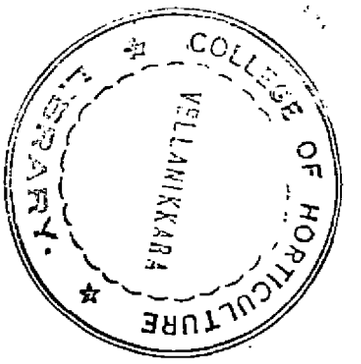
RESPONSE OF RAGI (*Eleusine coracana* Gaertn.) TO DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS & POTASSIUM UNDER RAINFED CONDITIONS

JOHNKUTTY. I.



THESIS

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DECLARATION

I hereby declare that this thesis entitled "Response of ragi (*Eleusine coracana* Gaertn.) to different levels of nitrogen, phosphorus and potassium under rainfed conditions" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,
18 -3 -1981.

(JOHNKUTTY, I.)

CERTIFICATE

Certified that this thesis, entitled "Response of ragi (Eleusine coracana Gaertn.) to different levels of nitrogen, phosphorus and potassium under rainfed conditions" is a record of research work done independently by Shri. Johnkutty, I., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Attaining self sufficiency in food production has been the prime goal of agricultural scientists. Inspite of the active strides taken in this direction, it is apparent that India has not yet achieved the objective. Area under cultivation as means of increasing the production, has only got a limited scope, for, every bit of land has already been brought under plough. Hence the tangible approach left for increasing the production is to resort to adoption of improved agricultural technology.

Cereals form the staple food of the people of India. Millets among cereals are of great importance since they are evidently suited for cultivation under very adverse conditions of moisture and fertility. Among the millets, finger millet (Eleusine coracana) locally known as ragi occupies an important place mainly because of its hardy nature and adaptability to varying soil and climatic conditions.

The most important aspect of ragi grain is its quality as a food. It is an excellent source of calcium which is estimated to be seven times more than rice (8.3%) and has good amount of phosphorus. However, its major asset would be the excellent quality of its protein and its richness in minerals and vitamins. The protein of

ragi 'Eleusinin' has a higher biological value and is considered to be superior to 'glaiadin' of wheat (Iyengar et al. 1945). Ragi malt is a valuable food for infants and mothers during pre and post natal periods.

Besides its use as a cereal grain, the fodder obtained is highly valued for feeding cattle and other ruminants, and it makes a good supplement to the income. It has been estimated that while about 42% of the total utilized nitrogen is accumulated in grain, about 58% is accumulated in straw (Ramanathan et al. 1979). So it is obvious that when ragi grain is considered as a protein rich cereal, its straw is not of less importance as a fodder for cattle. When properly dried, stored and silaged it could be a good feed to animals especially during off-season.

The cosmopolitan nature of the crop makes it suited to Kerala conditions. In Kerala, it is grown in an area of 4820 ha mostly in Palghat, Idukki, Alleppey and Quilon districts. It could be grown successfully as an intercrop in coconut gardens under both rainfed and irrigated conditions. There is scope for the inclusion of this crop in the multiple cropping pattern of the state. The expansion of the area, in conjuction with proper agronomic practices, especially fertilization would partly help in bridging the food gap.

In the science of plant nutrition every nutrient has certain specific functions to perform and the deficiency of any one element cannot be compensated by supplying any other element even in excess. The efficiency of a nutrient like nitrogen is greatly enhanced when it is used in conjuction with phosphorus. Just as phosphorus helps in better utilization of nitrogen, potassium also helps in the better accumulation of nitrogen and phosphorus. A certain balance among the various nutrients is essential for attaining the greatest efficiency in the use of fertilizers.

In Kerala, so far no trial has been conducted to assess the fertilizer requirement of the crop. Determination of the fertilizer requirement of the crop will help in the improvement of grain and straw yield and also the quality. Considering the possibility of growing ragi as an intercrop and as a component crop in multiple cropping pattern, proper fertilizer recommendation seems to be imperative. The present study, has, therefore, been taken up with the following objectives.

1. to study the effect of nitrogen, phosphorus and potassium on yield of grain and straw,
2. to fix the optimum and economic doses of the nutrients for the crop,

3. to study the influence of the nutrients on growth and yield attributes.

4. to study the uptake of nutrients by plant as influenced by the varying levels of nitrogen, phosphorus and potassium and

5. to study the chemical change in soil characteristics as affected by fertilization.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The importance of an adequate supply of plant nutrients to ensure efficient crop production is being well recognised now more than ever. The vital role of essential elements in the normal growth and development of plant community is well known. In the maintenance of cell organisation, energy transformations and enzyme actions they have definite functions.

Of the essential elements, nitrogen, phosphorus and potassium are used in large quantities. The influence of these primary nutrients in the improvement of growth, yield and quality of finger millet has been brought out by many experiments conducted in India and abroad. Literature pertaining to their effects on growth, yield and quality attributes are reviewed below:

A. Effect on growth and yield attributes

Height of plants

Many workers have reported increase in height of plants with increased levels of nitrogen. The plant height was increased from 58.98 cm to 74.24 cm when the fertilizer application was increased from 0 to 90 kg N/ha (Ranganathan, 1962). Thirupathy (1971) in a study on the influence of

nitrogen on ragi has reported significant increase in plant height.

Ramiah (1969) recorded significant increase in plant height by the addition of phosphorus. Kumaraswamy (1972) in his P-32 tracer studies observed that plant height had been increased by the application of phosphorus upto 52 kg P_2O_5/ha in ragi var: Co-10. Significant increase in plant height by P had been reported by Ramiah and Morachan (1978).

Ramakrishnan Nair (1963) reported a lack of response to phosphorus and potash application in ragi var: Co-7. Nitrogen had favourably influenced the plant height of finger millet but phosphorus and potash failed to evoke any response (Subramaniam, 1969).

Subramaniam et al. (1971) while studying the effects of N, P and K observed significant increase in plant height by increased doses of nitrogen while P and K failed to inflict any response. Interaction between N and P at the highest levels was also noticed.

Tiller number

Increase in tiller number by fertilization has been reported by various workers.

Karunakarashetty (1961) recorded an increase in tiller production from 2.16 to 2.58 by increased nitrogen application from zero to 90 kg N/ha. Ranganathan (1962) observed increase in tiller number from 2.96 to 4.01 when the nitrogen levels were increased from zero to 90 kg N/ha in which the increase was linear. Similar results were also reported by Narasimhamurthy and Rao (1961), Krishnamurthy (1967) and Singh and Rajat de (1978).

Subramanian (1969) reported a significant increase in the number of productive tillers on 60th day after planting by nitrogen application in ragi whereas P or K had no response. Thirupathy (1971) observed significant increase in the number of total and productive tillers by nitrogen application.

Ramakrishnan Nair (1963) observed an increase in tiller production when potash was applied at 20 lbs/acre. Usha (1966) recorded a beneficial influence of potash in paddy by way of promoting growth, tillering and straw yield. Ramankutty (1967) observed that potash had no significant effect on the number of tillers. Application of potash upto 80 kg/ha in rice had shown an increasing trend in the number of tillers (Vijayan, 1970).

Number of functional leaves

Significant increase in the number of functional leaves have been obtained by phosphorus fertilization in ragi (Ramiah and Morachan, 1978).

Length of earhead

Kolandaisamy (1964) reported a significant increase in the length of earhead of Co-7 ragi by nitrogen fertilization. Patel and Patel (1970) recorded an increase in length of earhead by 3.1 cm with the increase in nitrogen level from 34 to 102 kg/ha. Singh and Rajatde (1978) observed a significant increase in length of earhead by nitrogen application. However some workers are of the view that earhead length is a varietal character and is not affected by nitrogen application (Ranganathan, 1962 and Krishnamurthy, 1967).

The mean length of earhead was not affected by levels of nitrogen, phosphorus or potash (Subramanian et al. 1971). Ramiah and Morachan (1978) reported an increase in length of earhead by phosphorus fertilization in ragi.

Number of fingers per earhead

Ranganathan (1962) recorded significant increase in

the number of fingers by the application of nitrogen in Co-7 ragi. Similar significant increase in number of fingers due to nitrogen application was reported by Thirupathy (1971) and Puttaswamy and Krishnamurthy (1976).

Ramiah (1969) observed progressive increase in the number of fingers from 6.17 to 6.62 with increasing levels of phosphorus, the maximum being registered at 70 kg P_2O_5/ha. Subramanian et al. (1971) reported that none of the major nutrients had influenced the number of fingers per earhead. The interactions were also not significant.

Thousand grain weight

Weight of thousand grains was not affected when the levels of nitrogen was raised from zero to 110 kg/ha (Karunakarashetty, 1961).

Kamala Singh and Mahatim Singh (1975) and Mishra and Singh (1975) also have reported same results in ragi.

Elangoan (1970) reported a significant increase in thousand grain weight by nitrogen application. Ramiah (1969) observed highly significant increase in thousand grain weight by the application of phosphorus. Similar results have been reported by Ramiah and Moraohan (1978).

Bavappa and Rao (1956) recorded an increase in the thickness of grains and thousand grain weight when potash was applied. Vijayan (1970) reported that graded doses of potash upto 80 kg K_2O/ha significantly increased the thousand grain weight in rice.

Dry matter production

Mean dry matter production was increased in a linear manner from 44.4 to 56.2 when the N level was increased from 60 to 120 kg N/ha (Elangoan, 1970).

Rajagopal and Mehta (1971) reported significant increase in dry matter by phosphorus application.

Potash alone had no influence in increasing the dry matter yield. However, when potash was applied along with nitrogen, there was a marked response to potash application (Antoni Joseph and Dhanapalan Mosi, 1972).

Thandapani and Rao (1976) observed an increase in dry matter at tillering, flowering and at harvest by phosphorus fertilization.

B. Grain and straw yield

Anandapadmanaphan et al. (1967) reported that ragi crop had responded to nitrogen upto 60 lb N/acre. Krishnamurthy (1970) conducted an experiment to study the response

of six finger millet varieties to N under irrigated condition at UAS, Bangalore for 3 seasons. There was significant increase in grain yield between the levels of nitrogen upto 120 kg/ha. Nitrogen at 80 kg/ha was better for all varieties considering the economics.

Thirupathy (1971) tried the N levels of 0, 50, 100, 150, 200 and 250 kg/ha in ragi and the difference with each other was significant upto 150 kg beyond which the N addition did not reflect significantly on grain yield. But spectacular increase in straw yield with successive doses of nitrogen was observed. Linear response in grain yield of ragi var: H-22, from 621 kg to 1891 kg by the N addition from zero to 90 kg/ha was reported by Krishnamoorthy (1972). Early cultivars responded to increase in applied N upto 67.5 kg N/ha at which there was 21.4% yield increase over control. Medium duration cultivars responded to increase in applied N upto 112.5 kg N/ha at which rate there was 24.1 per cent increase in yield over untreated control (Rangaswamy, 1973).

Puttaswamy and Krishnamurthy (1976) observed linear yield increase to N application . Chandragiri et al.

(1977) found that 130 kg N/ha was optimum for economic yield in rabi season whereas 90 kg N/ha was adequate in kharif. A significant and linear increase in grain yield was noticed with increase in the level of nitrogen by Singh and Rajat de (1978). They also suggested the economic dose of N as 110 kg/ha.

The role of phosphorus in cereal nutrition is often thought of as supplementary to that of nitrogen. However, some experiments have shown a definite response to phosphorus. In preliminary experiments with ragi in Karnataka, Rao and Govindarajan (1956) obtained increased yields with applications of P_2O_5 upto 60 lb/ac at a constant level of 40 lb N/ac. Ramiah (1969) reported significant increase in grain and straw yield by phosphorus fertilization. The optimum rate of phosphorus was 35 kg P_2O_5/ha which resulted in 10 per cent higher grain yield and 9 per cent higher straw yield than control having no phosphorus (Ramiah et al. (1970). Linear response in grain yield upto 60 kg P_2O_5 was obtained in barley (Singh and Singh, 1971). Kumaraswamy (1972) reported that maximum grain and straw yield could be recorded at 39 kg P_2O_5/ha in calcareous soils. Grain yield was linear upto 120 kg P_2O_5/ha in non-calcareous soil. Phosphorus increased the straw yield also. Ramiah and Moraghan (1978)

reported significant increase in grain yield by phosphorus fertilization.

Experiments conducted in ragi by Rao and Sirur (1958) showed response to the application of potash. Michaelraj et al. (1965) have recorded significant increase in ragi grain due to the application of 60 lb K_2O/acre. There was, however, no response to application of 20 lb and 40 lb K_2O. Raheja et al. (1960) reporting on crop response to potash fertilizers in Indian soils, recommended study of the effect of potash at higher levels in view of the linear trend of response to potash which they observed with high yielding varieties of grain crops. The yield due to application of potash was about twice as high for HYV as compared to the existing varieties. Investigations on the efficient use of potassic fertilizers for ragi were done by Lobo (1973). He found that grain and straw yield increased with increase in the rate of K in both red and black soils, the optimum being 50 kg K_2O/ha. Ekambaran (1973) in his experiment to study the effect of graded doses of K on yield and uptake of Co-7 ragi found that application of K at 25 kg K_2O/ha increased the yield of grain and straw but not significantly.

Although many experiments have demonstrated no

appreciable response by the phosphorus and potash application, other evidences suggest that ragi does respond to both elements. Moreover much of the experiments that have been carried out were superimposed over a basal application of farm yard manure or other organic type compost. The residual effects of applying these two elements to previous crops have not been considered. The response of dry land ragi to application of nitrogen and phosphorus conducted in Karnataka with very high levels of fertilizer, 120 lb of N and 30 lb P_2O_5/acre, had conclusively proved that there was no adverse effect to the application of fertilizers on dry land ragi which was evident from grain yields, over control (Mysore - DA, 1965). Anonymous, 1965

Sharma and Singh (1971) studied the effect of phosphorus and nitrogen on yield of barley. Both nitrogen and phosphorus significantly increased the grain yield. But straw yield was influenced by nitrogen only. Sathyanarayana et al. (1978) conducted an experiment at GKVK Campus, Bangalore to study the effect of N and P on ragi var: P.R. 202 in 1973-74 and 1974-75. The crop responded well to both N and P, response to P was more conspicuous than to nitrogen. Highest yield of 29.4 q/ha and 79.49 q/ha of grain and straw respectively was obtained with an application of 50 kg N and 90 kg P_2O_5 in 1973-74

whereas in 1974-75 highest grain yield was recorded with 75 kg N and 60 kg P_2O_5.

Applications of 35 kg P_2O_5/ha did not influence the grain yield but increased the yield of straw over control though not significantly (Subramanian, 1969). He also reported that the grain yield was influenced favourably and significantly by P application. Effect of second increment of added P on grain yield was more pronounced than the first increment. Antoni Joseph (1969) studied the influence of K and N on yield of ragi and found that yield of grain and straw was significantly increased by fertilizer application. Application of K alone did not influence the grain and straw yield. But when K was applied along with N there was marked response to K application. So it could be concluded that response of soils to K is enhanced by the application of K along with N.

Venkataramana and Krishna Rao (1961) observed that in poor sandy soils potash application in combination with nitrogen and phosphorus increased the grain yield in ragi. Raniperumal, Ghouse and Soundararajan (1969) reported that application of N, P and K have independently increased the yield significantly. Subramanian et al.(1971) in a trial with Co-7 ragi, reported that grain and straw

yield was increased by dressings of N upto 180 kg/ha but the response was greatest at 60 kg nitrogen. Increase in applied P increased the grain yield but not the straw. Grain or straw yield was not affected by K application.

C. Quality characters

An experiment conducted at Makerere University in 1969 indicated that protein levels could be increased by more than 75% simply by increasing nitrogen levels (Rachie and Peters, 1977). Krishnamurthy (1967) obtained increase in protein content with increase in nitrogen fertilizers. Portch et al. (1968) concluded that nitrogen influences the crude protein content of grain. Nitrogen fertilization at 45 kg/ha increased the crude protein content of grain, 1.2 to 1.4 per cent over that of check treatment, regardless of the presence or absence of phosphorus or potash. Addition of P or K without nitrogen did not alter the yield of protein from that of the check.

Raniperumal et al. (1969) noted an increase in protein content by increase in nitrogen levels. Tosh and Misra (1973) reported that average grain protein content in rice was increased from 5.92 to 7.18 per cent by nitrogen application from 50 to 200 kg/ha.

The grain crude protein content of ragi ranged from 7 to 13 per cent by nitrogen increase upto 150 kg/ha (Staburskvik and Heide, 1974). Similar increase in crude protein by nitrogen fertilization was reported by Singh and Rajatde (1978).

Phosphorus nutrition in ragi resulted in increasing crude protein content, the maximum was being recorded with highest level of 70 kg P_2O_5/ha (Ramiah, 1969). Garg and Tomaria (1970) found an increase in P_2O_5 content of grain by phosphorus application upto 130 kg P_2O_5/ha. Kumaraswamy (1972) reported that application of P increased the P content of grain and straw.

Ramulu and Mariakulandai (1964) in Tamil Nadu found that super phosphate was more effective in raising the phosphorus content of grain and straw than farmyard manure on an equal phosphorus basis. Moreover increase in the amount of farmyard manure had a depressing effect on the phosphorus content of the straw, while the application of phosphates tended to increase both potash and nitrogen content. Phosphorus content was increased from 0.16 to0.33 per cent in grain and 0.13 to 0.62 per cent in straw by potash application which was significant in both grain and straw. Added nitrogen significantly increased

the crude protein percentage while levels of P and K failed to inflict any response (Subramanian, 1969).

Raniperumal et al. (1969) found that potash application had not increased its concentration in plants. Subramanian (1969) reported increase in potassium content of grain and straw by potash application.

D. Uptake of nutrients

Fine (1955) reported that application of nitrogen resulted in increased solubility of phosphorus hence, its increased uptake. Pandya et al. (1958) recorded increased absorption of phosphorus by the plants in the presence of nitrogen. Bennet et al. (1953) attributed this increase to physiological stimulation by nitrogen, rather than increased phosphorus solubility or increased ramification of the root system.

Raniperumal et al. (1969) reported an increase in yield due to fertilizers by increased uptake of nutrient elements. Beneficial effect of ammoniacal nitrogen on the uptake of potassium by ragi has been reported by Antoni Joseph, 1972. Pyarelal and Sharma (1974) reported that, enriching the soil with nitrogen increased the uptake of all nutrients appreciably.

Kumaraswamy (1972) observed that phosphorus application

increased the total uptake by ragi grain and it was linear upto 120 kg P_2O_5/ha.

Potash application resulted in increased uptake of potassium by grain and straw but it was significant only in the case of grain but it increased the upteke of nitrogen in both grain and straw (Subramanian, 1969). Lobo (1973) reported that uptake of N, P and K was increased by the addition of potash.

Kanakadoss et al. (1975) studied the progressive variation in available nutrients in soil, yield of ragi and uptake of nutrients as affected by different carriers of N and P, in the representative sandy soils of Tamil Nadu and it was found that the uptake values for N, P and K were closely related. In sorghum, the application of nitrogen upto 75 kg/ha and phosphorus upto 50 kg/ha increased the plant uptake of nitrogen and phosphorus (Lanjewar and Khot, 1977).

Satyanarayana et al. (1978) observed in ragi, PR.202, that nitrogen and phosphorus increased the uptake of all the major nutrients.

Venkataramana and Rao (1961) found that potassium was taken up by the straw, but the straw yields were not

proportional to the uptake of this element. They also recorded that grain yields of ragi responded to phosphorus and straw yields responded to nitrogen. In grain, the uptake was influenced by potash while in straw it was mostly affected by N. Ramanathan et al. (1979) observed that application of N has increased the N uptake in grain considerably indicating the enrichment of ragi grain due to N fertilization. Application of P and K did not have any marked effect on N uptake by grain. In straw also the trend was almost same.

E. Soil characteristics

pH of the soil after harvest of the crop was not affected by nitrogen or phosphorus fertilization (Satyanarayana et al. 1978). Ramiah (1969) also reported that phosphorus fertilization upto 70 kg P_2O_5/ha has not changed the pH of the soil.

Volk and Sweat (1956) conducted studies on the mobility of nitrogen applied to Floride soils. The lysimeter studies showed the removal of 33% of the applied nitrate nitrogen, 15% of the urea nitrogen but no measurable ammonium nitrogen after 24 hours.

Krishnakumari (1968) reported that the loss of

nitrogen depends on the texture of soil, maximum loss occurring in sandy soil and minimum in clayey soil. A general improvement in the available nitrogen content of soil by nitrogen application is evidenced from the investigation by Abraham (1978).

Raniperumal et al. (1969) found that application of P not only adds to the soil resources but act against seasonal odds as indicated by the significant positive linear relationship between application of P and years. But application of N and K did not have any effect. Satyanarayana et al. (1978) reported considerable rise in the av: P status of soil by fertilization. There was no much variation in soil pH, potassium and ~~av:~~ available N due to N and P fertilization in ragi.

Phosphorus is a relatively immobile element and it is recognized that proportion of fertilizer P taken up by a single crop is often low and the P fertilizers have residual value (Kanwar, 1978). He has also reported that the residual effect would be increased when the rate of application is increased, due to the increase in phosphate potential.

As a mobile cation, K is easily suceptible to loss

through leaching. However the phenomenon of fixation counteracts the loss through leaching and converts K into slowly available fixed condition (Kanwar, 1978).

F. Correlation of characters with grain yield

Correlation studies are helpful in determining the components of a complex trait like yield. Jain et al. (1969) suggested that morphological characters of plant although fluctuating are nevertheless the best indication of yield.

Subramanian et al. (1971) studied the influence of major nutrients in fingermillet yield attributes and found that plant height on 60th day and straw yield was significantly positively correlated with grain yield with the correlation values of + 0.5 and + 0.746 respectively. Number of fingers and number of earbearing tillers were slightly correlated with grain yield.

Puttaswamy (1973) observed in ragi var: E.C. 4840 and Purna that, the difference in grain yield was due to significant difference in ear number per plant and grain weight per ear. Krishnamurthy (1973) observed in H-22 ragi that yield increase was related mainly to an increase in the number of shoots, particularly that produced within 27 days of transplanting. Earnumber per plant also was related to yield.

Positive correlation of grain yield with plant height and number of fingers was reported by Goud and Lakshmi (1977). Ramanathan et al. (1977) found that number of fingers per earhead in ragi had the greatest influence on yield but thousand grain weight had small positive effect. Ramiah and Morachan (1978) observed positive correlation of grain yield with plant height, test grain weight and yield.

Many earlier investigations have proved that the yields are proportional to the uptake of nutrients. Venkataramana and Rao (1961) reported positive correlation between grain yield and uptake of nutrients. Elangoan (1970) observed positive significant correlation between grain yield and nitrogen uptake. Antoni Joseph and Mosi (1972) reported that grain yield in Co-7 ragi had significant positive correlation with exchangable potassium.

MATERIALS AND METHODS

MATERIALS AND METHODS

The investigation was taken up to determine the nutritional requirement of finger millet, variety PR-202, with a view to find out the economic doses of nitrogen, phosphorus and potash for maximum net returns and to study the influence of the nutrients on quality characters.

MATERIALS

Experimental site

The experiment was conducted at the Rice Research Station, Pattambi, Palghat district. Two plots IV b and V b of the upland area with facilities for proper drainage were selected for the experiment.

Cropping history of the experimental plot:-

The experimental plot was remaining fallow for nearly 10 months prior to laying out the experiment. A bulk crop of 'modan' rice was taken during the previous kharif season.

Season

The experiment was conducted during the first crop (kharif) season of 1979-80. The meteorological data for the crop season are given in Appendix I and is graphically represented in Fig.1.

Soil

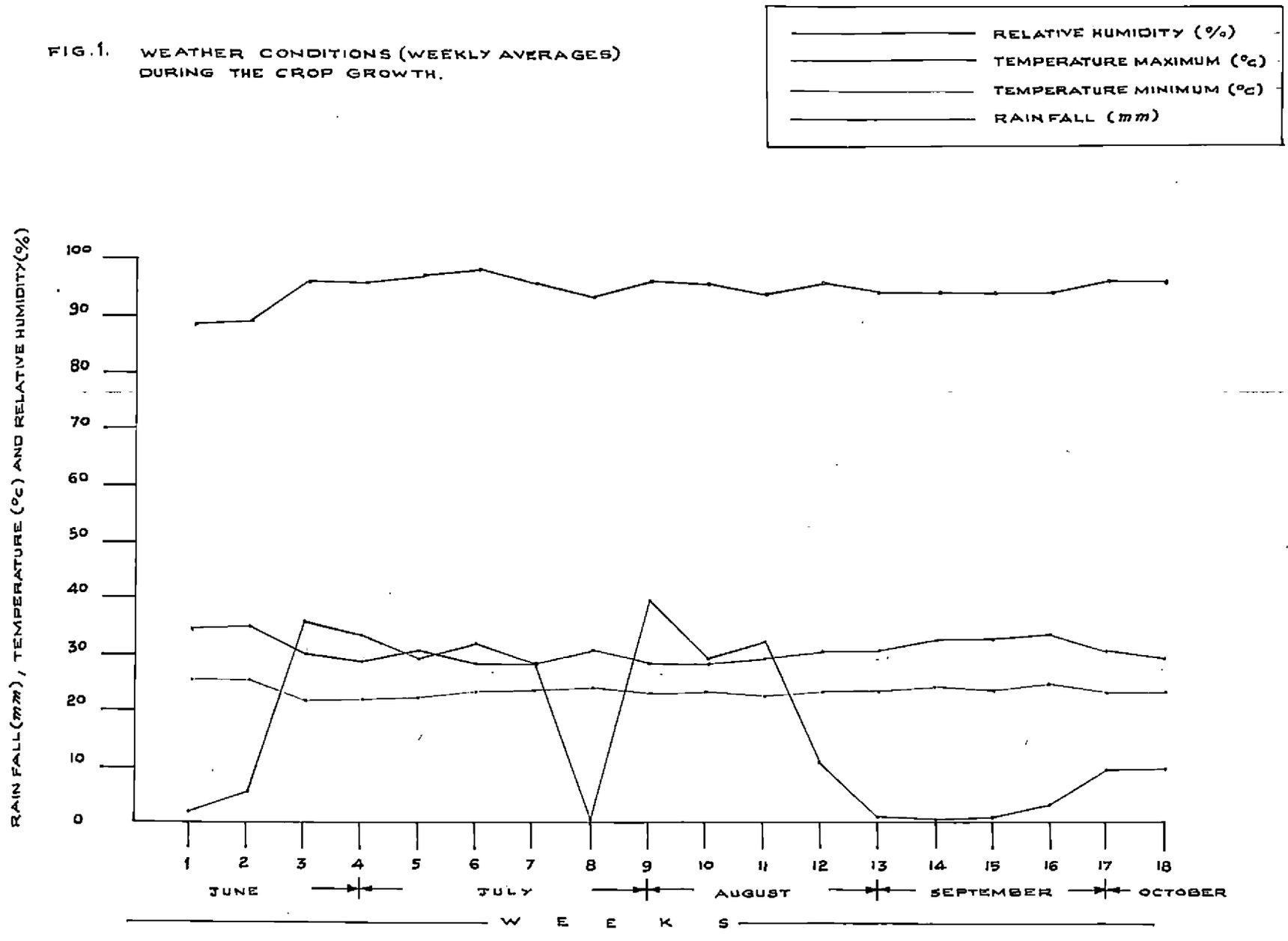
Soil type is loamy clay. The chemical composition of a composite soil sample collected from the experimental area is as follows:-

pH	:	4.95
Organic Carbon	:	1.136%
Available nitrogen	:	310 kg/ha
Available phosphoric acid	:	16.169 kg/ha
Available potash	:	339.5 kg/ha

Seeds

Quality seed of the variety PR-202 was obtained from the Cotton and Millet Expt. station, Kovilpatti. The seeds were tested for viability and were found to give 96% per cent germination. The varietal characteristics are given in Appendix II.

FIG.1. WEATHER CONDITIONS (WEEKLY AVERAGES) DURING THE CROP GROWTH.



Fertilizers

Fertilizers with the following analysis were used:-

Urea	:	46% N
Superphosphate	:	16% P_2O_5
Muriate of Potash	:	60% K_2O

METHODS

Treatments

Factorial combinations of three levels, each of nitrogen, phosphorus and potash constituted the treatments.

Levels of nitrogen

n_1	- 30 Kg. N/ha
n_2	- 60 kg N/ha
n_3	- 90 kg N/ha

Levels of phosphorus

P_1	- 20 kg P_2O_5/ha
P_2	- 40 kg P_2O_5/ha
P_3	- 60 kg P_2O_5/ha

Levels of potash

k_1	- 20 kg K_2O/ha
k_2	- 40 kg K_2O/ha
k_3	- 60 kg K_2O/ha

Treatment No.	Treatment Combinations	Treatment No.	Treatment Combinations
1	$n_1 p_1 k_1$	15	$n_2 p_2 k_3$
2	$n_1 p_1 k_2$	16	$n_2 p_3 k_1$
3	$n_1 p_1 k_3$	17	$n_2 p_3 k_2$
4	$n_1 p_2 k_1$	18	$n_2 p_3 k_3$
5	$n_1 p_2 k_2$	19	$n_3 p_1 k_1$
6	$n_1 p_2 k_3$	20	$n_3 p_1 k_2$
7	$n_1 p_3 k_1$	21	$n_3 p_1 k_3$
8	$n_1 p_3 k_2$	22	$n_3 p_2 k_1$
9	$n_1 p_3 k_3$	23	$n_3 p_2 k_2$
10	$n_2 p_1 k_1$	24	$n_3 p_2 k_3$
11	$n_2 p_1 k_2$	25	$n_3 p_3 k_1$
12	$n_2 p_1 k_3$	26	$n_3 p_3 k_2$
13	$n_2 p_2 k_1$	27	$n_3 p_3 k_3$
14	$n_2 p_2 k_2$		

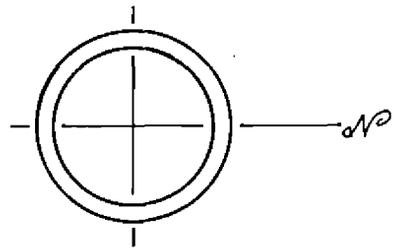
Lay out and design

The experiment was laid out as a partially confounded factorial experiment with two replications, confounding NP^2K^2 in the first replication and NP^2K in the second replication. The lay out of the experiment is given in Fig. 2.

Treatment combinations	: 27
Replications	: 2
Number of blocks	: 6
Number of plots per block	: 9
Total plots	: 54

FIG.2. LAY-OUT PLAN

3^3 PARTIALLY CONFOUNDED FACTORIAL EXPERIMENT.



REPLICATION I

$n_1p_1k_1$	$n_1p_3k_2$	$n_2p_1k_3$	$n_3p_3k_1$	$n_1p_1k_2$	$n_2p_2k_2$	$n_1p_2k_3$	$n_1p_2k_1$	$n_1p_3k_2$
$n_1p_1k_3$	$n_2p_2k_1$	$n_3p_3k_3$	$n_1p_3k_2$	$n_2p_1k_2$	$n_1p_3k_1$	$n_2p_1k_1$	$n_1p_2k_3$	$n_1p_2k_2$
$n_2p_1k_1$	$n_1p_2k_2$	$n_1p_1k_3$	$n_1p_3k_1$	$n_1p_1k_2$	$n_2p_2k_3$	$n_1p_2k_1$	$n_1p_3k_3$	$n_3p_3k_2$

REPLICATION II

$n_2p_1k_2$	$n_1p_2k_2$	$n_1p_1k_3$	$n_2p_2k_3$	$n_1p_3k_3$	$n_1p_1k_1$	$n_3p_3k_1$	$n_2p_1k_1$	$n_1p_3k_2$
$n_2p_1k_3$	$n_1p_3k_1$	$n_2p_1k_1$	$n_1p_2k_3$	$n_3p_3k_2$	$n_1p_3k_3$	$n_1p_2k_2$	$n_2p_2k_1$	$n_1p_1k_2$
$n_1p_1k_3$	$n_1p_1k_2$	$n_1p_3k_2$	$n_3p_3k_3$	$n_2p_1k_1$	$n_1p_2k_3$	$n_2p_2k_2$	$n_1p_3k_1$	$n_1p_2k_1$

PLOT SIZE : 6 M x 3·75 M.

TREATMENTS:	LEVELS OF NITROGEN	LEVELS OF PHOSPHORUS	LEVELS OF POTASH
	n_1 : 30 kg N/ha	p_1 : 20 kg P_2O_5/ha	k_1 : 20 kg k_2O/ha
	n_2 : 60 kg N/ha	p_2 : 40 kg P_2O_5/ha	k_2 : 40 kg k_2O/ha
	n_3 : 90 kg N/ha	p_3 : 60 kg P_2O_5/ha	k_3 : 60 kg k_2O/ha

Plot size

Gross plot size	:	6 m x 3.75 m
Net plot size	:	4 m x 2.55 m
Spacing	:	25 cmx 15 cm

Details of cultivation

Nursery

Seven hundred grammes of seeds were sown on 29-5-79 in the well prepared dry nursery in an area of 60 sq.m manured with 80 kg of farmyard manure. The nursery was irrigated daily. A top dressing with 0.6 kg Ammonium sulphate was given after one week of sowing. Seedlings were uprooted on the 21st day of sowing (20-6-79) and were dipped in 0.1 per cent Hinosan solution.

Mainfield

Preparatory cultivation

The experimental site was ploughed twice with power tiller and the plots were laid out. The individual plots were then dug and levelled.

Manuring

Half the amount of nitrogen and potash and full quantity of phosphorus were applied basally at the time of final digging of the plots on the day of transplanting and well incorporated. Half the nitrogen and potash were applied on the 21st day of planting.

Transplanting

Transplanting was done on 20-6-1979 using two seedlings per hill.

After cultivation

Gap filling was done on 28-6-1979.

The plots were hand weeded twice, on the 21st day and 41st day of transplanting.

Two prophylatic sprayings with 0.1 per cent Hinosan were given on 13-7-1979 and 23-8-1979 against blast disease.

Harvest

The crop was harvested in two stages, first harvest on 20-9-1979 and second harvest on 27-9-1979. The net plot was separately harvested, earheads dried, threshed, cleaned and grain yield recorded. The straw was also harvested separately, dried and weighed.

Observations

A. Growth characters

The fifth and seventh rows were marked out from both sides of the plots as sample rows. Five hills were marked at random from each of these four sample rows. Observations on height of the plant, number of tillers, productive tillers, and number of functional leaves were taken from these sample hills.

Height of the plant

Height of the tallest plant in the hills from the ground level to the top of the fully opened leaf was taken at vegetative stage and to the top of the apical grain at the grain stage. Average of 20 hills was worked out and recorded in cm.

Height was recorded on 41st day, 56th day and 71st day after planting and at harvest.

Number of tillers per hill

The number of tillers was recorded along with the height. The same hills selected for taking height measurements were used for recording number of tillers. Average of 20 hills was worked out and recorded.

Number of functional leaves

The number of functional leaves per hill was recorded at flowering stage. Total number of functional leaves in the twenty hill was taken and the mean recorded.

Dry matter production

Dry matter production was calculated at flowering and at harvest. Five hills at random, outside the net plot area but leaving the two border rows, were cut close to the ground, chopped, oven dried and weighed.

B. Yield characters

Productive tillers

Ear bearing tillers were counted from 20 observational hills at five days before harvest ie: on 15-9-1979 and the average number was recorded.

Length of earhead

The length of 40 earheads was measured in cm from the base of thumb finger to the tip of the apical grain. Average of 40 earheads was recorded.

Number of fingers per earhead

Total number of fingers in the 40 earheads was counted and the mean recorded.

Thousand grain weight

A representative sample of the grain from each plot was taken and out of this one thousand grains were counted by means of the working board, weighed by monopan balance and expressed in g.

C. Yield of grain and straw

Crop was harvested in two stages at full maturity. The border strips comprising of 4 rows on all the sides of

the plot were harvested and removed first. The remaining net plot of 4 m x 2.55 m size was then harvested for observation.

Yield of grain

The earheads harvested from the net plot were dried, cleaned, winnowed and weighed plotwise. The moisture content of the sample was noted and the weight was finally recorded adjusting the moisture content to 14 per cent and expressed in kg.

Yield of straw

The weight of sundried straw per plot was recorded in kg.

D. Quality characters

Oven dried samples of grain and straw were powdered and analysed for total nitrogen, phosphorus and potassium.

Total nitrogen and crude protein content

Total nitrogen in grain and straw was estimated by Kjeldahl's method (Jackson, 1964).

Protein content in grain was calculated by multiplying the nitrogen content in grain by the factor 6.25 (Simpson et al. 1965)

Nitrogen content and protein content are expressed in percentage.

Total phosphorus

Total phosphoric acid was estimated colorimetrically in an aliquot of the samples digested by Microdigestion with sulphuric, nitric and perchloric acid as described by Piper (1950). The intensity of the colour was read in ~~Klettsummerson~~ Klett summerson colorimeter and the concentration of P_2O_5 calculated by the help of a standard curve drawn for P_2O_5 and expressed in percentage.

Total potassium

Total potassium content in grain and straw was estimated from the diluted samples of the triple acid digest using EEL Flame photometer. Potassium content was arrived at by referring to a standard curve and expressed in percentage.

E. Uptake of nutrients

Uptake of nitrogen

Nitrogen uptake by grains was calculated from the nitrogen content of grain and yield of grain.

Nitrogen uptake by straw was calculated from the nitrogen content of straw and straw yield.

Total uptake of nitrogen was arrived at by adding the nitrogen uptake by grain and straw.

Uptake of nitrogen is expressed in kg N/ha.

Uptake of phosphorus

Phosphorus uptake by grain was calculated from the phosphorus content of grain and grain yield.

Phosphorus uptake by straw was calculated from the phosphorus content of straw and straw yield.

Total uptake of phosphorus was arrived at by adding the uptake by grain and straw.

Phosphorus uptake is expressed in kg P_2O_5/ha.

Uptake of potassium

Potassium uptake by the grain was calculated from the potassium content of grain and the grain yield.

Potassium uptake by the straw was calculated from the potassium content of straw and the straw yield.

The uptake of potassium by grain and straw was added to get the total uptake of potassium by the plant.

Potassium uptake is expressed in kg k/ha.

F. Post harvest soil analysis

The composite soil sample, collected from each plot, was air dried, powdered and passed through a two mm sieve. Analysis was done for soil reaction, organic carbon, available nitrogen, available phosphorus and available potash.

Soil reaction

The pH of the soil was measured in the air dry soil in 1: 2.5 soil water suspension using Elico photovolt pH meter.

Organic carbon

Organic carbon was estimated by Walkley and Black's rapid tritration method as described by Jackson (1967).

Available nitrogen

Available nitrogen in soil was estimated by Alkaline permanganate method (Subbiah and Asija, 1956) as described in Perur et al.(1973).

Available phosphorus

Available phosphorus was estimated vide procedure described in Jackson (1967) using Bray No. 1 as the extractant. The intensity of blue colour was read in a

Klett Summerson colorimeter using red filter. From the standard curve drawn for P_2O_5, concentration of P_2O_5 was arrived at.

Available Potash

Available potassium in the soil was estimated by ~~spraying~~ using neutral normal ammonium acetate extract of the soil in EEL Flame photometer. From the standard curve drawn for K_2O, the concentration of K_2O was arrived at.

C. Statistical analysis

Data related to each character were analysed statistically by applying the technique of analysis of variance (Snedecor and Cochran, 1967).

The data were analysed with the help of a Micro 2200 Hindustan computer, available in the Statistics Department of the College of Horticulture, Vellanikkara.

RESULTS

RESULTS

The results obtained in the experiment are presented in this chapter.

A.GROWTH CHARACTERS

Height of Plants

The mean height of plants on 41st, 56th and 71st day after planting and at harvest are given in table 1 and the analysis of variance in Appendix III.

Plant height at the lower levels of 60 kg and 30 kg nitrogen/ha were on par on 41st, 56th and 71st day after planting and at harvest. Nitrogen at 90 kg/ha had given significantly superior plant height to both the lower levels.

There was no significant difference in plant height due to phosphorus at any stage of plant growth. The effect of potash on plant height was significant only on 71st day after planting and at harvest. Height at 60 kg K_2O/ha was superior to the lower levels both on 71st day after planting and at harvest. The lower levels of 20 kg K_2O/ha and 40 kg K_2O/ha did not differ significantly.

None of the two factor interactions was significant at any stage.

Table 1. Mean height of plants in (cm) at various growth stages of the crop

Treatments		41st day after planting	56th day after planting	71st day after planting	At harvest
Nitrogen (Kg N/ha)					
n_1	30	51.59	79.09	91.43	81.05
n_2	60	54.77	80.65	93.36	85.06
n_3	90	60.43	91.08	107.01	95.26
'F' test		Sig.	Sig.	Sig.	Sig.
Phosphorus (Kg P_2O_5/ha)					
P_1	20	54.91	84.25	95.91	88.10
P_2	40	55.55	81.66	95.10	85.21
P_3	60	56.33	84.91	100.80	88.06
'F' test		N.S.	N.S.	N.S.	N.S.
Potash (Kg K_2O/ha)					
K_1	20	53.73	80.25	93.84	86.36
K_2	40	57.18	85.33	94.87	84.29
K_3	60	55.88	85.25	103.09	90.72
'F' test		N.S.	N.S.	Sig.	Sig.
C.D. (0.05)		4.10	8.02	6.34	4.60

Number of tillers

From the data in table 2 it is evident that the incremental doses of nitrogen had significant effect on tiller production at all stages. The analysis of variance is given in Appendix III.

Significant increase in the number of tillers could be noticed due to phosphorus at all stages. Phosphorus at 60 kg P_2O_5/ha made significant increase in number of tillers over 20 kg P_2O_5/ha. There was no significant difference in number of tillers due to potash at any stage.

Nitrogen x phosphorus interaction was significant on 56th day and 71st day of planting and at harvest. On 56th and 71st day after planting and at harvest the combination N_{90} P_{60} has recorded the maximum tiller number of 6.56, 6.74 and 6.71 respectively. The combined effect of nitrogen and phosphorus on number of tillers on 56th and 71st day after planting and at harvest are given in tables 3, 4 and 5 respectively.

Number of functional leaves at flowering

The data on the number of functional leaves at flowering are presented in table 6. The analysis of variance is given in Appendix III.

Table 2. Mean number of tillers at various growth stages of the crop

Treatments		41st day after planting	56th day after planting	71st day after planting	At harvest
Nitrogen (Kg N/ha)					
n_1	30	3.969	4.522	4.619	4.644
n_2	60	4.725	5.307	5.355	5.336
n_3	90	5.512	6.013	6.165	6.174
'F' test		Sig.	Sig.	Sig.	Sig.
Phosphorus (Kg P_2O_5/ha)					
P_1	20	4.511	5.023	5.141	5.176
P_2	40	4.710	5.325	5.397	5.411
P_3	60	4.936	5.493	5.601	5.569
'F' test		Sig.	Sig.	Sig.	Sig.
Potash (Kg K_2O/ha)					
k_1	20	4.572	5.081	5.177	5.175
k_2	40	4.717	5.319	5.376	5.379
k_3	60	4.917	5.442	5.585	5.602
'F' test		N.S.	N.S.	N.S.	N.S.
C.D. (0.05)		0.358	0.349	0.349	0.357

Table 3. Combined effect of nitrogen and phosphorus on number of tillers on 56th day after planting

	n_1	n_2	n_3	Mean
P_1	4.68	4.81	5.56	5.02
P_2	4.39	5.67	5.90	5.32
P_3	4.48	5.42	6.56	5.49
Mean	4.52	5.30	6.01	..

CD (0.05) for marginal means : 0.35

CD (0.05) for means of combinations : 0.60

Table 4. Combined effect of nitrogen and phosphorus on number of tillers on 71st day after planting.

	n_1	n_2	n_3	Mean
P_1	4.77	4.92	5.72	5.14
P_2	4.49	5.65	6.02	5.39
P_3	4.58	5.47	6.74	5.6
Mean	4.61	5.35	6.16	..

CD (0.05) for marginal means : 0.35

CD (0.05) for means of combinations: 0.60

Table 5. Combined effect of nitrogen and phosphorus on number of total tillers at harvest

	n_1	n_2	n_3	Mean
P_1	4.81	4.91	5.80	5.17
P_2	4.51	5.71	6.01	5.41
P_3	4.61	5.38	6.71	5.56
Mean	4.64	5.33	6.17	..

CD (0.05) for marginal means : 0.35

CD (0.05) for means of combinations: 0.60

Table 6. Mean number of functional leaves at flowering, dry matter production at flowering and harvest

Treatments		No. of functional leaves at flowering	Dry matter at flowering (tons/ha)	Dry matter at harvest (tons/ha)
Nitrogen (Kg N/ha)				
n_1	30	28.052	3.972	5.982
n_2	60	33.880	4.372	7.715
n_3	90	39.747	6.068	10.181
'F' test		Sig.	Sig.	Sig.
Phosphorus (Kg P_2O_5/ha)				
p_1	20	31.562	4.515	7.330
p_2	40	34.908	4.773	8.087
p_3	60	35.809	5.123	8.461
'F' test		N.S.	N.S.	Sig.
Potash (Kg K_2O/ha)				
k_1	20	32.525	4.489	7.547
k_2	40	32.840	4.828	8.103
k_3	60	36.815	5.094	8.228
'F' test		N.S.	N.S.	N.S.
C.D. (0.05)		4.231	0.868	0.738

The data reveal that the effect of nitrogen on the number of functional leaves was significant. Every incremental dose of the nitrogen had increased the number of leaves significantly.

Phosphorus or potash did not evoke any response inthe number of functional leaves. The interaction effects were also not significant.

Total dry matter production

The dry matter production at flowering stage and at harvest is presented in table 6. The analysis of variance is given in Appendix III.

It can be seen from the results that at flowering nitrogen had significant influence on the dry matter production. The highest dose of 90 kg N/ha produced a total dry matter of 6.068 tons/ha which was significantly superior to that at 60 kg and 30 kg N/ha. The lower levels were on par. The dry matter production was not affected due to phosphorus or potash at flowering.

Nitrogen and phosphorus had significant influence on the dry matter production at harvest. The difference in dry matter weight between each level of nitrogen was significant. The level of phosphorus at 40 kg P_2O_5/ha was superior to 20 kg P_2O_5/ha, but dry matter produced at 40 kg level and 60 kg level were on par. The dry matter production at harvest was not affected by potash.

B. YIELD CHARACTERS

Number of productive tillers

The data on mean number of productive tillers are presented in table 7 and the analysis of variance in Appendix IV. The combined effect of nitrogen and phosphorus is given in table 8. Effect of N, P_2O_5 and K_2O on number of productive tillers is illustrated in Fig. 3.

Nitrogen had significant effect on the productive tillrs. Mean number of productive tillers was increased significantly by each increment of nitrogen.

Phosphorus also gave significant result in the production of earbearing tillers. Number of productive tillers at 60 kg P_2O_5/ha was on par with 40 kg but superior to 20 kg. There was no significant difference between 20 kg and 40 kg P_2O_5/ha.

The higher doses of 40 kg K_2O/ha and 60 kg K_2O/ha were found to be on par and were significantly superior to the lowest level of 20 kg K_2O/ha.

Nitrogen x Phosphorus interaction was significant. Amongthe treatment comibnations, $N_{90}P_{60}$ recorded the maximum number of productive tillers at harvest.

Table 7. Mean values of no. of productive tillers, no. of fingers per earhead, length of earhead and thousand grain weight

Treatments		No.of productive tillers	No.of fingers per earhead	Length of earhead	Thousand grain weight
Nitrogen (Kg N/ha)					
n_1	30	4.098	5.154	5.670	3.207
n_2	60	4.783	5.479	5.943	3.268
n_3	90	5.492	5.659	6.243	3.266
'F' test		Sig.	Sig.	Sig.	N.S.
Phosphorus (Kg P_2O_5/ha)					
p_1	20	4.565	5.366	5.154	3.226
p_2	40	4.805	5.181	5.617	3.233
p_3	60	5.008	5.545	6.085	3.281
'F' test		Sig.	N.S.	Sig.	N.S.
Potash (Kg K_2O/ha)					
k_1	20	4.555	5.264	5.803	3.266
k_2	40	4.874	5.443	5.920	3.210
k_3	60	4.949	5.585	6.133	3.264
'F' test		Sig.	Sig.	Sig.	N.S.
C.D. (0.05)		0.311	0.242	0.228	0.079

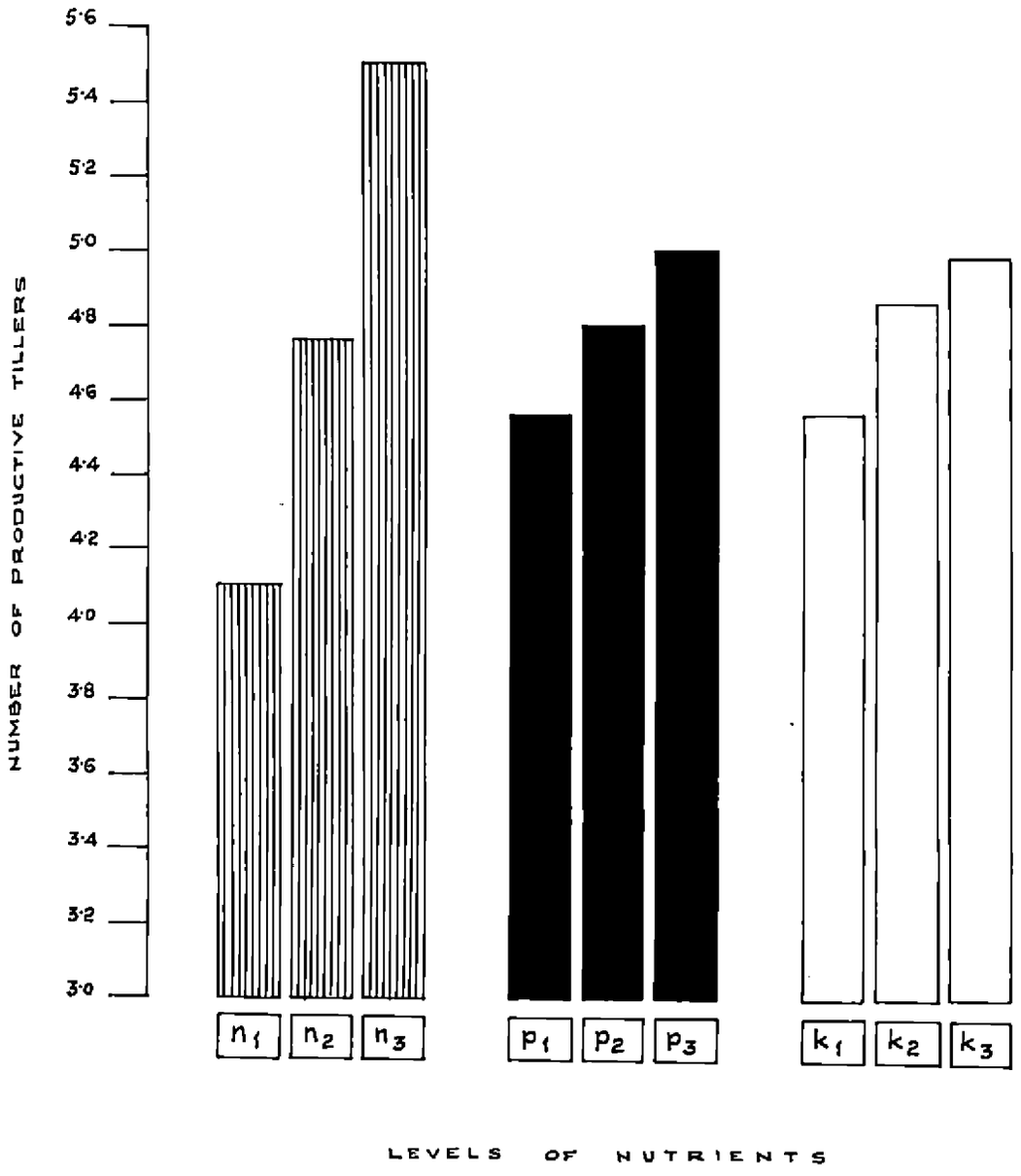
Table 8. Combined effect of nitrogen and phosphorus on number of productive tillers

	n_1	n_2	n_3	Mean
P_1	4.21	4.38	5.09	4.56
P_2	3.99	5.03	5.38	4.80
P_3	4.08	4.94	6.00	5.00
Mean	4.09	4.78	5.49	..

CD (0.05) for marginal means : 0.31

CD (0.05) for means of combinations : 0.53

FIG. 3. EFFECT OF N, P_2O_5 AND K_2O ON NUMBER OF PRODUCTIVE TILLERS.



Number of fingers per earhead

The data on the number of fingers per earhead are given in table 7 and the graphical representation in Fig.4. The analysis of variance is presented in Appendix IV.

From the data it is seen that nitrogen and potash had significant effect on the number of fingers per earhead. N_{60} was superior to N_{30}, but N_{60} and N_{90} were on par. There was no significant difference between the levels of phosphorus. Potash at 60 kg/ha was superior to that at 20 kg/ha but was on par with 40 kg/ha which in turn was on par with 20 kg level.

Nitrogen x Potash interaction was significant. N_{90} K_{60} level has recorded the maximum number of fingers per earhead (5.796). The combined effect is given in table 9.

Length of earhead

The data on length of earhead for various treatments are given in table 7 and graphically represented in Fig. 5. The combined effect of phosphorus and potash on length of earhead is presented in table 10. The analysis of variance is given in Appendix IV.

FIG. 4. EFFECT OF N, P_2O_5 AND K_2O ON NUMBER OF FINGERS PER EARHEAD.

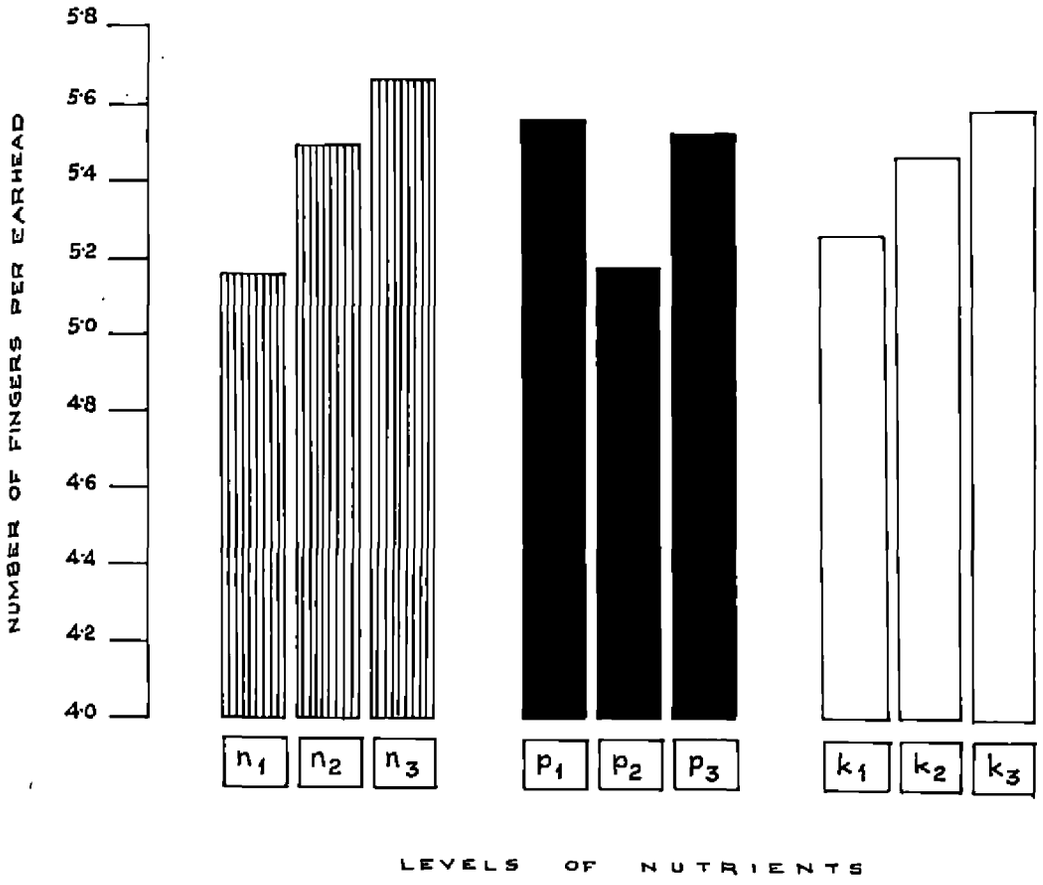


Table 9. Combined effect of nitrogen and potash on number of fingers per earhead

	n_1	n_2	n_3	Mean
K_1	4.800	5.298	5.695	5.264
K_2	5.133	5.711	5.486	5.443
K_3	5.530	5.428	5.796	5.585
Mean	5.154	5.479	5.659	..

CD (0.05)for marginal means : 0.242

CD (0.05) for means of combinations : 0.420

FIG. 5. EFFECT OF N, P_2O_5 AND K_2O ON LENGTH OF EARHEAD.

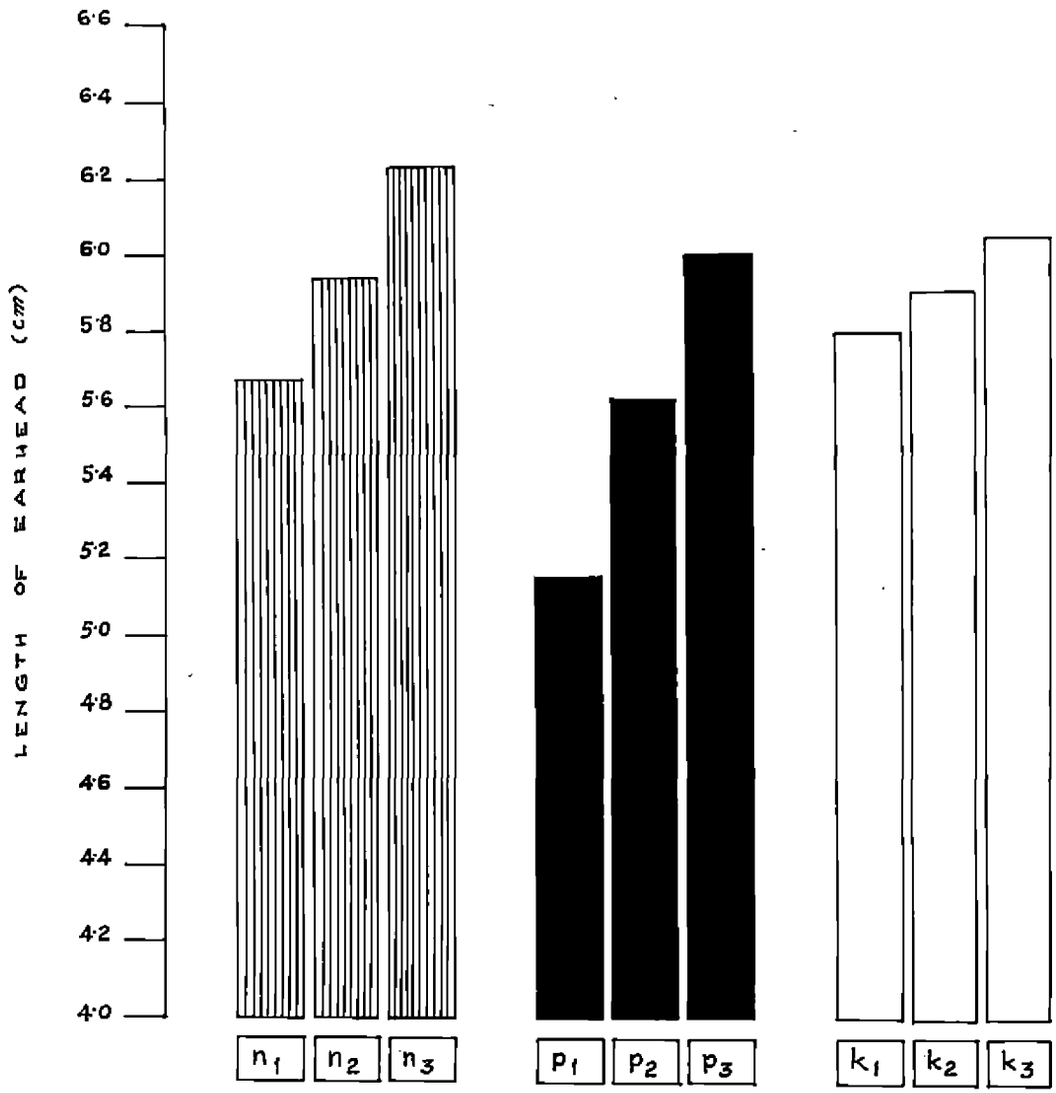


Table 10. Combined effect of phosphorus and potash on length of earhead

	P_1	P_2	P_3	Mean
K_1	5.718	5.666	6.025	5.803
K_2	6.393	5.360	6.008	5.920
K_3	6.351	5.826	6.223	6.133
Mean	5.154	5.617	6.085	..

CD (0.05) for marginal means : 0.228
CD (0.05) for means of combinations: 0.396

The length of earhead was influenced by nitrogen, phosphorus and potash. Each level of nitrogen and phosphorus increased the length of earhead significantly over the lower doses. There was no significant difference between the adjacent levels of potash. Potash at 60 kg/ha has recorded the maximum length of earhead which was superior to 20 kg K_2O/ha but on par with 40 kg K_2O/ha.

The interaction effect of phosphorus and potash was significant on length of earhead. $P_{20}K_{40}$ has recorded the maximum length of earhead.

Thousand grain weight

The mean 1000 grain weight under different treatments are given in table 7. The analysis of variance is presented in Appendix IV.

None of the 3 factors (Nitrogen, phosphorus or potash) or their interactions showed any significant effect with respect to this character.

C. YIELD

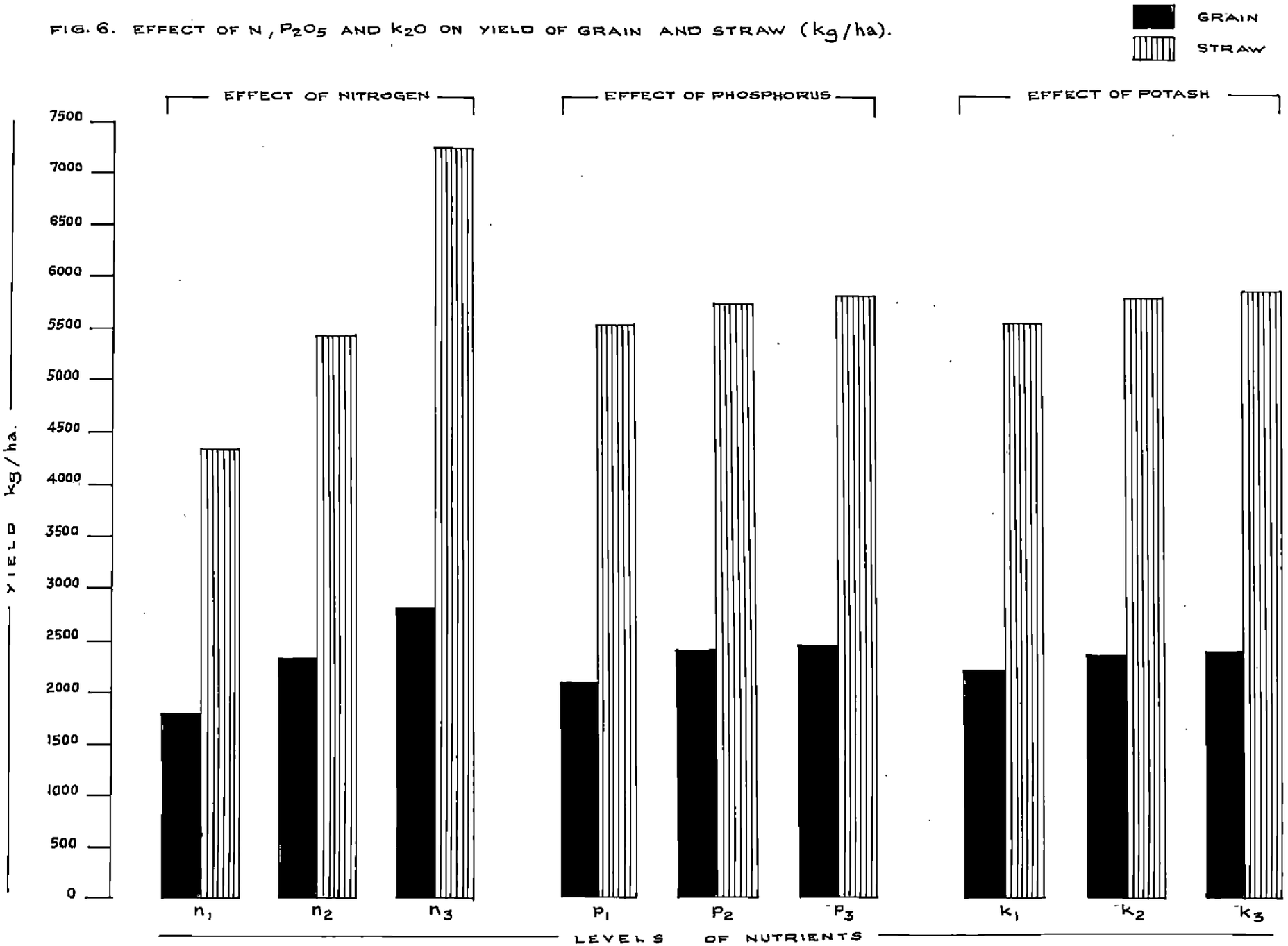
Yield of grain

Yield of grain under the various treatments are given in table 11 and Fig. 6. The analysis of variance for yield is given in Appendix V.

Table 11. Mean yield of grain and straw

Treatments		Yield of grain (kg/ha)	Yield of straw (q/ha)
Nitrogen (kg N/ha)			
n_1	30	1786.60	43.53
n_2	60	2290.50	54.33
n_3	90	2814.00	73.72
'F' test		Sig.	Sig.
Phosphorus (kg P_2O_5/ha)			
p_1	20	2094.00	55.74
p_2	40	2387.00	57.60
p_3	60	2410.20	58.24
'F' test		Sig.	N.S.
Potash (Kg K_2O/ha)			
k_1	20	2187.00	55.25
k_2	40	2339.00	57.97
k_3	60	2365.00	58.34
'F' test		Sig.	N.S.
C.D. (0.05)		151.36	4.85

FIG. 6. EFFECT OF N, P_2O_5 AND K_2O ON YIELD OF GRAIN AND STRAW (kg/ha).



The results reveal that the yield of grain was significantly increased due to increase in nitrogen levels. Nitrogen at 90 kg/ha gave the maximum yield (2814 kg/ha) followed by 60 kg/ha (2290.5 kg/ha) and 30 kg/ha (1786.60 kg/ha).

Phosphorus showed significant difference with respect to yield of grain. Phosphorus levels at 60 kg and 40 kg/ha were on par and found superior to 20 kg/ha. The highest yield of grain (2365 kg/ha) was observed at 60 kg K_2O/ha which was on par with 40 kg K_2O/ha (2339 kg/ha). Both 60 and 40 kg potash were significantly superior to 20 kg K_2O level.

N x K and P x K interactions were also significant. Among the N x K combinations N_{90} K_{60} produced the maximum grain yield of 3091 kg/ha. Among P x K combinations P_{40} K_{40} recorded the maximum grain yield of 2634.7 kg/ha. The combined effects of N and K and P and K are presented in tables 12 and 13 respectively.

Yield of straw

The data on yield of straw are given in table 11 and the analysis of variance in Appendix V. The effect of N, P and K on yield of straw is illustrated in Fig. 6.

Table 12. Combined effect of nitrogen and potash on yield of grain (kg/ha)

	n_1	n_2	n_3	Mean
K_1	1843.60	2188.70	2528.70	2187.00
K_2	1771.70	2423.30	2822.00	2339.00
K_3	1744.50	2259.70	3091.00	2365.00
Mean	1786.60	2290.50	2814.00	..

CD (0.05) for marginal means : 151.36

CD (0.05) for means of combinations : 262.17

Table 13. Combined effect of phosphorus and potash on yield of grain (kg/ha)

	P_1	P_2	P_3	Mean
K_1	1813.70	2361.70	2385.60	2187.00
K_2	2082.70	2634.70	2299.50	2339.00
K_3	2385.30	2164.30	2545.50	2365.00
Mean	2094.00	2387.00	2410.20	..

CD (0.05) for marginal means : 151.36

CD (0.05) for means of combinations: 262.17

Application of graded doses of nitrogen recorded significant increase in yield of straw. The highest mean yield of straw (73.72 q/ha) was observed with 90 kg N/ha. It was observed that there was significant increase when the dose of nitrogen was increased from 30 to 60 and from 60 to 90 kg/ha.

Neither Phosphorus nor potash had any significant influence on straw yield. None of the two factor interactions was found to be significant.

D. OPTIMUM DOSE OF NUTRIENTS

Optimum dose of nitrogen

The linear response curve was found to be the best fit and is shown in Fig. 7. Since it follows the linear function, the optimum dose of nitrogen could not be determined. The response model calculated is furnished below:-

$$Y = 256.75\ x + 2297.3 \text{ where } x = \frac{N - 60}{15}$$

Optimum dose of phosphorus

The quadratic response curve was found to be the best fit and is shown in Fig. 8.

The response model calculated is furnished below:-

$$Y = -33.75\ x^2 + 79\ x + 2387 \text{ where } x = \frac{P - 40}{10}$$

FIG. 7. RESPONSE OF NITROGEN ON GRAIN YIELD.

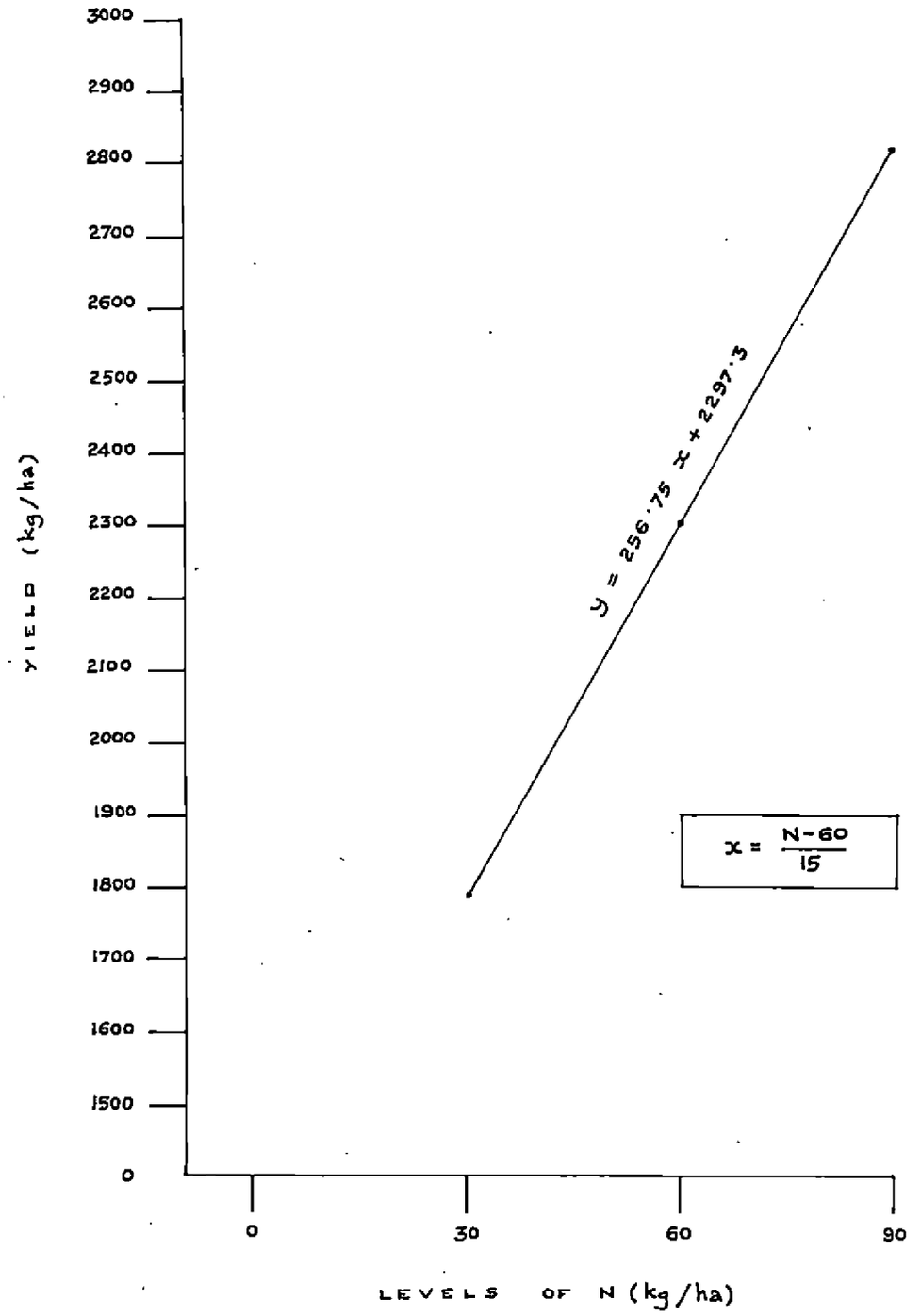
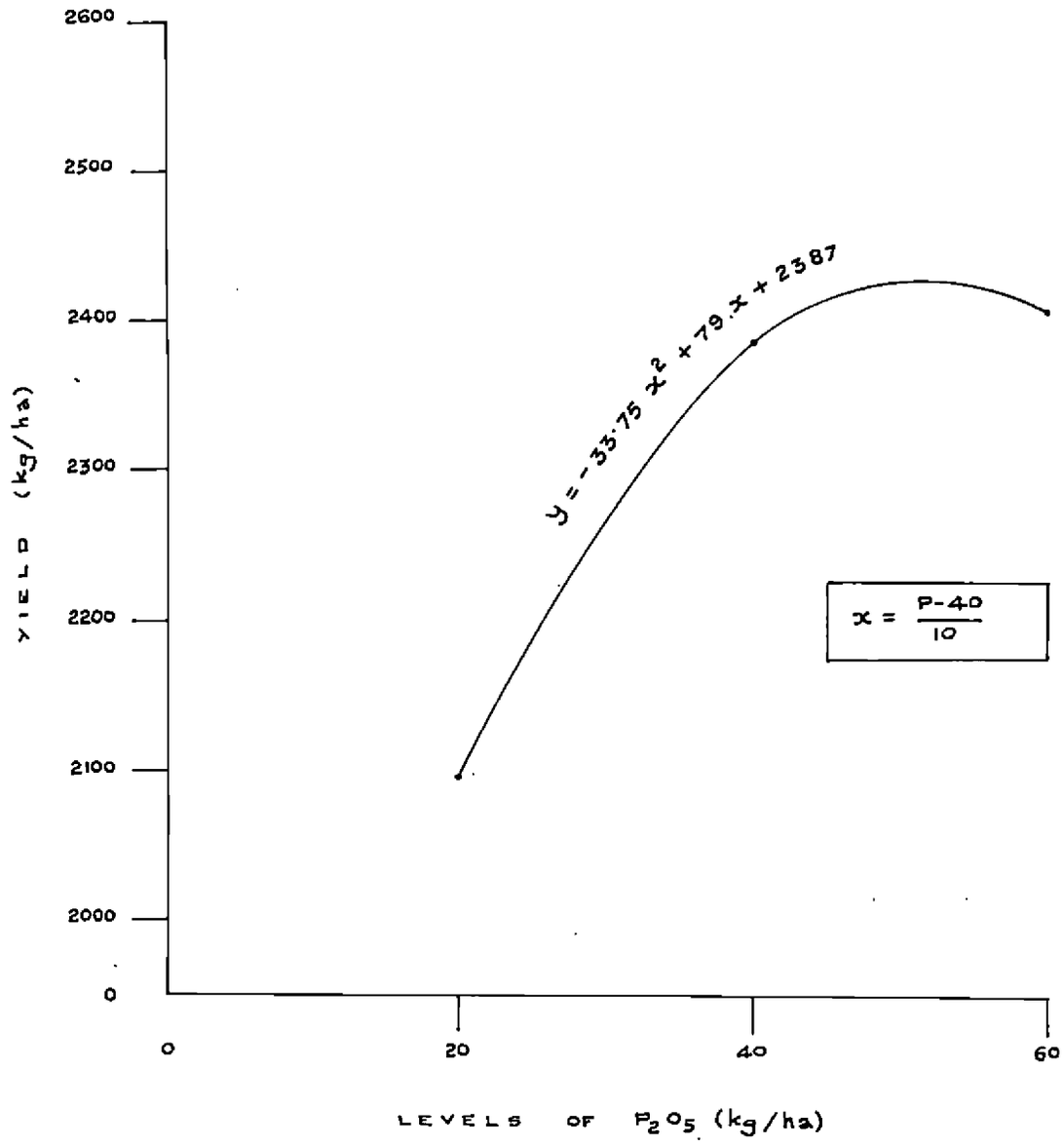


FIG. 8. RESPONSE OF PHOSPHORUS ON GRAIN YIELD.



The optimum dose for the variety under trial was calculated using the formula $\frac{-b}{2a}$ where 'b' and 'a' represented the parameters of the regression equation. The optimum dose of the phosphorus was found to be 51.7 kg P_2O_5/ha.

Optimum dose of potash

For potash also, the quadratic response curve was found to be the best fit and it is shown in Fig. 9.

The response model calculated is

$Y = -15.75 X^2 + 44.5X + 2339$ where $X = \frac{K - 40}{10}$

The optimum dose was found to be 54.13 kg K_2O/ha.

E. ECONOMIC DOSE OF NUTRIENTS

The economic dose was calculated using the formula,

$E = \frac{-b}{2a} + \frac{px}{2a \times py}$ where

E= Economic dose

px = Price of 1 kg ~~nitrogen~~ nutrient

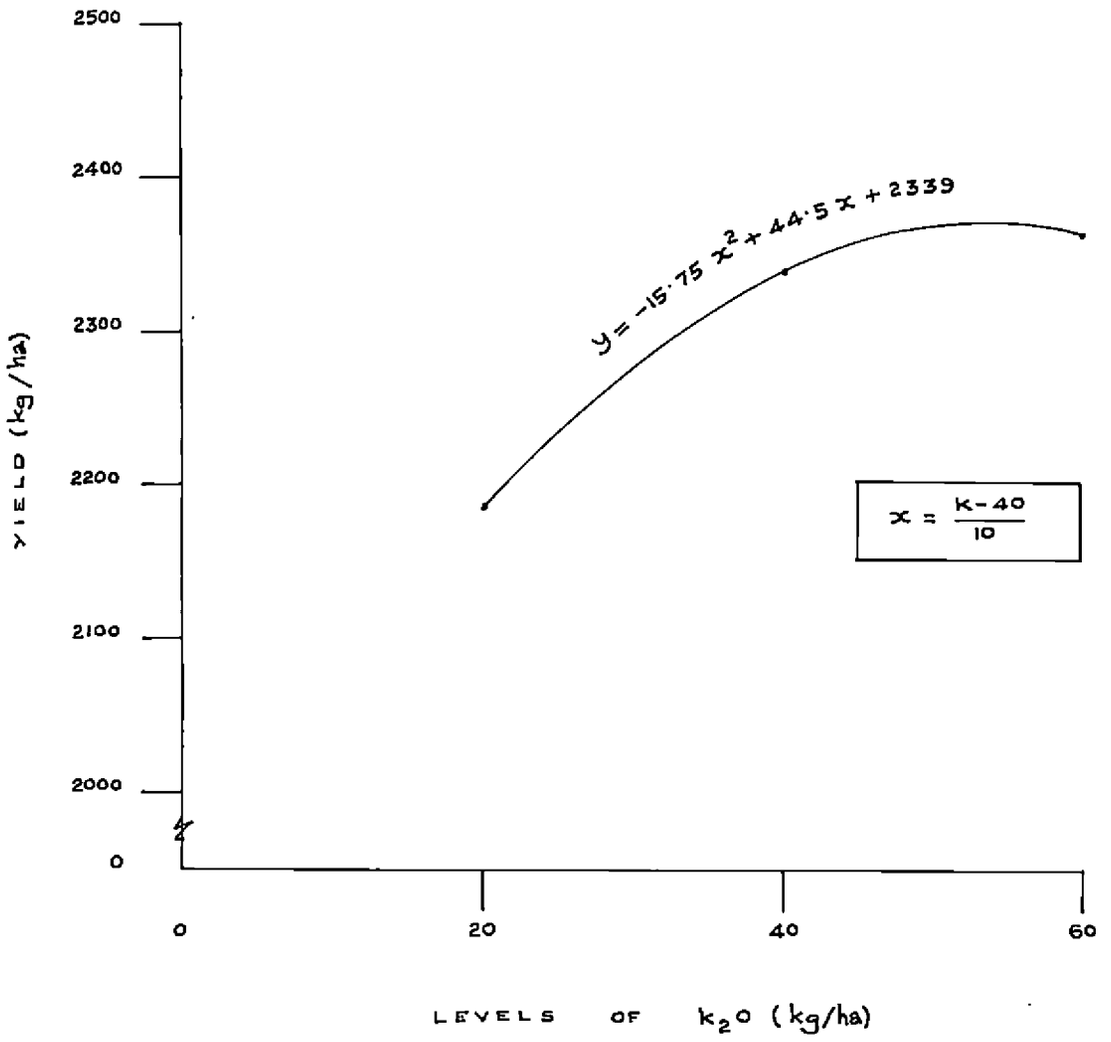
py = Price of 1 kg grain

a, b= Parameters of the regression equation.

Price of 1 kg grain = Rs. 2/-

Price of 1 kg superphosphate = Re.1/-

FIG. 9. RESPONSE OF POTASH ON GRAIN YIELD.



Price of 1 kg P_2O_5 = Rs.5.55

1 kg Muriate of Potash = Rs. 1.2

1 kg K_2O = Rs. 2/-

Economic dose of phosphorus was found to be 51.65 kg/ha and that of potash, 54.09 kg/ha.

F. QUALITY CHARACTERS

Nitrogen content of grain and straw

The data on nitrogen content of grain and straw for various treatments are presented in tables 14 and 15 respectively. The analysis of variance is given in Appendix VI.

There was significant increase in the nitrogen content of grain due to increase in nitrogen levels. Nitrogen at 90 kg/ha recorded the highest nitrogen content which was significantly superior to 60 kg/ha which in turn was superior to 30 kg/ha. The nitrogen content of grain was not influenced by phosphorus or potash or the interaction effects of NPK.

Nitrogen content in straw was significantly influenced by the levels of nitrogen. Application of phosphorus also influencedthe nitrogen content. Phosphorus

Table 14. Mean nitrogen, phosphorus, potassium and protein content of grain

Treatments		N%	P_2O_5%	K%	Protein %
Nitrogen (Kg N/ha)					
n_1	30	0.966	0.328	0.446	6.038
n_2	60	1.090	0.355	0.415	6.804
n_3	90	1.246	0.316	0.439	7.788
'F' test		Sig.	N.S.	N.S.	Sig.
Phosphorus (Kg P_2O_5/ha)					
p_1	20	1.098	0.312	0.412	6.862
p_2	40	1.082	0.329	0.444	6.754
p_3	60	1.122	0.359	0.444	7.004
'F' test		N.S.	N.S.	N.S.	N.S.
Potash (Kg K_2O/ha)					
k_1	20	1.092	0.356	0.395	6.827
k_2	40	1.107	0.327	0.448	6.912
k_3	60	1.102	0.317	0.465	6.892
'F' test		N.S.	N.S.	Sig.	N.S.
C.D. (0.05)		0.069	0.047	0.042	0.445

Table 15. Mean nitrogen, phosphorus and potassium content of straw

Treatments		N%	P_2O_5%	K%
Nitrogen (Kg N/ha)				
n_1	30	0.658	0.247	1.706
n_2	60	0.800	0.250	1.646
n_3	90	0.882	0.261	1.639
'F' test		Sig.	N.S.	N.S.
Phosphorus (Kg P_2O_5/ha)				
p_1	20	0.720	0.230	1.736
p_2	40	0.762	0.250	1.691
p_3	60	0.857	0.279	1.564
'F' test		Sig.	Sig.	Sig.
Potassium (Kg K_2O/ha)				
k_1	20	0.762	0.260	1.520
k_2	40	0.763	0.251	1.670
k_3	60	0.814	0.247	1.800
'F' test		N.S.	N.S.	Sig.
C.D. (0.05)		0.063	0.021	0.097

at 60 kg P_2O_5/ha recorded maximum nitrogen content which was significantly superior to 40 kg/ha. The first two levels viz. 20 kg and 40 kg were on par.

Among the interactions, N x P interaction was significant. $N_{90}P_{60}$ recorded the maximum nitrogen content in straw (1.042%). The combined effect is presented in table 16.

Protein content of grain

The data on protein content of grain are presented in table 14. The analysis of variance is given in Appendix VI.

Effect of nitrogen was significant with regard to protein content of seeds. N_{90} recorded the maximum protein content which was significantly superior to N_{60} which in turn was significantly superior to N_{30}. There was no significant influence by phosphorus or potash. The interaction effects were also not significant.

Phosphoric acid content of grain and straw

The phosphorus content of grain and straw are summarised and presented in tables 14 and 15 respectively. The analysis of variance is given in Appendix VI.

Table 16. Combined effect of nitrogen and phosphorus on nitrogen content of straw (%)

	n_1	n_2	n_3	Mean
p_1	0.710	0.710	0.748	0.720
p_2	0.678	0.754	0.855	0.762
p_3	0.585	0.949	1.042	0.857
Mean	0.658	0.800	0.882	..

CD (0.05) for marginal means : 0.063

CD (0.05) for means of combinations: 0.108

Noneof the nutrients nor their two factor interactions influenced the phosphorus content of grain.

Phosphorus content of straw was significantly influenced by the addition of phosphorus. P_{60} recorded the maximum phosphorus content in straw which was significantly superior to P_{40} and P_{20}. There was no significant difference between 40 kg level and 20 kg level. Nitrogen or potash did not influence the phosphorus content of straw. The interactions were also not significant.

Potassium content of grain and straw

Potassium content of grain and straw are presented in tables 14 and 15 respectively. The analysis of variance is given in Appendix VI.

Nitrogen or phosphorus has not influenced the potassium content of grain. Application of potash has significantly influenced the potassium content of grain. Potash level at 40 kg K_2O/ha has significantly increased the potassium content of grain over 20 kg level. The potassium content at the levels of 40 kg and 60 kg were on par. None of the interactions was significant.

The potassium content in straw was influenced only by phosphorus and potash. Increase in the dose of

phosphorus fertilizer, decreased the potassium content of straw and P_{20} recorded the maximum potassium in straw which was significantly superior to P_{40}. Application of 60 kg P_2O_5/ha again decreased the percentage of potassium though not significantly.

Every increase in the dose of potash has significantly increased the potassium content in straw over the lower doses. Application of 60 kg K_2O/ha has recorded the highest potassium content which was significantly superior to 40 kg and 20 kg/ha.

Among the interaction effects, N X P interaction alone was significant. The treatment combination, N_{90} P_{20} recorded the maximum potassium percentage of 1.838 in straw. The combined effect of nitrogen and phosphorus on potassium content of straw is presented in table 17.

G. UPTAKE OF NUTRIENTS

Uptake of nitrogen

The data on the uptake of nitrogen by plants at harvest is presented in table 18. The analysis of variance is presented in Appendix VII. There was significant difference in the uptake of nitrogen among the varying levels of nitrogen. Nitrogen level at 90 kg/ha

Table 17. Combined effect of nitrogen and phosphorus on potassium content of straw (%)

	n_1	n_2	n_3	Mean
p_1	1.671	1.700	1.838	1.736
p_2	1.791	1.590	1.691	1.691
p_3	1.656	1.648	1.387	1.564
Mean	1.706	1.646	1.639	..

CD (0.05) for marginal means : 0.097

CD (0.05) for means of combinations : 0.168

Table 18. Mean value of total uptake of nitrogen, phosphorus and potassium at harvest

Treatments		Uptake of N (kg/ha)	Uptake of P_2O_5 (kg/ha)	Uptake of K (kg/ha)
Nitrogen (Kg N/ha)				
n_1	30	44.50	17.04	82.84
n_2	60	68.44	21.95	98.99
n_3	90	100.15	28.25	154.00
'F' test		Sig.	Sig.	Sig.
Phosphorus (Kg P_2O_5/ha)				
p_1	20	63.66	19.73	100.49
p_2	40	70.10	25.51	108.56
p_3	60	79.33	24.98	100.99
'F' test		Sig.	Sig.	N.S.
Potash (Kg K_2O/ha)				
k_1	20	67.26	22.59	92.63
k_2	40	69.90	22.51	107.83
k_3	60	76.07	22.14	115.58
'F' test		N.S.	N.S.	Sig.
C.D. (0.05)		6.725	2.201	14.339

recorded the highest nitrogen uptake which was significantly superior to 60 kg level which in turn was superior to 30 kg level.

The effect of phosphorus on nitrogen uptake was significant. Application of 60 kg P_2O_5/ha increased the uptake of nitrogen significantly over 40 kg P_2O_5/ha which in turn was significantly superior to that at 20 kg level.

Nitrogen uptake was not influenced by the application of potash.

Among the interaction effects, NP interaction was significant with respect to nitrogen uptake. $N_{90}P_{60}$ recorded the maximum uptake of nitrogen of 110.49 kg/ha. The combined effect is presented in table 19.

Uptake of phosphoric acid

The data on the uptake of phosphoric acid by plants at harvest are presented in table 18. The analysis of variance is given in Appendix VII.

The effect of nitrogen on the uptake of phosphoric acid was significant. The maximum value of phosphoric acid uptake of 28.25 kg/ha was obtained at 90 kg N/ha. Each increase in the dose of nitrogen,

Table 19. Combined effect of nitrogen and phosphorus on total N uptake at harvest (kg/ha)

	n_1	n_2	n_3	Mean
p_1	44.28	62.68	85.00	63.65
p_2	43.42	60.92	105.96	70.10
p_3	45.68	81.72	110.49	79.33
Mean	44.50	68.44	100.15	..

CD (0.05) for marginal means : 6.723

CD (0.05) for means of combinations: 11.645

increased the uptake of phosphoric acid over the lower doses.

Phosphorus at 40 kg P_2O_5/ha significantly increased the uptake of phosphorus over 20 kg level. Uptake of phosphorus at the higher levels of 40 kg and 60 kg P_2O_5/ha were on par. Fertilizer level of 20 kg, 40 kg and 60 kg P_2O_5/ha recorded the uptake of phosphorus as 19.73 kg, 25.51 kg and 24.98 kg P_2O_5/ha respectively.

Uptake of potassium

The data on the uptake of potassium by the plants at harvest are presented in Table 18. The analysis of variance is given in Appendix VII.

Significant difference due to nitrogen application was noticed in the uptake of potassium. The incremental doses of nitrogen increased the uptake of potassium significantly.

Phosphorus application did not evoke any significant influence on the uptake of potassium.

Potash application has influenced the uptake of potassium by plants. Potash at 40 kg level has recorded the uptake significantly over 20 kg level. But the uptake of potassium at 40 kg and 60 kg levels were on par.

H.POST HARVEST SOIL ANALYSIS

Soil reaction

The data on soil pH after the harvest of crop are presented in table 20. The analysis of variance is presented in Appendix VIII.

Noneof the 3 factors (nitrogen, phosphorus and potassium) nor their interactions showed any significant effect on this character.

Organic carbon

The data on organic carbon in soil after harvest of the crop are presented in table 20. The analysis of variance is given in Appendix VIII.

Organic carbon was not influenced by nitrogen, phosphorus, potash and their interactions.

Available nitrogen

The data on available nitrogen in soil are summarised in table 20. The analysis of variance is presented in Appendix VIII.

It was found that nitrogen and potash significantly influenced the nitrogen content in soil. Application

Table 20. Mean values of soil pH, organic carbon, available nitrogen, phosphorus and potash

Treatments		pH	O.C. (%)	Available nutrients (Kg/ha)		
				N	P_2O_5	K_2O
Nitrogen (Kg N/ha)						
n_1	30	5.194	1.296	321.24	25.835	338.60
n_2	60	5.138	1.307	342.84	25.150	344.80
n_3	90	5.077	1.331	348.00	27.516	320.34
'F' test		N.S.	N.S.	Sig.	N.S.	Sig.
Phosphorus (Kg P_2O_5/ha)						
P_1	20	5.136	1.288	335.47	22.850	325.40
P_2	40	5.136	1.301	339.37	24.675	336.70
P_3	60	5.138	1.344	337.27	30.997	341.70
'F' test		N.S.	N.S.	N.S.	Sig.	N.S.
Potash (Kg K_2O/ha)						
k_1	20	5.113	1.319	342.13	24.763	325.10
k_2	40	5.166	1.302	332.97	25.044	333.20
k_3	60	5.130	1.312	337.00	28.713	346.80
'F' test		N.S.	N.S.	Sig.	Sig.	Sig.
C.D. (0.05)		0.092	0.048	4.377	2.226	15.951

of 90 kg N/ha recorded the maximum nitrogen content which was significantly superior to all other levels. Each level of nitrogen significantly increased the nitrogen content in soil. Nitrogen content in plots receiving 20 kg K_2O/ha was found to be significantly superior to that of the plots receiving 40 kg and 60 kg/ha No significant difference in soil nitrogen could be noticed between 40 kg and 60 kg K_2O/ha.

N x P and N X K interactions were significant and N_{90} P_{20} recorded the maximum nitrogen in soil. (358.58 kg N/ha) among the N P combinations. Among the NK combinations N_{90} K_{20} recorded the maximum nitrogen in soil (359.88 kg N/ha). The combined effects of N and P and N and K are given in tables 21 and 22 respectively.

Available phosphorus

The data on available phosphorus of soil after harvest for various treatments are presented in table 20. The analysis of variance is given in Appendix VIII.

Phosphorus content in soil was not influenced by application of nitrogen. Phosphorus significantly influenced the phosphorus content of soil.

Table 21. Combined effect of nitrogen and phosphorus on available nitrogen content in soil after harvest (kg/ha)

	n_1	n_2	n_3	Mean
p_1	320.88	326.95	358.58	335.47
p_2	329.55	336.20	332.37	339.37
p_3	313.30	345.37	353.15	337.27
Mean	321.24	342.84	348.00	..

CD (0.05) for marginal means : 4.377

CD (0.05) for means of combinations : 6.189

Table 22. Combined effect of nitrogen and potash on available nitrogen content in soil after harvest (kg/ha)

	n_1	n_2	n_3	Mean
K_1	316.30	350.20	359.88	342.13
K_2	323.70	339.00	336.27	332.97
K_3	323.70	339.70	347.75	337.00
Mean	321.24	342.84	348.00	..

CD (0.05) for marginal means : 4.377

CD (0.05) for means of combinations: 6.169

Application of 60 kg P_2O_5/ha recorded significantly higher phosphorus content than 40 kg and 20 kg/ha. There was no significant difference between 20 kg and 40 kg P_2O_5/ha. Phosphorus content in soil was also significantly influenced by potash levels. Potash levels of 20 kg and 40 kg were on par but there was significant increase from 40 kg level to 60 kg level.

The effect due to the interaction between nitrogen and phosphorus was found to be significant. The treatment combination $N_{90}P_{60}$ gave the highest value for phosphorus content in soil. The combined effect is presentedin table 23.

Available potash content

The data on potash content in soil are presented in table 20. The analysis of variance is given in Appendix VIII.

There was significant difference in potash content of soil due to nitrogen application. Nitrogen level at 60 kg/ha recorded the maximum potash content in soil

Table 23. Combined effect of nitrogen and phosphorus on P_2O_5 in soil after harvest (Kg/ha)

	n_1	n_2	n_3	Mean
p_1	22.016	22.966	23.566	22.850
p_2	27.625	22.633	23.766	24.675
p_3	27.925	29.850	35.216	30.997
Mean	25.855	25.150	27.516	

CD (0.05) for marginal means : 2.226

CD (0.05) for means of combinations : 3.856

(344.80 kg/ha) which was on par with 30 kg N/ha (338.60 kg). Potash content in soil at 90 kg N level (320.34) was significantly lower than that at 60 kg N level.

Levels of phosphorus had no influence on the potash content of soil.

Application of potash significantly influenced the potash content of soil after harvest. Potash content at 60 kg level was on par with 40 kg level and superior to that at 20 kg level.

The interaction effect between nitrogen and phosphorus was significant. Among the N P combinations $N_{60}P_{60}$ recorded the maximum potash content in soil. The combined effect is given in table 24.

I. CORRELATIONS

The relationships between grain yield and yield components such as number of productive tillers, length of ear head and number of fingers per earhead were studied. Correlation coefficients were worked

Table 24. Combined effect of nitrogen and phosphorus on K_2O in soil after harvest (Kg/ha)

	n_1	n_2	n_3	Mean
p_1	347.40	315.10	313.63	325.40
p_2	325.40	332.20	351.40	336.70
p_3	343.10	386.06	296.00	341.70
Mean	338.60	344.80	320.34	

CD (0.05) for marginal means : 15.951

CD (0.05) for means of combinations: 22.559

out for height of plants at harvest, total tiller number at harvest and total nitrogen, phosphorus and potassium uptake at harvest. The correlation values are given in table 25.

Significant positive correlations were obtained between grain yield and height of plants at harvest, number of tillers at harvest, number of productive tillers, length of earhead, number of fingers per earhead, total nitrogen uptake, total phosphoric acid uptake and total potassium uptake by the plants.

Table 25. Coefficient of correlation between grain yield and yield contributing characters

	Character	Correlation coefficient
1.	Height of plants at harvest	0.544**
2.	Number of tillers at harvest	0.630**
3.	Number of productive tillers	0.530**
4.	Length of earhead	0.352**
5.	Number of fingers per ear head	0.310*
6.	Total N uptake	0.792**
7.	Total P_2O_5 uptake	0.790**
8.	Total K uptake	0.750**

*Significant at 0.05 level

** Significant at 0.01 level

DISCUSSION

DISCUSSION

The results obtained in the present study are discussed in the light of the research findings obtained from elsewhere.

A. GROWTH CHARACTERS

Height of plants

The plant height was significantly influenced by the levels of nitrogen at all stages. Significant increase in height was registered by the treatment N_{90} over N_{60} and N_{30}. The same trend was observed at all growth stages. The increases in plant height noticed in this study by the application of nitrogen is in agreement with the results obtained by Ranganathan (1962) and Thirupathy(1971). Further it is well known that nitrogen hastens the meristematic activity resulting in the increase of plant height.

Levels of phosphorus had no influence as far as plant height was concerned. Ramakrishnan Nair (1963), Subramanian (1969) and Subramanian *et al.* (1971) obtained similar results in response to phosphorus application.

Potash exerted a significant influence in increasing the plant height of ragi on 71st day after planting and at harvest. Bavappa and Rao (1956) and Vijayan (1970) have reported significant increase in plant height by potash upto 80 kg/ha in rice.

Number of tillers

Production of tillers was significantly influenced by nitrogen and phosphorus, while potash had no effect. N x P interaction was significant and the treatment combination of N_{90} P_{60} recorded the maximum number of tillers at later stages.

Increase in tiller number by the application of nitrogen had been reported by many workers(Karunakara Shetty, 1961; Ranganathan, 1962; Krishnamurthy, 1967 and Singh and Rajatde, 1978). The increase in the number of tillers observed by the incremental doses of phosphorus may be due to the increased uptake and utilization of nitrogen in association with phosphorus. The lack of response to potash noticed in this study is in conformity with the finding of Subramanian(1969).

In this investigation interaction between nitrogen and phosphorus was significant on 56th and 71st day after planting and at harvest. The combination of N_{90} and P_{60} increased the number of tillers significantly. Evidently this is a case of increased metabolism resulting through the complementary effects of these two primary nutrients.

Number of functional leaves at flowering

Increased doses of nitrogen increased the number of functional leaves, while phosphorus and potash did not evoke any response. The increase in the number of functional leaves recorded may be due to increased metabolism resulting from increased uptake of nitrogen.

Dry matter production

At flowering nitrogen alone had exerted significant influence on dry matter production. But at harvest nitrogen and phosphorus had increased the dry matter significantly. Potash did not have any influence at any stage.

The results obtained in this trial is in agreement with the findings of Elangoan (1970) who recorded linear response in dry matter production due to nitrogen in ragi. Rajagopal and Mehta (1971) and Thandapani and Rao (1976) also reported similar results.

B. YIELD CHARACTERS

Number of productive tillers

The number of earbearing tillers was influenced by nitrogen, phosphorus and potash. Subramanian (1969) reported significant increase in the number of productive tillers with increasing levels of nitrogen. The increase in the number of productive tillers as influenced by phosphorus and potash may be due to increased uptake of nitrogen by the influence of phosphorus and potassium.

Nitrogen x Phosphorus interaction had significant effect. The combination $N_{90}P_{60}$ recorded the maximum number of productive tillers. This is also a case of increased metabolism, resulting through the complementary action of these two primary nutrients.

Number of fingers per earhead

Nitrogen and potash influenced the number of fingers per earhead significantly. Ranganathan (1962), Thirupathy (1971) and Puttaswamy and Krishnamurthy(1976) reported significant increase in the number of fingers by the application of nitrogen in ragi. The results of the present study are in corroboration with the above findings. The combined effect of nitrogen and potash

resulted in significant increase in the number of fingers per earhead. The combination $N_{90}K_{60}$ recorded the maximum number. The result indicates that the number of fingers per earhead was not influenced by P_2O_5 levels and the result was found erratic.

Length of earhead

The levels of nitrogen, phosphorus and potash had influenced the length of earhead significantly.

The progressive increase in the length of earhead noticed with the incremental doses of nitrogen is supported by the findings of Kolandaiswamy (1964) and Singh and Rajatde (1978) in ragi. Ramiah and Moraohan (1978) reported increase in the length of earhead by phosphorus application. The increase in the length of earhead observed by the graded levels of N, P and K may be due to the balanced nutrition and also due to their complementary effect.

Thousand grain weight

None of the nutrients nor their interactions did influence the thousand grain weight. The results obtained in this study is in conformity with the findings of Karunakarashetty (1961), Kamala Singh and Mahatim Singh (1975), Misra and Singh(1975) and Puttaswamy and Krishnamurthy(1976).

C. YIELD

Yield of grain

(a) Effect of nitrogen The results reveal that, the applied nitrogen favourably influenced the grain yield. The trend noticed in the case of yield attributes was reflected in the yield as well.

Thus these findings corroborate with those of the earlier investigators on ragi (Anandapadamanabhan et al.1967, Krishnamurthy, 1970, Thirupathy 1971, Krishnamoorthy, 1972, Puttaswamy and Krishnamurthy, 1976 and Singh and Rajatde, 1978). The foregoing discussion leads to the conclusion that nitrogen increases the yield in ragi.

(b) Effect of phosphorus Phosphorus is found to influence the yield favourably and significantly. The effect of first increment (20 to 40 kg) of added phosphorus on the grain yield was more pronounced than the second increment of 40 to 60 kg/ha.

Increase in the grain yield of ragi by increasing levels of phosphorus was reported earlier (Rao and Govindarajan, 1956; Mustafa and Durairaja, 1967, Ramiah, 1969

Kumareswamy, 1972 and Ramiah and Morachan,1978). Sathyanarayana et al. (1978) reported that, response to phosphorus was more conspicious than to nitrogen in ragi var: P.R. 202.

(c) Effect of potash Significant response to potash application was noticed only upto 40 kg K_2O/ha. Generally crop response to potash depends primarily on the available potassium status of the soil. Soil rich in available potassium does not show any response to added potash in many conditions. The response of ragi to Potash in the present study may be resolved in the light of medium potassium status of the experimental field. While the observations made by Subramanian(1969) was against the resultsof the present study the findings of Antoni Joseph(1969) confirm the same.

(d) Interaction effect Besides the main effect of nutrients, significant interaction between nitrogen and potash and phosphorus and potash was observed. Among the N x K combinations, $N_{90}K_{60}$ recorded the maximum grain yield. This clearly brings out the existence of interaction between these two nutrients. Among the

P x K combinations, P_{40} K_{40} recorded the maximum grain yield. It could be concluded that the yield boosting ability of one nutrient is enhanced when combined with other nutrients.

Yield of straw

The straw yield was significantly influenced by the levels of nitrogen.

Thirupathy (1971) and Subramanian et al.(1971) reported spectacular increase in straw yield with successive doses of nitrogen. The present finding parallels these results. This increase is evidently a reflection of the trend observed under plant height, number of tillers and number of leaves.

Neither phosphorus nor potash influenced the straw yield. Interaction of any kind was absent. Ramakrishnan Nair (1963), Subramanian et al. (1971) and Singh and Singh (1971) reported the failure of phosphorus and potassium to confer any beneficial effect on ragi. The results of this study are in agreement with their findings.

D. QUALITY CHARACTERS

Nitrogen and protein content of grain

The effect of nitrogen in increasing the nitrogen and protein content of grain was significant.

The significant differences between the levels of nitrogen viz. 30, 60 and 90 kg/ha might be due to the larger uptake of nitrogen from the applied nitrogen for the productive purposes. At higher levels there was sufficient availability of nitrogen for the seed development and hence more nitrogen content in grain. Increase in the content of organic nitrogen compounds in plant cells as a result of increased rate of nitrogen supply has been universal. The superiority of higher levels of nitrogen in increasing the protein content of ragi was reported by Krishnamurthy (1967), Portch et al. (1968), Raniperumal, Ghouse and Sundarajan (1969), Rachie and Peters (1977) and Singh and Rajat de (1978).

Phosphorus, potash or the interaction effects were not having any influence on nitrogen or protein content of grain.

Nitrogen content of straw

Nitrogen content in straw was favourably and significantly influenced by the levels of nitrogen and phosphorus. Among the NP combinations $N_{90}P_{60}$ recorded the maximum nitrogen content.

Phosphoric acid content of grain and straw

None of the nutrients or their interactions influenced the phosphorus content of grain.

But the phosphorus content of straw was significantly influenced by the application of phosphorus. Kumaraswamy (1972) has reported similar increase in phosphorus content of straw by phosphorus application.

Potassium content of grain and straw

Nitrogen or phosphorus had no influence on the potassium content of grain. Application of potash had influenced the potassium content of grain significantly. The results obtained in the present investigation is in conformity with the observation of Subramanian(1969).

The potassium content of straw was influenced by the application of potash significantly. Similar result was obtained by Subramanian (1969). Among the interaction effects, N x P interaction was significant and $N_{90}P_{20}$ combination recorded the maximum potassium percentage in straw. The highest level of nitrogen in association with phosphorus might have promoted a proportionate absorption of potassium to maintain a proper balance which might have resulted in maximum potassium content in straw.

E. UPTAKE OF NUTRIENTS

Uptake of nitrogen

Significant differences were noticed between all the three levels of nitrogen on the nitrogen uptake by the plants. The increase in added nitrogen has resulted in the increase in grain yield, straw yield and nitrogen content of grain and straw which resulted in the increased uptake of nitrogen (Raniperumal *et al.* 1969 and Pyarelal and Sharma, 1974).

Uptake of nitrogen was significantly influenced by phosphorus. It has already been established that there exists a complementary action between the nutrients.

Application of phosphorus increased the phosphoric acid content of straw and the yield of grain. This might have resulted in increased uptake of nitrogen. Satyanarayana et al.(1978) observed in ragi Var: PR. 202, increased uptake of all the major nutrients due to nitrogen and phosphorus.

Nitrogen uptake was not influenced by the application of potash. Among the interaction effects, N x P interaction was significant, the maximum uptake of nitrogen being recorded at $N_{90}P_{60}$.

Uptake of phosphorus

The effect of nitrogen on the uptake of phosphoric acid was significant. Pandya et al. (1958) recorded that the absorption of phosphorus was increased in the presence of nitrogen. This might be due to the physiological stimulation of the plant caused by nitrogen uptake.

Phosphorus at 40 kg P_2O_5/ha increased the uptake of phosphorus over 20 kg level significantly. Uptake of phosphorus at the higher levels of 40 kg and 60 kg P_2O_5/ha were on par.

Uptake of potassium

Significant differences in the uptake of potassium among the different levels of nitrogen were noticed. Beneficial effect of nitrogen on the uptake ofpotassium by ragi has been reported by Antoni Joseph and Dhanapalan Mosi (1972).

Potash influenced the uptake of potassium. Significant increase was noticed from 20 kg level to 40 kg level. The potassium uptake at 40 kg and 60 kg levels were on par. Lobo (1973) and Subramanian(1969) reported increased uptake of potassium by potash fertilization.

Phosphorus did not evoke any significant influence on the uptake of potassium.

F. POST HARVEST SOIL ANALYSIS

Soil reaction

None of the three factors nor their interactions showed any significant effect on this character. This is in accordance with the findings of Ramiah (1969) and Sathyanarayana et al. (1978).

The fertilizer application was done just for one season which is too short a period for altering the pH of the soil perceptibily.

Organic carbon

Organic carbon also was not influenced by nitrogen, phosphorus, potash or their interactions.

Available nitrogen

Application of nitrogen significantly influenced the nitrogen content in soil after harvest. The loss of nitrogen depends on the texture of soil (Krishnakumari, 1968). The soil in which the experiment conducted, was loamy clay in texture, which could retain nitrogen. However it could be possible that the applied nitrogen might not have been fully utilized by the crop. A similar result was reported by Abraham (1978).

Plots which received 20 kg K_2O/ha showed maximum nitrogen content in soil which was significantly superior to other two levels. Among the N x P and N x K combinations $N_{90}P_{20}$ and $N_{90}K_{20}$ respectively recorded the maximum nitrogen content in soil.

Available phosphorus

Available phosphorus content ofthe soil measured immediately after harvest increased with the quantum of application of phosphorus.

The result is in agreement with the findings of Raniperumal et al.(1969) and Sathyanarayana et al.(1978). Phosphorus being relatively an immobile element and the proportion of fertilizer phosphorus recovery by a single crop being low, phosphatic fertilization has residual effect on soil. The residual effect increases with increase in phosphorus application (Kanwar, 1978).

Phosphorus content in soil was also significantly influenced by potash. Significant increase in the phosphorus content of soil was noticed with 60 kg level of potash. Among the NP combinations $N_{90}P_{60}$ gave the highest value of phosphorus content.

Available potash

There was significant increase in potash content in soil due to the increase of potash fertilization from 20 kg/ha to 40 kg/ha, beyond which the increase was not significant.

Application of nitrogen increased the potash content of soil. Phosphorus had no effect on the potash content. The interaction effect between nitrogen and

phosphorus was significant and the combination $N_{60}P_{60}$ recorded the maximum potash content in soil.

G. CORRELATIONS

Significant correlation could be noticed between grain yield and height of plants at harvest, number of tillers at harvest, number of productive tillers, length of earhead, number of fingers per earhead, and total nitrogen, phosphorus and potassium uptake by plants.

Subramanian et al. (1971) reported significant positive correlation between grain yield and plant height. Krishnamurthy (1973) observed that yield increase was mainly due to an increase inthe number of shoots and ear number per plant. Ranganathan et al. (1977) and Ramiah and Moraohan (1978) suggested positive correlation of grain yield with plant height. Many earlier workers have proved that yields are proportional to the uptake of nutrients (Venkata Ramana and Krishna Rao, 1961, Elangoan, 1970 and Antoni Joseph and Dhanapalan Mosi 1972). The above results confirm the findings of the present investigation.

SUMMARY

SUMMARY

A field experiment was conducted at the Rice Research Station, Pattambi during the first crop season of 1979-80 to study the effect of nitrogen, phosphorus and potash on ragi var: PR.202. Nitrogen at 3 levels (30, 60 and 90 kg N/ha), phosphorus at three levels (20, 40 and 60 kg P_2O_5/ha) and potash at three levels (20, 40 and 60 kg K_2O/ha) were tried.

During the study, the various growth and productive attributes were recorded. The yield of grain and straw were noted. Plant samples were analysed for content of nitrogen, phosphorus and potassium for finding out the status and the uptake of nutrients. Soil samples collected immediately after harvest were analysed for soil reaction, organic carbon, available nitrogen, phosphorus and potash.

The data were statistically analysed and the highlights of the study are given below:

The plant height and total tillers on 41st, 56th and 71st day after planting and at harvest were increased significantly by nitrogen. Potash significantly increased the height of plants on 71st day after planting and at harvest.

The increasing levels of nitrogen increased the number of functional leaves significantly. On the other hand, the increasing levels of phosphorus and potash did not influence the number of functional leaves.

Number of productive tillers, number of fingers per earhead and length of earhead were significantly increased by nitrogen and potash. Phosphorus enhanced the number of productive tillers and length of earhead. Regarding the interaction effects, N x P interaction was significant on productive tillers and the combination N_{90} P_{60} recorded the maximum number. The combined effect of nitrogen and potash was significant on number of fingers and the combination N_{90} K_{60} gave the highest value. The combined effect of phosphorus and potash was significant on length of earhead and the combination P_{20} K_{40} recorded the maximum length.

The grain yield was favourably influenced by the added nutrients. In the case of nitrogen the response was linear. With regard to phosphorus and potash the responses were quadratic. The optimum dose of phosphorus was found to be 51.7 kg P_2O_5/ha and that of potash, 54.13 kg K_2O/ha. The economic doses of phosphorus and potash were found to be 51.65 kg P_2O_5/ha and 54.09 kg K_2O/ha respectively. The interaction effects of N x K and P x K

were significant on grain yield and the combinations $N_{90}K_{60}$ and $P_{40}K_{40}$ respectively gave the maximum grain yield.

Increase in nitrogen levels recorded progressive increase in straw yield. Neither phosphorus nor potash influenced the straw yield.

Nitrogen and protein in grain were significantly increased by increase in the nitrogen doses. Significant increase in nitrogen content of straw was also noticed due to nitrogen application. Nitrogen content in straw was significantly influenced by the combined effect of nitrogen and phosphorus. The combination $N_{90}P_{60}$ recorded the maximum value of N percentage in straw.

Phosphorus levels increased the phosphorus content in straw only.

Potassium content in both grain and straw was significantly increased by the graded doses of potash. Potassium content in straw was significantly influenced by N x P interaction, where $N_{90}P_{20}$ has recorded the maximum content.

Application of all the nutrients resulted in the increased uptake of the respective nutrients. Phosphorus significantly influenced the uptake of nitrogen and nitrogen influenced the uptake of phosphorus and potassium.

The analysis of the soil for available nutrients has shown that the available nitrogen, phosphorus and potash in the soil were increased by the application of NPK fertilizers. The combined effects of N x P and N x K were significant on the nitrogen content in soil after harvest and the combinations N_{90} P_{20} and $N_{90}K_{20}$ respectively recorded the maximum values. The interaction between nitrogen and phosphorus gave significant influence on phosphorus and potash content in soil after harvest, where $N_{90}P_{60}$ gave the highest values.pH and organic carbon content of the soil remained unaffected.

There was significant positive correlations between grain yield and height of plants at harvest, number of tillers at harvest, number of productive tillers, length of earhead, number of fingers per earhead and total nitrogen, phosphorus and potassium uptake by the plants.

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APPENDICES

APPENDIX I

Meteorological data recorded in the Class B observatory at the Rice Research Station, Pattambi, during the period of crop growth

(Weekly averages)

Number of weeks	Week ending	Temperature in C° Maximum	Minimum	Relative humidity percentage	Rainfall (mm)*
1	4-6-1979	34.31	25.1	88.4	0.086
2	11-6-1979	34.11	24.5	89.1	4.314
3	18-6-1979	29.54	22.8	96.1	34.63
4	25-6-1979	28.54	22.0	96.1	33.24
5	2-7-1979	30.0	21.5	97	29
6	9-7-1979	28.1	22.5	97.9	30.5
7	16-7-1979	28.2	22.4	96.3	28.0
8	23-7-1979	30.4	23.7	93.38	1.35
9	30-7-1979	27.9	22.4	96.64	33.36
10	6-8-1979	27.7	22.4	96.3	27.81
11	13-8-1979	28.7	21.7	93.3	31.63
12	20-8-1979	30.0	22.5	96.4	10.25
13	27-8-1979	30.2	23.1	94.4	1.54
14	3-9-1979	32.3	23.6	94	0
15	10-9-1979	31.9	25.0	93.7	0.45
16	17-9-1979	32.5	23.6	93.6	2.79
17	24-9-1979	29.8	23	96.1	8.2
18	1-10-1979	29.4	22.6	96	8.87

*Rainfall is given as weekly total

APPENDIX II

Characteristics of ragi variety PR.202
(P.R. 1 Paddapuram Ragi)

Parentage	Pureline
Duration (days)	107 - 110
Season	Both
Rainfed/Irrigated	Both
Grain yield kg/ha	
i. Irrigated	4000
ii. Rainfed	2500
Straw yield kg/ha	
i. Irrigated	7000
ii. Rainfed	4500
Stem	Erect
Height (cm)	110 - 120
Tillers	5 - 6
Days to 50% flowering	75 - 80
Ear size and shape	Incurved
Fingers	6 - 8
Ear length (cm)	6 - 7
Grain colour	Orange Brown
1000 grain wt (g)	2.89

APPENDIX V

Analysis of variance

Source	DF	Mean squares	
		Yield of grain	Yield of straw
Block	5	470672**	294.51**
N	2	4748383**	4184.69**
P	2	559291**	56.04
NP	4	88269	130.27
K	2	166502*	53.14
NK	4	205380*	48.29
PK	4	375852**	16.00
NPK	2	83194	109.33
NPK^2	2	135194	107.39
NP^2K^2	2	79573	237.47*
NP^2K	2	80664	30.81
Error	22	48122	49.41

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX VI

Analysis of variance table

Source	DF	Mean squares						
		Nitrogen content in grain	Nitrogen content in straw	Protein content in grain	Phospho-ric acid content in grain	Phosphoric acid con-tent in straw	Potassium content in grain	Potassium content in straw
Block	5	0.0086	0.0640	0.361	0.0065	0.0024	0.01360*	0.0281
N	2	0.3545**	0.2310**	13.801**	0.0069	0.0010	0.00450	0.0248
P	2	0.0074	0.0890**	0.261	0.0101	0.0108**	0.00628	0.1440**
NP	4	0.0144	0.0843**	0.553	0.0015	0.0018	0.00573	0.1120**
K	2	0.0013	0.0843**	0.035	0.0073	0.0008	0.02240**	0.3528**
NK	4	0.0082	0.0158	0.292	0.0030	0.0004	0.00280	0.0002
PK	4	0.0138	0.0200	0.572	0.0091	0.0011	0.00616	0.0191
NPK	2	0.0060	0.0180	0.232	0.0063	0.0004*	0.00193	0.0143
NPK^2	2	0.0152	0.1470**	0.577	0.0069	0.0021	0.00094	0.0291
NP^2K^2	2	0.0028	0.0098	0.119	0.0038**	0.0008	0.00124	0.0469
NP^2K	2	0.0001	0.0056	0.004	0.0084	0.0035*	0.00017	0.0872*
Error	22	0.0101	0.0034	0.415	0.0048	0.0009	0.00380	0.0198

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX VII

Analysis of variance table

Source	DF	Mean squares		
		Total uptake of nitrogen	Total uptake of phosphoric acid	Total uptake potassium
Block	5	442.89*	60.58**	828.47
N	2	13973.20**	563.46**	14479.28**
P	2	1705.39**	188.55**	145.53
NP	4	446.92**	27.60	543.89
K	2	30.88	0.851	1753.11*
NK	4	147.77	11.23	372.91
PK	4	26.52	11.57	631.29
NPK	2	706.50**	29.02	454.8
NPK^2	2	199.00	23.33	85.10
NP^2K^2	2	309.40	45.93*	711.11
NP^2K	2	9.17	43.26*	938.49
Error	22	94.95	10.18	431.87

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX VIII

Analysis of variance table

Source	DF	Mean squares				
		Soil reaction	Organic carbon in soil after harvest	Available nitrogen in soil after harvest	Phosphorus in soil after harvest	Potash in soil after harvest
Block	5	0.117*	0.06090**	292.24**	6.628	913.91
N	2	0.061	0.00575	3633.27**	26.574	2290.58*
P	2	0.000046	0.01530	68.69	329.035**	313.27
NP	4	0.023	0.00748	1359.80**	51.926**	6663.25**
K	2	0.013	0.00135	681.66**	87.438**	2155.89*
NK	4	0.016	0.00507	405.39**	14.985	958.75
PK	4	0.020	0.00399	64.61	23.434	945.50
NPK	2	0.016	0.01560	645.38**	8.135	346.59
NPK^2	2	0.0046	0.01930	143.48†	21.890	95.18
NP^2K^2	2	0.0003	0.00413	65.98	14.704	833.44
NP^2K	2	0.012	0.02060*	327.30**	17.663	62.66
Error	22	0.0181	0.00496	40.23	10.371	534.47

*Significant at 5 per cent level

**Significant at 1 per cent level

RESPONSE OF RAGI (*Eleusine coracana* Gaertn.) TO DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS & POTASSIUM UNDER RAINFED CONDITIONS

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ABSTRACT OF A THESIS

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ABSTRACT

Response of ragi (Eleusine coracana Gaertn.) to different levels of nitrogen, phosphorus and potassium under rain-fed conditions.

An experiment was conducted at the Rice Research Station, Pattambi during the Kharif season of 1979-80 to study the effect of nitrogen, phosphorus and potassium on growth, yield and quality of ragi (Eleusine coracana Gaertn.). Three levels each of nitrogen (30, 60 and 90 kg/ha), phosphorus (20, 40 and 60 kg P_2O_5/ha) and potash (20, 40 and 60 kg K_2O/ha) have been tried. The trial was laid out as partially confounded factorial experiment with two replications.

The study revealed that nitrogen had significant influence on plant height, number of tillers, functional leaves at flowering and dry matter both at flowering and harvest. Phosphorus influenced the production of tillers and dry matter at harvest. Potash significantly increased the plant height on 71st day after planting and at harvest. Potash did not evoke any response on any other growth character at any stage.

Among the yield attributes, number of productive tillers, number of fingers per earhead and length of earhead

were significantly increased by nitrogen and potash. Phosphorus enhanced the number of productive tillers and length of earhead.

Application of nitrogen increased the grain and straw yield significantly and the response of grain yield was linear. Phosphorus and potash significantly increased the grain yield only and the responses were quadratic. The optimum and economic doses of phosphorus were 51.7 and 51.65 kg P_2O_5/ha and that of potash, 54.13 and 54.09 kg K_2O/ha respectively.

Application of nitrogen and potash significantly increased their content in grain and straw and the uptake of the respective nutrients. Addition of nitrogen increased the uptake of phosphorus and potassium significantly. Application of phosphorus increased the content of nitrogen, phosphorus and potassium in straw and the total uptake of nitrogen and phosphorus at harvest. Protein content of grain was increased significantly by nitrogen only.

Nitrogen and potash fertilization significantly increased the nitrogen and potash content in soil after harvest. The phosphorus content in soil was significantly increased by phosphorus and potash fertilization. Soil

reaction and the organic carbon content in soil remained unaffected by the fertilization.

There was significant positive correlation between grain yield and height of plants at harvest, number of tillers at harvest, number of productive tillers, length of earhead, number of fingers per earhead and total nitrogen, phosphorus and potassium uptake.

The combined effect of nitrogen and phosphorus was found to be significant and the combination $N_{90}P_{60}$ gave the maximum values of number of tillers on 56th and 71st day after planting and at harvest, productive tillers, nitrogen content in straw, phosphorus and potash content in soil after harvest and the total uptake of nitrogen by the plants. The combination $N_{90}P_{20}$ gave the highest value of nitrogen content in soil.

The combined effect of nitrogen and potash was found significant and the combination $N_{90}K_{60}$ gave the highest values of number of fingers per earhead and grain yield. The combination $N_{90}K_{20}$ gave the maximum value of nitrogen content in soil.

The interaction between phosphorus and potash was significant on length of earhead and grain yield. The combinations $P_{20}K_{40}$ and $P_{40}K_{40}$ gave the highest values of length of earhead and grain yield respectively.