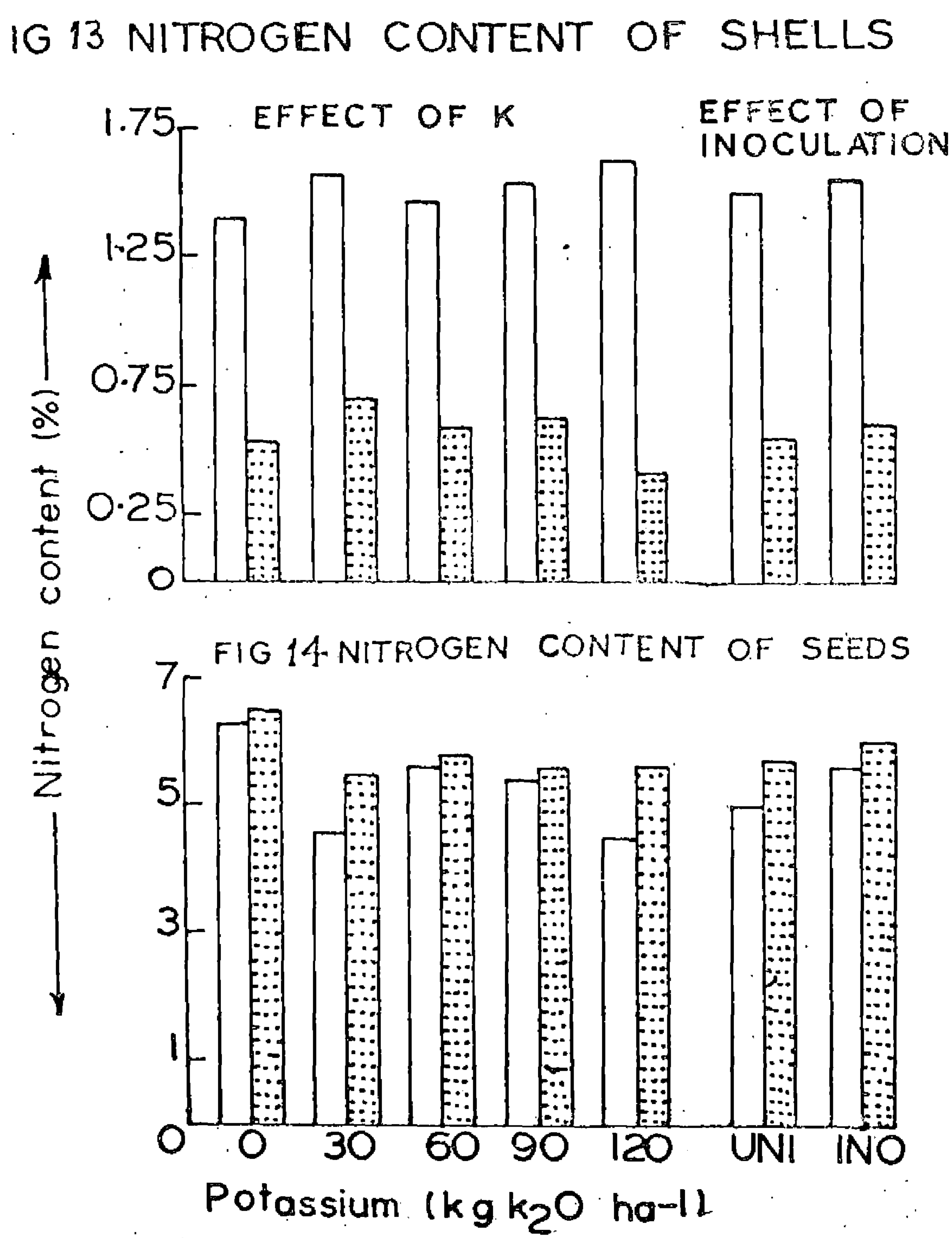
Inoculation increased the nitrogen content of shells significantly on both the stages and the inoculated treatment was superior to the uninoculated ones.

On 90th day and at harvest, interaction effect was significant and 30 kg K_2O ha^{-1} along with inoculation recorded the highest values in both stages.

It was also observed that there was a conspicuous decline in nitrogen content of shells at harvest compared

Table 15. Effect of potassium and inoculation on nitrogen content of shells, seeds and plants at various growth stages.

Treatments	Nitrogen content (%)							
	Shells		Seeds		Plants			
	90th day after sowing	Harvest	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest
Levels of potassium (K_2O kg ha^{-1})								
0	1.389	0.543	6.275	6.513	2.063	1.888	2.488	3.238
30	1.584	0.695	4.606	5.501	2.175	1.813	2.100	2.803
60	1.476	0.603	5.638	5.844	2.538	1.938	2.263	2.688
90	1.541	0.605	5.363	5.638	2.563	1.963	2.250	2.941
120	1.632	0.422	4.538	5.638	2.350	1.963	2.113	2.813
SEm ±	0.019	0.028	0.057	0.062	0.187	0.043	0.080	0.171
C.D. at 5%	0.057	0.082	0.166	0.182	NS	NS	0.232	NS
Rhizobial inoculation								
Uninoculated	1.506	0.552	4.977	5.658	2.390	1.655	2.205	2.917
Inoculated	1.544	0.595	5.590	5.995	2.285	1.970	2.280	2.880
SEm ±	0.013	0.018	0.036	0.040	0.118	0.027	0.050	0.108
C.D. at 5%	0.036	0.052	0.105	0.115	NS	0.079	NS	NS


IG 13 NITROGEN CONTENT OF SHELLS
EFFECT OF K
EFFECT OF INOCULATION
1.75
1·25
0·75
0·25
0
FIG 14 NITROGEN CONTENT OF SEEDS
7
5
3
1
0
0
30
60
90
120
UNI
INO
Potassium (kg k2O ha-1)
Nitrogen content (%)
90th Day
At harvest

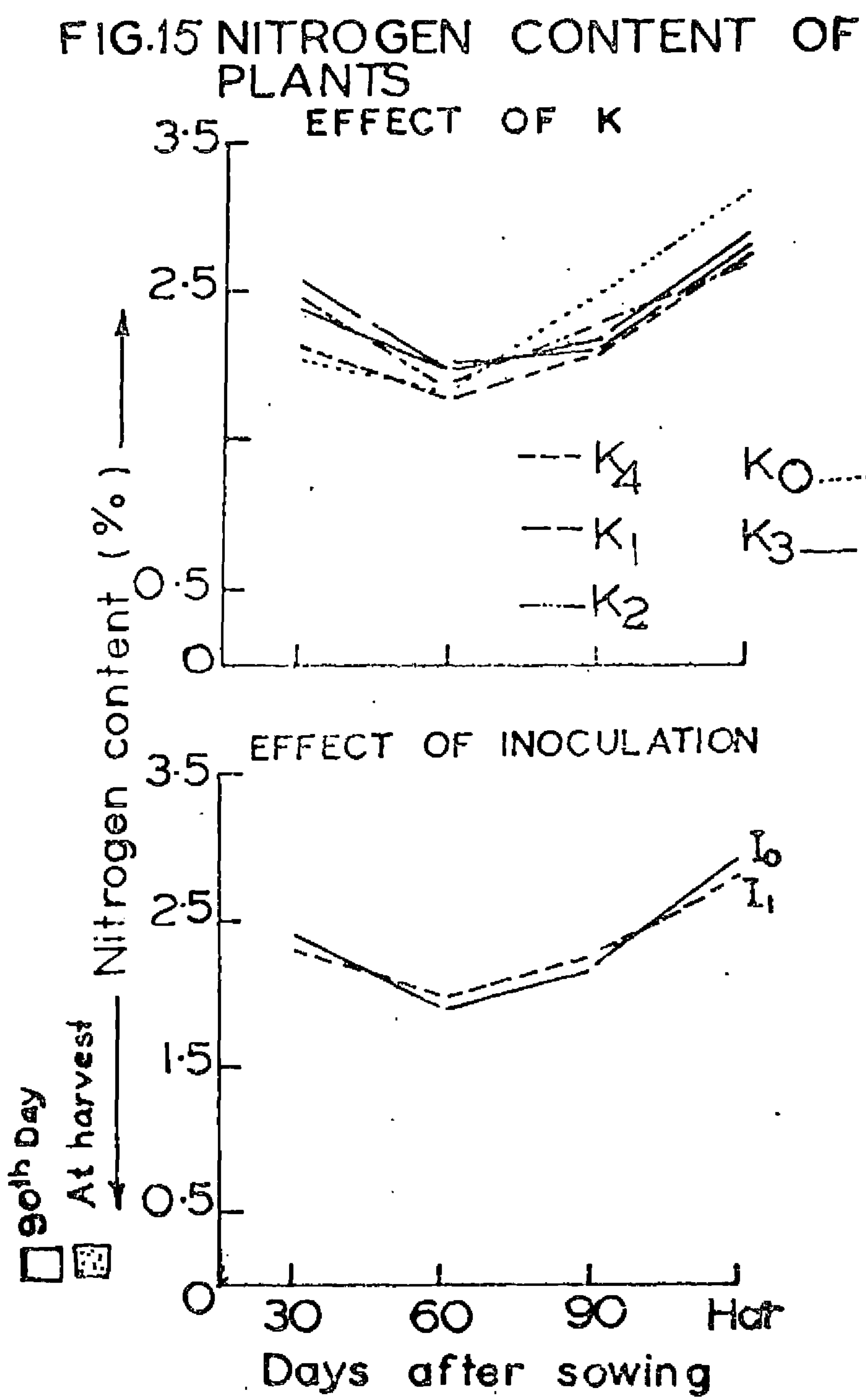


FIG.15 NITROGEN CONTENT OF PLANTS
EFFECT OF K
3·5
2·5
0·5
0
K4
K1
K2
K0
K3
EFFECT OF INOCULATION
3·5
2·5
1·5
0·5
0
I0
I1
30
60
90
Har
Days after sowing
Nitrogen content (%)

to that on 90th day in all the treatments. The reduction in nitrogen content may be due to translocation of nitrogen to the sink.

d) Nitrogen content of seeds

The data on nitrogen content of seeds on 90th day after sowing and at harvest are presented in Table 15 and Fig. 14. The analysis of variance and the mean tables for two factor combinations are given in Appendices 10 and 38 to 39 respectively.

Potassium levels influenced the nitrogen content of seeds on both 90th day and at harvest. On 90th day, the control plot recorded the highest nitrogen content of 6.275 per cent and was superior to all other treatments. The next highest value was recorded at 60 kg K_2O ha^{-1} followed by 90 kg K_2O ha^{-1}. At harvest also, the same trend was noticed and the control plot gave the highest per cent of 6.313 which was significantly superior to all other treatments.

Inoculation also influenced the nitrogen content of seeds at both the above stages and the inoculated treatment was superior to the uninoculated ones.

Interaction effect was significant on 90th day and at harvest. The treatment 0 kg K_2O ha^{-1} along with inoculation recorded the highest per cent in both the stages.

It was also observed that there was a slight increase in nitrogen content of seeds from 90th day to harvest.

Though there was no definite pattern of change in nitrogen content due to potassium application, a general decrease in nitrogen content was noticed with higher doses of potassium in both the stages. In this study it was observed that the oil content of seed increased with applied potassium. The decrease in nitrogen content of seeds with higher levels of potassium may be due to the mobilisation of the plant metabolites to synthesise oil at the expense of organic nitrogen compounds.

The significant increase in nitrogen content due to inoculation indicate the beneficial effect of this treatment to absorb nitrogen and increase protein content of seeds.

c) Nitrogen content of plants

The data on nitrogen content of plants at different stages of growth are presented in Table 15 and Fig. 15 and the analysis of variance in Appendix 10.

At none of the stages, except 90th day, potassium exerted any influence on the nitrogen content of plants. On 90th day, control plots recorded the highest per cent of 2.488 which was on a par with 60 kg K_2O ha^{-1}, but superior to all other levels.

Effect of inoculation on nitrogen content of plants was significant only on 60th day and the highest per cent of 1.97 was recorded in the inoculated plot. In all other stages, the effect was not significant.

The effect of interaction was not significant in all the stages studied.

Comparing between stages, there was a decline in nitrogen content of plants between 30th and 60th day, and after that there was a steady increase in all the treatments.

The decline in nitrogen content of the plants between 30th and 60th day indicates that the rate of absorption of this nutrient was slower than the rate of carbohydrate production during these stages. Increase in the content of this nutrient from 60th day onwards may be due to the higher rate of absorption of nitrogen to meet the demand of the developing seeds. The results thus indicate the importance of maintaining conditions favourable for nitrogen fixation during both vegetative and reproductive stages of the crop.

A.2. Uptake of nitrogen

a) Uptake of nitrogen by stem

Uptake of nitrogen by stem at different stages of growth are furnished in Table 16. The analysis of variance and the mean table for two factor combinations are given in Appendices 11 and 40 respectively.

Potassium levels did not influence the uptake of nitrogen by stem at any stage of plant growth.

No significant difference was noted due to inoculation on any of the stages except on 90th day and the inoculated treatment registered an uptake value of 19.122 kg ha^{-1} against

Table 16. Effect of potassium and inoculation on uptake of nitrogen by stem and leaves at various growth stages.

Treatments	Uptake of nitrogen (kg ha^{-1})						
	Stem				Leaves		
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})							
0	1.143	15.970	12.764	6.249	3.260	38.539	13.921
30	1.070	17.526	16.529	6.931	3.898	44.948	22.901
60	1.103	21.860	17.839	6.745	4.056	51.481	20.249
90	0.944	24.348	18.054	5.855	5.169	50.655	16.785
120	1.216	19.750	17.954	6.769	4.808	44.334	23.882
SEm ±	0.136	2.199	1.992	0.879	0.481	4.458	2.694
C.D at 5%	NS	NS	NS	NS	NS	NS	NS
Rhizobial inoculation							
Uninoculated	1.024	21.600	14.134	5.990	3.623	48.220	16.014
Inoculated	1.167	18.182	19.122	7.030	4.054	43.763	23.082
SEm ±	0.086	1.391	1.260	0.556	0.304	2.819	1.704
C.D. at 5%	NS	NS	3.656	NS	NS	NS	4.943

FIG. 16 NITROGEN UPTAKE BY PLANTS AT DIFFERENT STAGES

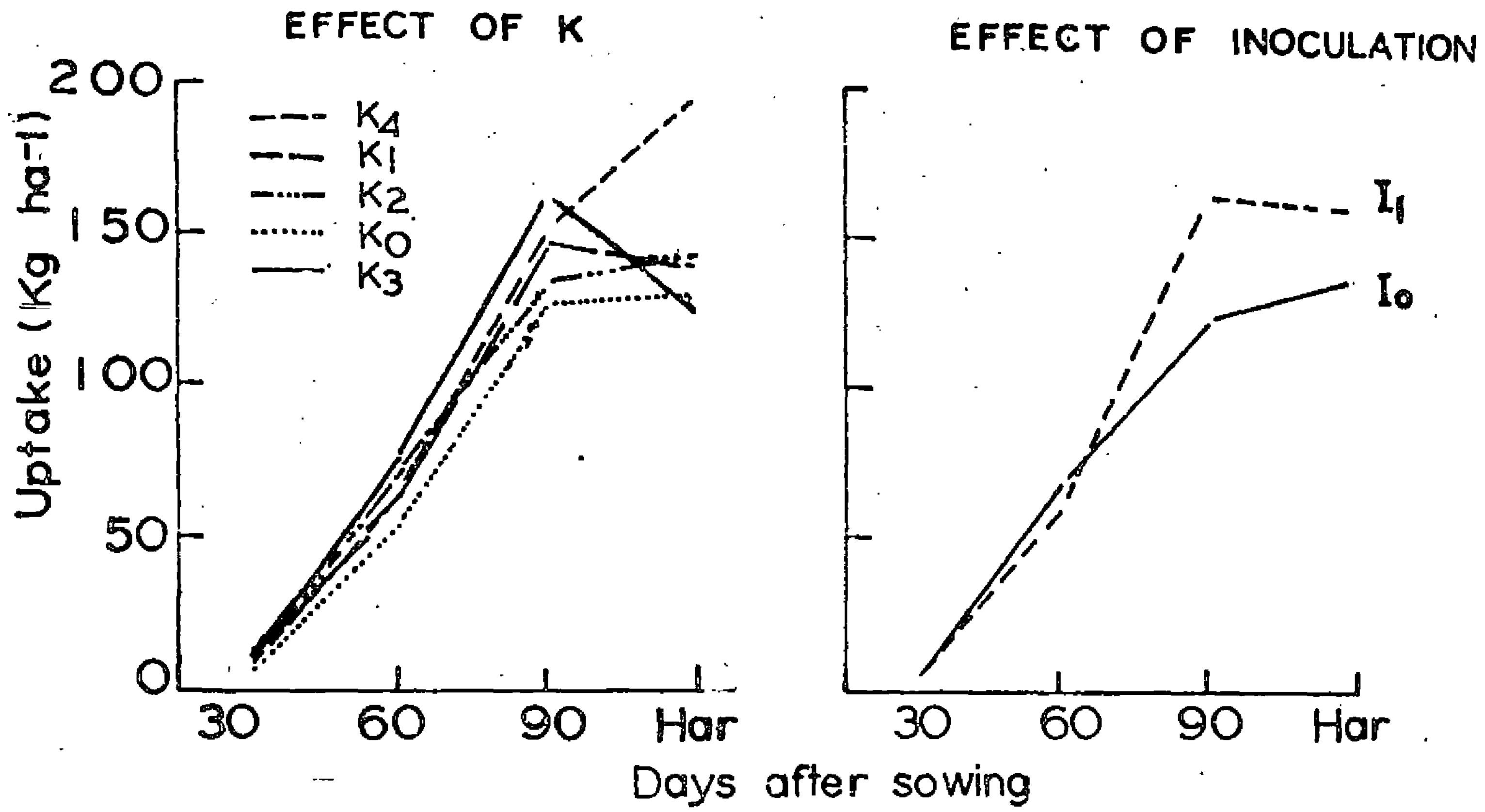
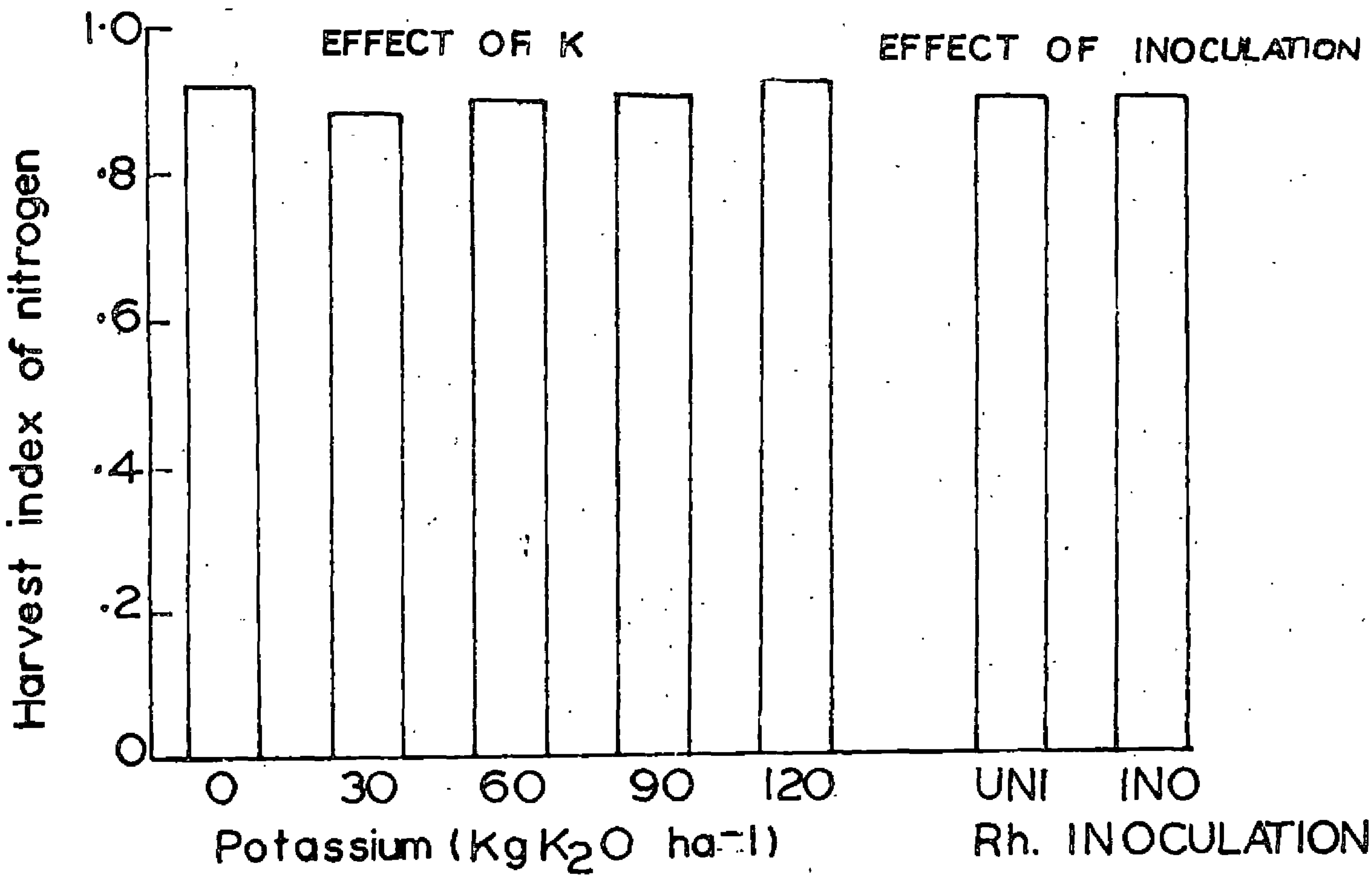


FIG. 17 HARVEST INDEX OF NITROGEN



14.134 kg ha^{-1} in the uninoculated one. In all the other stages except on 60th day, the uptake was higher, though not significant with inoculation.

Interaction effect was significant only at harvest and 60 kg K_2O ha^{-1} along with inoculation recorded the highest uptake of 10.11 kg ha^{-1}.

Between 30th and 60th days, there was a conspicuous increase in uptake of nitrogen by stem after which there was a decline. The decrease in uptake in the later stages may be due to the self destructive mechanism of the plant.

b) Uptake of nitrogen by leaves

The data regarding the uptake of nitrogen by leaves on 30th, 60th and 90th days are presented in Table 16 and the analysis of variance in Appendix 11.

At none of the stages did potassium exert any significant influence on the uptake of nitrogen by leaves. However, there was an increase in uptake by leaves upto 30 kg K_2O ha^{-1} in all the above stages.

Effect of inoculation on uptake of nitrogen by leaves was significant only on 90th day and the inoculated treatment recorded an uptake of 23.082 kg ha^{-1} against 16.014 kg ha^{-1} in the uninoculated plot.

Interaction effect remained non-significant in all the above stages.

The same pattern of nitrogen uptake by stem was noticed here also between stages. The reasons explained under uptake of nitrogen by stem are applicable here also.

c) Uptake of nitrogen by shells

The data on the uptake of nitrogen by shells are presented in Table 17 and the analysis of variance in Appendix 11.

The results presented in Table 17 show that uptake of nitrogen by shells was not influenced by the levels of potassium on 90th day and at harvest.

Inoculation significantly increased the uptake of nitrogen by shells only on 90th day. An uptake value of 28.441 kg ha^{-1} was registered in the inoculated plot against 21.848 kg ha^{-1} in the uninoculated one.

Interaction effect was not significant on both the stages.

It was also observed that the uptake of nitrogen by shells decreased from 90th day after sowing to harvest.

The reduction in uptake of nitrogen by shells noticed between 90th day and harvest is due to the fall in dry weight and nitrogen content of shells observed during the above stages as evidenced from Tables 7 and 15. The reasons for the reduction in dry weight and nitrogen content of shells have already been explained.

Table 17. Effect of potassium and inoculation on uptake of nitrogen by shells and seeds at various growth stages.

Treatments	Uptake of nitrogen (kg ha^{-1})			
	Shells		Seeds	
	90th day after sowing	Harvest	90th day after sowing	Harvest
Levels of potassium (K_2O kg ha^{-1})				
0	18.702	5.185	82.431	118.304
30	28.941	8.512	81.016	123.945
60	20.873	7.182	76.763	126.753
90	28.078	6.330	99.344	115.175
120	29.128	6.930	81.159	182.466
SEm ±	3.062	1.109	12.665	18.850
C.D. at 5%	NS	NS	NS	NS
Rhizobial inoculation				
Uninoculated	21.848	6.332	73.213	122.818
Inoculated	28.441	7.327	95.072	143.839
SEm ±	1.933	0.702	8.008	11.922
C.D. at 5%	5.619	NS	NS	NS

Further discussions on this aspect will be covered subsequently while dealing with the total uptake of nitrogen by plants.

d) Uptake of nitrogen by seeds

Uptake of nitrogen by seeds on 90th day and at harvest are furnished in Table 17 and the analysis of variance in Appendix 12.

The levels of potassium, inoculation or their interactions exerted no significant influence in the uptake of nitrogen by seeds.

Nitrogen uptake by seeds increased from 90th day to harvest.

The increase in uptake noticed at harvest may be due to the increase in dry weight and nitrogen content of seeds observed during the above stages as evidenced from Tables 7 and 15. The translocation of nitrogen from the vegetative parts to the sink during the seed filling stage might have contributed to this.

Further discussion on this aspect will be covered while dealing with the total uptake of nitrogen by plants.

e) Uptake of nitrogen by plants

The data on uptake of nitrogen by plants are given in Table 18 and Fig. 16 and the analysis of variance in Appendix 12.

Table 18. Effect of potassium and inoculation on the total uptake of nitrogen by plants at various growth stages and harvest index of nitrogen.

Treatments	Uptake of nitrogen by plants (kg ha^{-1})				Harvest index of nitrogen
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	
Levels of potassium (K_2O kg ha^{-1})					
0	4.403	54.509	127.830	131.222	0.92
30	4.968	62.474	149.428	139.431	0.89
60	5.159	73.341	135.718	140.681	0.90
90	4.113	75.003	162.260	127.360	0.91
120	6.024	64.084	152.126	196.471	0.93
SEm ±	0.588	6.569	18.562	20.648	0.005
C.D. at 5%	NS	NS	NS	NS	0.01
Rhizobial inoculation					
Uninoculated	4.646	69.819	125.226	135.153	0.91
Inoculated	5.220	61.945	165.719	158.914	0.91
SEm ±	0.372	4.155	11.739	13.057	0.003
C.D. at 5%	NS	NS	34.062	NS	NS

From the data, it can be seen that there was no significant difference in the uptake of nitrogen by plants due to potassium application at any of the growth stages.

Inoculation increased the uptake of nitrogen by plants only on 90th day. The highest uptake of 165.719 kg ha^{-1} was recorded in the inoculated plot against 125.226 kg ha^{-1} in the uninoculated one.

Interaction effect was not significant.

It can be seen from Tables 8 and 15 that the total dry weight and nitrogen content of plants were not influenced significantly by levels of potassium in almost all stages. From the results on total nitrogen uptake and nitrogen uptake by plant parts at different stages, it may generally be concluded that application of potassium did not have any significant effect on nitrogen uptake. In the present study, potassium had no consistent effect either in nitrogen content or in nitrogen uptake by plant parts. As concluded earlier, the results indicate adequacy of available native potassium in the soil and hence a non-significant effect.

A favourable response was expected from culture inoculation. The lack of consistent significant effect noticed in this trial is in agreement with the findings of Kurien (1979) in same type of soil.

f) Harvest index of nitrogen

The data on harvest index of nitrogen are presented in Table 18 and Fig. 17. The analysis of variance and mean table for two factor combinations are given in Appendices 12 and 41 respectively.

The data revealed that the effect of potassium on harvest index of nitrogen was significant and 120 kg K_2O ha^{-1} recorded the highest value of 0.93 and was on a par with control and superior to all other levels.

Inoculation failed to produce any significant difference.

Interaction effect was significant and 120 kg K_2O ha^{-1} with and without inoculation were on a par and produced the highest values on harvest index of nitrogen.

The data revealed that 93 per cent of the total nitrogen absorbed by the plant has gone to the sink in the treatment 120 kg K_2O ha^{-1}. Though there was significant influence of potassium on harvest index of nitrogen, the results are not consistent enough to draw valid conclusions.

The reasons for the lack of response of inoculation have already been discussed.

B1. Phosphorus content

a) Phosphorus content of stem

The mean values on phosphorus content of stem are presented in Table 19 and Fig. 18. The analysis of variance

Table 19. Effect of potassium and inoculation on phosphorus content of stem and leaves at various growth stages.

Treatments	Phosphorus content (%)						
	Stem				Leaves		
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})							
0	0.183	0.121	0.070	0.072	0.192	0.233	0.155
30	0.175	0.097	0.079	0.099	0.263	0.200	0.159
60	0.223	0.132	0.086	0.053	0.278	0.253	0.162
90	0.192	0.114	0.151	0.035	0.287	0.209	0.124
120	0.190	0.120	0.075	0.038	0.288	0.203	0.172
SEm ±	0.005	0.003	0.035	0.019	0.007	0.004	0.004
C.D. at 5%	0.015	0.007	NS	NS	0.019	0.011	0.011
Rhizobial inoculation							
Uninoculated	0.180	0.110	0.104	0.054	0.263	0.210	0.143
Inoculated	0.205	0.124	0.079	0.064	0.260	0.229	0.166
SEm ±	0.003	0.001	0.023	0.012	0.004	0.002	0.002
C.D. at 5%	0.009	0.004	NS	NS	NS	0.007	0.007

FIG. 18 PHOSPHORUS CONTENT OF STEM AT DIFFERENT GROWTH STAGES

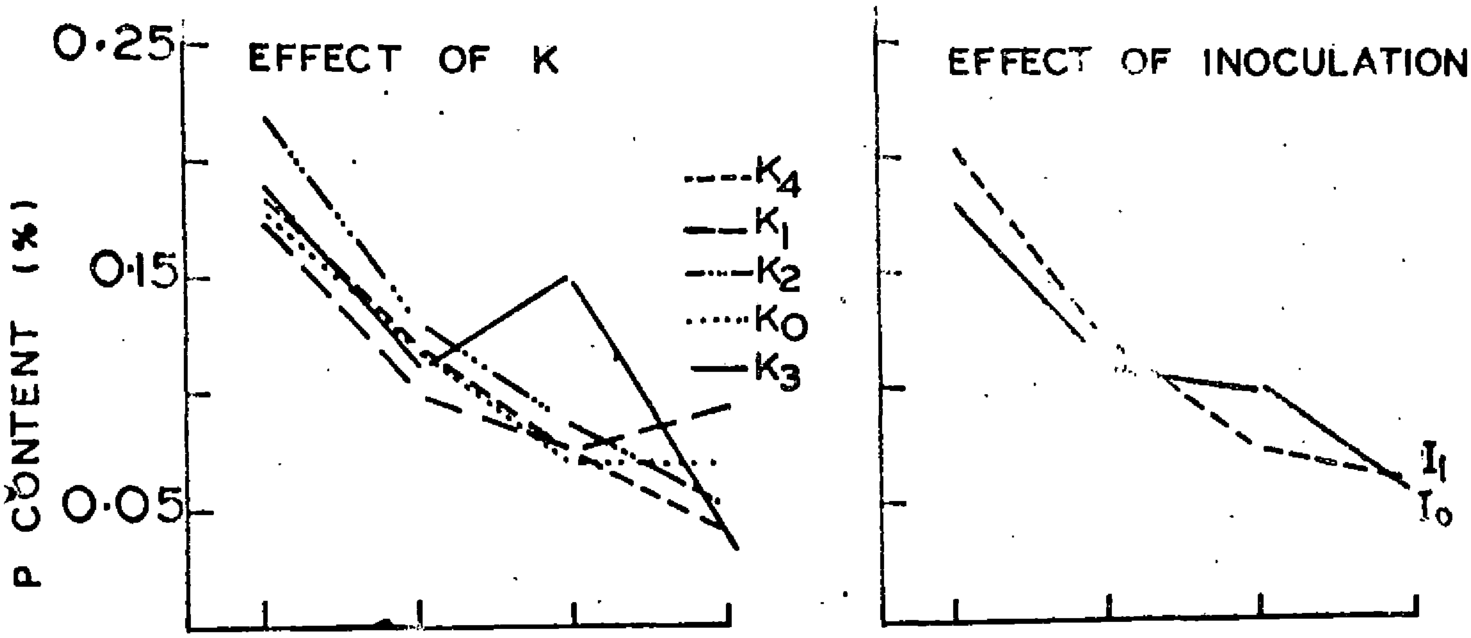
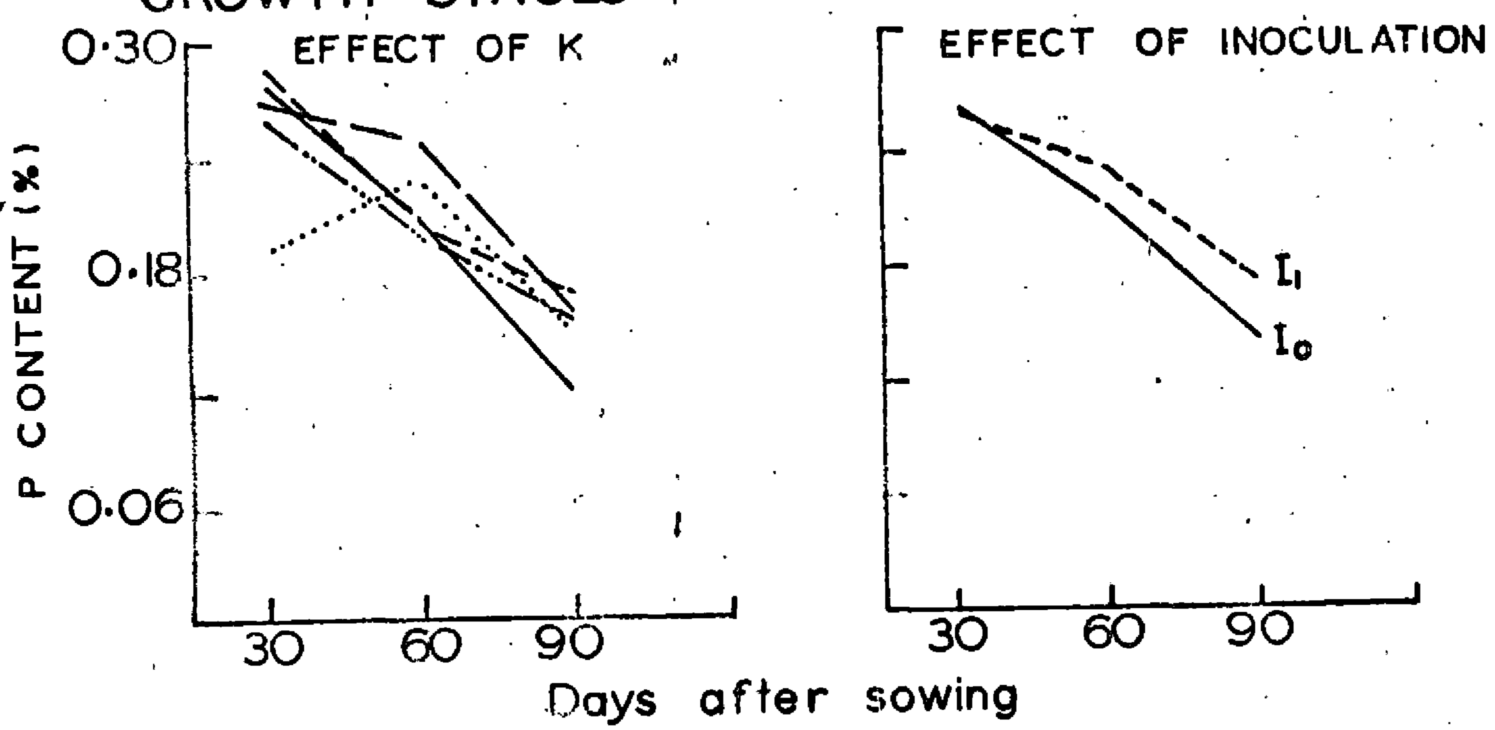


FIG. 19 PHOSPHORUS CONTENT OF LEAVES AT DIFFERENT GROWTH STAGES



and mean tables for two factor combinations are given in Appendices 13 and 42 to 43 respectively.

The data revealed that the effect of potassium was significant on 30th day and 60th day and in both stages, 60 kg K_2O ha^{-1} recorded the highest phosphorus content in the stem. In all other stages, potassium did not make any significant difference.

Increase in phosphorus content of stem due to inoculation was found to be significant on 30th and 60th days and the inoculated treatment registered a higher content compared to the uninoculated plot. On 90th day and at harvest, the effect of inoculation remained non-significant.

Interaction effect was also significant on 30th and 60th days. On 30th day, 60 kg K_2O ha^{-1} along with inoculation recorded the highest per cent of 0.25 and was superiod to all other levels. On 60th day, 0 kg K_2O ha^{-1} along with inoculation recorded the highest content.

A decrease in the phosphorus content of the stem was observed from 30th day upto harvest.

The decrease in phosphorus content over stages may be due to the dilution of this nutrient in the bulk of the dry matter and translocation to the sink.

b) Phosphorus content of leaves

The data on phosphorus content of leaves on different stages of growth are presented in Table 19 and Fig. 19. The analysis of variance and the mean tables for two factor combinations are given in Appendices 13 and 44 to 46 respectively.

The results revealed that the phosphorus content of leaves was influenced by levels of potassium on all the stages of growth. On 30th day, 120 kg K_2O ha^{-1} recorded the highest per cent and was on par with 90 kg K_2O ha^{-1} and 60 kg K_2O ha^{-1}. On 60th day, 60 kg K_2O ha^{-1} recorded the highest per cent of 0.233 and was superior to all other levels. On 90th day, 120 kg K_2O ha^{-1} recorded the highest per cent of 0.172 and was on par with 60 kg K_2O ha^{-1}.

Inoculation effect was significant on 60th and 90th days and the inoculated treatment was superior to the uninoculated one in both the stages. On 30th day, the effect of inoculation was not significant.

Interaction between potassium and inoculation was significant in all the three stages. On 30th day, 60 kg K_2O ha^{-1} along with inoculation recorded the highest per cent of 0.302 while on 60th and 90th days, the highest values of 0.259 and 0.188 per cent were recorded by 0 kg K_2O ha^{-1} along with inoculation and 120 kg K_2O ha^{-1} along with inoculation respectively.

A decrease in phosphorus content of leaves was noted over stages except in control which has shown an initial increase upto 60th day and a decline thereafter.

The general decline in phosphorus content observed is due to the distribution of this nutrient in the bulk of the plant during development.

(c) Phosphorus content of shells

The data on phosphorus content of shells on 90th day and at harvest are presented in Table 20 and Fig. 20. The analysis of variance and the mean table for two factor combinations are given in Appendices 14 and 47 respectively.

Phosphorus content of shells was influenced by the levels of potassium only on 90th day and 120 kg K_2O ha^{-1} recorded the highest per cent of 0.233 and was superior to all other levels.

Inoculation increased the phosphorus content of shells on 90th day and the inoculated treatment was superior to the uninoculated plot.

Interaction effect was also significant on 90th day and 30 kg K_2O ha^{-1} along with inoculation registered the highest value of 0.252 per cent.

Effect of potassium, inoculation or their interactions were not significant at harvest.

A conspicuous decline in phosphorus content of shells was noticed between 90th day and harvest which may be due to the translocation of this nutrient to the sink during the seed development.

Table 20. Effect of potassium and inoculation on phosphorus content of shells, seeds and plants at various growth stages.

Treatments	Phosphorus content (%)							
	Shells		Seeds		Plants			
	90th day after sowing	Harvest	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest
Levels of potassium (K_2O kg ha^{-1})								
0	0.183	0.038	0.337	0.375	0.220	0.163	0.178	0.210
30	0.204	0.111	0.315	0.337	0.270	0.134	0.185	0.194
60	0.206	0.050	0.382	0.353	0.298	0.179	0.191	0.184
90	0.171	0.032	0.276	0.347	0.266	0.154	0.153	0.166
120	0.233	0.047	0.340	0.282	0.266	0.151	0.194	0.154
SEm ±	0.005	0.028	0.015	0.024	0.015	0.005	0.006	0.011
C.D. at 5%	0.013	NS	0.042	NS	0.044	0.013	0.017	0.036
Rhizobial inoculation								
Uninoculated	0.187	0.040	0.330	0.319	0.256	0.146	0.178	0.174
Inoculated	0.211	0.071	0.329	0.358	0.273	0.166	0.182	0.191
SEm ±	0.003	0.018	0.009	0.015	0.010	0.003	0.003	0.007
C.D. at 5%	0.008	NS	NS	NS	NS	0.008	NS	NS

FIG. 20 PHOSPHORUS CONTENT OF SHELLS

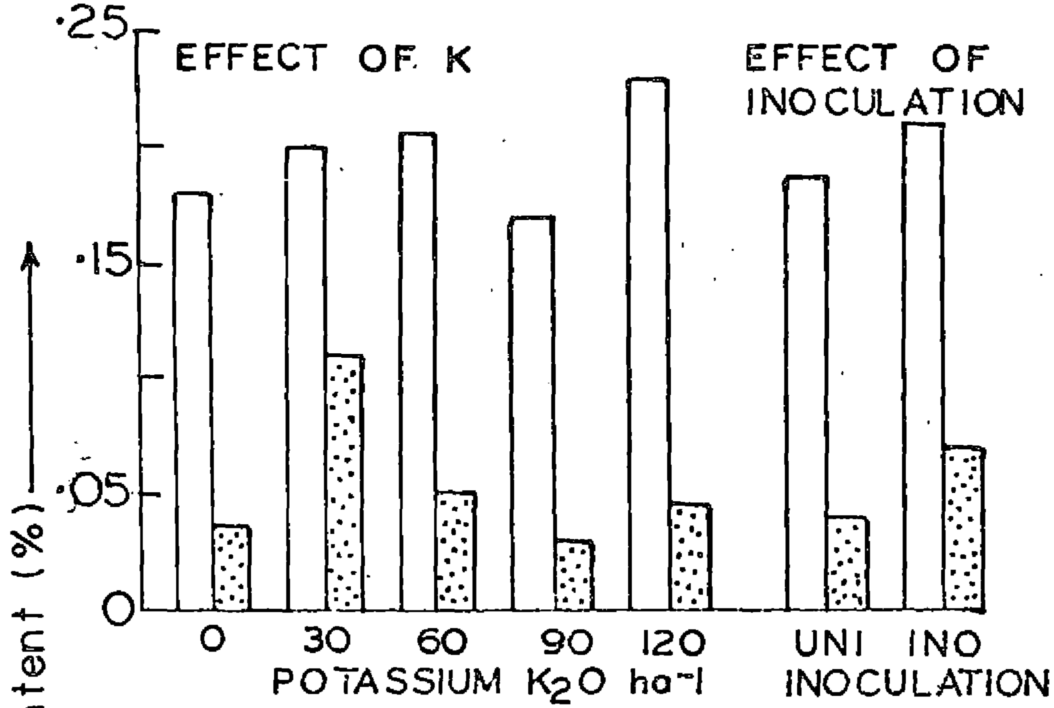


FIG. 21 PHOSPHORUS CONTENT OF SEEDS

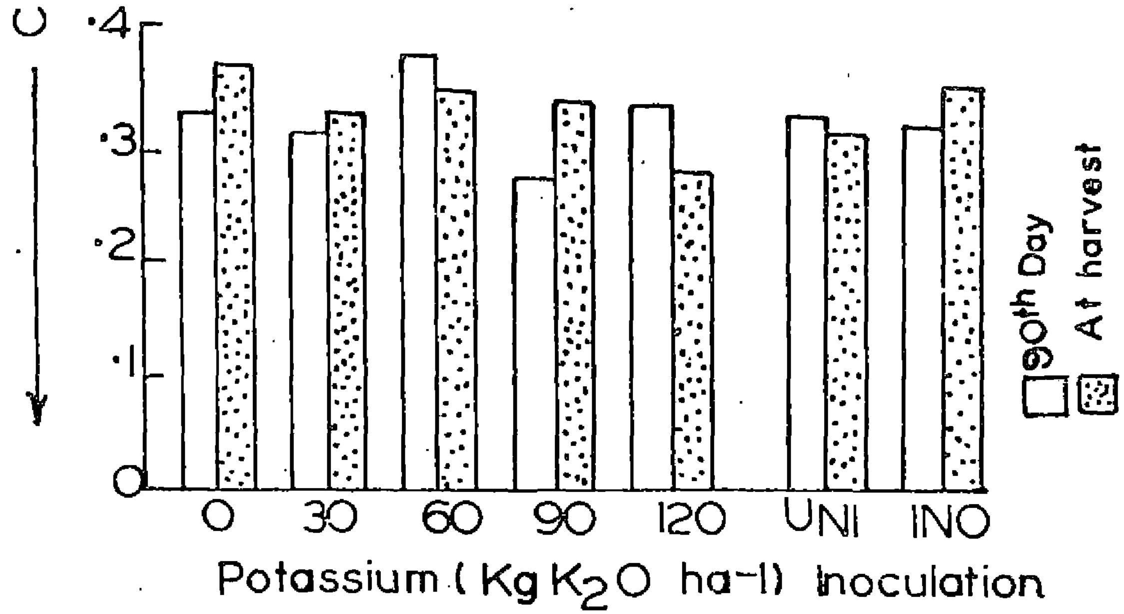
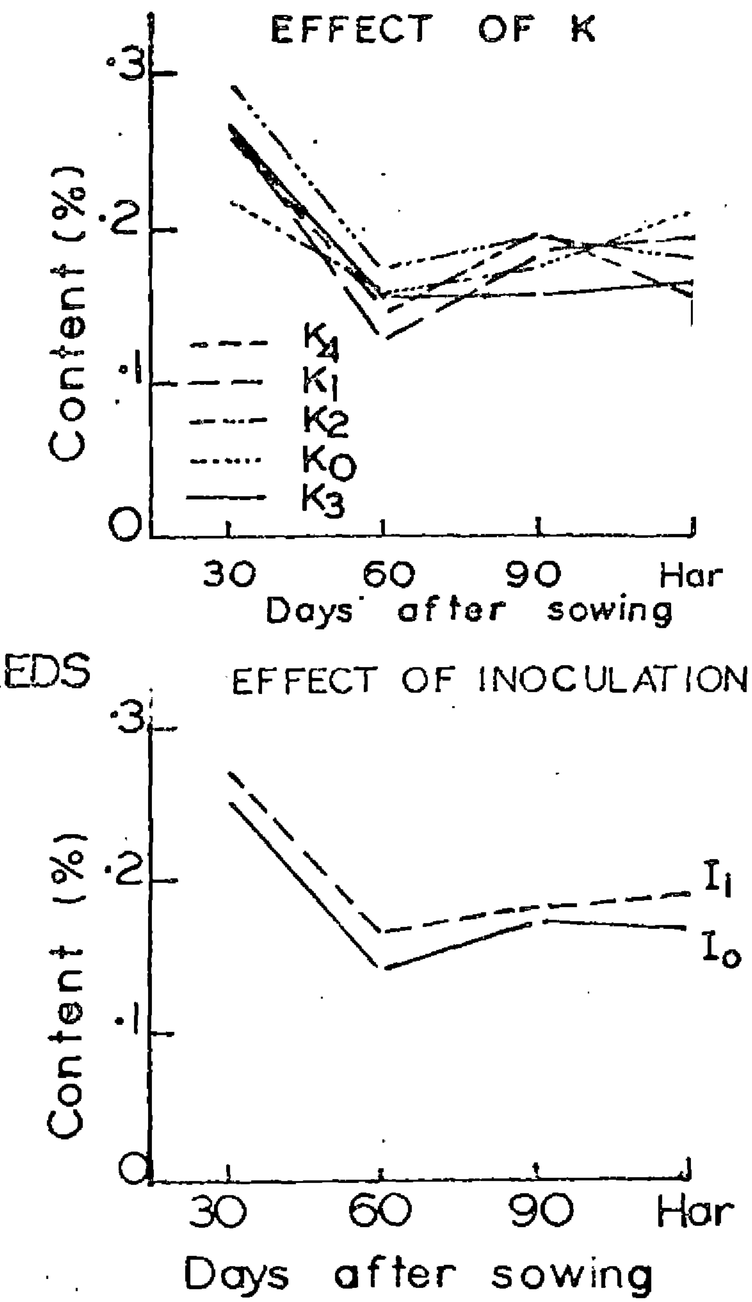


FIG. 22 PHOSPHORUS CONTENT OF PLANTS AT DIFFERENT STAGES OF GROWTH



d) Phosphorus content of seeds

Table 20 and Fig. 21 show the data on phosphorus content of seeds. The analysis of variance and mean table for two factor combinations are given in Appendices 14 and 48 respectively.

The data revealed that the effect of potassium was significant only on 90th day and 60 kg K_2O ha^{-1} recorded the highest content of 0.582 per cent and was on a par with 120 kg K_2O ha^{-1}.

Inoculation failed to produce any significant effect on phosphorus content of seeds.

Interaction effect was significant on 90th day and 60 kg K_2O ha^{-1} without inoculation recorded the highest percentage of 0.595.

At harvest, the phosphorus content of seeds remained unaffected due to levels of potassium, inoculation and their interactions.

e) Phosphorus content of plants

Data on phosphorus content of plants are presented in Table 20 and Fig.22. The analysis of variance and the mean tables for two factor combinations are given in Appendices 14 and 49 to 50 respectively.

There was significant difference in phosphorus content of plants due to levels of potassium in all the stages. The treatment 60 kg K_2O ha^{-1} recorded the highest content of phosphorus on 30th and 60th days. On 90th day, 120 kg K_2O ha^{-1} recorded the highest content and was on par with 60, 30 and 0 kg K_2O ha^{-1}. At harvest, control plot was superior but on par with 30 and 60 kg K_2O ha^{-1}.

The effect of inoculation was significant on 60th day and the inoculated treatment was superior to the uninoculated plot.

Interaction effect was significant on 60th and 90th days. The treatment 0 kg K_2O ha^{-1} along with inoculation recorded the highest content of phosphorus on 60th day while on 90th day, 30 kg K_2O ha^{-1} along with inoculation recorded the highest value.

From the data on phosphorus content of plant parts, it may generally be concluded that there was no significant variation between levels of inoculation in many of the stages. Hence the phosphorus content of the plant was not affected due to inoculation in most of the stages.

The interaction between potassium and inoculation on phosphorus content of plant parts was significant in most of the stages, though in some cases there was non-significant interaction between them. It was also noticed that even in cases when the interaction effects were significant, the results were inconsistent and difficult to explain.

Comparing between stages, it is seen that the phosphorus content of the plant and the plant parts decreased substantially from 30th day to 60th day and after that a slight increase was noticed upto 90th day. The decrease in phosphorus content of plant and plant parts, except seeds, with age may be due to the distribution of this nutrient in the bulk of the dry matter as the plant developed.

B.2. Uptake of phosphorus

a) Uptake of phosphorus by stem

The data on uptake of phosphorus by stem on different stages are presented in Table 21. The analysis of variance and the mean tables for two factor combinations are given in Appendices 15 and 51 to 54 respectively.

There was significant difference in the uptake of phosphorus by stem due to applied potassium in all the stages. On 30th day, 60 kg K_2O ha^{-1} recorded the highest uptake of 0.234 kg ha^{-1} and was on par with 120 kg K_2O ha^{-1}. On 60th day, 90 kg K_2O ha^{-1} recorded the highest uptake of 3.211 kg ha^{-1}, which was on par with 60 kg K_2O ha^{-1} and superior to all other levels. On 90th day and at harvest, 30 kg K_2O ha^{-1} recorded the highest uptake of 2.061 and 0.875 kg ha^{-1} respectively and was superior to all other levels.

Table 21. Effect of potassium and inoculation on uptake of phosphorus by stem and leaves at various growth stages.

Treatments	Uptake of phosphorus (kg ha^{-1})						
	Stem				Leaves		
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})							
0	0.183	2.008	1.284	0.814	0.236	2.570	1.190
30	0.180	1.990	2.061	0.875	0.331	2.779	1.515
60	0.234	2.923	1.979	0.502	0.361	3.817	1.325
90	0.185	3.211	1.857	0.583	0.303	3.355	1.007
120	0.226	2.305	1.772	0.762	0.427	2.722	1.672
SEm ±	0.005	0.228	0.018	0.032	0.008	0.052	0.030
C.D. at 5%	0.013	0.662	0.054	0.092	0.024	0.152	0.088
Rhizobial inoculation							
Uninoculated	0.182	2.656	1.451	0.762	0.317	3.199	1.061
Inoculated	0.221	2.319	2.129	0.652	0.346	2.898	1.622
SEm ±	0.003	0.144	0.011	0.019	0.005	0.033	0.018
C.D. at 5%	0.009	NS	0.034	0.058	0.015	0.096	0.056

The effect of inoculation on uptake of phosphorus by stem was significant on all the stages except on 60th day. The inoculated treatment was superior to the uninoculated plot on 30th and 90th day while at harvest the uninoculated plot recorded the highest value.

Interaction effect was significant on all the above stages. On 30th day, 60 kg K_2O ha^{-1} along with inoculation recorded the highest value of 0.25 kg ha^{-1}, while on 60th day, 90 kg K_2O ha^{-1} without inoculation recorded the highest uptake of 4.111 kg ha^{-1}. On 90th day, 30 kg K_2O ha^{-1} with inoculation and at harvest, 30 kg K_2O ha^{-1} without inoculation recorded the highest uptakes of 3.053 and 1.395 kg ha^{-1} respectively.

Uptake of phosphorus by stem increased till 60th day after which there was a decline.

The results will be discussed while dealing with the total uptake of phosphorus by plants.

b) Uptake of phosphorus by leaves

The data on the uptake of phosphorus by leaves are presented in Table 21. The analysis of variance and the mean tables for two factor combinations are given in Appendices 15 and 55 to 57 respectively.

The data revealed that the effect of potassium on uptake of phosphorus by leaves was significant on all the stages. On 30th and 90th days, 120 kg K_2O ha^{-1} recorded the highest uptakes of 0.427 and 1.672 kg ha^{-1} respectively, and was superior to all other levels. On 60th day, 60 kg K_2O ha^{-1} recorded the highest uptake of 3.817 kg ha^{-1} and was superior to all other levels.

Effect of inoculation was also significant on all the above stages. On 30th and 90th days, the inoculated treatments were superior to the uninoculated ones, but on 60th day, the uninoculated plot registered higher value than the inoculated set.

Interaction effect was also significant in all the stages studied. On 30th day, 120 kg K_2O ha^{-1} without inoculation recorded the highest uptake. But on 60th day, 60 kg K_2O ha^{-1} without inoculation gave the highest value and was superior to all other combinations. On 90th day, 30 kg K_2O ha^{-1} along with inoculation recorded highest uptake and was superior to all other combinations.

It was also observed that there was an increase in uptake of phosphorus by leaves from 30th day to 60th day and then declined.

The results will be discussed while dealing with the total uptake of phosphorus by plants.

c) Uptake of phosphorus by shells

The values on uptake of phosphorus by shells on 90th day and at harvest are presented in Table 22. The analysis of variance and the mean table for two factor combinations are given in Appendices 15 and 58 respectively.

Table 22. Effect of potassium and inoculation on uptake of phosphorus by shells and seeds at various growth stages.

Treatments	Uptake of phosphorus (kg ha^{-1})			
	Shells		Seeds	
	90th day after sowing	Harvest	90th day after sowing	Harvest
Levels of potassium (K_2O kg ha^{-1})				
0	2.518	0.353	4.498	6.808
30	3.830	0.599	5.580	7.648
60	2.800	0.632	4.743	8.238
90	3.209	0.329	5.135	7.290
120	4.218	0.776	5.773	8.826
SEm ±	0.431	0.933	0.853	1.340
C.D. at 5%	NS	0.272	NS	NS
Rhizobial inoculation				
Uninoculated	2.715	0.466	4.709	6.836
Inoculated	3.915	0.609	5.493	8.698
SEm ±	0.273	0.059	0.540	0.848
C.D. at 5%	0.792	NS	NS	NS

The effect of potassium was non-significant on 90th day but significant at harvest. The treatment 120 kg K_2O ha^{-1} registered the highest uptake value of 0.776 kg ha^{-1} and was on par with 60 and 30 kg K_2O ha^{-1} at harvest.

Inoculation significantly increased the phosphorus uptake by shells on 90th day and the inoculated treatment recorded the highest value of 3.915 kg ha^{-1} as against 2.715 kg ha^{-1} in the uninoculated one. Inoculation remained ineffective at harvest.

Interaction effect was significant only on 90th day and 30 kg K_2O ha^{-1} along with inoculation recorded the highest uptake of 5.608 kg ha^{-1}.

There was a conspicuous reduction in the uptake of phosphorus by shells from 90th day to harvest.

Discussion on this will be covered under the total uptake of phosphorus by plants.

d) Uptake of phosphorus by seeds

The mean values on uptake of phosphorus by seeds on 90th day and at harvest are presented in Table 22 and the analysis of variance in Appendix 16.

Neither the effects of levels of potassium and inoculation nor their interactions were significant at any stages of plant growth.

It was also noticed that there was an increase in uptake of phosphorus by seeds from 90th day to harvest.

Discussion on this will be covered under the total uptake of phosphorus by plants.

e) Uptake of phosphorus by plants

The data on the uptake of phosphorus by plants at various growth stages are presented in Table 23 and Fig.23. The analysis of variance and the mean tables for two factor combinations are given in Appendices 16 and 59 to 60 respectively.

The data revealed that the effect of potassium on uptake of phosphorus by plants was significant on 30th day and 60th day. On 30th day, 120 kg K_2O ha^{-1} recorded the highest uptake of 0.653 kg ha^{-1} while on 60th day, the highest uptake of 6.74 kg ha^{-1} was recorded by 60 kg K_2O ha^{-1}. On 90th day and at harvest the effect of potassium was uniform.

Inoculation effect was significant on all the stages except at harvest. On 30th and 90th days, the inoculated treatments were superior to the uninoculated ones while on 60th day, a significant reduction in uptake was noticed due to inoculation.

Interaction effect was significant only on 30th and 60th days. On 30th day, 120 kg K_2O ha^{-1} without inoculation recorded the highest uptake of 0.672 kg ha^{-1}, while on 60th day, 90 kg K_2O ha^{-1} without inoculation registered the highest value of 8.04 kg ha^{-1}.

Table 23. Effect of potassium and inoculation on the total uptake of phosphorus by plants at various growth stages and harvest index of phosphorus.

Treatments	Uptake of phosphorus by plants (kg ha^{-1})				Harvest index of phosphorus
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	
Levels of potassium (K_2O kg ha^{-1})					
0	0.419	4.578	9.453	8.901	0.85
30	0.511	4.768	12.963	9.114	0.83
60	0.594	6.740	12.605	9.361	0.87
90	0.488	6.570	11.128	8.201	0.83
120	0.653	5.030	13.435	10.360	0.84
SEm ±	0.009	0.236	1.605	1.453	0.03
C.D. at 5%	0.029	0.686	NS	NS	NS
Rhizobial inoculation					
Uninoculated	0.498	5.856	9.986	8.065	0.85
Inoculated	0.568	5.218	13.848	10.315	0.84
SEm ±	0.006	0.149	1.016	0.919	0.019
C.D. at 5%	0.018	0.434	2.946	NS	NS

FIG. 23 PHOSPHORUS UPTAKE BY PLANTS AT DIFFERENT STAGES OF GROWTH

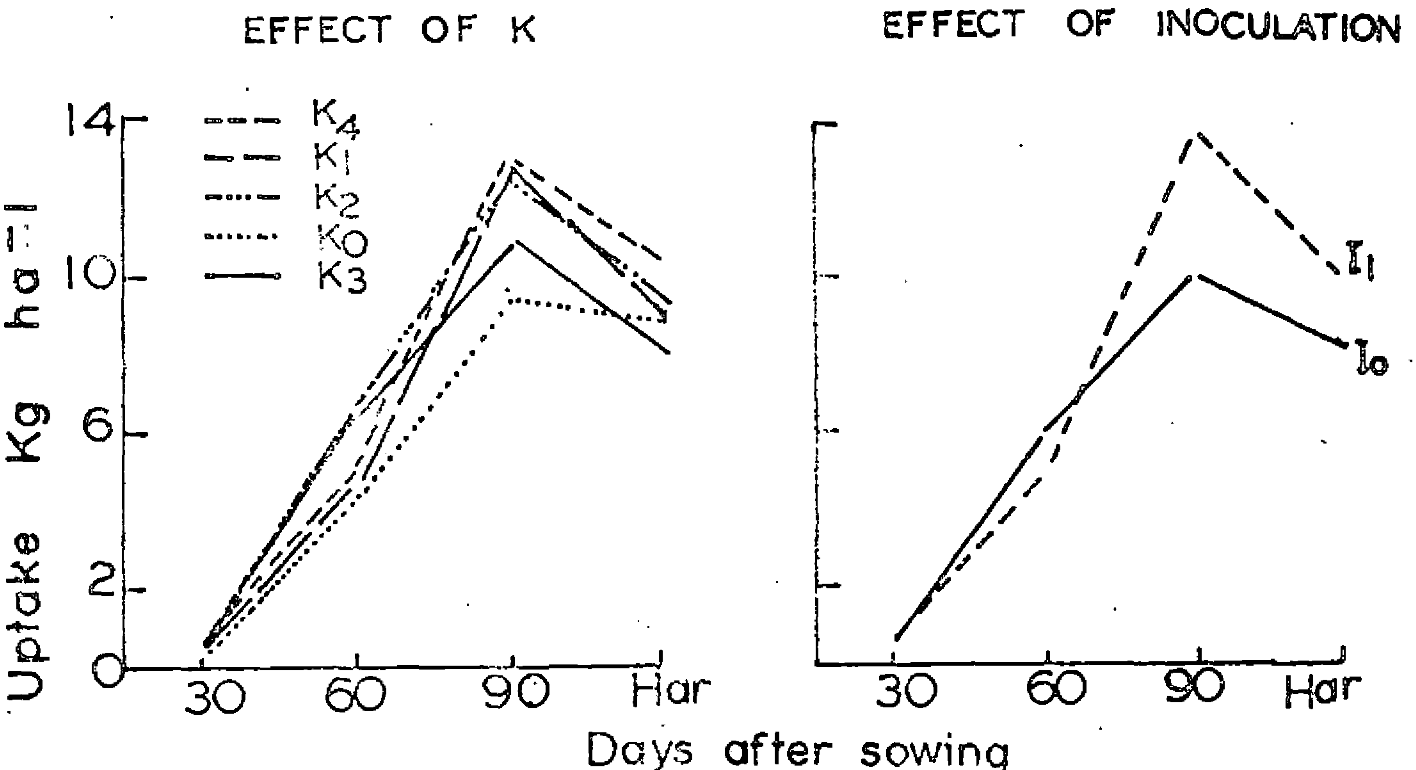
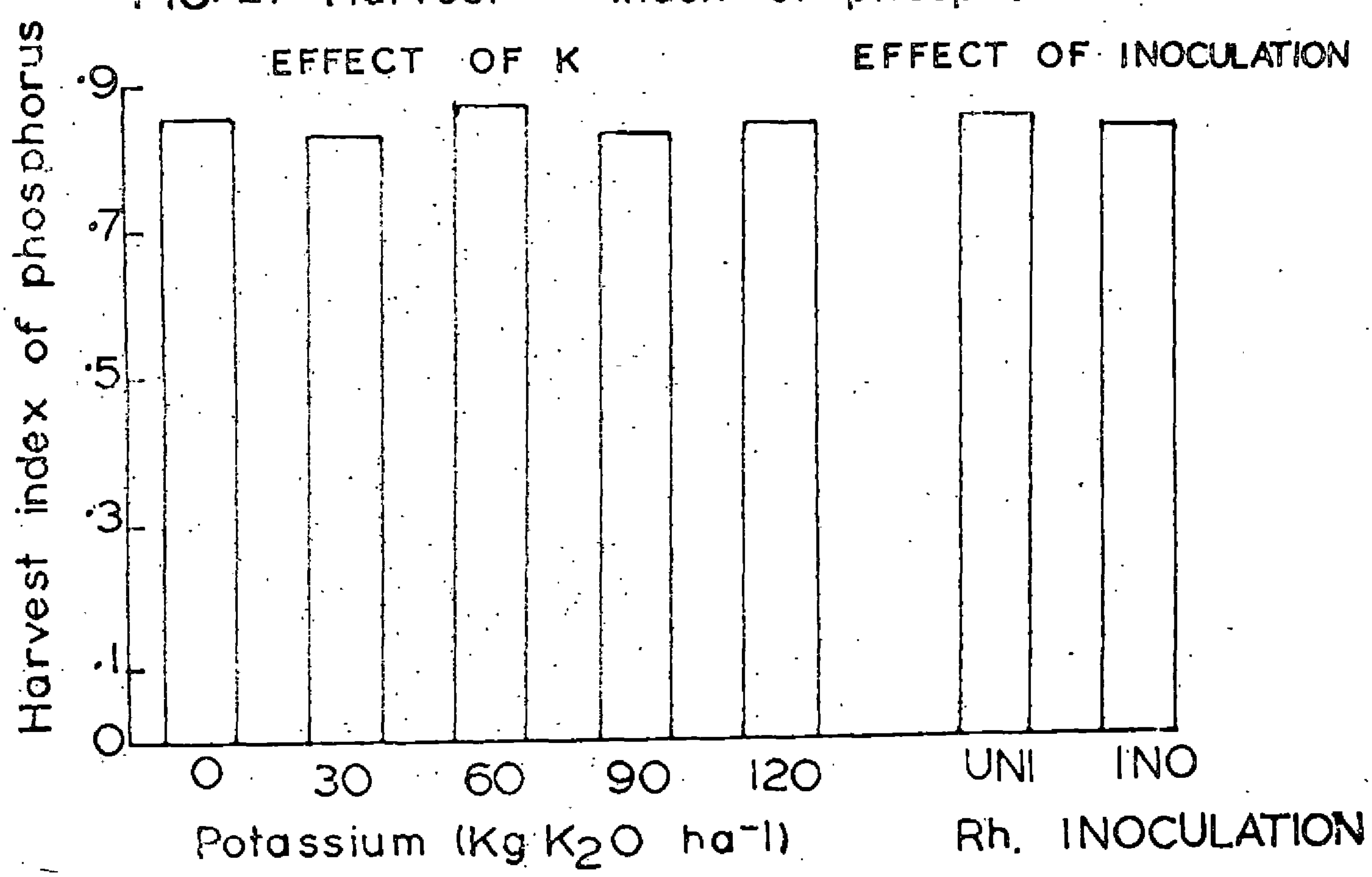


FIG. 24 Harvest index of phosphorus



It was also observed that there was a steady and conspicuous increase in the total uptake of phosphorus by plants upto 90th day and after that there was a gradual decline.

An evaluation of the effects of potassium on the uptake of phosphorus by plant parts will reveal that there was significant differences in phosphorus uptake by all the plant parts except seeds in many of the growth stages. The significant difference noticed in the phosphorus uptake by plants on 30th and 60th days may be due to the significant influence of potassium on the uptake of phosphorus by stem and leaves in these stages. The non-significant influence of this nutrient on the uptake of phosphorus by shells and seeds during advanced stages of growth might have resulted in a non-significant phosphorus uptake by plants on 90th day and at harvest.

It can be seen from the data on uptake of phosphorus by plant parts, that the effect of inoculation was significant in almost all stages, in all plant parts except shells and seeds. Hence the effect of inoculation, on phosphorus uptake of plants was also significant in almost all stages.

The individual effects of potassium and inoculation on the uptake of phosphorus by plant and plant parts, were significant on 30th and 60th days. Moreover, the interaction effects of potassium and inoculation on uptake of phosphorus by stem and leaves were also significant in the initial stages. Hence, the interaction effects on the uptake of phosphorus by plants were also significant in the above stages. But during the advanced stages of growth, the individual effects of potassium and inoculation were more or less uniform and hence their interaction effects were not significant on 90th day and at harvest.

It was also observed that there was a steady increase in the phosphorus uptake of stem and leaves in the initial stages. Between 90th day and harvest, though there was a reduction in the phosphorus uptake by shells, the phosphorus removal by seeds showed an increasing trend. The general increasing trend in the phosphorus uptake, noticed in the bulk of the dry matter namely, stem and leaves, resulted in a conspicuous increase in the rate of removal of this nutrient upto 90th day. The reduction in phosphorus removal noticed in the maturity phase my be due to the decrease in uptake trend noticed in leaves, stem and shells, consequent to decreased root activity, in the advanced stages of growth.

f) Harvest index of phosphorus

The data on harvest index of phosphorus are presented in Table 23 and Fig. 24 and the analysis of variance in Appendix 16.

Neither the individual effects of potassium and inoculation nor their interactions were significant on harvest index of phosphorus.

It can be seen from Table 22 that the effects of potassium, inoculation and their interactions on phosphorus uptake by seeds were non-significant. Similarly, the effects of different treatments on the uptake of phosphorus by plants at harvest were also non-significant. These may be the reasons for a non-significant difference in the harvest index of phosphorus due to the various treatments under study.

C.1. Potassium content

a) Potassium content of stem

The mean values on potassium content of stem at different stages are furnished in Table 24 and Fig. 25. The analysis of variance and the mean tables for two factor combinations are given in Appendices 17 and 61 to 63 respectively.

The results revealed that the effect of potassium was significant on all the stages. On 30th and 60th days and at harvest, 60 kg K_2O ha^{-1} recorded the highest percentage of potassium. On 90th day, 30 kg K_2O ha^{-1} recorded the highest value, which was on par with 60 kg K_2O ha^{-1} and superior to all other levels.

Increase in potassium content of stem due to

Table 24. Effect of potassium and inoculation on potassium content of stem and leaves at various growth stages.

Treatments	Potassium content (%)						
	Stem				Leaves		
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})							
0	2.713	1.863	1.350	0.563	1.838	2.050	1.538
30	2.925	2.125	1.450	0.601	2.613	2.188	1.613
60	3.369	2.400	1.413	0.875	2.876	2.325	1.750
90	3.363	2.313	1.311	0.450	2.614	2.100	1.628
120	3.225	2.125	1.350	0.775	2.488	2.025	1.581
SEm ±	0.059	0.045	0.033	0.190	0.042	0.010	0.011
C.D. at 5%	0.172	0.128	0.096	0.061	0.120	0.029	0.038
Rhizobial inoculation							
Uninoculated	3.043	2.098	1.370	0.565	2.531	2.100	1.628
Inoculated	3.195	2.253	1.380	0.741	2.441	2.175	1.616
SEm ±	0.037	0.028	0.021	0.021	0.026	0.0004	0.007
C.D. at 5%	0.109	0.081	NS	0.038	0.076	0.018	NS

FIG. 25 POTASSIUM CONTENT OF STEM AT DIFFERENT STAGES OF GROWTH

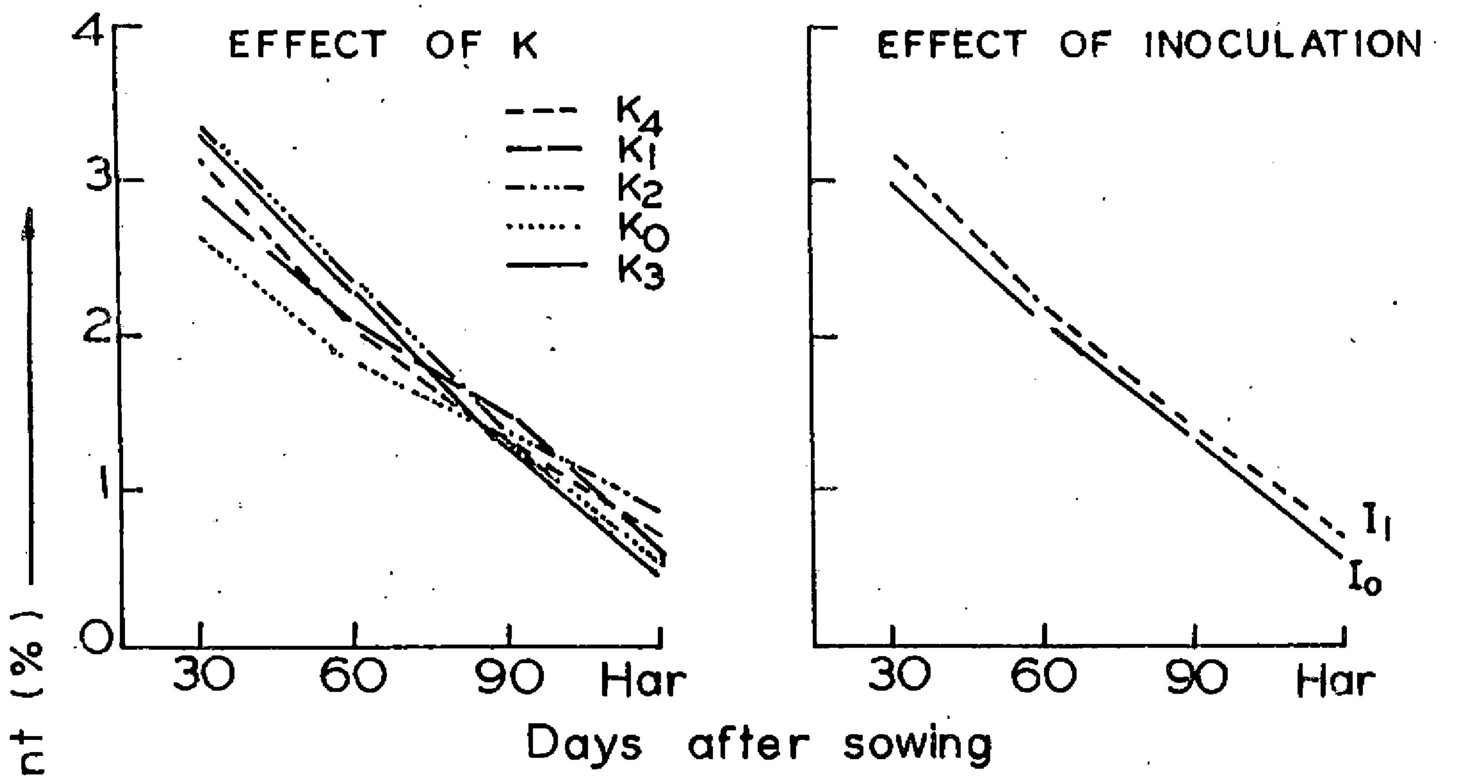
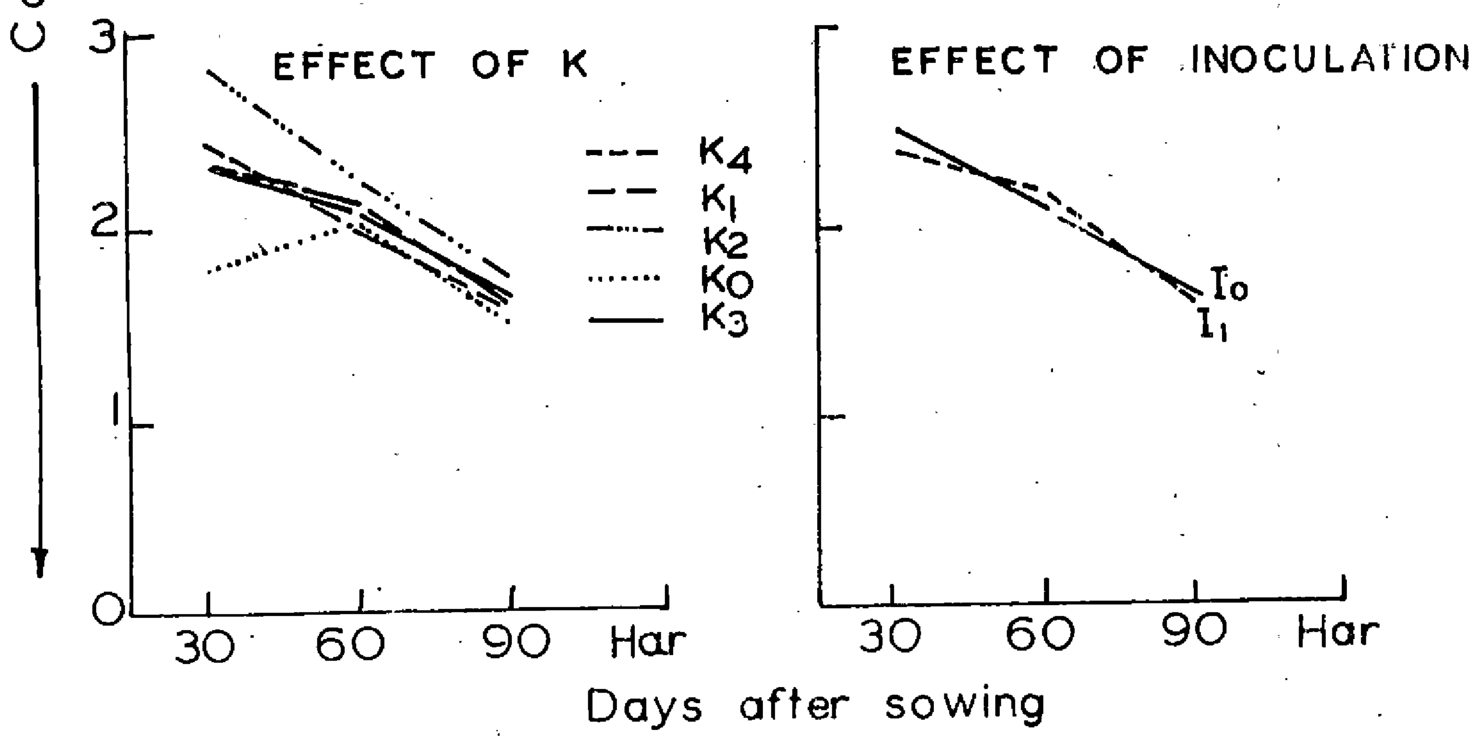


FIG. 26 POTASSIUM CONTENT OF LEAVES AT DIFFERENT STAGES OF GROWTH



inoculation was found to be significant in all the stages except on 90th day and the inoculated treatments were superior to the uninoculated ones.

Interaction effect was significant on 60th and 90th days and at harvest. On 60th day, 60 kg K_2O ha^{-1} along with inoculation recorded the highest percentage of potassium while on 90th day, 60 kg K_2O ha^{-1} without inoculation recorded the highest content. At harvest, 120 kg K_2O ha^{-1} along with inoculation registered the highest value and was superior to all other combinations.

There was a steady and conspicuous reduction in the potassium content of stem with advancement of age.

The discussion on this aspect will be done while dealing with potassium content of plants.

b) Potassium content of leaves

The data on the potassium content of leaves at different stages of growth are given in Table 24 and Fig.26. The analysis of variance and the mean tables for two factor combinations are given in Appendices 17 and 64 to 66 respectively.

Potassium content of leaves was influenced by the levels of potassium on all the stages. The treatment 60 kg K_2O ha^{-1} recorded the highest values in all the stages and was superior to all other levels.

Inoculation influenced the potassium content of leaves on 30th and 60th days. On 30th day, the uninoculated plot was superior to the inoculated one, while on 60th day, the reverse was true. The effect of inoculation on 90th day was not significant.

Interaction effect was significant in all the three stages. On 30th day, 60 kg K_2O ha^{-1} without inoculation recorded the highest value and was superior to all other combinations. On 60th day, 60 kg K_2O ha^{-1} with and without inoculation registered same values. Similarly on 90th day also 60 kg K_2O ha^{-1} with and without inoculation, recorded same values.

There was a general decrease in potassium content of leaves with advancement of growth.

Discussion on this aspect will be covered while dealing with potassium content of plants.

c) Potassium content of shells

The data on potassium content of shells on 90th day and at harvest are presented in Table 25 and Fig. 27. The analysis of variance and the mean tables for two factor combinations are given in Appendices 18 and 67 to 68 respectively.

Potassium content of shells was influenced by the levels of potassium at both stages. On 90th day, 60 kg K_2O ha^{-1} registered the highest content and was superior

Table 25. Effect of potassium and inoculation on potassium content of shells, seeds and plants at various growth stages.

Treatments	Potassium content (%)							
	Shells		Seeds		Plants			
	90th day after sowing	Harvest	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest
Levels of potassium (K_2O kg ha^{-1})								
0	1.013	1.663	1.528	1.563	2.208	1.904	1.338	1.299
30	2.238	2.050	1.653	1.638	2.849	2.115	1.858	1.423
60	2.350	1.988	1.674	1.775	3.110	2.331	1.745	1.520
90	2.025	1.775	1.580	1.688	2.918	2.224	1.609	1.434
120	2.150	1.850	1.556	1.713	2.819	1.986	1.649	1.474
SEm ±	0.025	0.019	0.009	0.013	0.054	0.015	0.084	0.075
C.D. at 5%	0.074	0.054	0.027	0.038	0.157	0.045	0.244	NS
Rhizobial inoculation								
Uninoculated	1.945	1.870	1.582	1.668	2.765	2.052	1.690	1.453
Inoculated	1.965	1.860	1.615	1.683	2.796	2.172	1.589	1.407
SEm ±	0.016	0.012	0.006	0.008	0.034	0.010	0.053	0.047
C.D. at 5%	NS	NS	0.017	NS	NS	0.028	NS	NS

FIG. 27 POTASSIUM CONTENT OF SHELLS

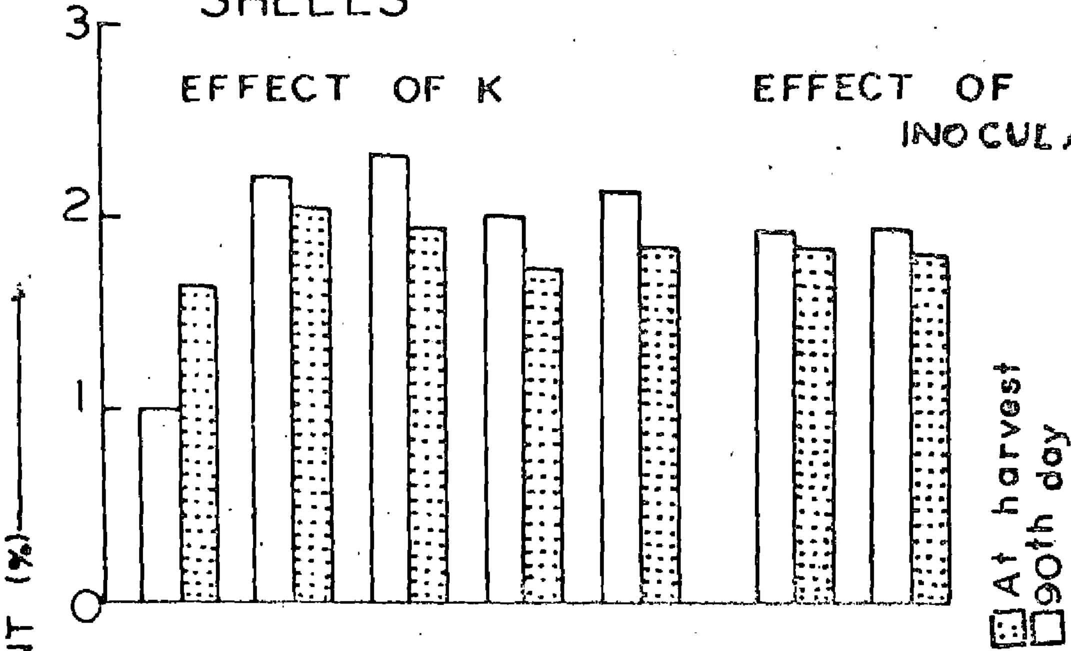


FIG. 28 POTASSIUM CONTENT OF SEEDS

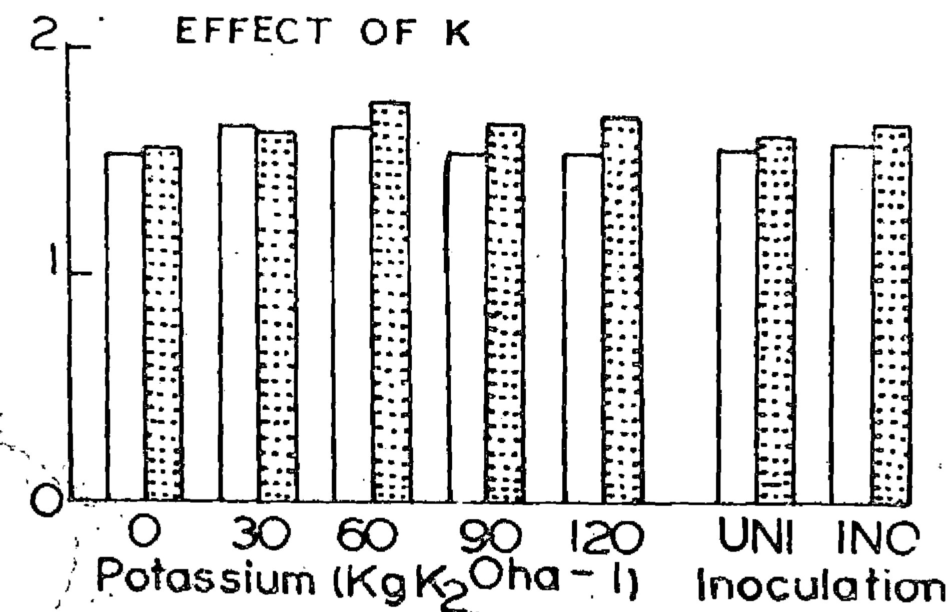
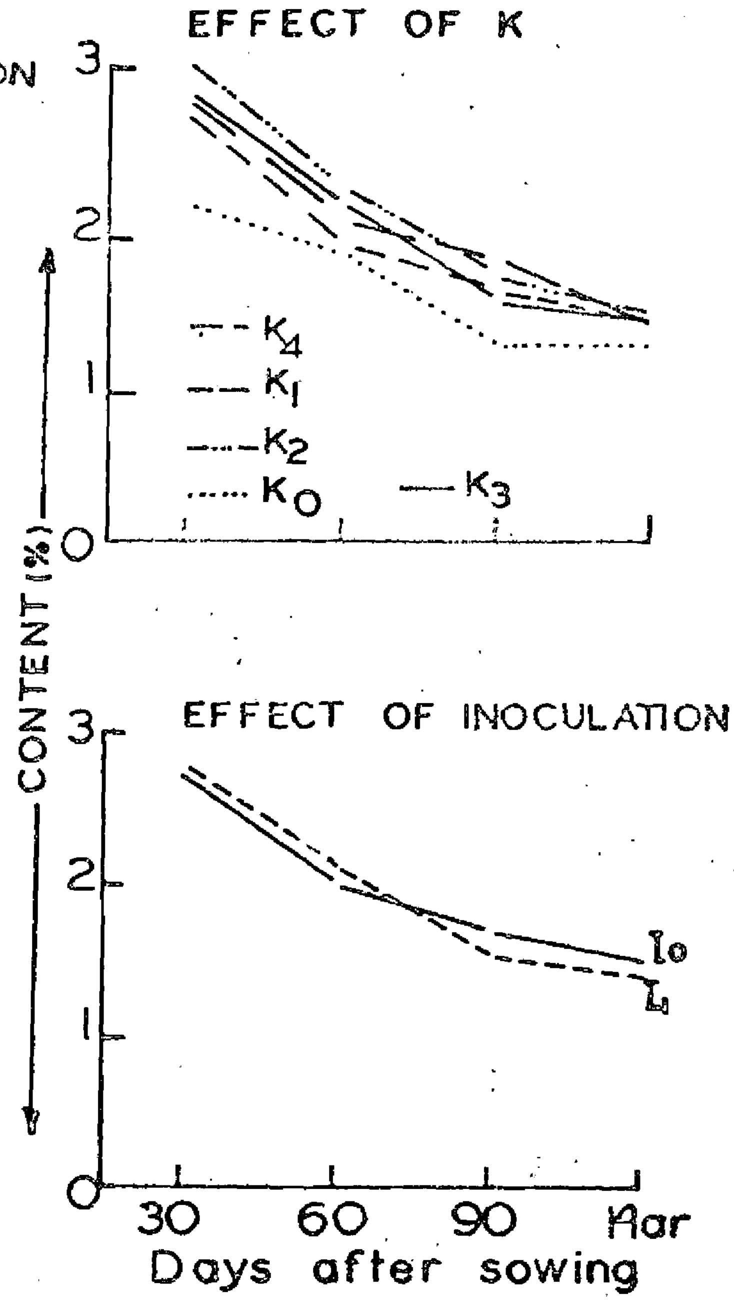


FIG. 29 POTASSIUM CONTENT OF PLANTS AT DIFFERENT STAGES OF PLANT GROWTH



to all other levels. At harvest, 30 kg K_2O ha^{-1} recorded the highest value and was superior to all other levels.

Inoculation failed to influence the potassium content of shells at both stages.

Interaction effect was significant and 60 kg K_2O ha^{-1} along with inoculation and 30 kg K_2O ha^{-1} without inoculation recorded the highest values on 90th day and at harvest respectively.

The general trend showed a reduction in potassium content of shells between 90th day and harvest.

The results will be discussed while dealing with the potassium content of plants.

d) Potassium content of seeds

The data on potassium content of seeds on 90th day and at harvest are presented in Table 25 and Fig. 28. The analysis of variance is given in Appendix 18.

Levels of potassium had significant effect on the potassium content of seeds at both stages. On 90th day, 60 kg K_2O ha^{-1} recorded the highest value and was on par with 30 kg K_2O ha^{-1}. At harvest, 60 kg K_2O ha^{-1} recorded the highest content and was superior to all other levels.

Inoculation influenced the potassium content of seeds significantly only on 90th day and the inoculated treatment was superior to the uninoculated one.

Interaction effect was not significant at both stages.

A slight increase in potassium content of seeds was noticed between 90th day and harvest.

Discussion on this aspect will be done subsequently while dealing with the potassium content of plants.

e) Potassium content of plants

The data on potassium content of plants at different growth stages are presented in Table 25 and Fig. 29. The analysis of variance and the mean table for two factor combinations are given in Appendices 18 and 69 respectively.

The data revealed that the effect of potassium was significant in all stages except at harvest. On 30th and 60th days, 60 kg K_2O ha^{-1} recorded the highest potassium content and was superior to all other levels. The treatment 30 kg K_2O ha^{-1} recorded the highest content of potassium on 90th day which was on par with 60 and 120 kg K_2O ha^{-1} and superior to all other levels. The effect of potassium at harvest remained non-significant.

Rhizobial inoculation significantly influenced the potassium content of plants on 60th day and the inoculated treatment was superior to the uninoculated plot. In all other stages, inoculation could not produce any significant difference in the potassium content of plants.

Interaction effect was significant only on 60th day and 60 kg K_2O ha^{-1} along with inoculation recorded the highest content of potassium.

There was a gradual and steady decline in the potassium content of plants with advancement of age.

The luxury consumption of potassium is well known (Tisdale and Nelson, 1975). It can be seen from Table 24 and 25 that the potassium contents of stems, leaves, shells and seeds were significantly increased with higher doses of potassium in all the stages studied. The significant differences in the potassium content of plants noticed in almost all the stages may be due to the above fact. Similar increase in potassium content in different plant parts due to application of potassium was reported by Bhangoo et al. (1972), Lutz et al. (1975), Chevalier (1976), Mascarenhas et al. (1976), Jones et al. (1977) and Terman (1977).

Though inoculation could influence the potassium content of plant parts in some of the stages, the results were not consistent enough to draw valid conclusions. The non-significant effect of inoculation on the potassium content of plants in almost all stages may be due to the inability of this treatment to produce a definite pattern of change. Hence, the effects of inoculation, in general, on potassium content of plant and plant parts, may thus be taken as non-significant.

A steady decline noticed in the potassium content of plant and plant parts due to age may be due to the distribution of this nutrient in the bulk of the dry matter.

This is in agreement with the findings of Chevalier (1976) and Jones et al. (1977).

6.2. Uptake of potassium

a) Uptake of potassium by stem

The data on uptake of potassium by stem at different stages of growth are presented in Table 26. The analysis of variance and the mean table for two factor combinations are given in Appendices 19 and 70 respectively.

There was significant difference in uptake of potassium by stem due to levels of potassium on 60th day and at harvest. But on 30th and 90th days, the effects were not significant. On 60th day, the highest uptake was recorded by 90 kg K_2O ha^{-1} which was on par with 60 and 30 kg K_2O ha^{-1} and superior to all other levels. The treatment 120 kg K_2O ha^{-1} recorded the highest uptake at harvest and was on a par with 60 kg K_2O ha^{-1}.

Rhizobial inoculation significantly influenced the uptake of potassium by stem on 90th day and at harvest and the inoculated treatment was superior to the uninoculated one. On 30th and 60th days, the effect was not significant.

Interaction effect was significant only at harvest and 120 kg K_2O ha^{-1} along with inoculation recorded the highest uptake which was on a par with 60 kg K_2O ha^{-1} along with inoculation and superior to all other combinations.

Table 26. Effect of potassium and inoculation on uptake of potassium by stem and leaves at various growth stages.

Treatments	Uptake of potassium (kg ha^{-1})						
	Stem				Leaves		
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Levels of potassium (K_2O kg ha^{-1})							
0	2.708	31.493	24.925	6.305	2.231	23.143	11.806
30	3.010	43.304	36.428	8.931	3.348	30.410	14.658
60	3.541	54.113	35.731	15.804	3.748	34.853	14.134
90	3.131	54.806	30.493	9.687	2.779	34.063	13.038
120	3.858	39.664	33.578	16.300	3.680	26.426	15.165
SEm ±	0.383	4.853	3.632	1.163	0.387	2.811	1.764
C.D. at 5%	NS	15.084	NS	3.374	1.123	8.158	NS
Rhizobial inoculation							
Uninoculated	3.031	46.651	27.624	7.857	3.067	31.454	11.999
Inoculated	3.468	42.753	36.838	14.951	3.248	27.996	15.520
SEm ±	0.243	3.070	2.297	0.735	0.245	1.778	1.116
C.D. at 5%	NS	NS	6.665	2.134	NS	NS	3.237

There was a steady and conspicuous increase in uptake upto 60th day and after that a gradual decline.

The results will be discussed while dealing with the total potassium uptake by plants.

b) Uptake of potassium by leaves

The data on the uptake of potassium by leaves on 30th, 60th and 90th days are presented in Table 26 and the analysis of variance in Appendix 19.

The data revealed that the effect of potassium was significant on 30th and 60th days. During both the stages, 60 kg K_2O ha^{-1} recorded the highest values of 3.748 and 34.853 kg ha^{-1} respectively. On 90th day, the effect of potassium was not significant.

Inoculation influenced the uptake of potassium by leaves only on 90th day and the inoculated treatment recorded the highest uptake of 15.52 kg ha^{-1} against 11.999 kg ha^{-1} in the uninoculated plot.

Interaction effect remained non-significant in all the stages.

A sharp increase in the potassium uptake by leaves was noted between 30th and 60th day and after that a gradual reduction.

Discussion on this will be covered while dealing with the total uptake of potassium by plants.

c) Uptake of potassium by shells

The data on uptake of potassium by shells on 90th day and at harvest are given in Table 27 and the analysis of variance in Appendix 19.

There was significant difference in the uptake of potassium by shells on 90th day and 30 kg K_2O ha^{-1} recorded the highest uptake of 39.761 kg ha^{-1} which was on a par with 120, 90 and 60 kg K_2O ha^{-1}. The effect remained non-significant at harvest.

The effect of inoculation was significant only on 90th day. The highest uptake of 36.915 kg ha^{-1} was recorded in the inoculated treatment.

Interaction effect was not significant during both stages.

A general decrease in potassium uptake by shells was noticed between 90th day and harvest.

Discussion on this aspect will be covered while dealing with total potassium uptake by plants.

d) Uptake of potassium by seeds

The results on the uptake of potassium by seeds are presented in Table 27 and the analysis of variance in Appendix 20.

The results revealed that the effect of potassium on potassium uptake by seeds was significant only at harvest and that 120 kg K_2O ha^{-1} recorded the highest

Table 27. Effect of potassium and inoculation on uptake of potassium by shells and seeds at various growth stages.

Treatments	Uptake of potassium (kg ha^{-1}) Shells: 90th day after sowing	Shells: Harvest	Seeds: 90th day after sowing	Seeds: Harvest
Levels of potassium (K_2O kg ha^{-1})				
0	13.601	16.175	20.070	28.445
30	39.761	24.805	22.400	37.636
60	32.164	23.991	22.526	38.481
90	36.930	18.538	29.109	34.616
120	39.516	30.585	27.008	54.170
SEm ±	4.522	3.457	3.893	5.549
C.D. at 5%	13.122	NS	NS	16.102
Rhizobial inoculation				
Uninoculated	27.878	21.917	22.972	36.587
Inoculated	36.915	23.720	27.905	40.753
SEm ±	2.860	2.173	2.462	3.509
C.D. at 5%	8.299	NS	NS	NS

uptake of 54.17 kg ha^{-1} which was on a par with 60 kg K_2O ha^{-1} and superior to all other levels. On 90th day, the effect was not significant.

The effect of inoculation was found to be not significant during both the stages. However, the inoculated treatment showed a marginal increase in uptake over the uninoculated ones.

The interaction effects also were not significant.

Comparing between stages, an increase in potassium uptake by seeds was noticed between 90th day and harvest.

The results will be discussed subsequently while dealing with the uptake of potassium by plants.

e) Uptake of potassium by plants

The data on uptake of potassium by plants at different stages of growth are presented in Table 28 and Fig. 30 and the analysis of variance in Appendix 20.

Uptake of potassium by plants was influenced by the levels of potassium on 60th day and at harvest. The treatment 60 kg K_2O ha^{-1} recorded the highest uptake of 89.34 kg ha^{-1} on 60th day which was on a par with 90 and 30 kg K_2O ha^{-1} and superior to all other levels. At harvest, the highest uptake was recorded by 120 kg K_2O ha^{-1} which was on a par with 60 kg K_2O ha^{-1} and superior to all other levels. The effect was not significant on 30th day and 90th day.

Table 28. Effect of potassium and inoculation on the total uptake of potassium by plants at various growth stages and harvest index of potassium at various growth stages.

Treatments	Uptake of potassium by plants (kg ha^{-1})				
	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	Harvest index of potassium
Levels of potassium (K_2O kg ha^{-1})					
0	4.939	54.635	70.403	50.925	0.57
30	6.358	72.634	119.326	71.373	0.53
60	7.289	89.340	104.555	78.276	0.49
90	5.910	88.949	109.576	62.783	0.55
120	7.538	66.090	115.264	101.053	0.54
SEm ±	0.733	7.461	12.906	9.631	0.011
C.D. at 5%	NS	21.652	NS	27.949	0.030
Rhizobial inoculation					
Uninoculated	6.098	77.761	90.472	66.341	0.55
Inoculated	6.716	70.899	117.178	79.425	0.52
SEm ±	0.464	4.719	8.163	1.091	0.007
C.D. at 5%	NS	NS	23.688	NS	0.02

FIG. 30 POTASSIUM UPTAKE OF PLANT AT DIFFERENT STAGES OF GROWTH

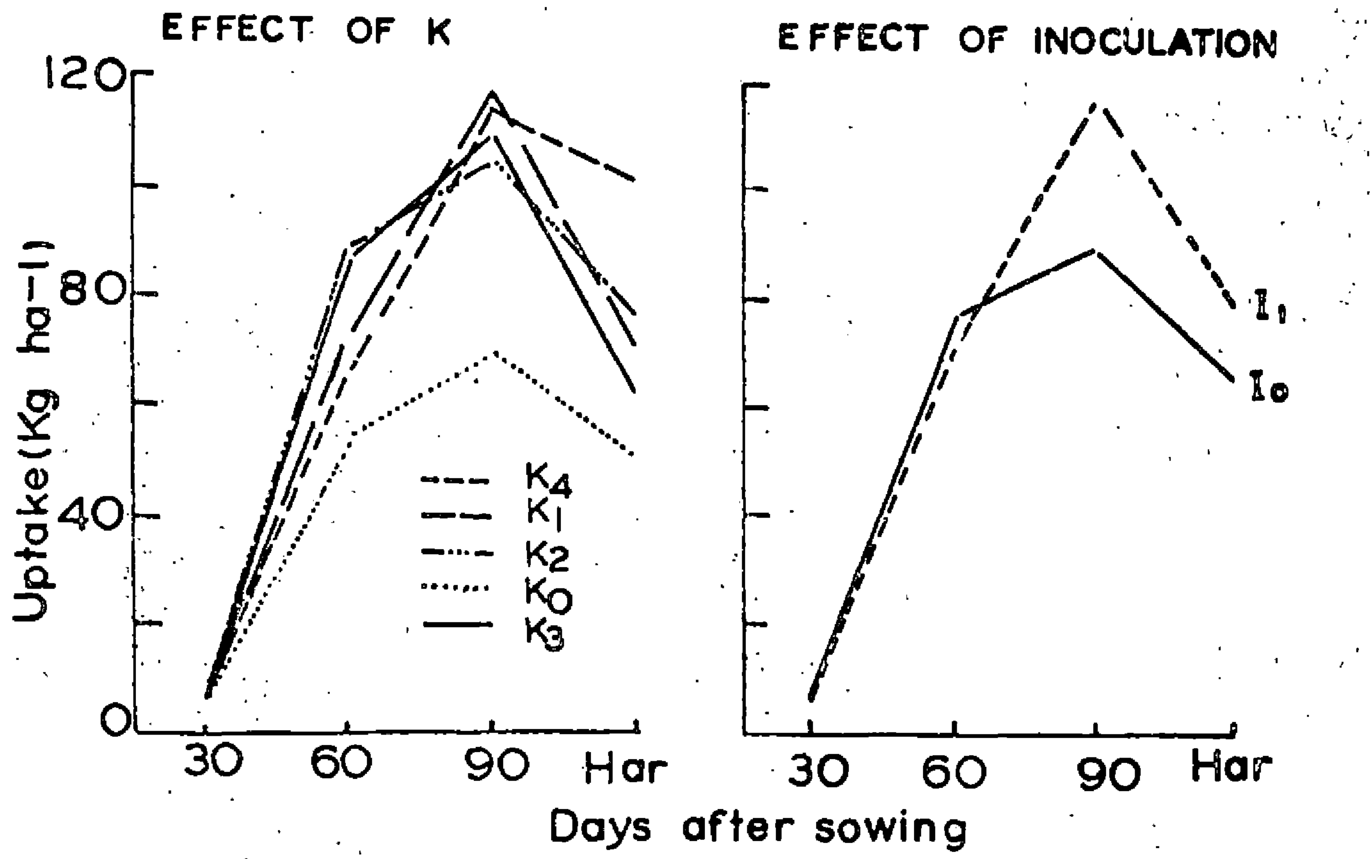
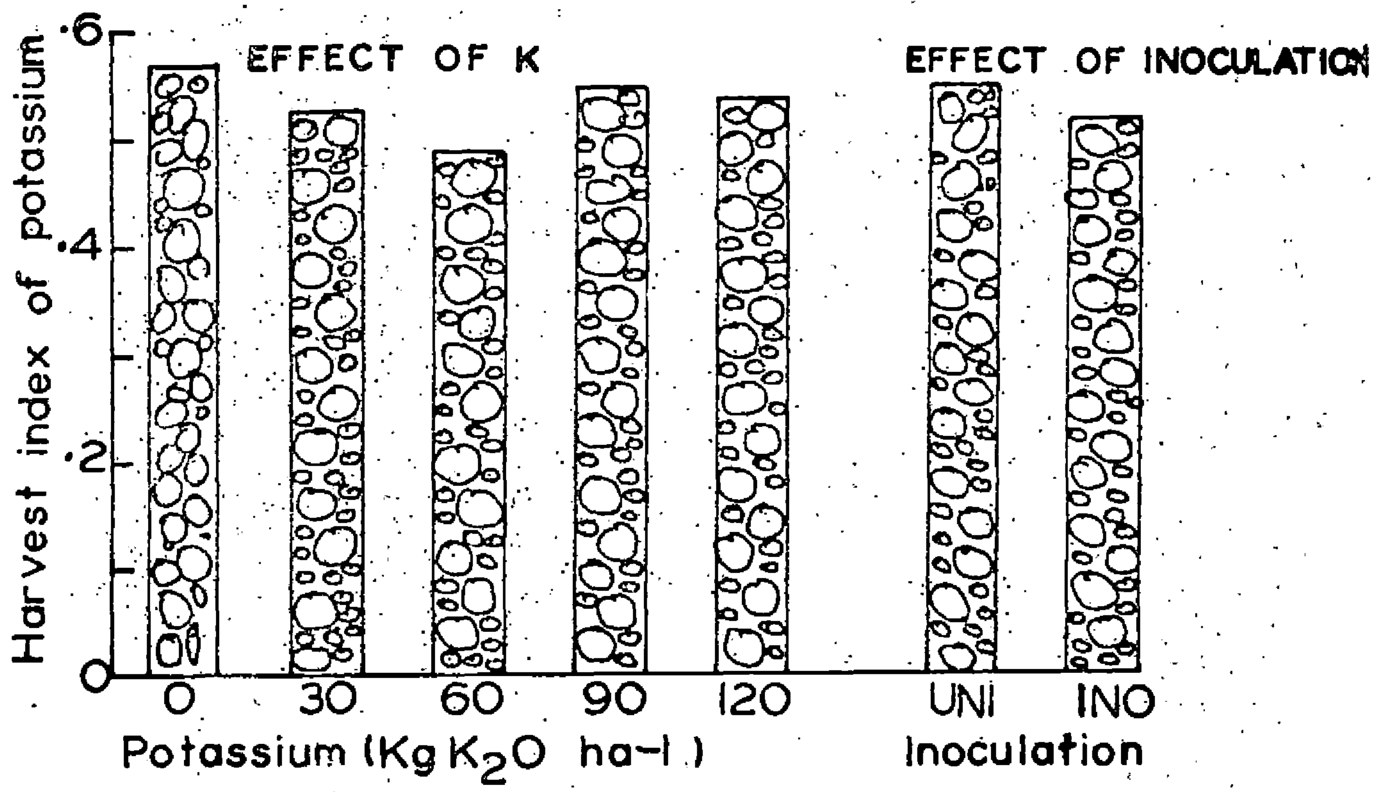


FIG. 31 HARVEST INDEX OF POTASSIUM



Increase in uptake due to inoculation was significant only on 90th day and the inoculated treatment was superior to the uninoculated plot. In all other stages the effect of inoculation remained non-significant.

Interaction effect was not significant in any of the stages.

A steady and conspicuous increase in uptake of potassium by plants was noticed upto 90th day and after that there was a decline.

It can be seen from Table 25 and 8 that, though the potassium contents of plants were significant on 30th and 90th days, the total dry matter production remained unaffected at these stages. The non-significant difference in the potassium uptake during these stages can be attributed to the inability of potassium to influence dry matter production. On 60th day, though significant differences were noticed in the potassium uptake by plants, the results were not consistent enough to draw definite conclusions. Hence, in general, the effect of potassium on potassium uptake, upto 90th day may be taken as non-significant. The significant effect of potassium on the potassium uptake by seeds and stem at harvest might have resulted in a marked difference in the potassium uptake by plants at this stage.

In general, inoculation failed to produce any significant effect on dry matter production and potassium content of plants and plant parts in almost all the stages. Though significant differences were noticed in some cases, there was no definite pattern of change and the results were erratic and inconsistent. The non-significant effect of inoculation on potassium uptake noticed in almost all the stages can be attributed to the above facts.

A steady increase in the uptake of potassium upto the 90th day indicated a higher rate of absorption of this nutrient upto this stage. A decrease in uptake noticed thereafter can be attributed to the reduction in total dry matter production, mainly due to the leaf fall during this stage.

It was also noticed that the potassium uptake was lowest in the control plot and it went on increasing with increased supply of available potassium indicating its luxury consumption.

f) Harvest index of potassium

The data on harvest index of potassium are presented in Table 28 and Fig.31. The analysis of variance is given in Appendix 20.

Potassium levels influenced the harvest index of recovered potassium, the control plot recording the highest value of 0.57 which was on a par with 90 and 120 kg K_2O ha^{-1} levels.

Inoculation also influenced the harvest index of potassium and the uninoculated treatment was superior to the inoculated one.

Interaction effect was not significant.

Though there was significant variation in harvest index of potassium with the levels of added potassium, the results were erratic and hence difficult to explain. However, the data revealed that the highest proportion of the total potassium absorbed by the plant had gone to the sink in the plot receiving 0 kg K_2O ha^{-1}.

A significant reduction noticed due to inoculation indicated the unfavourable effect of this treatment to accumulate potassium in the seeds compared to the uninoculated one.

C.3. Potassium utilization efficiency

a) Response

The data on response of seed yield to applied potassium are presented in Table 29.

Though levels of potassium were not significant with respect to yield, the highest response value was recorded by 30 kg K_2O ha^{-1}. The response was found to be decreasing gradually upto 120 kg K_2O ha^{-1}.

The decrease at higher levels is due to the fact that the yield increase was not proportionate with levels of applied potassium. That is, marginal returns went on decreasing. It may also be noted that in this experiment,

Table 29. Potassium utilisation efficiency of soybean.

Levels of potassium (K_2O kg ha^{-1})	Response	Productive efficiency
30	6.89	10.11
60	5.18	11.36
90	4.19	31.79
120	1.56	3.73

applied potassium did not increase the seed yield significantly.

b) Productive efficiency

The data on the productive efficiency of potassium are presented in Table 29.

The data revealed that the productive efficiency increased upto 90 kg K_2O ha^{-1} and declined drastically thereafter.

An increase in productive efficiency upto 90 kg K_2O ha^{-1} indicated that there was a steady increase in marginal yield with every kg of additional potassium uptake. With increased potassium uptake beyond this level, there was a steady increase in the contribution of this nutrient for the nonproductive purposes of increasing the potassium content of tissues of the vegetative part as shown in Table 24.

IV. Quality characters

a) Protein content of seeds

The data on the protein content of seeds are presented in Table 30 and Fig. 32. The analysis of variance and the mean table for two factor combinations are given in Appendices 21 and 71 respectively.

The data revealed that the levels of potassium significantly influenced the protein content of seeds and the control plot recorded the highest protein content of

Table 30. Effect of potassium and inoculation on protein content, protein yield, oil content and oil yield of seeds at harvest.

Treatments	Protein content (%)	Protein yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
Levels of potassium (K_2O kg ha^{-1})				
0	40.71	791.13	19.41	376.67
30	34.38	740.15	21.91	470.41
60	36.52	822.68	22.70	510.15
90	35.24	816.75	21.14	490.67
120	35.24	750.00	23.11	491.33
SEm ±	0.237	0.037	0.154	23.277
C.D. at 5%	0.68	NS	0.447	67.55
Rhizobial inoculation				
Uninoculated	35.36	747.75	22.82	483.74
Inoculated	37.47	820.60	20.49	451.95
SEm ±	0.15	23.00	0.097	14.722
C.D. at 5%	0.43	68.17	0.283	NS

FIG. 32 PROTEIN CONTENT OF SEEDS

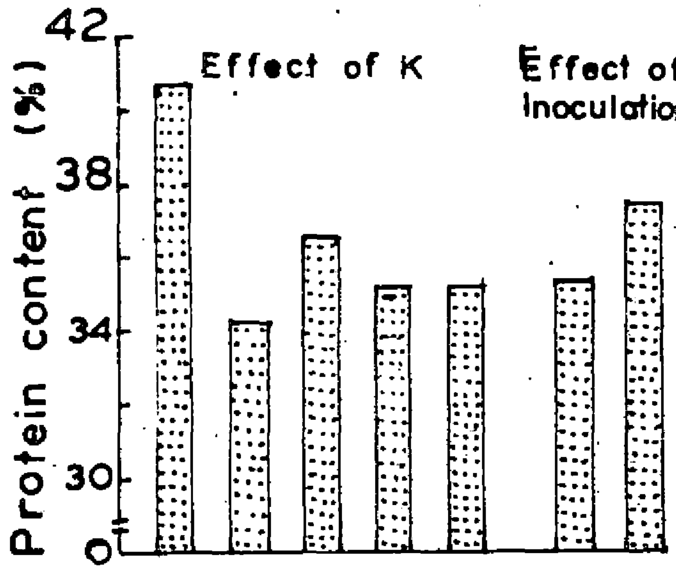


FIG. 33 PROTEIN YIELD

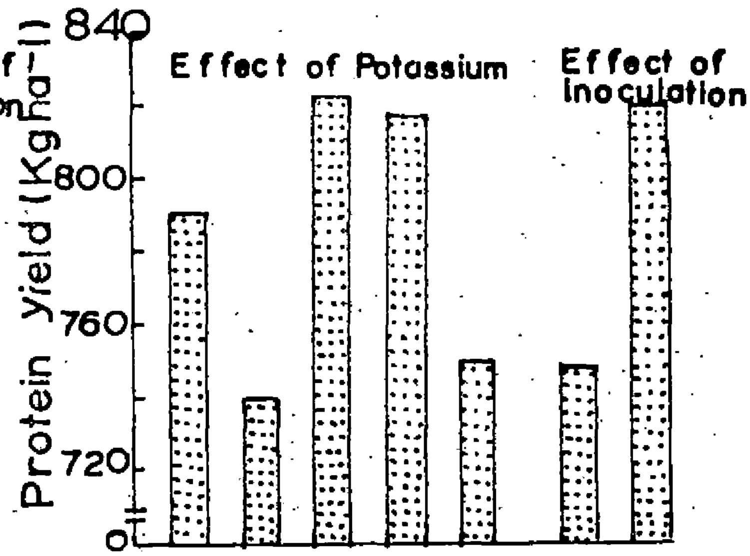


FIG. 34 OIL CONTENT OF SEEDS

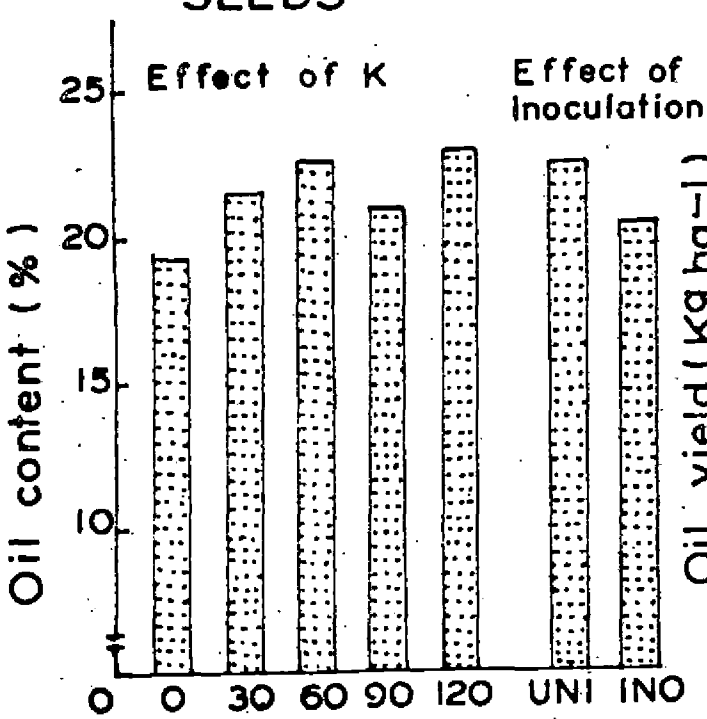
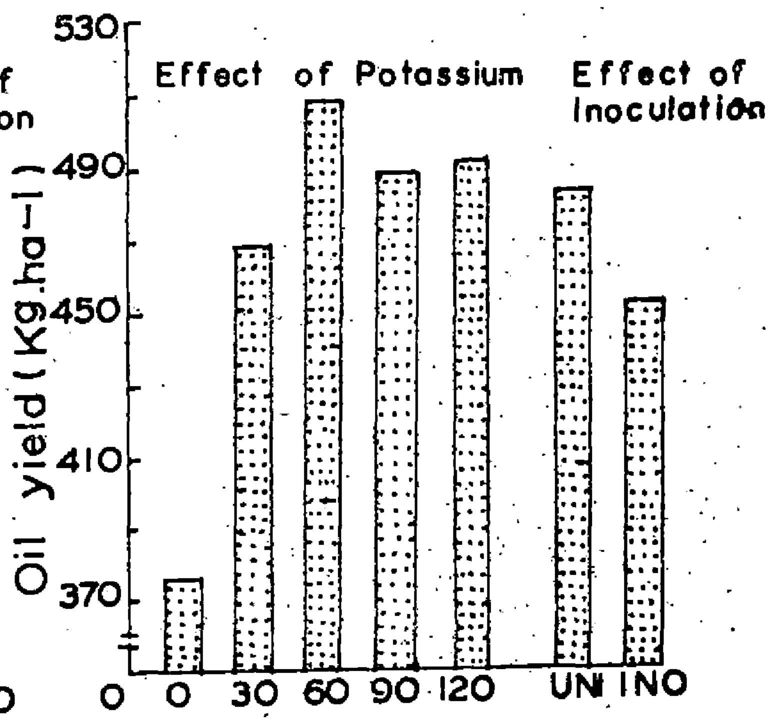


FIG. 35 OIL YIELD



Potassium (Kg K_2O ha−1) Inoculation

40.71 per cent and was superior to all other levels.

Inoculation also influenced the protein content of seeds and the inoculated plot was superior to the uninoculated one.

Interaction effect was significant and 0 kg K_2O ha^{-1} along with inoculation recorded the highest protein content and was superior to all other combinations.

It can be seen from Table 15 that potassium had significant influence on the nitrogen content of seeds both on 90th day and at harvest. This may be the reason for a significant difference in protein content of seeds due to levels of potassium. While there was a decrease in the protein content of seeds with applied potassium, there was an increase in the oil content of seeds. The above decline in protein content may be due to the mobilisation of plant metabolites to synthesise oil at the expense of protein synthesis. Similar decrease in protein content due to potassium application was reported by Chevalier (1976).

The effect of inoculation on nitrogen content of seed was significant both on 90th day and at harvest (Table 15) and the inoculated plots recorded the highest nitrogen contents. Hence the protein content of seeds was also significant due to inoculation. Similar results were reported by Prokopenko and Vashchenko (1974), Ruschel et al. (1975) and Sable and Khuspe (1977).

b) Protein yield

The data on protein yield are presented in Table 30 and Fig. 33 and the analysis of variance in Appendix 21.

Protein yield was not influenced by levels of potassium. However, the highest protein yield of 822.88 kg ha^{-1} was recorded by 60 kg K_2O ha^{-1}.

Inoculation increased the protein yield significantly and highest protein yield of 820.6 kg ha^{-1} was recorded in the inoculated treatment against 747.75 kg ha^{-1} in the uninoculated plot.

Interaction effect was not significant.

Though the protein content of seeds was influenced by levels of potassium, the seed yield remained unaffected. This may be the main reason for the non-significant difference in protein yield due to applied potassium.

The significant effect of inoculation on protein content of seeds coupled with the marginal increase in seed yield due to inoculation might have resulted in recording significantly higher protein yield in the inoculated plots.

c) Oil content of seeds

The mean values on oil content of seeds are presented in Table 30 and Fig. 34. The analysis of variance and the mean table for two factor combinations are given in Appendices 21 and 72 respectively.

Levels of potassium had significant effect on the oil content of seeds and the highest oil content of 25.11 per cent was recorded by 120 kg K_2O ha^{-1} which was on a par with 60 kg K_2O ha^{-1}, but superior to all other levels.

Inoculation also influenced the oil content of seeds negatively and the uninoculated plot was superior to the inoculated one.

Interaction effect was significant and 60 kg K_2O ha^{-1} without inoculation recorded the highest content of 24.66 per cent which was on a par with 120 kg K_2O ha^{-1} without inoculation and superior to all other combinations.

An inverse relationship between protein and oil content was noticed due to potassium application. The reasons for such a result has already been discussed while dealing with protein content of seeds. The result obtained in the present investigation is in agreement with the findings of Chevalier (1976).

Inoculation has significantly reduced the oil content of seeds. The results obtained in this study is in agreement with the findings of Ruschel et al. (1975), Varma and Tiwari (1976) and Sable and Khuspe (1977).

d) Oil yield

The data on oil yield are presented in Table 30 and Fig. 35. The analysis of variance is given in Appendix 21.

There was significant difference in the oil yield due to levels of potassium and 60 kg K_2O ha^{-1} recorded the highest oil yield of 510.15 kg ha^{-1} and was on a par with 120, 90 and 30 kg K_2O ha^{-1}.

Inoculation failed to influence the oil yield. However, the highest oil yield was recorded in the uninoculated plot.

Interaction effect was not significant.

Since there was significant difference in oil content due to potassium application, its effect on oil yield was also significant. Similar increase in oil yield due to applied potassium was reported by Chevalier (1978).

Though there was significant variation in oil content of seeds due to inoculation, it could not exert any effect on oil yield. This may be due to the non-significant effect of inoculation on seed yield.

V. Soil analysis after the experiment

a) Total nitrogen content

The data on total nitrogen content of soil are presented in Table 31 and the analysis of variance in Appendix 21.

There was no significant difference in total nitrogen content of soil due to application of potassium.

Inoculation significantly influenced the total nitrogen content of soil and the inoculated treatment was

Table 31. Effect of potassium and inoculation on total nitrogen, available phosphorus, and available potassium of soil after harvest of the crop.

Treatments	Total nitrogen (%)	Available phosphorus (ppm)	Available potassium (ppm)
Levels of potassium (K_2O kg ha^{-1})			
0	0.080	2.29	107.75
30	0.110	2.80	119.50
60	0.097	3.16	129.00
90	0.084	1.06	144.75
120	0.086	2.54	141.75
SEm ±	0.009	0.652	4.754
C.D. at 5%	NS	NS	11.71
Rhizobial inoculation			
Uninoculated	0.082	2.00	127.70
Inoculated	0.101	2.74	129.40
SEm ±	0.006	0.412	3.006
C.D. at 5%	0.018	NS	NS

superior to the uninoculated one.

Interaction effect was not significant.

It can be seen from Table 18 that the uptake of nitrogen by plants was also not influenced by levels of applied potassium at any of the growth stages.

The data on nitrogen uptake presented in Table 18 revealed that the nitrogen removal by the plant remained unaffected due to inoculation in most of the stages but the effect was significant on the 90th day. It can also be seen from Table 4 and 6 that there was significant difference in nodule number on 45th day and dry weight of leaves on 90th day, due to inoculation. Since the crop sheds leaves at maturity, that will also add to the nitrogen content of soil. Above all, the effect of inoculation in enriching the soil by nitrogen fixation is well established. The above reasons can be attributed to the significant increase in total nitrogen content of soil in the inoculated plots.

A comparison of nitrogen content of soil before and after the experiment indicates that the mean values on the nitrogen content of soil in all the treatments registered a higher value than the initial level.

b) Available phosphorus content

The data on available phosphorus content of soil are presented in Table 31 and the analysis of variance in

Appendix 21.

The available phosphorus content of the soil was not significantly influenced by levels of potassium, inoculation and their interactions.

It can be seen from Table 23 that the uptake of phosphorus by plants was not affected by potassium application in the advanced stages of crop growth, though it did have some influence in the initial stages.

Similarly, the effect of inoculation on phosphorus removal remained unaffected at harvest. These are the only reasons that would justify the non-significant effect of the various treatments under study, on the available phosphorus status of soil.

A comparison of available phosphorus status of soil before and after the experiment revealed that in general, the mean values on the available phosphorus content was high. This may either be due to the residue left over from the applied phosphatic fertilisers or due to bringing up of phosphorus from deeper layers of the soil (i.e., below the zone from which soil samples were drawn). Through root activity and then returning it to the top soil as organic phosphorus.

c) Available potassium content

The data on the available potassium content of soil are presented in Table 31 and the analysis of variance in Appendix 21.

Levels of potassium significantly influenced the available potassium content of soil and 90 kg K_2O ha^{-1} recorded the highest value which was on a par with 120 kg K_2O ha^{-1} and superior to all other levels.

The effect of inoculation on the available potassium content of soil was not significant. Similarly the interaction effects were also not significant.

An evaluation of the potassium uptake by plants revealed that the effect of potassium on the crop removal of this nutrient was significant on 60th day and at harvest. Similarly, the effect of potassium on dry weight of leaves and stem was significant on 75th day. The content of this nutrient in the leaves was also significant in all the stages of growth. During maturity the crop shed ~~all~~ the entire leaves, returning thus a part of the absorbed nutrients back to the soil. All these factors might have contributed to a significant variation in the available potassium content of the soil.

The non-significant effect of inoculation on the potassium removal by the plants noticed in most of the growth stages might have resulted in a non-significant difference in the available potassium status of the soil due to inoculation.

A comparison of the potassium content of soil before and after the experiment revealed that there was a decline in the available potassium content of the soil after the experiment.

It may be noted that a total rainfall of 2843.57 mm was received during the crop season which might have resulted in a considerable loss of this element by leaching. This coupled with the high rates of crop removal of this nutrient at harvest may be considered the reasons attributable to such a decline in potassium status of surface soil.

SUMMARY

SUMMARY

A field experiment was conducted in the Instructional Farm attached to the College of Horticulture, Vellanikkara during the period from June to September 1980, to study the effect of graded levels of potassium and rhizobial inoculation on growth, yield and quality of soybean. The treatments consisted of factorial combinations of five levels of potassium (0, 30, 60, 90 and 120 kg K_2O ha^{-1}) and two levels of culture inoculation (no inoculation and inoculation). The experiment was laid out in randomised block design with four replications. The results are summarised below.

1. No significant difference was noticed on height of plants due to application of potassium or culture inoculation at any stage of plant growth.

2. Number of branches, weight of nodules per plant, dry weight of seeds per plant, LAI and LWR were not significantly influenced by levels of potassium, inoculation and their interactions.

3. The effect of inoculation on number of root nodules per plant was significant only on 45th day and the inoculated treatment was superior to the uninoculated one.

4. Effects of potassium and inoculation on dry weights of stem, leaves and total phytomass production were

significant on 75th and 90th days respectively. The highest values were recorded by 120 kg K_2O ha^{-1} and in the inoculated treatment in both the stages.

5. Dry weight of shells was influenced by inoculation only on 90th day and the inoculated treatment was superior to the uninoculated one.

6. Between 60th and 75th day, the influence of inoculation on SLA was significant and the inoculated treatment was superior.

7. AGR, CGR and NAR were influenced by potassium between 60th and 75th day and the highest values were recorded by 120 kg K_2O ha^{-1}. Interaction effects were significant on AGR and CGR between 30th and 45th day and 120 kg K_2O ha^{-1} along with inoculation recorded the highest values.

8. Potassium, inoculation and their interactions failed to influence number of pods per plant, weight of pods per plant, 1000 seed weight, shelling percentage and seed yield.

9. Number of seeds per pod was influenced only by potassium and the highest value was recorded by 30 kg K_2O ha^{-1}.

10. The main effects of potassium and inoculation on stover yield and moisture per cent of seeds were not significant but their interaction effects were significant.

11. The effect of potassium alone was significant on harvest index and 90 kg K_2O ha^{-1} recorded the highest value.

12. The content of nitrogen in stem was influenced by levels of potassium on 30th and 60th days and at harvest. On 30th day and at harvest, potassium at 0 kg K_2O ha^{-1} recorded the highest content, while on 60th day the highest content was registered by 90 kg K_2O ha^{-1}. The effect of inoculation was marked on 30th day and at harvest. On 30th day, the inoculated treatment registered the highest content while at harvest the uninoculated plot gave the highest value. Interaction was significant on 30th and 60th days and at harvest.

13. The influence of potassium on leaf nitrogen content was significant on 30th, 60th and 90th days. On 30th day, 120 kg K_2O ha^{-1} recorded the highest content while at 60th and 90th days, the highest values were recorded by 60 kg K_2O ha^{-1}. Inoculation influenced the nitrogen content of leaves only on 90th day and the inoculated treatment was superior. The interaction effect was significant on 30th and 90th days.

14. Effects of potassium, inoculation and interactions on nitrogen content of shells and seeds were significant on 90th day and at harvest. On 90th day, 120 kg K_2O ha^{-1} registered the highest nitrogen content in shells while at harvest, 30 kg K_2O ha^{-1} recorded the highest value.

Potassium at 0 kg K_2O ha^{-1} recorded the highest content of nitrogen in seeds both on 90th day and at harvest. The inoculated treatments were superior in all the stages.

15. Though there was variation in nitrogen content of plant parts in many of the stages due to potassium, inoculation and their interactions, the nitrogen content of the plant remained unaffected at all the stages.

16. Potassium did not influence the uptake of nitrogen by stem, leaves, shells and seeds and total uptake at any of the stages. Effects of inoculation on the uptake of nitrogen by the plant and plant components except seeds were significant on 90th day and inoculated treatment recorded the highest values. Nitrogen uptake by stem at harvest was significantly influenced by interaction.

17. Effect of potassium on harvest index of nitrogen was significant on 90th day and the highest accumulation of 93 per cent of total absorbed nitrogen in seeds was recorded by 120 kg K_2O ha^{-1}.

18. Phosphorus content of stem was influenced by levels of potassium, inoculation and by their interactions. Potassium at 60 kg K_2O ha^{-1} recorded the highest values on 30th and 60th days and the inoculated plots were superior to the uninoculated ones.

19. On 30th, 60th and 90th days, the effect of potassium on leaf phosphorus content was significant.

On 60th day, 60 kg K_2O ha^{-1} recorded the highest value while in the other two stages, 120 kg K_2O ha^{-1} was superior. Effect of inoculation on phosphorus content of leaves was significant on 60th and 90th days and the inoculated treatments were superior to the uninoculated ones.

20. Levels of potassium, inoculation and interactions influenced the phosphorus content of shells on 90th day and 120 kg K_2O ha^{-1} and inoculated treatments were superior.

21. Seed phosphorus content was significant on 90th day and 60 kg K_2O ha^{-1} recorded the highest value. Interaction effect was also significant on 90th day and 60 kg K_2O ha^{-1} without inoculation gave the highest phosphorus content.

22. Potassium had significant influence on the phosphorus content of plants on 30th, 60th and 90th days and at harvest. On 90th day and at harvest, 120 kg K_2O ha^{-1} and 0 kg K_2O ha^{-1} recorded the highest values while in the other two stages 60 kg K_2O ha^{-1} gave highest contents. Effect of inoculation was significant on 60th day and the inoculated treatment was superior to the uninoculated one.

23. Effects of potassium and interactions were significant on the phosphorus uptake by stem in all the stages studied. On 30th day, 60 kg K_2O ha^{-1} recorded the highest value while on 60th day, the highest uptake was noticed with 90 kg K_2O ha^{-1}. On 90th day and at harvest,

30 kg K_2O ha^{-1} recorded the highest values. On 30th and 90th days, the inoculated treatments were significantly superior while at harvest the uninoculated plot recorded the highest value.

24. Effects of potassium, inoculation and interactions on uptake of phosphorus by leaves were significant in all the stages studied. On 30th and 90th days, the highest uptake was noticed in the plots receiving 120 kg K_2O ha^{-1} while on 60th day, the highest value was obtained with 60 kg K_2O ha^{-1}. Inoculated treatments were superior on 30th and 90th days while the uninoculated plot registered the highest value on 60th day.

25. Uptake of phosphorus by shells was influenced by potassium at harvest and 120 kg K_2O ha^{-1} recorded the highest value. The effects of inoculation and interactions were significant on 90th day.

26. None of the treatments affected the uptake of phosphorus by seeds.

27. Effect of potassium on total uptake of phosphorus by the plant was significant on 30th and 60th days and 120 and 60 kg K_2O ha^{-1} recorded the highest values respectively. Inoculation influenced phosphorus uptake by plants on 30th, 60th and 90th days and inoculated treatments were superior on 30th and 90th days. Interaction effects were also marked on 30th and 60th days.

28. Harvest index of phosphorus was not influenced by any of the treatments under study.

29. Levels of potassium significantly influenced the potassium content of stem in all the stages and 30 kg K_2O ha^{-1} recorded the highest value on 90th day, while in all the other stages the highest values were recorded by 60 kg K_2O ha^{-1}. Interaction effects were also significant in all the stages except on 30th day.

30. Effect of potassium on potassium content of leaf was significant in all the stages and 60 kg K_2O ha^{-1} recorded the highest value. Interaction effect was also significant in all the stages.

31. Potassium content of shells was influenced by applied potassium on 90th day and at harvest and 60 and 30 kg K_2O ha^{-1} recorded the highest values respectively. Interaction effect was also significant in all the stages.

32. On 90th day and at harvest, the effect of potassium on potassium content of seed was significant and 60 kg K_2O ha^{-1} recorded the highest content.

33. Potassium at 60 kg K_2O ha^{-1} registered the highest content of potassium in plants on 30th and 60th days while on 90th day, the highest value was recorded by 30 kg K_2O ha^{-1}. Interaction effect was also significant on 60th day.

34. Effect of potassium on uptake of potassium by stem was significant on 60th day and at harvest and the

highest values were recorded by 90 and 120 kg K_2O ha^{-1} respectively.

35. Potassium uptake by leaves was markedly influenced by applied potassium on 30th and 60th days and 60 kg K_2O ha^{-1} gave the highest values. Inoculated treatment recorded significantly higher value on 90th day.

36. Levels of potassium and inoculation influenced the uptake of potassium by shells on 90th day and 30 kg K_2O ha^{-1} and inoculated treatments recorded the highest values.

37. Uptake of potassium by seeds was significant at harvest and 120 kg K_2O ha^{-1} gave the highest value.

38. Total uptake of potassium by the plant was significant at harvest and 120 kg K_2O ha^{-1} gave the highest uptake. Inoculated treatment was superior on 90th day.

39. Harvest index of potassium was significantly influenced by levels of potassium and inoculation and 0 kg K_2O ha^{-1} and uninoculated plot gave the highest values.

40. Effect of potassium on protein content of seeds was marked and 0 kg K_2O ha^{-1} gave the highest content. Inoculated treatment also gave significantly higher protein content. Interaction effect was significant and 0 kg K_2O ha^{-1} along with inoculation gave the highest protein content.

41. Inoculated treatment recorded significantly higher protein yield.

42. Oil content was influenced by levels of potassium and inoculation and 120 kg K_2O ha^{-1} and the uninoculated plots gave the highest oil content. Interaction effect was also significant and 60 kg K_2O ha^{-1} without inoculation recorded the highest oil content.

43. Applied potassium markedly influenced the oil yield and 60 kg K_2O ha^{-1} registered the highest oil yield.

44. Total nitrogen content of the soil after the experiment was significantly higher in the inoculated plot.

45. None of the treatments under study could influence the available phosphorus status of the soil after the experiment.

46. Available potassium status of the soil after the experiment was influenced by levels of potassium and 90 kg K_2O ha^{-1} gave the highest potassium content.

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*Originals not seen

APPENDICES

APPENDIX 1

Analyses of variance for height of plant and number of branches at different growth stages

Source	df	Mean squares							
		Height of plant					Number of branches		
		30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing
Blocks	3	8.087	76.520	323.057**	311.358**	308.393**	0.283	0.438**	0.020
K	4	4.824	30.760	83.901	97.773	111.215	0.143	0.018	0.017
I	1	18.198	65.178	117.101	95.852	58.370	0.466	0.035	0.015
K x I	4	7.185	74.792	264.120**	280.098**	227.678*	0.138	0.022	0.021
Error	27	6.825	32.509	58.444	62.850	59.784	0.124	0.076	0.057

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 2

Analyses of variance for number of root nodules and weight of root nodules at different growth stages

Source	df	Mean squares							
		Number of root nodules per plant				Weight of root nodules per plant			
		45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing
Blocks	3	3.504**	3.824**	13.736**	6.083	7.080**	0.055**	0.257**	0.018
K	4	0.025	0.573	1.655	1.222	0.003	0.002	0.049	0.018
I	1	1.670*	1.640	0.762	2.283	0.006	0.005	0.017	0.016
K x I	4	0.284	0.757	1.800	1.139	0.010	0.004	0.032	0.017
Error	27	0.272	0.714	2.523	2.940	0.008	0.004	0.050	0.027

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 3

Analyses of variance for dry weight of stem and leaves at different growth stages

Source	df	Mean squares										
		Dry weight of stem per plant						Dry weight of leaves per plant				
		30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing	Harvest	30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing
Blocks	3	0.013	0.089	2.750	1.071	14.665**	4.398	0.004	0.051	2.279**	0.692	7.886**
K	4	0.004	0.347	2.341	15.906*	3.266	4.774	0.009	0.307	1.462	4.593*	0.267
I	1	0.004	0.042	5.256	0.030	22.877*	5.476	0.009	0.001	2.262	0.177	2.480*
K x I	4	0.003	0.468	2.002	2.939	3.326	3.594	0.008	0.539*	1.103	0.616	0.655
Error	27	0.007	0.222	1.955	4.644	3.128	1.911	0.010	0.157	0.733	1.497	0.487

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 4

Analyses of variance for dry weight of shells, seeds and total phytomass production at different growth stages

Source	df	Mean squares									
		Dry weight of shells per plant		Dry weight of seeds per plant		Total phytomass production per plant					
		90th day after sowing	Harvest	90th day after sowing	Harvest	30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing	Harvest
Blocks	5	6.097*	3.161	11.462*	17.764*	0.024	0.100	10.267	4.957	147.495**	61.038
K	4	2.563	2.764	2.404	12.083*	0.023	1.295	7.706	64.407*	26.565	48.882
I	1	8.556*	0.452	4.096	2.678	0.022	0.029	14.448	0.790	130.502*	21.756
K x I	4	2.147	1.104	2.639	3.634	0.017	2.001**	5.941	11.697	29.909	23.349
Error	27	1.723	1.305	2.504	4.383	0.030	0.714	5.122	18.002	24.102	19.716

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 5

Analyses of variance for specific leaf area and leaf weight ratio at different growth stages

Source	df	Mean squares							
		Specific leaf area				Leaf weight ratio			
		Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing	Between 75th and 90th day after sowing	Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing	Between 75th and 90th day after sowing
Blocks	3	38366.50*	7334.26	1512.80	2005.22	0.0022*	0.0013	0.0002	0.0028**
K	4	1821.71	2103.78	395.61	3923.82	0.0019	0.0001	0.0002	0.0002
I	1	6849.47	941.19	8294.40*	843.28	0.0004	0.0002	0.00002	0.0002
K x I	4	6653.51	2604.66	369.82	2222.07	0.0002	0.0002	0.0002	0.0001
Error	27	2954.78	3183.85	1862.02	2019.21	0.0007	0.0005	0.0002	0.0004

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 6

Analysis of variance for leaf area index at different growth stages

Source	df	Mean squares				
		Leaf area index				
		30th day after sowing	45th day after sowing	60th day after sowing	75th day after sowing	90th day after sowing
Blocks	3	0.194**	0.138	6.170	3.916	13.079**
K	4	0.045	1.852	4.996	7.803	0.597
I	1	0.003	0.225	0.298	0.980	3.938
K x I	4	0.018	1.811	3.322	4.402	1.657
Error	27	0.032	0.056	2.851	2.929	1.059

** Significant at 1 per cent level

APPENDIX 7

Analyses of variance for absolute growth rate, crop growth rate and net assimilation rate at different growth stages

Source	df	Mean squares								
		Absolute growth rate			Crop growth rate			Net assimilation rate		
		Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing	Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing	Between 30th and 45th day after sowing	Between 45th and 60th day after sowing	Between 60th and 75th day after sowing
Blocks	3	0.001	0.036	0.074	1.463	71.625	146.766	7.379*	1.575	4.488
K	4	0.006	0.051	0.263*	12.025	101.116	518.288*	1.969	4.420	14.489*
I	1	0.005	0.103	0.040	0.024	203.934	80.004	0.262	9.235*	4.382
K x I	4	0.009*	0.006	0.136	18.126*	11.932	269.614	1.027	1.069	7.115
Error	27	0.003	0.026	0.074	5.324	51.221	146.581	2.457	2.200	5.399

* Significant at 5 per cent level

APPENDIX 8

Analyses of variance for number of pods, weight of pods, number of seeds, test weight, shelling percentage, moisture percentage of seeds, seed yield, stover yield and harvest index.

Source	df	Mean squares									
		Number of pods per plant	Weight of pods per plant	Number of seeds per pod	1000 seed weight	Shelling percentage		Moisture percentage of seeds	Yield of seeds	Yield of stover	Harvest index
						90th day after sowing	Harvest				
Blocks	3	0.04	13.42*	0.0022	88.65	1124.35	105.18**	0.30	126198.69	415281.22	0.0124**
K	4	2.40	10.24*	0.0095*	32.91	10.65	4.62	0.66	164952.29	205986.01	0.0044*
I	1	0.60	2.09	0.0001	0.44	2.49	0.08	3.04	67313.82	38650.47	0.0050
K x I	4	0.46	3.41	0.0021	46.80	37.11	10.16	4.30	12720.40	438409.25*	0.0002
Error	27	0.94	3.72	0.0034	40.87	66.39	12.34	0.96	80423.41	147504.24	0.0014

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 9

Analyses of variance for nitrogen content of stem and leaves at different growth stages

Source	df	Mean squares						
		Nitrogen content of stem				Nitrogen content of leaves		
		30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Blocks	3	0.00004	0.0056*	0.0013	0.0002	0.0082	0.187	0.0005
K	4	0.020**	0.046**	0.017	0.082**	0.375**	0.625*	0.705**
I	1	0.019**	0.002	0.00004	0.008**	0.019	0.011	0.342**
K x I	4	0.025**	0.019**	0.0028	0.052**	0.133**	0.241	0.326**
Error	27	0.00008	0.0016	0.0067	0.00008	0.0097	0.225	0.011

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 10

Analyses of variance for nitrogen content of shells, seeds and plants at different growth stages

Source	df	Mean squares							
		Nitrogen content of shells		Nitrogen content of seeds		Nitrogen content of plants			
		90th day after sowing	Harvest	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest
Blocks	3	0.001	0.0001	0.005	0.006	0.055	0.011	0.041	0.986*
K	4	0.072**	0.081**	4.261**	1.296**	0.386	0.033	0.195*	0.352
I	1	0.014*	0.019	3.754**	1.135**	0.110	0.132**	0.056	0.013
K x I	4	0.128**	0.037**	0.118**	0.214**	0.497	0.006	0.089	0.356
Error	27	0.003	0.006	0.026	0.032	0.281	0.015	0.051	0.235

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 11

Analyses of variance for uptake of nitrogen by stem, leaves and shells at different growth stages

Source	df	Mean squares								
		Uptake of nitrogen by stem				Uptake of nitrogen by leaves			Uptake of nitrogen by shells	
		30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	90th day after sowing	Harvest
Blocks	3	0.180	46.050	133.672*	9.276	0.618	468.719	803.117**	281.733*	18.415
K	4	0.081	89.447	40.397	1.594	3.546	222.534	139.635	197.264	11.844
I	1	0.204	116.793	248.752**	10.806	1.858	198.604	499.496**	434.762*	9.885
K x I	4	0.057	67.809	53.762	25.588**	0.935	202.777	108.908	163.028	0.598
Error	27	0.147	38.694	31.752	6.176	1.849	158.907	58.034	74.977	9.853

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 12

Analyses of variance for uptake of nitrogen by seeds and plants at different growth stages and harvest index of nitrogen

Source	df	Mean squares						
		Uptake of nitrogen by seeds		Uptake of nitrogen by plants				Harvest index of nitrogen
		90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	
Blocks	3	5888.691*	11509.459	1.105	772.938	17245.921**	13452.457*	0.001**
K	4	614.309	6202.205	4.393	566.049	1496.305	6358.541	0.002**
I	1	4778.202	4418.635	3.295	619.999	16397.235*	5646.088	0.0002
K x I	4	1516.543	1872.475	1.355	473.997	4272.319	2160.277	0.001**
Error	27	1282.384	2842.676	2.762	345.175	2755.385	3409.034	0.0002

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 13

Analyses of variance for phosphorus content of stem and leaves at different growth stages

Source	df	Mean squares						
		Phosphorus content of stem				Phosphorus content of leaves		
		30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Blocks	3	0.0001	0.0001	0.0100	0.0060	0.0001	0.0001	0.0001
K	4	0.0037**	0.0015**	0.0090	0.0060	0.0130**	0.0041**	0.0026**
I	1	0.0062**	0.0020**	0.0060	0.0010	0.0001	0.0034**	0.0056**
K x I	4	0.0022**	0.0010**	0.0110	0.0010	0.0030**	0.0014**	0.0013**
Error	27	0.0002	0.0001	0.0100	0.0030	0.0004	0.0001	0.0001

** Significant at 1 per cent level

APPENDIX 14

Analyses of variance for phosphorus content of shells, seeds and plants at different growth stages

Source	df	Mean squares							
		Phosphorus content of shells		Phosphorus content of seeds		Phosphorus content of plants			
		90th day after sowing	Harvest	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest
Blocks	3	0.0005*	0.0056	0.0010	0.0006	0.0100**	0.0001	0.0001	0.0030
K	4	0.0045**	0.0081	0.0120**	0.0097	0.0060*	0.0020**	0.0020**	0.0040*
I	1	0.0057**	0.0101	0.0001	0.0152	0.0030	0.0040**	0.0082	0.0030
K x I	4	0.0056**	0.0071	0.0059*	0.0102	0.0010	0.0010**	0.0020**	0.0030
Error	27	0.0002	0.0062	0.0017	0.0046	0.0020	0.0002	0.0003	0.0010

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 15

Analyses of variance for uptake of phosphorus by stem, leaves and shells at different growth stages

Source	df	Mean squares								
		Uptake of phosphorus by stem				Uptake of phosphorus by leaves			Uptake of phosphorus by shells	
		30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	90th day after sowing	Harvest
Blocks	3	0.0001	0.4770	0.0003	0.0008	0.0002	0.0031	0.0140	5.3690*	0.1270
K	4	0.0054**	2.4510**	0.7400**	0.2000**	0.0390**	2.1830**	0.5490**	3.9850	0.2950**
I	1	0.0157**	1.1340	4.6000**	0.1190**	0.0090**	0.901**	3.1550**	14.3880**	0.2040
K x I	4	0.0047**	1.8270**	1.1670**	0.6060**	0.0030**	1.4920**	0.7210**	4.5610*	0.1440
Error	27	0.0002	0.4160	0.0027	0.0080	0.0006	0.0220	0.0070	1.4890	0.0700

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 16

Analyses of variance for uptake of phosphorus by seeds and plants at different growth stages and harvest index of phosphorus

Source	df	Mean squares						
		Uptake of phosphorus by seeds		Uptake of phosphorus by plants				Harvest index of phosphorus
		90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	
Blocks	3	25.048*	38.625	0.0003	0.555	30.698	31.301	0.015
K	4	2.290	5.011	0.0670**	8.568**	21.136	4.965	0.002
I	1	4.956	34.281	0.0480**	4.070**	149.150**	50.535	0.0004
K x I	4	9.793	24.057	0.0140**	6.244**	36.379	31.583	0.010
Error	27	5.822	14.374	0.0008	0.447	20.612	16.884	0.007

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 17

Analyses of variance for potassium content of stem and leaves at different growth stages

Source	df	Mean squares						
		Potassium content of stem				Potassium content of leaves		
		30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing
Blocks	3	0.030	0.021	0.021	0.006	0.039	0.003*	0.00004
K	4	0.672**	0.343**	0.025*	0.232**	1.210**	0.119**	0.051**
I	1	0.233**	0.182**	0.001	0.308**	0.081*	0.056**	0.002
K x I	4	0.054	0.043*	0.136**	0.293**	0.073**	0.018**	0.006**
Error	27	0.028	0.016	0.009	0.003	0.014	0.001	0.001

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 18

Analyses of variance for potassium content of shells, seeds and plants at different growth stages

Source	df	Mean squares							
		Potassium content of shells		Potassium content of seeds		Potassium content of plants			
		90th day after sowing	Harvest	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest
Blocks	3	0.004	0.0002	0.002	0.001	0.025	0.008*	0.055	0.093
K	4	2.334**	0.197**	0.032**	0.051**	0.924**	0.239**	0.302**	0.055
I	1	0.004	0.001	0.010**	0.002	0.010	0.144**	0.102	0.021
K x I	4	0.062**	0.020**	0.001	0.003	0.049	0.019**	0.095	0.078
Error	27	0.005	0.003	0.001	0.001	0.024	0.002	0.057	0.045

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 19

Analyses of variance for uptake of potassium by stem, leaves and shells at different growth stages

Source	df	Mean squares								
		Uptake of potassium by stem				Uptake of potassium by leaves			Uptake of potassium by shells	
		30th day after sowing	60th day after sowing	90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	90th day after sowing	Harvest
Blocks	3	3.420	251.460	590.524**	48.508	0.382	208.802*	402.426**	494.415*	216.726
K	4	1.640	788.212**	176.151	157.188**	3.317*	198.979*	14.503	957.733**	256.129
I	1	1.910	150.428	849.070**	506.161**	0.328	119.578	123.974*	816.674*	32.490
K x I	4	0.376	236.568	189.716	137.653**	1.198	104.273	37.749	175.029	76.762
Error	27	1.177	188.442	105.507	10.815	1.199	65.219	24.889	163.575	94.482

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 20

Analyses of variance for uptake of potassium by seeds and plants at different growth stages and harvest index of potassium

Source	df	Mean squares						
		Uptake of potassium by seeds		Uptake of potassium by plants				Harvest index of potassium
		90th day after sowing	Harvest	30th day after sowing	60th day after sowing	90th day after sowing	Harvest	
Blocks	3	607.590**	984.151*	5.645	955.972	6793.633**	2392.729*	0.013**
K	4	124.970	724.676*	8.921	1795.352*	3043.614	2818.127*	0.006**
I	1	243.345	173.514	3.819	470.870	7131.857*	1711.518	0.011**
K x I	4	128.326	219.028	2.693	671.320	1722.022	871.236	0.003
Error	27	121.261	246.305	4.298	445.333	1332.601	742.055	0.001

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 21

Analyses of variance for protein content, protein yield, oil content and oil yield of seed at harvest and for total nitrogen, available phosphorus and available potassium of soil after harvest of the crop

Source	df	Mean squares						
		Protein content	Protein yield	Oil content	Oil yield	Total nitrogen	Available phosphorus	Available potassium
Blocks	3	0.430	1923.000	0.560*	7284.840	0.001	12.747*	191.033
K	4	50.750**	1143.050	17.18**	22364.480**	0.002	5.121	1902.850**
I	1	44.370**	5307.000*	54.360**	10107.950	0.004*	5.455	28.900
K x I	4	8.380**	507.500	2.040**	856.980	0.001	2.477	310.150
Error	27	0.450	1104.700	0.190	4334.910	0.001	3.399	180.811

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX 22

Mean values of treatments and their interactions on height of plant on 60th day after sowing (cm)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	76.38	77.67	77.02
30	75.35	69.50	72.48
60	64.64	86.80	75.72
90	84.40	78.59	81.50
120	73.82	79.06	76.44
Mean	74.92	78.34	

SEm ± 3.826

C.D.(0.05) for comparing means of combinations = 10.963

APPENDIX 23

Mean values of treatments and their interactions on height of plant on 75th day after sowing (cm)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	78.35	78.45	78.40
30	75.95	70.16	73.06
60	66.01	88.23	77.12
90	86.17	79.30	82.73
120	76.15	81.96	79.06
Mean	76.52	79.62	

SEm ± 3.967

C.D.(0.05) for comparing means of combinations = 11.369

APPENDIX 24

Mean values of treatments and their interactions on height of plant on 90th day after sowing (cm)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	78.82	78.93	78.87
30	76.06	70.26	73.15
60	66.12	88.51	77.82
90	86.40	79.53	82.96
120	76.80	82.05	79.42
Mean	76.84	79.72	

SEm ± 3.868

C.D.(0.05) for comparing means of combinations = 11.080

APPENDIX 25

Mean values of treatments and their interactions on dry weight of leaves on 45th day after sowing ($g\ plant^{-1}$)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.190	1.460	1.330
30	1.320	1.370	1.350
60	1.140	1.170	1.150
90	1.680	1.580	1.630
120	1.220	1.930	1.580
Mean	1.450	1.440	

SEm ± 0.198

C.D. (0.05) for comparing means of combinations = 0.575

APPENDIX 26

Mean values of treatments and their interactions on total phytomass production on 45th day after sowing ($g\ plant^{-1}$)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	2.925	2.503	2.714
30	2.758	2.998	2.878
60	2.340	2.458	2.399
90	3.408	3.358	3.383
120	2.698	3.923	3.290
Mean	3.006	3.059	

SEm ± 0.422

C.D.(0.05) for comparing means of combinations = 1.228

APPENDIX 27

Mean values of treatments and their interactions on absolute growth rate between 30th and 45th day ($g\ day^{-1}$)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.229	0.133	0.181
30	0.153	0.162	0.157
60	0.118	0.131	0.124
90	0.202	0.188	0.195
120	0.129	0.230	0.179
Mean	0.167	0.168	

SEm ± 0.026

C.D. (0.05) for comparing means of combinations = 0.075

APPENDIX 28

Mean values of treatments and their interactions on crop growth rate between 30th and 45th day
($g\ m^{-2}\ day^{-1}$)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	10.155	5.888	8.021
30	6.788	7.188	6.988
60	5.233	5.822	5.527
90	8.988	8.366	8.677
120	5.900	10.043	7.971
Mean	7.413	7.462	

SEm ± 1.154

C.D. (0.05) for comparing means of combinations = 3.348

APPENDIX 29

Mean values of treatments and their interactions on moisture percentage of seeds

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	6.400	8.580	7.490
30	7.920	6.300	7.110
60	7.190	7.420	7.300
90	5.990	7.580	6.790
120	7.260	7.640	7.450
Mean	6.950	7.500	

SEm ± 0.490

C.D. (0.05) for comparing means of combinations = 1.423

APPENDIX 30

Mean values of treatments and their interactions on stover yield (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	2893.500	2883.600	2888.600
30	2807.500	2380.900	2594.200
60	2142.900	2972.900	2557.900
90	2595.900	2450.400	2523.100
120	2764.600	2827.400	2795.900
Mean	2640.900	2703.000	

SEm ± 192.031

C.D. (0.05) for comparing means of combinations = 550.800

APPENDIX 31

Mean values of treatments and their interactions on nitrogen content of stem on 30th day after sowing (%)

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.024	1.264	1.144
30	1.050	1.038	1.044
60	1.025	1.038	1.032
90	1.063	1.035	1.049
120	1.013	1.014	1.015
Mean	1.035	1.078	

SEm ± 0.004

C.D. (0.05) for comparing means of combinations = 0.013

APPENDIX 32

Mean values of treatments and their interactions on nitrogen content of stem on 60th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.953	0.908	0.930
30	0.858	0.863	0.860
60	0.918	1.028	0.973
90	1.128	0.970	1.049
120	1.013	1.035	1.024
Mean	0.974	0.961	

SEm ± 0.019

C.D. (0.05) for comparing means of combinations = 0.058

APPENDIX 33

Mean values of treatments and their interactions on nitrogen content of stem at harvest (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.542	0.568	0.555
30	0.648	0.335	0.491
60	0.320	0.413	0.367
90	0.313	0.355	0.334
120	0.330	0.339	0.334
Mean	0.431	0.402	

SEm ± 0.041

C.D. (0.05) for comparing means of combinations = 0.013

APPENDIX 34

Mean values of treatments and their interactions on nitrogen content of leaves on 30th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Means
	Uninoculated	Inoculated	
0	2.819	2.635	2.727
30	2.933	3.168	3.050
60	3.042	3.228	3.135
90	3.143	2.858	3.000
120	3.188	3.455	3.321
Mean	3.025	3.069	

SEm ± 0.050

C.D. (0.05) for comparing means of combinations = 0.143

APPENDIX 35

Mean values of treatments and their interactions on nitrogen content of leaves on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.609	2.073	1.841
30	2.400	2.591	2.496
60	2.408	2.588	2.498
90	2.330	1.858	2.094
120	2.176	2.738	2.457
Mean	2.184	2.369	

SEm ± 0.052

C.D. (0.05) for comparing means of combinations = 0.151

APPENDIX 36

Mean values of treatments and their interactions on nitrogen content of shells on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.348	1.430	1.389
30	1.388	1.780	1.584
60	1.413	1.540	1.476
90	1.635	1.448	1.541
120	1.745	1.520	1.633
Mean	1.506	1.544	

SEm ± 0.028

C.D. (0.05) for comparing means of combinations = 0.081

APPENDIX 37

Mean values of treatments and their interactions on nitrogen content of shells at harvest (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.484	0.603	0.543
30	0.656	0.733	0.695
60	0.695	0.511	0.603
90	0.523	0.688	0.605
120	0.402	0.443	0.422
Mean	0.552	0.595	

SEm ± 0.040

C.D. (0.05) for comparing means of combinations = 0.116

APPENDIX 38

Mean values of treatments and their interactions on nitrogen content of seeds on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	6.050	6.500	6.275
30	4.262	4.950	4.606
60	5.225	6.050	5.638
90	5.225	5.500	5.363
120	4.125	4.950	4.538
Mean	4.977	5.590	

SEm ± 0.008

C.D. (0.05) for comparing means of combinations = 0.235

APPENDIX 39

Mean values of treatments and their interactions on nitrogen content of seeds at harvest (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	6.150	6.875	6.513
30	5.228	5.775	6.501
60	5.913	5.775	5.844
90	5.500	5.775	5.638
120	5.500	5.775	5.638
Mean	5.658	5.995	

SEm ± 0.009

C.D. (0.05) for comparing means of combinations = 0.258

APPENDIX 40

Mean values of treatments and their interactions on uptake of nitrogen by stem at harvest (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	6.228	6.270	6.249
30	8.505	5.358	6.931
60	3.380	10.110	6.745
90	5.595	6.115	5.855
120	6.243	7.295	6.769
Mean	5.990	7.030	

SEm ± 1.243

C.D. (0.05) for comparing means of combinations = 3.606

APPENDIX 41

Mean values of treatments and their interactions on harvest index of nitrogen

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.92	0.91	0.92
30	0.87	0.90	0.89
60	0.91	0.90	0.90
90	0.92	0.90	0.91
120	0.93	0.93	0.93
Mean	0.91	0.91	

SEm ± 0.007

C.D. (0.05) for comparing means of combinations = 0.021

APPENDIX 42

Mean values of treatments and their interactions on phosphorus content of stem on 30th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.171	0.196	0.183
30	0.162	0.187	0.175
60	0.196	0.250	0.223
90	0.168	0.216	0.192
120	0.205	0.176	0.190
Mean	0.180	0.205	

SEm ± 0.007

C.D. (0.05) for comparing means of combinations = 0.021

APPENDIX 43

Mean values of treatments and their interactions on phosphorus content of stem on 60th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.101	0.140	0.121
30	0.080	0.115	0.097
60	0.135	0.130	0.132
90	0.109	0.120	0.114
120	0.125	0.115	0.120
Mean	0.110	0.124	

SEm ± 0.004

C.D. (0.05) for comparing means of combinations = 0.010

APPENDIX 44

Mean values of treatments and their interactions on phosphorus content of leaves on 30th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.188	0.196	0.192
30	0.290	0.236	0.263
60	0.253	0.302	0.278
90	0.301	0.273	0.287
120	0.284	0.293	0.288
Mean	0.263	0.260	

SEm ± 0.009

C.D. (0.05) for comparing means of combinations = 0.027

APPENDIX 45

Mean values of treatments and their interactions on phosphorus content of leaves on 60th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.207	0.259	0.233
30	0.179	0.222	0.200
60	0.256	0.250	0.253
90	0.207	0.210	0.209
120	0.202	0.204	0.203
Mean	0.210	0.229	

SEm ± 0.005

C.D. (0.05) for comparing means of combinations = 0.016

APPENDIX 46

Mean values of treatments and their interactions on phosphorus content of leaves on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.165	0.145	0.155
30	0.136	0.182	0.159
60	0.142	0.182	0.162
90	0.114	0.135	0.124
120	0.157	0.188	0.172
Mean	0.143	0.166	

SEm ± 0.005

C.D. (0.05) for comparing means of combinations = 0.015

APPENDIX 47

Mean values of treatments and their interactions on phosphorus content of shells on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.186	0.180	0.183
30	0.156	0.252	0.204
60	0.174	0.237	0.206
90	0.186	0.156	0.171
120	0.234	0.231	0.233
Mean	0.187	0.211	

SEm ± 0.007

C.D. (0.05) for comparing means of combinations = 0.019

APPENDIX 48

Mean values of treatments and their interactions on phosphorus content of seeds on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.364	0.311	0.337
30	0.304	0.327	0.315
60	0.395	0.369	0.382
90	0.235	0.317	0.276
120	0.355	0.324	0.340
Mean	0.330	0.329	

SEm ± 0.021

C.D. (0.05) for comparing means of combinations = 0.059

APPENDIX 49

Mean values of treatments and their interactions on phosphorus content of plants on 60th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.140	0.185	0.163
30	0.113	0.155	0.134
60	0.183	0.175	0.179
90	0.153	0.155	0.154
120	0.143	0.160	0.151
Mean	0.146	0.166	

SEm ± 0.007

C.D. (0.05) for comparing means of combinations = 0.018

APPENDIX 50

Mean values of treatments and their interactions on phosphorus content of plants on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.190	0.165	0.178
30	0.160	0.210	0.185
60	0.190	0.193	0.191
90	0.150	0.155	0.153
120	0.200	0.188	0.194
Mean	0.178	0.182	

SEm ± 0.008

C.D. (0.05) for comparing means of combinations = 0.024

APPENDIX 51

Mean values of treatments and their interactions on uptake of phosphorus by stem on 30th day after sowing ($kg\ ha^{-1}$)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.171	0.196	0.183
30	0.153	0.208	0.180
60	0.217	0.250	0.234
90	0.130	0.240	0.185
120	0.238	0.214	0.226
Mean	0.182	0.221	

SEm ± 0.006

C.D. (0.05) for comparing means of combinations = 0.019

APPENDIX 52

Mean values of treatments and their interactions on uptake of phosphorus by stem on 60th day after sowing (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	2.125	1.892	2.008
30	1.567	2.413	1.990
60	3.154	2.696	2.925
90	4.111	2.312	3.211
120	2.324	2.285	2.305
Mean	2.656	2.319	

SEm ± 0.322

C.D. (0.05) for comparing means of combinations = 0.936

APPENDIX 53

Mean values of treatments and their interactions on uptake of phosphorus by stem on 90th day after sowing (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.272	1.295	1.284
30	1.068	3.053	2.061
60	1.675	2.222	1.979
90	1.609	2.105	1.857
120	1.632	1.912	1.772
Mean	1.451	2.129	

SEm ± 0.026

C.D. (0.05) for comparing means of combinations = 0.076

APPENDIX 54

Mean values of treatments and their interactions on uptake of phosphorus by stem at harvest (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.666	0.961	0.814
30	1.395	0.355	0.875
60	0.355	0.649	0.502
90	0.643	0.523	0.583
120	0.749	0.776	0.762
Mean	0.762	0.652	

SEm ± 0.045

C.D. (0.05) for comparing means of combinations = 0.131

APPENDIX 55

Mean values of treatments and their interactions on uptake of phosphorus by leaves on 30th day after sowing (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.205	0.267	0.236
30	0.323	0.338	0.331
60	0.357	0.364	0.361
90	0.264	0.343	0.303
120	0.434	0.420	0.427
Mean	0.317	0.346	

SEm ± 0.011

C.D. (0.05) for comparing means of combinations = 0.034

APPENDIX 56

Mean values of treatments and their interactions on uptake of phosphorus by leaves on 60th day after sowing (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	2.804	2.337	2.570
30	2.260	3.299	2.779
60	4.271	3.362	3.817
90	3.927	2.782	3.355
120	2.732	2.713	2.722
Mean	3.199	2.898	

SEm ± 0.074

C.D. (0.05) for comparing means of combinations = 0.215

APPENDIX 57

Mean values of treatments and their interactions on uptake of phosphorus by leaves on 90th day after sowing (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.303	1.076	1.190
30	0.805	2.225	1.515
60	1.028	1.622	1.325
90	0.850	1.164	1.007
120	1.318	2.026	1.672
Mean	1.061	1.622	

SEm ± 0.042

C.D. (0.05) for comparing means of combinations = 0.124

APPENDIX 58

Mean values of treatments and their interactions on uptake phosphorus by shells on 90th day after sowing (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	2.570	2.465	2.518
30	2.053	5.608	3.830
60	2.463	3.138	2.800
90	3.168	3.250	3.209
120	3.323	5.113	4.218
Mean	2.715	3.915	

SEm ± 0.610

C.D. (0.05) for comparing means of combinations = 1.771

APPENDIX 59

Mean values of treatments and their interactions on total uptake of phosphorus by plants on 30th day after sowing (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.376	0.463	0.419
30	0.476	0.546	0.511
60	0.574	0.614	0.594
90	0.394	0.583	0.483
120	0.672	0.634	0.653
Mean	0.498	0.568	

SEm ± 0.014

C.D. (0.05) for comparing means of combinations = 0.040

APPENDIX 60

Mean values of treatments and their interactions on total uptake of phosphorus by plants on 60th day after sowing (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	4.925	4.230	4.578
30	3.830	5.705	4.768
60	7.425	6.055	6.740
90	8.040	5.100	6.570
120	5.060	5.000	5.030
Mean	5.856	5.218	

SEm ± 0.335

C.D. (0.05) for comparing means of combinations = 0.970

APPENDIX 61

Mean values of treatments and their interactions on potassium content of stem on 60th day after sowing (%)

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.775	1.950	1.863
30	2.000	2.250	2.125
60	2.375	2.425	2.400
90	2.350	2.275	2.313
120	1.988	2.263	2.125
Mean	2.098	2.233	

SEm ± 0.063

C.D. (0.05) for comparing means of combinations = 0.181

APPENDIX 62

Mean values of treatments and their interactions on potassium content of stem on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.375	1.325	1.350
30	1.375	1.525	1.450
60	1.600	1.225	1.413
90	1.148	1.475	1.311
120	1.350	1.350	1.350
Mean	1.370	1.380	

SEm ± 0.047

C.D. (0.05) for comparing means of combinations = 0.136

APPENDIX 63

Mean values of treatments and their interactions on potassium content of stem at harvest (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.525	0.600	0.563
30	0.600	0.603	0.601
60	0.850	0.900	0.875
90	0.500	0.400	0.450
120	0.350	1.200	0.775
Mean	0.565	0.741	

SEm ± 0.027

C.D. (0.05) for comparing means of combinations = 0.086

APPENDIX 64

Mean values of treatments and their interactions on potassium content of leaves on 30th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	2.000	1.675	1.838
30	2.600	2.625	2.613
60	3.003	2.750	2.876
90	2.625	2.603	2.614
120	2.425	2.550	2.488
Mean	2.531	2.441	

SEm ± 0.059

C.D. (0.05) for comparing means of combinations = 0.169

APPENDIX 65

Mean values of treatments and their interactions on potassium content of leaves on 60th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	2.050	2.050	2.050
30	2.175	2.200	2.188
60	2.325	2.325	2.325
90	2.025	2.175	2.100
120	1.925	2.125	2.025
Mean	2.100	2.175	

SEm ± 0.014

C.D. (0.05) for comparing means of combinations = 0.041

APPENDIX 66

Mean values of treatments and their interactions on potassium content of leaves on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.550	1.525	1.538
30	1.600	1.625	1.613
60	1.750	1.750	1.750
90	1.678	1.578	1.628
120	1.565	1.600	1.581
Mean	1.528	1.616	

SEm ± 0.016

C.D. (0.05) for comparing means of combinations = 0.054

APPENDIX 67

Mean values of treatments and their interactions on potassium content of shells on 90th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.900	1.125	1.013
30	2.250	2.225	2.238
60	2.300	2.400	2.350
90	2.150	1.900	2.025
120	2.125	2.175	2.150
Mean	1.945	1.965	

SEm ± 0.035

C.D. (0.05) for comparing means of combinations = 0.105

APPENDIX 68

Mean values of treatments and their interactions on potassium content of shells at harvest (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.725	1.600	1.663
30	2.075	2.025	2.050
60	2.000	1.975	1.988
90	1.700	1.850	1.775
120	1.850	1.850	1.850
Mean	1.870	1.860	

SEm ± 0.026

C.D. (0.05) for comparing means of combinations = 0.076

APPENDIX 69

Mean values of treatments and their interactions on potassium content of plants on 60th day after sowing (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	1.860	1.948	1.904
30	2.040	2.190	2.115
60	2.330	2.333	2.331
90	2.178	2.270	2.224
120	1.853	2.120	1.986
Mean	2.052	2.172	

SEm ± 0.022

C.D. (0.05) for comparing means of combinations = 0.064

APPENDIX 70

Mean values of treatments and their interactions on uptake of potassium by stem at harvest (kg ha^{-1})

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	5.980	6.630	6.305
30	7.973	9.890	8.931
60	9.578	22.030	15.804
90	8.935	10.323	9.629
120	6.718	25.883	16.300
Mean	7.837	14.951	

SEm ± 1.644

C.D. (0.05) for comparing means of combinations = 4.772

APPENDIX 71

Mean values of treatments and their interactions on protein content of seed at harvest (%)

Levels of potassium (kg K_2O ha^{-1})	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	38.435	42.985	40.710
30	32.675	36.088	34.381
60	36.952	36.095	36.523
90	34.380	36.090	35.235
120	34.380	36.096	35.238
Mean	35.364	37.471	

SEm ± 0.335

C.D. (0.05) for comparing means of combinations = 0.968

APPENDIX 72

Mean values of treatments and their interactions on oil content of seeds at harvest (%)

Levels of potassium ($kg\ K_2O\ ha^{-1}$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	20.310	18.500	19.410
30	23.160	20.660	21.910
60	24.660	20.750	22.700
90	21.750	20.540	21.140
120	24.220	22.000	23.110
Mean	22.820	20.490	

SEm ± 0.218

C.D. (0.05) for comparing means of combinations = 0.632

EFFECT OF LEVELS OF POTASSIUM AND RHIZOBIAL CULTURE INOCULATION ON THE GROWTH AND YIELD OF SOYBEAN [*Glycine max* (L.) Merrill]

BY

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ABSTRACT OF A THESIS

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ABSTRACT

An experiment was conducted at the Instructional Farm attached to the College of Horticulture, Vellanikkara, during July to September 1980, to study the effect of levels of potassium and rhizobial culture inoculation on the growth, yield and quality of soybean (Glycine max (L.) Merrill).

The investigation was taken up with the objective of arriving at the potassium requirement of the crop, to evaluate the effect of rhizobial inoculation and to study the possible interaction effects between them.

The experiment was laid out in randomised block design with ten treatment combinations and four replications.

The study revealed that, in general, applied potassium and inoculation did not significantly affect any of the growth characters and yield attributes in the sandy clay loam soils of Vellanikkara. The seed yield and stover yield also remained unaffected by levels of potassium and inoculation.

Protein content of seed was significantly influenced by potassium and the highest value of 40.71 per cent was recorded in the control plot. The effect of inoculation on protein content of seed was significant and the inoculated plot gave the highest content of 37.47 per cent. Interaction effect was significant and 0 kg K_2O ha^{-1} along with

inoculation recorded the highest protein content. Protein yield was markedly influenced by inoculation and the inoculated plot registered the highest yield of 820.60 kg ha^{-1}. Oil content of seeds was significantly influenced by applied potassium and inoculation. The highest oil contents of 23.11 and 22.82 per cent were recorded by 120 kg K_2O ha^{-1} and the uninoculated treatments respectively. Interaction effect on oil content was significant and 60 kg K_2O ha^{-1} without inoculation registered the highest oil content of 24.66 per cent. Oil yield was significantly influenced by levels of potassium and 60 kg K_2O ha^{-1} recorded the highest oil yield of 510.15 kg ha^{-1}.

Total nitrogen content of the soil after the experiment was significantly higher in the inoculated plot. None of the treatments under study could influence the available phosphorus status of the soil after the experiment. Available potassium status of the soil after the experiment was influenced by levels of potassium and 90 kg K_2O ha^{-1} gave the highest content.