RESPONSE OF CO.7 RAGI (*Eleusine coracana*) TO PHOSPHATE AND POTASH

By

K RAMAKRISHNAN NAIR, B Sc B Sc (Ag)

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CHAPTER I

INTRODUCTION

Millets, as a cultivated group among cereals, occupy a unique place among world crops. The pride of place millets hold among the cereal crops can be guaged from the fact that it forms the source of staple food for a fourth of the world population. This group with its high temperature adaptability, short duration maturity and efficient capacity for proper utilisation of water, has become highly important particularly in the tropics.

India is one of the major millet producing countries in the world with an annual output of 16 million tons grains from a total cultivated area of 86.5 million acres of land. In Madras State 30 percent of the human and 60 percent of the cattle population depend directly on this important group of cereals.

Ragi (_Eleucine coracana_, Gertn.) the 'Finger Millet' occupies an important place among millets mainly on account of its hardiness, adaptability to varying soil and climatic conditions and its nutritive value.

In India, Ragi is cultivated over 6.2 million acres, with an annual output of the order of 1.88 million tons of food grain. The provinces growing this crop are Mysore, Madras, Gujarat, Maharashtra, Bihar, Andhra, Orissa and Uttar Pradesh. Out of this, Madras State ranks first in per acre yield, though second in extent of cultivation and production in our country. In this State, Ragi cultivation extents over 0.87 million acres, with an annual production of 0.35 million tons of grain. Out of 8,75,000 acres of land under this crop, 45 percent of the area is under irrigated cultivation which could be the probable reason for the higher per acre output in this State.

Ragi stands out among other cereals with its relatively higher nutritive value. Some strains of Ragi can compare favourably well with the high nutitive barleys in protein content. In the supply of available calcium, Ragi has a higher rating than rice or other cereals. The protein of Ragi, "Eleusinin" has a high biological value and is considered superior to gliadin of wheat. The nutritive value of the average diet largely based on rice could be profitably improved by replacing part of the rice with Ragi (Gopal Iyengar, et al. 1945).

The grain can be stored even upto 50 years if kept out of contact with moisture. Ragi grain is extensively used in malt industry.

Besides, the crop provides excellent fodder for cattle and the green straw is fed to milch cattle with advantage. Ragi straw could also be ensilaged successfully, the same having a sweet smell usually relished by cattle (Mudaliar, 1960). Considering all the above factors, Ragi promises to take the premier place among millets in India.

Millets in general, extensively grown in scarcity tracts of low rainfall, received scant attention in improved cultivation practices till the first quarter of this century.

Due to low cost of Ragi grain prevailing during these years, farmers were generally averse to improved methods. Not being a cash crop, the application of fertilisers also was not very common.

The above situation would roughly hold true in so far as scientific investigations in Ragi also are concerned. Investigations into the nutritional requirements of the crop have been very limited.

According to Ignatieff and Page (1960) factors such as availability of plant nutrients, physico-chemical properties of soil, plant diseases and insect pests, weeds, and hazards of flood and violent winds are responsible in deciding the performance of any crop in general.

Engledow (1929) discussing the problem on cereal yields attributed two factors for the variations in yield; (i) the internal factors - inherent to the plant - and (ii) the external factors - environmental factors. Comparatively much work seems to have been undertaken as regards the internal factors. The evolution and subsequent release of numerous high fertility strains in the cultivated crops is a direct result of such works. However, work on the external factors seems to be very limited.

Having established that the increase in crop production is the interactional function of the inherent capacity of the individual plant population on one side, and the external factors of production on the other, it stands to reason to presume, that a judicious selective utilization of both these is the surest way for securing higher yields in any crop. Adequate supply of the essential nutrients to the plant through manuring will go a long way towards ensuring success in the production of crops (Tisdale and Nelson, 1961). As a result of this broad finding, great progress in fertilizer technology and in the use of plant nutrients have been made in modern agriculture.

The cereal crops in India have responded very well to applications of major nutrients with special reference to nitrogen. Nitrogen uptake in crops like rice wheat, sorghum and maize was studied by Sen (1916), Tremble (1926), Acharya (1951), Weinman (1956) and others to determine the nutritional status of the crops and to fix up manurial schedules.

Manurial experiments conducted on Ragi on a very limited scale at Coimbatore in 1931 showed that a combined application of N, P and K gave the maximum yields (Viswanath, 1931).

Venkataramana and Krishna Rao (1961) investigating into the nutrient uptake of Ragi reported 21 lb. N, 15 lb. P_2O_5 and 20 lb. K_2O as the figures per acre.

In the deliberations of the Fertilizer Seminar held in April 1959 at Coimbatore an arbitrary manurial schedule of 40 lb. N, 20 lb. P_2O_5 and 20 lb. K_2O over a basal dressing of five tons of farm yard manure was recommended for Ragi.

Investigations carried out by Karunakara Shetty (1961) showed Ragi responded to 40 lb. N. Similar studies by Ranganathan (1962) showed response for N at still higher levels - viz., 80 lb N per acre.

Thus it will be seen that apart from nitrogen, data is limited in regard to studies with levels of P_2O_5 and K_2O in combination with N.

There appears to be considerable scope for further augmenting crop yields of Ragi by adopting suitable manurial schedule based on the balancing of nutritional requirement of the crop. Therefore, the present investigation is an attempt to find out effect of graded doses of P_2O_5 and K_2O in combination with a common dose of 60 lb. N and five tons of farm yard manure on the yield potential of popular high fertility Ragi strain Co. 7 of the Madras State and to make a suitable recommendation thereby.

CHAPTER II

REVIEW OF LITERATURE

Role of Elements in Plant Growth.

Of the thirteen essential elements obtained from the soil by plant six are used in relatively large quantities and consequently receive first attention. Of these six itself, in a country like ours, with its agricultural background attention is found focused on the three major essential elements viz., Nitrogen, Phosphorus and Potassium, as they are required in larger proportions. The investigations into requirements of nitrogen have been found to be more, numerically as nitrogen fertilizers have been found to be most effective in increasing yield in almost all trials (Abhichandani, 1959).

In summaring the effect of nitrogen on crops, Lyon et al (1952) states as follows: "Nitrogen encourages above ground vegetative growth and imparts to the leaves a deep green colour. With cereals it increases the plumpiness of the grain and their percentage of protein. It is a regulator by governing the utilisation of potassium, phosphorous and other constituents. Plants receiving insufficient nitrogen are stunted in growth and leaves turn yellow. Over supply of nitrogen is also detrimental. It may delay maturity by encouraging excessive vegetative growth, weakens the straw and encourages lodging, lower the quality and it may also decrease resistance to diseases".

(1) Response to nitrogen and organic matter requirement:

Several experiments conducted particularly in Ragi have conclusively shown that the crop had a positive response to nitrogen when applied as a nutrient. The response quantitatively evaluated for the Coimbatore district stood at 6.88 maund for 30 lb. per acre.

Sanyasiraju (1952) recorded response in Ragi at Coimbatore to applications of nitrogen alone and in combinations with P_2O_5 and K_2O. Narasimhamurthi (1952) reported response of Ragi for 30 lb. nitrogenous groundnut cake at Agricultural Research Station, Anakapalli, which was found to be the economic dose. Narasimhamurthi (1956) at Anakapalli recommended 20 lb. N along with 4000 lb. of green leaf or 40 lb. N as groundnut cake for irrigated Ragi.

Reports on the comparative trials on the efficiency of compost and farm yard manure on the yield of Ragi, at Coimbatore and Palur showed that the manured plots recorded significantly increased yield but among the forms there was no difference at 60 lb. N level.

Narasimhamurthy <u>et al</u>.(1958) reported that at Anakapalli the Punasa (early season) Ragi responded to top dressing of 40 lb. nitrogen and 20 lb. nitrogen as ammonium sulphate better than the application of 4500 lb. green leaf and 10 tons of farm yard manure.

Willimott and Anthony (1958) reported that 76 lb. N per acre gave a significant increase in grain yield of Ragi on a dark sandy loam in Sudan, while 38 lb. N per acre increased the yield only slightly.

Karunakara Shetty (1961) in his studies on the varietal response of Ragi to nitrogen recorded that Co. 7 Ragi responded well to nitrogen doses upto 60 lb. per acre.

Ranganathan (1962) investigating the nitrogen requirements of Ragi reported positive response at levels of 60 lb. per acre and above.

(ii) Response to Phosphorous:

The relationship of phosphorous to growth has long been recognised but its important role in plant life is only now beaing fully realised. This element has long been known to be a constituent of nucleic acid, phytin and phospholipids. It has also been associated with early maturity of crops particularly the cereals and a shortage of this element is manifested by a marked reduction in plant growth.

Excess of phosphates over the amount required by the crop sometimes depresses crop yields (Russel, 1961).

Of the three essential plant nutrients, next to nitrogen, phosphorous is found to be very important. Sethi (1959) estimated that about 60 per cent of the agricultural soils in India do not contain a high reserve of phosphorous and out of the total quantity of nutrients present, only one fifth is available to plants.

Dutoit and Seater (1939) found that green plants absorb more of phosphorous in the presence of nitrogen. Sircar and

Sen (1941) growing paddy at three different levels of phosphorous found that the greatest intake of nitrogen was associated with the highest phosphorous level. Grenes, Miller and Schenehl (1958) while investigating the influence of various elements on plant absorption have recorded that the absorption of phosphate is stimulated by the presence of nitrogen. Grenes et al. (1958) have recorded that the addition of nitrogenous fertilizers generally increased the percentage of the total phosphorous absorbed by plants from bands of super phosphate. The addition of ammonium sulphate with the phosphorous band was effective in increasing the percentage of the total plant phosphorous derived from the fertilisers.

Phosphorous is known to influence the development of roots, maturation of crops and the composition of the crop in general. Noll, as quoted by Collings (1954) found out that phosphorous hastened maturity of small grains and corn in Pennysilvania Experiment Station. Panikkar (1960) reported that Indian soils are deficient in phosphorous and recorded positive results on phosphate fertilization on sorghum. In paddy there are several experiments to prove the positive response of P_2O_5 invariably in combination with N.

Raheja (1960) in discussing the simple fertiliser trials conducted on paddy and the respective responses of the crop to both N and P_2O_5 stated that at 40 lb. per acre level the responce to P_2O_5 and N was 1½ times that at 20 lb. per acre levels. The response to a combination of 20 lb. N + 20 lb. P_2O_5 per acre was almost equal to 40 lb. N per acre in paddy and wheat. Further works are also available to prove the efficiency of P_2O_5 for accelerating the absorption of N by rice and thus hastening the maturity as reported by Okada (1931).

Govindarajan and Venkata Rao (1952) reported that significant yield increases were obtained in rice and Ragi by applying P_2O_5 through a preceding green manure crop.

However, there are several parallel findings also showing partial or total lack of response to P_2O_5 fertilization.

Stewart (1947) discussing the manurial experiments in India observed that numerous experiments of broadcast dressings of phosphate fertilizers have failed to show a response in yield but many conflicting results obtained showed that shallow rooted crops responded better than the deep rooted crops. He also recorded that in many instances, where phosphate alone had little effect on yield, its combination with nitrogen might be markedly superior to nitrogen alone.

Panse *et al.* (1947) observed that there was little or no response to phosphorous singly or in combination with nitrogen in linseed in 24 trials.

Chin (1950) stated that the response to P_2O_5 was significant in red soils, low in P_2O_5, but there was little response on alluvial soils higher in phosphorous. Takijima, Shiojima and Konno (1959) expressed the opinion that increased P_2O_5 rate accelerated tillering but inhibited panicle growth.

Raghavan (1959) discussing the model agronomic experiments on sorghum showed that at all centres the response to P_2O_5 was absent or low, except at Akola where it was moderate with 2.3 maunds increased yield of grain for 20 lb. P_2O_5.

Kapp (1938) stated that though the addition of 500 lb. per acre of Ca $(H_2 PO_4)_2$ increased the phosphorous content of rice plants at 57 and 88 days of growth, did not affect the final yields of rice favourably.

Ayi (1935) reporting on certain retarding effects of P_2O_5 showed that top dressing of super caused a decrease in yield of both straw and grain in early stages of growth. The minimum amount of P_2O_5 retarding growth depended on variety as well as on the temperature throughout the period of plant growth.

According to Mahapatra and Sahu (1961) the response to P_2O_5 is lower than that of N applied at equal level. Three levels viz., 0,20 and 40 lb. P_2O_5 per acre were tried and the optimum dose appeared to be 20 lb. though the difference in yield due to levels of P_2O_5 was not significant.

Angladette <u>et al</u>. as quoted by Ignatieff and Page (1960) reported that in India where millets are most successfully grown on the black soils, gave the greatest response to nitrogen but phosphorous had little effect while sorghum responded best to ammonium sulphate. They also reported that on the whole for millets a balanced nitrogen phosphorous fertilizer appeared to be most satisfactory.

In the presence of adequate doses of N, better response is thus generally reported for P_2O_5. Persuing an investigation on this basis in the Bombay State, Pandya, Chavan and Shendge (1955) showed that there was considerable response, to N and P_2O_5, 40 lb. and 20 lb. respectively per acre with a basal dose of three cartloads of farm yard manure for which treatment the highest yield was recorded.

(iii) Responce to potassium:

The importance of potash fertilization has received full recognition only in comparitively recent years. The reasons that widespread deficiency of this element did not develop until recently are at least twofold. Firstly, the supply of available potassium originally was so high in most soils that it took many years of cropping for a serious depletion to make its appearance. Secondly, even though the potassium in certain soils may have been insufficient for optimum crop yields, production was much more drastically limited by a lack of nitrogen and phosphorous.

John Russel (1961) stated that the potassium supply in the soil may be adequate for crops growing under conditions of low nitrogen and phosphorous supply, but becomes inadequate if they are increased. Signs of potassium starvation are seen when only nitrogen and phosphorous fertilizers are applied to the crop. Hence of late, most of the crops show signs of potash deficiency though potash is available in Indian soils (Jacob, 1959).

In the U.S.A. both negative and positive responses to application of potash have been reported by Christidis and

Harrison (1955).

In Egypt, potash application showed a slight effect in increasing yield only in six cases out of 23 trials carried out in 1955. Skinner *et al.*(1944) obtained a response to 36 lb. of potash in Georgia Experiment Station and afterwards a negative response was noticed due to increased doses. Mukerjee (1956) in India studied potash response in paddy and obtained a mean response of 1.4 maund per acre and 1.98 maund per acre respectively for 20 lb. and 40 lb. of potash.

Bederkar, Joshi and Shaligram (1958) discussing the studies in Agronomy of application of organic manures stated that Indian soils were generally speaking sufficiently supplied with potash. Ghose, Ghatge and Subramanyan (1960) have stated that potassic fertilizers have generally given no response except in Bihar. Wehant, Ralph, Stelly and Collins (1947) reported similar findings after investigating the potash behaviour in corn and stated that potash generally increased the K content and yield of corn; but in contrast to N these effects were more outstanding when the original content of the exchangeable K was low in the soil. Rahoja and Yawalkar (1959) while discussing crop response to potash under Indian conditions held the view that response to potash fertilizers cannot be predicted from exchangeable potassium content of soils or from textural classification of soils. On the other hand, perhaps the degree of K_2O saturation would be a more reliable index for potash response as all the soils that gave good response to potash have relatively poor K_2O saturation.

In the report of the results of Fertizer Demonstrations in India, 'Kharif' 1957-58 - conducted by the Indian Council of Agricultural Research while discussing the response to potash it was recorded that in Bombay soils 40 lb. per acre gave a response of the order of 5.4 maunds in paddy.

A soil may contain as much as 20 tons of total potash per acre, yet need potash fertilizer to supply readily available potash for proper plant growth.

(iv) Balanced Fertilization:

In the science of plant nutrition every nutrient has a certain specific function to perform and the deficiency of any one element cannot be compensated by supplying some other element in excess. Again, the efficiency of a nutrient like nitrogen is greatly enhanced when it is used in conjunction with phosphorous.

Just as phosphorous helps in the better utilization of nitrogen, potash also helps in the better assimilation of nitrogen and phosphorous.

A certain balance among the various nutrients is essential if the greatest efficiency in the use of fertalizer is to be obtained. Under Indian conditions, experiments have shown that it is possible to obtain a considerable increase in crop yield for a few years by applying nitrogen fertilizer alone, the soil providing P_2O_5, K_2O and other nutrients from its mineral resources. This however is a short sighted policy.

(v) Interaction of nutrients:

Russel (1961) elaborating on the "Law of the Minimum" stated that if the crop response to the two factors together equalled the sum of its response to each separately, we would say the two factors showed no interaction - or worked entirely independently of each other and if the response to the two factors together was less than the sum of the responces to each factor separately, they are said to have a negative interaction with each other.

(vi) N and P interactions and requirements:

Hendry (1928) reviewing the manurial experiments in paddy pointed out that best yields in paddy were obtained where N and P_2O_5 were in the ratio 1:1 and 1:3. According to Okada (1952) application of P_2O_5 increased the absorption of N by rice and hastened maturity. Wyche (1941) in his studies on the fertilizer aspects for rice in Texas pointed out that there was a linear response to N as far as the yield was concerned. He also stated that there was response to P_2O_5 alone, but N + P was found superior to N alone. Opinions expressed by Anandan and Srinivasan (1945) were also in conformity with these findings in general and reported that P alone or N alone was not satisfactory and remunerative as 30 lb. N + 20 lb. P_2O_5 for rice. Karunakar (1951) has also expressed similar opinion.

Sethi, Ramiah and Abraham (1952) reviewing the survey of fertilizer trials in India, observed that though many of the rice soils were deficient in P_2O_5 its application did not give appreciable response. They were of the opinion that repeated application of N may aggravate the P deficiency. In order to offset the malady they have suggested the pre-treatment of seed with P_2O_5 to overcome the deficiency. Paul (1953) obtained slightly different findings in his combined varietal cum manurial experiments in rice. He observed significant increase in yield for both 20 lb. and 40 lb. N, but for P_2O_5 significant increase was obtained only at 40 lb. Discussing the findings over 2500 demonstrations and trials conducted on paddy in Madras State, Mariakulandai and Srinivasan (1959) reported the superiority of a combination of P_2O_5 and N in increasing the yield by 39.4 percent and the profit by Rs. 49:9 per acre.

However, Relwani (1959) on the contrary under different conditions, found that phosphorous fertilisation was uneconomic and that 40 lb. per acre N was more profitable than 20 lb. N or combination with P_2O_5.

(vii) NPK - Interaction and requirements:

Arakeri *et al.* (1962) discussing about extensive fertilizer trials on the farmers' fields pointed out that most of the Indian soils gave an economic response to the application of P_2O_5 and some response to K_2O. Similarly the application of phosphates and potash fertilizers according to Kohnlein and Mauern (1959) have shown that phosphatic fertilizers given in a slight excess over the actual P_2O_5 uptake by the crop suffice to produce high yields; very high rates rarely produce surplus.

According to Abichandani (1959) the soils in India need both nitrogen and phosphorous for increasing production. Response to potash applications have however not been adequate enough. Nitrogen fertilizers have been found most effective but highly significant yield increase to phosphate applications have been obtained only in a few localised areas in the country.

Crowther and Yates (1941) were of the opinion that response to phosphate and potash was substantially reduced in presence of dung. Discussing on the interaction of the positive and negative type they suggested that there was positive interaction between N and P with some indications of a similar but smaller interaction between N and P. Little interaction was reported between K and P.

Aiyar (1948) obtained data to show the depressing effect of P and K when the two nutrients were used together. Mukherjee and Sinha (1953) working on potash response in Bihar soils came out with different findings. They found that K_2O in combination with N and P_2O_5 would increase the yield of paddy by 2.3 maunds per acre, in almost all the soil types of Bihar State.

Dubey and Das (1961) after analysing the results of experiments with three levels of N, P and K found that P_2O_5 was not efficaceous at higher levels. They also found that K at higher levels depressed the yield which was not significant.

Commenting on the results obtained at Coimbatore, Panse et al. (1946) observed a depressing effect of 50 lb. K_2O on crop yields in the old series of plots and a response of 0.8 and 0.5 lb. of jowar per pound of K_2O in new series with and without basal manures.

Norris (1923) in his 'Note on the Permanent Manurial plots at Coimbatore' after studying the results of a series of observations over a large period reported as follows;

1. In the early years of the experiment the plots responded to both nitrogen and phosphoric acid.
2. The phosphates have been more rapidly exhausted than the nitrogen and has now become a limiting factor so that the addition of nitrogen alone produce but a small increase of crop whereas the effect of phosphate becomes more marked each year.
3. Addition of potash has had no consistent effect in the case of cholam or wheat but has materially increased yield of Ragi both in grain and straw though chemical analysis indicated that the soil was already well supplied with available potash.
4. The addition of phosphate has also enabled the grains to take up a further supply of potash though the difference in this case is not so marked.

Viswanath (1931) reviewing the above series of experiments pointed out that it was evident that phosphate had become a limiting factor in those plots. There was no response to nitrogen, but it was much less due to phosphate. In the case of plots receiving no phosphate, the response to N was limited by the deficiency of P_2O_5. This was seen when the increases due to nitrogen and potash singly and in combination between themselves were compared. According to him the actions of potash was not clear. While in the case of cholam and wheat it tended to show a depressing action, in the case of Ragi it had a marked beneficial effect.

Venkataramana and Krishna Rao (1961) working on the uptake of Ragi at Hydrabad found that the nutrients removed by a crop yielding 1000 lb. of grain and 4000 lb. of straw were of the order of 21 lb. N, 15 lb. P_2O_5, and 20 lb. K_2O per acre.

Sanyasiraju (1952) recorded response in Ragi at Coimbatore to applications of nitrogen alone and in combination with phosphorous and potash. Mariakulandai (1960) recommended a manurial schedule of 40 lb. N, 20 lb. P_2O_5 and 20 lb. K_2O per acre over a basal dose of five tons of cattle manure for irrigated Ragi crop. Ponnaiya and Subramanian (1962) recorded response of Co. 7 Ragi to doses of 40 lb. N, 40 lb. P_2O_5 and 20 lb. K_2O per acre. Though nitrogen is a predominant factor in increasing the yield in Ragi grain, phosphorous and potassium are also necessary for the satisfactory plant growth (S.S.S.1960).

From the fertilizer trials conducted in Uganda for three years in Ragi from 1946 to 48, it was observed that combinations of N and P_2O_5 gave an yield increase of about 50 percent, while the increase in yield due to P_2O_5 alone was only 15 percent (Manning and apGriffith, 1949).

In the fertilizer trials conducted by the 'potash scheme' on Ragi and as reported in 1960, highest yields and profit was attributed to an even dose of 30 lb. N, 30 lb. P_2O_5 and 30 lb. K_2O over a basal dressing of over 5000 lb. farm yard manure.

From the foregoing review, it is clear that the application of N, P and K in varying levels have contributed for higher yields in Ragi. Though deleterious effects were recorded at higher dosages of N, P and K fertilizers in crops like rye, oats and barley, Ragi has been found to respond positively to such high levels as 60 lb. N, 40 lb. P_2O_5 and over 30 lb. K_2O individually and in combinations. Hence it is evident that inspite of conflicting views in adopting increased dose of nutrients, very little work seems to have been done in finding out a proper balance of P and K to be applied with N for Ragi, especially for the high fertility strains. Such a precise investigation on the proper balancing of P and K on Ragi seems highly called for.

Hence this investigation was initiated with a view to study the effect of graded doses of phosphoric acid and potash both individually and in combination with a uniform basal dose of nitrogen and organic matter on the yield and allied economic characters of Ragi.

CHAPTER III

MATERIALS AND METHODS

The investigation was undertaken to fix up an optimum level of P_2O_5 and K_2O for irrigated Ragi crop.

1. Seed Material:

The Ragi strain selected for the investigation was Co. 7. This is one of the most popular short duration strains of Coimbatore being an extracted type from Rajampet variety released for cultivation in the year 1963. The variety combines in itself the desirable characters like adaptability to wide range of soil types, climatic conditions and high fertility and also gives a good response to heavy doses of manures. This short duration strain with 100 days from seed to seed is a popular variety widely cultivated in Madras State, mainly on account of its adaptability to be cultivated as a rainfed or an irrigated crop. Plants are non pigmented with incurved earheads. Agronomic investigations on this are very limited and hence the strain was selected for the investigation.

Millet Breeding Station, Coimbatore supplied the seed material.

2. Field

The investigation was laid out in the field No. 6 of the New Area Block of the Central Farm, Agricultural College and Research Institute, Coimbatore.

Soil analysis was conducted for total and available P_2O_5 and K_2O and the following values were obtained.

Total P_2O_5	--	0.0565 percent.
Available P_2O_5	--	0.0527 percent.
Total K_2O	--	0.6530 percent.
Available K_2O	--	0.0269 percent.

3. (i) Manures: A dose of five tons of farm yard manure was applied as basal dressing.

Nitrogen was applied in all the plots at a uniform dose of 60 lb. per acre as ammonium sulphate. Ammonium sulphate has been proved to be the best source of nitrogen for Ragi crop by various workers (Miller, 1955 and Willimott *et al.*, 1956; Narasimhamurthy *et al.*, 1956).

The level of nitrogen selected for the study was a flat dose of 60 lb. per acre for all treatments as previous investigations with the same strain under similar conditions have shown positive response for this dose (Karunakara Shetty, 1961; Ranganathan, 1962).

P_2O_5 was applied in the form of superphosphate at three levels of 0 lb. 20 lb. and 40 lb. per acre, one level graded above and one below to the dose recommended by the fertilizer workshop in Madras for Ragi.

Similarly, K_2O was applied in the form of muriate of potash at three levels 0 lb. 20 lb. and 40 lb. per acre based on the above recommendations.

(ii) Treatments: The following were the nine combinations of treatments included in the trial.

Treatment No. as in the layout.	N	P_2O_5	K_2O
	lb.	lb.	lb.
7	60	0	0
8	60	20	0
9	60	40	0
5	60	20	20
4	60	0	40
1	60	20	20
6	60	40	40
2	60	40	20
3	60	40	40

Farm yard manure at five tons per acre was applied as basal dressing.

The different levels of nutrients are denoted by the following symbols.

A. Fertilizer levels.

60 lb.	Nitrogen	N_1
0 lb.	Phosphoric acid	P_0
20 lb.	Phosphoric acid	P_1
40 lb.	Phosphoric acid	P_2
0 lb.	Potash	K_0
20 lb.	Potash	K_1
40 lb.	Potash	K_2

D. Stages.

First stage	30 days	S_1
Second stage	60 days	S_2
Third stage	90 days	S_3

(iii) Application of manures: Farm yard manure in well rotted condition was applied 20 days before planting and well worked into the soil.

The full quantity of the three fertilisers was applied in a single dose before transplanting and worked into the soil with two pronged light hand rakes.

4. Layout:

Design - Randomised Block

Size of plot

Gross - 22' x 10'

Net - 21' x 9'

Replications - Four

Spacing - 6" x 6"

Since the number of treatments involved were nine, the design and the number of replications as shown above was selected and fixed as suggested for standard Agricultural experimental techniques.

5. Sowing and Transplanting:

The required quantity of seed material was sown in separately prepared nurseries adjoining to the main field, the nursery area having been previously manured with well rotten farm yard manure. Irrigation source for the nursery and main field was from well No.8. Sowing in the nursery was done in the middle of February.

Seedlings were pulled out for transplanting on the 25th day after sowing and planted in the main field the same day. Based on the findings at Anakapalli (1946-49) and by Ranganathan (1962) at Coimbatore, single seedlings were planted, the main field being put under life irrigation. Seedlings thus transplanted were found established in six days.

Irrigation was given once every week on the average, taking into consideration the rainfall that was available.

The general condition of the plant was good and hence necessity for any plant protection works did not arise.

6. Characters studied:

Forty four plants per plot were selected at random, labelled and the following attributes were studied.

All measurements were recorded in the metric units. Measurements were taken and observations made at stages of 30 days, 60 days and 90 days of the growth of the crop, for characters available at each stage respectively.

(i) Number of tillers: The total number of tillers - both productive and unproductive - was recorded at three stages.

(ii) Height of plants: The height of the plants was measured from the base to the tip of the panicle.

(iii) Number of leaves: Total number of leaves in the plant was recorded.

(iv) Number of earheads: Total number of earheads in the plant was counted at two stages.

(v) Length of main earhead: Length of the main earhead from the base of the panicle to its tip was recorded.

(vi) Number of fingers in earhead: Number of fingers in the main earhead was counted.

(vii) Weight of earhead: Weight of the main earhead was recorded.

(viii) Weight of grain: The yield of grain from the marked plants in each treatment and total yield of grain from each treatment was recorded.

(ix) Weight of straw: Wet weight of straw also was recorded treatmentwise.

7. Harvest:

At the mature stage two rows on all sides of each treatment plot were removed to eliminate the border effect and earheads were harvested. Collection of earheads were taken up in two stages with an interval of seven days. The marked plants were separately harvested.

C. Analysis of grain for N, P and K.

The chemical analysis for the nutrients were done as per procedures suggested by the A.O.A.C. (1955) through the following methods;

Nitrogen	Kjeldahl's method
Phosphorus	A.O.A.C. method
Potash	Cobalt nitrate method

9. Analysis of data.

The yield data and other characters as shown above were subjected to statistical analysis for significance in yield, correlations and interactions.

CHAPTER IV

EXPERIMENTAL RESULTS

The observations made at different growth phases of the crop Co. 7 Ragi and the data thus collected on the various plant characters, analysed statistically are presented in the tables below:

Analysis of variance table for each characters observed was worked out.

I. A. Number of tillers:

Table I - A. indicates the effect of different treatments on the number of tillers.

TABLE - I -A.

	Treatments	Mean No. of tillers average of 3 stages	S.E.	C.D.
1.	$N_1 P_1 K_1$	144.0		
2.	$N_1 P_2 K_1$	151.2		
3.	$N_1 P_2 K_2$	148.3		
4.	$N_1 P_0 K_2$	145.0		
5.	$N_1 P_0 K_1$	163.4	-	-
6.	$N_1 P_1 K_2$	154.1		
7.	$N_1 P_0 K_0$	150.3		
8.	$N_1 P_1 K_0$	158.3		
9.	$N_1 P_2 K_0$	159.6		

Conclusion: Though treatment $N_1 P_0 K_1$ has recorded the highest number of tillers, statistically it is not significant, no difference being found between treatments.

I. B. <u>Tillers - Stages.</u>

Table I - B indicates the influence of three stages on the production of tillers.

TABLE I - B

Stages of observations		Mean No. of tillers	S.E.	C.D. (P = 0.05)
First stage (30 days)	S_1	178.50		
Second stage(60 days)	S_2	149.89	3.05	8.06
Third stage (90 days)	S_3	129.09		

<u>Conclusion</u> S_1 S_2 S_3

Increased number of tillers during the first stage of the crop is highly significant over the second and third.

II - A. <u>Number of Ear heads:</u>

The number of ear heads as affected by the various treatments are furnished in Table II-A.

TABLE II - A

Treatments	Mean earhead No. averged over S_2 S_3	S.E.	C.D.
1. N_1 P_1 K_1	111.5		
2. N_1 P_2 K_1	119.2		
3. N_1 P_2 K_2	119.1		
4. N_1 P_0 K_2	136.1		
5. N_1 P_0 K_1	137.5		
6. N_1 P_1 K_2	134.1		
7. N_1 P_0 K_0	123.8		
8. N_1 P_1 K_0	123.7		
9. N_1 P_2 K_0	136.6		

<u>Conclusion:</u> Though treatment N_1 P_0 K_1 has given highest number of

earhead, the superiority of any of the treatment is not statistically significant.

II - B Number of earheads - Stages.

Table II - B indicates the influence of stages on the number of earheads;

TABLE II - B

Stages of observations		Mean No. of earheads per treatment	S.E.	C.D. (P = 0.05)
Second stage (60 days)	S_2	135.17	-	-
Third stage (90 days)	S_3	116.14		

Conclusion: S_2 S_3

The number of earheads formed was highly significant at the 60th day and was superior over the third stage (90 days).

III. A. Yield of grain.

The yield of grain as affected by the various treatments is given in Table III -A.

TABLE III -A.

Treatments	Mean grain weight per plot (gms)	S.E.	C.D (P = 0.05)
1. N_1 P_1 K_1	7895		
2. N_1 P_2 K_1	8541		
3. N_1 P_2 K_2	8469		
4. N_1 P_0 K_2	8457		
5. N_1 P_0 K_1	9283		
6. N_1 P_1 K_2	9055	309	900
7. N_1 P_0 K_0	8337		
8. N_1 P_1 K_0	7626		
9. N_1 P_2 K_0	8733		

<u>Conclusion:</u> 5 6 9 4 3 2 7 8 1

Treatment N_1 P_0 K_1 was found significantly superior but was on par with six other treatments as indicated above. $N_1P_1K_2$ was found to be superior, next in order.

III - D. Yield of grains - Interaction - P x K

Further splitting up of P and K in respect of interaction is given in Table No. III-D.

TABLE III-D.

K \ P	P x K Interaction mean			S.E.	C.D. ($P = 0.05$)
	0	20	40		
0	8337	7626	8738		
20	9209	7598	8341	320	960
40	8437	9056	8460		

Conclusion:

Level of K	Level of P	Level of P	Level of K
0	40 0 20	0	20 40 0
20	0 40 20	20	40 0 20
40	20 0 40	40	0 40 20

The only significance was seen at 20 lb. P_2O_5 with 40 lb. K_2 the other interactions showing some trends of results which are discussed later.

IV - A. Height of Plant.

The height of the plant as influenced by the different treatments is given in Table IV - A.

TABLE IV - A.

Treatments	Mean height of plant (cm.)	S.E.	C.D.
1. N_1 P_1 K_1	74.10		
2. N_1 P_2 K_1	73.56		
3. N_1 P_2 K_2	73.90		
4. N_1 P_0 K_2	72.90		
5. N_1 P_0 K_1	70.30	-	-
6. N_1 P_1 K_2	73.33		
7. N_1 P_0 K_0	74.30		
8. N_1 P_1 K_0	73.56		
9. N_1 P_2 K_0	73.70		

Conclusion: No statistically significant superiority was observed for any treatment as regards the height of the plants.

IV - B. <u>Height of Plant</u> - <u>Stages.</u>

Table IV - B indicates the influence of stages on the height of the plant.

TABLE IV - B

Stages of observation		Mean height of plant (cm.)	S.E.	C.D. ($P = 0.05$)
First stage (30 days)	S_1	59.04		
Second stage (60 days)	S_2	81.99	1.30	3.82
Third stage (90 days)	S_3	79.20		

Conclusion: $\underline{S_2 \; S_3} \; S_1$

The second stage (60 days) is significantly higher regarding the height factor of the plant but is on par with the third stage (90 days). The reduction in the height in the final stage is due to the maturing, drying and incurving.

V. Weight of straw.

Weight of the straw as influenced by the various treatments is furnished in Table V.

TABLE V

Treatments	Mean weight per plot (Kilogram)	S.E.	C.D.
1. N_1 P_1 K_1	26.43		
2. N_1 P_2 K_1	26.10		
3. N_1 P_2 K_2	28.10		
4. N_1 P_0 K_2	26.33		
5. N_1 P_0 K_1	26.53	-	-
6. N_1 P_1 K_2	27.19		
7. N_1 P_0 K_0	23.64		
8. N_1 P_1 K_0	26.82		
9. N_1 P_2 K_0	25.18		

Conclusion: None of the treatment was found superior as far as influence over straw yield was concerned.

VI - A. Grain - Nitrogen content.

Nitrogen content of the grain, as influenced by the various treatments is furnished in Table VI - A.

TABLE VI - A.

Treatments	Mean value percent	S.E.	C.D.
1. $N_1 P_1 K_1$	1.22		
2. $N_1 P_2 K_1$	1.33		
3. $N_1 P_2 K_2$	1.31		
4. $N_1 P_0 K_2$	1.26		
5. $N_1 P_0 K_1$	1.23	-	-
6. $N_1 P_1 K_2$	1.20		
7. $N_1 P_0 K_0$	1.26		
8. $N_1 P_1 K_0$	1.33		
9. $N_1 P_2 K_0$	1.37		

Conclusion: None of the treatment was found significantly superior in contributing to the nitrogen content of the grain.

VI - B. Grain - Phosphoric acid content.

Phosphoric acid content of the grain as influenced by the various treatments is furnished in Table VI - B.

TABLE VI - B

Treatments	Mean value percent	S.E.	C.D.
1. $N_1 P_1 K_1$	0.756		
2. $N_1 P_2 K_1$	0.773		
3. $N_1 P_2 K_2$	0.839		
4. $N_1 P_0 K_2$	0.776	-	-
5. $N_1 P_0 K_1$	0.777		
6. $N_1 P_1 K_2$	0.770		
7. $N_1 P_0 K_0$	0.806		
8. $N_1 P_1 K_0$	0.801		
9. $N_1 P_2 K_0$	0.763		

Conclusion: None of the treatment was found significantly superior in contributing to the phosphoric acid content of the grainC.

VI - C. Grain - potash content.

Potash content of the grains as influenced by the various treatments is furnished in Table VI - C.

TABLE VI - C.

Treatments	Mean value per cent	S.E.	C.D.
1. N_1 P_1 K_1	1.146		
2. N_1 P_2 K_1	1.089		
3. N_1 P_2 K_2	1.050		
4. N_1 P_0 K_2	1.088		
5. N_1 P_0 K_1	1.159	-	-
6. N_1 P_1 K_2	1.149		
7. N_1 P_0 K_0	1.103		
8. N_1 P_1 K_0	1.049		
9. N_1 P_2 K_0	0.990		

Conclusion: None of the treatment was found significantly superior in contributing to the potash content of the grain.

V~ Economics

The econom[illegible] c o t o ap l a [illegible] o d a treatment is furnishe[d] in Table [illegible]

TABLE VII

	Treatment			Grain yield lb/Ac	Value [illegible]		Straw [illegible] lb/Ac	Value [illegible]		Total value of produce np	
		P	K								
		1		2	3		4			6	
1	60	20	20	1750	61	[illegible]	[illegible]60			4	42
	60	40	20	1982	67		[illegible]			05	05
3	60	40	40	1958	603	[illegible]	601		30	1	63
4	60	0	40	956	604	60	60[illegible]	3	4		09
5	60	0	20	125	743		[illegible]		4		24
6	60	20	40	20[illegible]	7[illegible]		[illegible]	5		[illegible]	65
7	60	0	0	1921	67	30				03	07
8	60	20	0	1750	[illegible] 5	30	60	30	0	746	20
9	60	40	0	201	704	[illegible]	6467	14	7	646	91

Rates

100 kilogra[m] straw = Rs 2 2[illegible] np

1 kilogram grain Rs 0 35

1 lb P_2O_5 = 0 70 np

1 l[b] [illegible] = Rs 0 50

Conclusion Treatment [illegible] 60 lb [illegible] and 20 lb K_2O has given the [highest] pro[fit] of Rs 63 37np when compared with the control

Iincrease or decrease over control Rs np		Cost o er lizer k np		ost of Ferti l zer (F O np		Total cost L np		Profit or Loss R. np	
7				9		10		11	
( ) 62	45	4		1	0	24	00	( ) 58	45
(+) 1	16	2		1	0[illegible]	3[illegible]	0[illegible]	(36	84
(+) 11	66	2[illegible]	00	[illegible]0	00	46	00	(36	34
(+) 14	22				00	2[illegible]	00	([illegible]	75
(+) 73	37			1	0	10	0[illegible]	(+ 63	37
(+) 64	70	14	0		[illegible]	34	00	+ 30	70
( ) 87	67	14	0[illegible]			14	0[illegible]	1	67
(+) 48	04		00			2	0	+ 1	04

Treatment No 7 with 60 lb [illegible] 1 [illegible] a. 0 1 [illegible] 0 has been taken as the co trol o co [illegible] on [illegible] nc eases are indi c te [illegible] the symbol + a [illegible] de [illegible] t o s

CHAPTER V

DISCUSSION AND CONCLUSION

The present investigation was an attempt to study and find out effect of graded doses of P_2O_5 and K_2O over a basal dose of 60 lb. N and five tons of farm yard manure per acre, on the yield potential of popular high fertility Ragi Co.7 of the Madras State and to make a suitable recommendation.

Except for nitrogen, data is limited in regard to studies in the balancing of proper levels of P_2O_5 and K_2O in combination.

Field experiments were laid out in the Central Farm, Agricultural College and Research Institute, Coimbatore with three levels of P_2O_5, three levels of K_2O, a basal dressing of 60 lb. N and five tons of farm yard manure per acre.

The analysis of data for the grain yield indicated that there is a positive response for the 60 lb. N, 0 lb. P_2O_5, 20 lb. K_2O per acre treatment out of the nine combinations, while others were found to be on a par with this and some others inferior. Significant responses were not observed in all the plant characters studied. The interaction effect also however did not come out as significant in any of the characters. These are discussed hereunder.

1. Number of tillers:

From the observations recorded on this factor (Table I-A) it was found that, though a dose of 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O gave the highest mean values for the tiller count, the response was not significant for this character. Since the production of tillers, a vegetative aspect, is solely a function of nitrogen and the dose of this nutrient being uniform for all treatment combinations it is probable that no significant variation was observed between treatments as tiller production is positively influenced by nitrogen (Narasimhamurthy, et al., 1960).

However, highly significant increase in the production of tillers has been noted in the first stage i.e., 30 days phase followed by second and third respectively (Table I - B). This could be explained to be due to the comparatively faster rate of tiller production during the first stage, followed by second and third. In fact, at the second and third stages, there are some progressive loss of the tillers produced.

Tillering is said to be closely associated to the yielding capacity in cereals (Bonnet and Woodworth, 1931; Ayyangar, 1936; Simlote, 1947; Graphicus, et al., 1952 and Sikkar and Jain, 1950). However, Engledow and Ramiah (1930) working on wheat observed that beyond a critical level tillering did not influence the yield. This is attributed partly to the reduction in population and the progressive production of smaller earheads by the late formed tillers. This finding has been corroborated by Suryayya (1932) and Ramiah (1938). In the present investigations also, tillering was not found affected by different treatments.

2. Number of Earheads:

A comparison of the influence of the treatments (Table II-A) showed that though the fifth treatment viz., 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O per acre has given numerical superiority over others, it was not statistically significant.

However, in the study of the stages with regard to the above factor, it was found that the second stage i.e., 60th day was significantly superior to the third i.e., 90th day. This goes to show that there is a progressive loss of earheads between the second and third stage their becoming ineffective at the final stage. This could more be explained as a result of physical factors of extraneous nature, than due to any nutritional function as the treatments were not found to have influenced the characters under study at any stage.

3. Height of Plant:

The height of the plant (Table IV-A) has not been influenced significantly by any of the treatments. This could be explained to be due to the uniform dose of nitrogen and farm yard manure applied.

But, when comparisons between stages weremade (Table IV-B), the second stage showed significant superiority over the third and first. This goes to show that the plants have attained its maximum height by the 60th day compared to the 30th day stage and later there was a progressive reduction in height between the 60th day and 90th day. This could be attributed to maturing, drying and incurving of earheads at the final stage.

4. Yield of straw:

This factor also has not been positively influenced by any of the treatments(Table V). However, a significant positive correlation was observed between the grain yield and straw yield as furnished in Plate VIII. This finding is in support of the application of optimum doses of nitrogen for the full beneficial exploitation of the high fertility strain used in the present trial.

5. Chemical analysis of grain:

Chemical analysis of the grain for the major nutrients, nitrogen, phosphorous and potash (Table VI-A, VI-B and VI-C) showed that none of the treatments was significantly superior in contributing to the different nutrient elements.

6. Yield of grain:

A study of the comparative effects of the various treatments on the yield of grain (Table VII-A) shows that the maximum yield of 9222 gm. of grain per plot has been attributed to treatment No. 5 i.e., 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O per acre, closely followed by treatment No. 6 with an yield of 9059 gm. of grains per plot, the treatment being 60 lb. N, 20 lb. P_2O_5 and 40 lb. K_2O per acre. The superiority of treatment No. 5 is statistically significant. It is also noticed that six other treatments as shown in the tables were on par with treatment No.5 i.e., 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O per acre.

Nitrogen:

Several experiments conducted in Ragi have conclusively shown that the crop had a positive response to nitrogen when applied as a nutrient. Sanyasiraju (1952) recorded response in Ragi at Coimbatore to applications of nitrogen. Narasimhamurthy (1953) has reported a progressive increase in yield for irrigated Ragi for nitrogen levels of upto 50 lb. per acre.

Since the variety of Ragi used in the present investigation, Co. 7, was a recognised high fertility strain and the findings of Karunakara Shetty (1961) and Ranganathan (1962) were in favour of higher doses of nitrogen, the economic dose of 60 lb. was applied. The vegetative performance of the crop as seen from the tables have been justifiably favourable for this level of N.

Phosphorous

The fifth treatment combination i.e., 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O (Table I-I-A) has emerged as the most superior with a grain yield of 9222 gm. per plot (2125 kg = 4675 lb. per acre). In other words, applications of P_2O_5 at 20 lb. and 40 lb. per acre in different treatments have not favourably contributed to increased grain yields. From a study of the effect of P_2O_5 at the above levels, it goes to prove that at higher levels than 0 lb. P_2O_5, there has even been a depression of grain yield, treatment No. 8 with 20 lb. P_2O_5 yielding 7626 gm., treatment No. 9 with 40 lb. P_2O_5 yielding 8732 gm. per plot.

There are several experimental evidences to prove the partial or total lack of response to P_2O_5 fertilization. Stewart (1947) observed that numerous experiments of broadcast dressings of phosphate fertilizers in rice have failed to show a response in yield. Panse et al. (1947) observed that there was little or no response to phosphorous singly or in combination with nitrogen in linseed in 74 trials.

Chin (1960) stated that the response to P_2O_5 was significant in red soils low in P_2O_5, but there was little response in alluvial soils, higher in P_2O_5. Takijima, Shiojima and Konno (1955) expressed the opinion that increased P_2O_5 rate accelerated tillering but inhibited panicle growth. Raghavan (1959) reported the non response of cholam to P_2O_5 application, while Aye (1955) observed certain retarding effect for the nutrient in the yield of grain and straw in cholam.

Angladette et al as quoted by Ignatieff and Page (1960) reported that in India, where millets are most successfully grown on the black soils, gave the greatest response to nitrogen, but phosphorous had little effect.

With the value of the available P_2O_5 in the soil in which the present investigation has been conducted, standing at 0.0027 percent, which could be classed as high and the total P_2O_5 supplied through the farm yard manure showing 0.38 percent on analysis, estimated at 42.86 lb. per acre, it is reasonable to conclude that sufficient available P_2O_5 has been provided in the investigation, even in the 0 lb. P_2O_5 treatment combination. All other treatment combinations with higher levels of P_2O_5 have probably, therefore failed to significantly influence the yield.

The indications of the present findings when viewed in the light of the P_2O_5 status in the black soil and the quantity of P_2O_5 supplied through the farm yard manure thus gives a clearer picture of a trend for the nutrient under reference to show a lack of response. Thus there seems to be considerable experimental evidence in support of the lack of response and depressing effect of P_2O_5 on the grain yield. This trend again is in keeping with findings of Russel (1961) who reported that excess of phosphates over the amount required by the crop sometimes depressed crop yields.

Potash:

As regards potash, the common trend of opinion has been to the effect that Indian soils were generally speaking, sufficiently supplied with potash (Bedarker, Joshi and Shaligram, 1959). Ghose, Ghatge and Subramanian (1960) stated that potassic fertilizers have generally given no response except in Bihar.

In this investigation, 20 lb. of K_2O in combination with 60 lb. N per acre, has recorded the highest grain yield (2125 Kg = 4675 lb. per acre). Norris (1923) reviewing on the Permanent Manurial Plots at Coimbatore reported that the addition of potash has had no consistent effect in the case of cholam or wheat, but has materially increased yields of Ragi, both in grain and straw, though the chemical analysis indicated that the soil was already well supplied with available potash. Viswanath (1931) also reported the beneficial effects of potash in increasing the grain yield in Ragi.

The trend in yield as influenced by K_2O alone and in combination with three levels of P_2O_5 are discussed below;

A. Taking the P_0 level, the yields with graded doses of K_2O are given as follows;

	K_0	-	8337 gm.
P_0	K_1	-	9282 gm.
	K_2	-	8487 gm.

In P_0 and K_0 above, an output of 8337 gm. of grain yield per plot is observed. When the level of K_2O was raised to 20 lb. per acre the highest yield was obtained. But further raising of the level of K_2O to 40 lb. per acre seems to have had a depressing effect though the yield is slightly higher than no K_2O treatment. Panse et al (1948) reported a depressing effect of K_2O at 50 lb. per acre as observed in the old series of Permanent Manurials at Coimbatore. Similarly, Dubey and Das (1961) reported depression of yield at higher levels of K_2O application.

Thus treatment No. 5. i.e., 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O is found to be the outstanding combination in presence of a basal dressing of five tons of farm yard manure. Application of the above dose of fertilizers without the basal dressing of farm yard manure would deplete the P_2O_5 content of the soil to a precariously low level with adverse after effects in a few years. Welete (1961) stressing upon this fact, pointed out that it was not always possible to draw the conclusion that there was no need to apply a plant nutrient if it did not show a crop response.

Sethi and Ramiah (1952) pointed out that the absence of immediate response to phosphorous should not however preclude the addition of this important nutrient in any manuring programme as repeated applications of nitrogen alone would further aggravate phosphate deficiency and ultimately, there may be more harm to the soil resulting from such practice. These findings have to be kept in mind and the basal dressing found suitable in this investigations has to be maintained.

B. Taking the P_1 level, the yields with graded doses of K_2O are given as follows:

	K_0	-	7620 gm.
P_1	K_1	-	7598 gm.
	K_2	-	8080 gm.

In P_1, at K_0 i.e., in the presence of medium levels of P_2O_5 viz., 20 lb. per acre and at 0 lb. K_2O, lower yields were obtained. When the levels of K_2O also was raised to medium i.e., 20 lb. per acre the lowest yield in the whole series with an output of only 7598 gm. grains was recorded. Aiyar (1949) observed similar depressions in yield when both P_2O_5 and K_2O were applied together. However, a further increase of K_2O to 40 lb. per acre seem to have shown better effect, this being the second best of all the combinations. Thus it is seen that for fair response to K_2O, at higher levels of P_2O_5, the K_2O levels have to be porportionately raised.

c. Taking the P_2 level, the yields with graded doses of K_2O are given as follows:

	K_0	- 8732 gm.
P_2	K_1	- 8341 gm.
	K_2	- 8468 gm.

At the highest levels of P_2O_5 the responce to K_2O takes a different pattern. At the level of 40 lb. P_2O_5 per acre, 0 lb. K_2O has recorded higher yields than 20 lb. or 40 lb. per acre, thus showing that K_2O at any level in combination with 40 lb. P_2O_5 gave only reduced yield. Combinations of higher levels of K_2O with the highest level of P_2O_5 has shown depression of yield in this investigation.

Taking the overall picture, the positive response shown to 20 lb. dose of K_2O per acre can be explained as due to proper utilisation of the supplied nutrient. The black soil is reputedly rich in total potassium content as shown in the analysis data. However, it is observed that this quantity is not in an available state. This could possibly be due to the very high calcium saturation and the subsequent depressing effect of calcium on the potassium availability in black soils (Chinnadurai, 1961).

Russel (1956) stated that under low nitrogen and phosphorous supply, the potassium supply in the soil may be adequate but becomes inadequate if they are increased. Jacob (1959) reported that most of the crops of late, show signs of potash deficiency, due to the above reasons, though potash is available in Indian soils.

Considering the various interactions of P_2O_5 and K_2O found in the investigation, it is broadly observed that there appears to exist a quantitative relationship between P_2O_5 and K_2O for their optimum utilisation.

Taking the supply of P_2O_5 and K_2O through farm yard manure into consideration, the basal application of the quantity utilised in this investigation supplies about 46 lb. P_2O_5 and 25 lb. K_2O per acre as the sample on analysis gave 0.38 percent P_2O_5 and 0.2[illegible] percent K_2O.

Hence the P_2O_5/K_2O ratio in the different combinations is as follows:

		P_2O_5 : K_2O	
	K_0	43 : 25	(1.7:1)
P_0	K_1	43 : 45	(1:1)
	K_2	43 : 65	(1:1.3)
	K_0	63 : 25	(2.5:1)
P_1	K_1	65 : 45	(1.4:1)
	K_2	65 : 65	(1:1)
	K_0	83 : 25	(3.3:1)
P_2	K_1	83 : 45	(1.8:1)
	K_2	83 : 65	(1.2:1)

It will be clear from the above that the 1:1 ratio of P_2O_5 to K_2O has given the maximum yield and therefore a balancing of the two nutrients whether given as a basal dressing in the form of farm yard manure, or through fertilizers is indicated.

Economics of fertilization:

Table VII provides the economics of grain and straw yield compared between treatments, the profit or loss having been calculated on the basis of yield per acre. Evaluation for the value of nitrogen and farm yard manure have not been taken into consideration as it is common for all treatments. Treatment No. 7 with 60 lb. N, 0 lb. P_2O_5 and 0 lb. K_2O per acre has been taken as the base for comparison.

On evaluation of the economics of treatments, it was found that treatment No. 5 with 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O per acre was significantly outstanding with a profit of Rs. 63:37 followed by treatment No.6 with 60 lb. N. 20 lb. P_2O_5 and 40 lb. K_2O per acre with a profit of Rs. 30:75.

Third in order is treatment No. 9 with 60 lb. N, 40 lb. P_2O_5 and 0 lb. K_2O per acre, with a profit of Rs. 15:04. The rest of the five treatments have resulted in varying degrees of losses compared to the base, the highest loss of Rs. 88.48 having been recorded by treatment No. 1 with 60 lb. N, 20 lb. P_2O_5 and 20 lb. K_2O per acre, closely followed by treatment No. 8 with 60 lb. N, 20 lb. P_2O_5 and 0 lb. K_2O per acre the loss sustained being Rs. 71:67.

The economics of the various treatments is provided hereunder:

Treatment		Profit/Loss	
		Rs.	nP
1. 60 : 20 : 20	(-)	80	- 45
2. 60 : 40 : 20	(-)	36	- 84
3. 60 : 40 : 40	(-)	30	- 34
4. 60 : 0 : 40	(-)	6	- 78
5. 60 : 20 : 20	(+)	63	- 37
6. 60 : 20 : 40	(+)	30	- 78
7. 60 : 0 : 0	(Control)		-
8. 60 : 20 : 0	(-)	71	- 67
9. 60 : 40 : 0	(+)	18	- 04

Summarising the above discussion Co. 7 Ragi is found to respond best to a dose of 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O over a basal dressing of five tons of farm yard manure which supplies enough P_2O_5 and K_2O to give an ultimate 1:1 ratio of P and K supply to the crop.

CHAPTER VI

SUMMARY

With a view to study the effect of graded doses of P_2O_5 and K_2O on the yield potential of popular high fertility Ragi, strain Co. 7, field experiment was laid out in the Central Farm, Agricultural College and Research Institute, Coimbatore during 1962-63 (February -) [illegible]. Three levels of P_2O_5 and K_2O at 0 lb. 20 lb. and 40 lb. alone and in combination with one level of nitrogen at 60 lb. over a basal dressing of five tons of farm yard manure were the treatments adopted for the investigation. The farm yard manure was found by analysis to have 0.38 percent P_2O_5 and 0.22 percent K_2O supplying 43 lb. of P_2O_5 and 25 lb. of K_2O per acre.

A spacing of 6" x 6" as per established findings was selected.

Plant characters such as number of tillers, height, number of leaves, number of earheads, length of earheads, weight of earheads, weight of grain and weight of straw were recorded. Selected characters were statistically analysed and the following conclusions were drawn.

1. (a) the number of tillers was not found influenced significantly by any of the treatment when compared between themselves.

(b) Production of tillers was found to be significantly highest at the 30th day stage of growth than the 60th and 90th. The 90th day (third stage) showed a downward trend in the productio

of tillers, when compared to the 60th day (second stage).

2 (a) No single treatment was found to be superior over the others in contributing to the number of earheads.

(b) Between the 60th day and the 90th day, the former was significantly superior for the above factor.

3 (a) Plant height was not significantly influenced by any of the treatments.

(b) The 60th day showed significant increase in plant height when compared with the 90th day and 30th day stages respectively.

4. Weight of straw was not significantly influenced by any of the treatments.

5. A high positive correlation was observed between the gain yield and straw yield.

6. Chemical analysis of the grain brought out that the content of nitrogen, phosphorus and potassium was not influenced significantly by any of the treatments.

7. The treatment combination of 60 lb. N, 0 lb. P_2O_5 and 20 lb. K_2O per acre in presence of five tons of farm yard manure was found to give the highest yield.

8. It was also brought out by the investigation that the net profit obtained was the highest under the above combination, the profit being Rs. 63:37 per acre over 60 lb. N, 0 lb. P_2O_5

and 0 lb. K_2O per acre with five tons of farm yard manure.

9. In summarising, it is clear that the 1:1 ratio of P_2O_5 to K_2O has given the maximum yield and therefore a balancing of the two nutrients whether given as a basal dressing in the form of farm yard manure or through fertilisers is indicated

10. Any imbalancing of the above ratio shows trends towards depression in the yield of grain.

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APPENDICES

APPENDIX I

Number of tillers - Different stages - Analysis of variance.

Source	D.F.	S.S.	M.S.	'F'
Replications	3	4476.55	1492.18	
Stages of observation	2	44980.73	22490.37	78.65**
Treatments	8	4546.50	568.31	1.94
P	2	6.23	3.12	
K	2	966.89	483.45	1.65
P x K	4	3573.38	893.35	3.05
Stages x treatment	16	2472.94	154.56	
Stages x P	4	573.88	143.47	
Stages x K	4	28.22	7.06	
Stages x P x K	8	1870.84	233.86	
Error	78	22818.20	292.54	
Total	107	79294.92		

** Significant at $p = 0.01$ level.

APPENDIX VI

Number of earheads -Analysis of variance

Source	D.F.	S.S.	M.S.	'F'
Replications	3	5076	1692	
Stages	1	6517	6517	15.70**
Treatments	8	5098	637	1.53
P	2	473	237	
K	2	408	204	
P x K	4	4217	1054	2.54
Stages x Treatments	8	1538	192	
Stages x P	2	712	356	
Stages x K	2	59	30	
Stages x P x K	4	767	192	
Error	51	21161	415	
Total	71	39284		

** Significant at P = 0.01 level.

APPENDIX III

Yield of grain - Analysis of variance

Source	D.F.	S.S.	M.S.	'F'
Replications	3	15090448	5030149	
Treatments	8	9914256	1239282	2.86*
P	2	2208702	1104351	2.55
K	2	1195835	597918	1.38
P x K	4	6509719	1627430	3.76*
Error	24	10369570	432065	
Total	35	35374274		

* Significant at P = 0.05 level.

APPENDIX IV

Height of plant- Analysis of variance

Source	D.F.	S.S.	M.S.	'F'
Replications	3	42.85	14.28	
Stages	2	10384.62	5192.31	85.33**
Treatments	8	120.54	15.07	
P	2	12.93	6.47	
K	2	56.47	28.24	
P x K	4	51.14	12.79	
Stages x treatments	16	37.28	2.33	
Stages x P	4	12.98	3.25	
Stages x K	4	11.67	2.92	
Stages x P x K	8	12.63	1.58	
Error	78	4746.61	60.85	
Total	107	15331.90		

** Significant at P = 0.01 level.

APPENDIX V

Yield of straw - Analysis of variance.

Source	D.F.	S.S.	M.S.	'F'
Replications	3	254.01	84.67	
Treatments	8	21.44	2.68	
P	2	3.03	1.52	
K	2	3.27	1.64	
P x K	4	15.14	3.79	
Error	24	93.12	3.88	
Total	35	368.57		

Not significant.

APPENDIX VI

Grain - Nitrogen content - Analysis of variance.

Source	D.F.	S.S.	M.S.	'F'
Replications	3	0.3506	0.1169	
Treatments	8	0.0744	0.0093	
P	2	0.0112	0.0056	
K	2	0.0506	0.0253	2.04
P x K	4	0.0126	0.0032	
Error	24	0.2983	0.0124	
Total	35	0.7235		

Not significant.

APPENDIX VII

Grain - Phosphorous content -Analysis of variance

Source	D.F.	S.S.	M.S.	F
Replications	3	0.028711	0.009570	
Treatments	8	0.011638	0.001455	
P	2	0.001478	0.000739	
K	2	0.004695	0.002348	
P x K	4	0.005465	0.001366	
Error	24	0.076343	0.003181	
Total	35	0.116692		

Not significant.

APPENDIX VIII

Grain - potash content -Analysis of variance

Source	D.F.	S.S.	M.S.	F
Replications	3	0.255641	0.085214	
Treatments	8	0.129524	0.016191	
P	2	0.040238	0.020119	1.11
K	2	0.031606	0.015803	
P x K	4	0.057681	0.014420	
Error	24	0.433882	0.018076	
Total	35	0.819047		

Not significant.

APPENDIX IX

Grain yield in grams per plot

Treatments (lb. per acre) N	P	K	Replications I	II	III	IV
1. 60	20	20	8150	7179	8619	8432
2. 60	40	20	8729	8067	7781	7017
3. 60	40	40	9346	7341	8902	8086
4. 60	0	40	9302	8169	7646	8752
5. 60	0	20	10840	9184	8623	8242
6. 60	20	40	10480	9273	8554	7927
7. 60	0	0	9465	8501	7157	8225
8. 60	20	0	8370	8275	7600	6359
9. 60	40	0	9475	9425	7909	8447

APPENDIX X

Straw weight in kilograms per plot

Treatments (lb. per acre) N	P	K	Replications I	II	III	IV
1. 60	20	20	30.19	25.88	21.11	24.62
2. 60	40	20	26.28	29.28	22.47	23.58
3. 60	40	40	28.98	27.60	24.97	22.47
4. 60	0	40	28.53	27.69	21.79	27.01
5. 60	0	20	29.06	26.79	25.42	24.06
6. 60	20	40	30.40	28.38	27.24	22.70
7. 60	0	0	27.69	26.83	23.61	23.61
8. 60	20	0	26.56	30.42	25.20	21.11
9. 60	40	0	33.14	32.[illegible]	28.93	23.01

[illegible]

PLATE I Mean Tiller production per plant

PLATE No 1

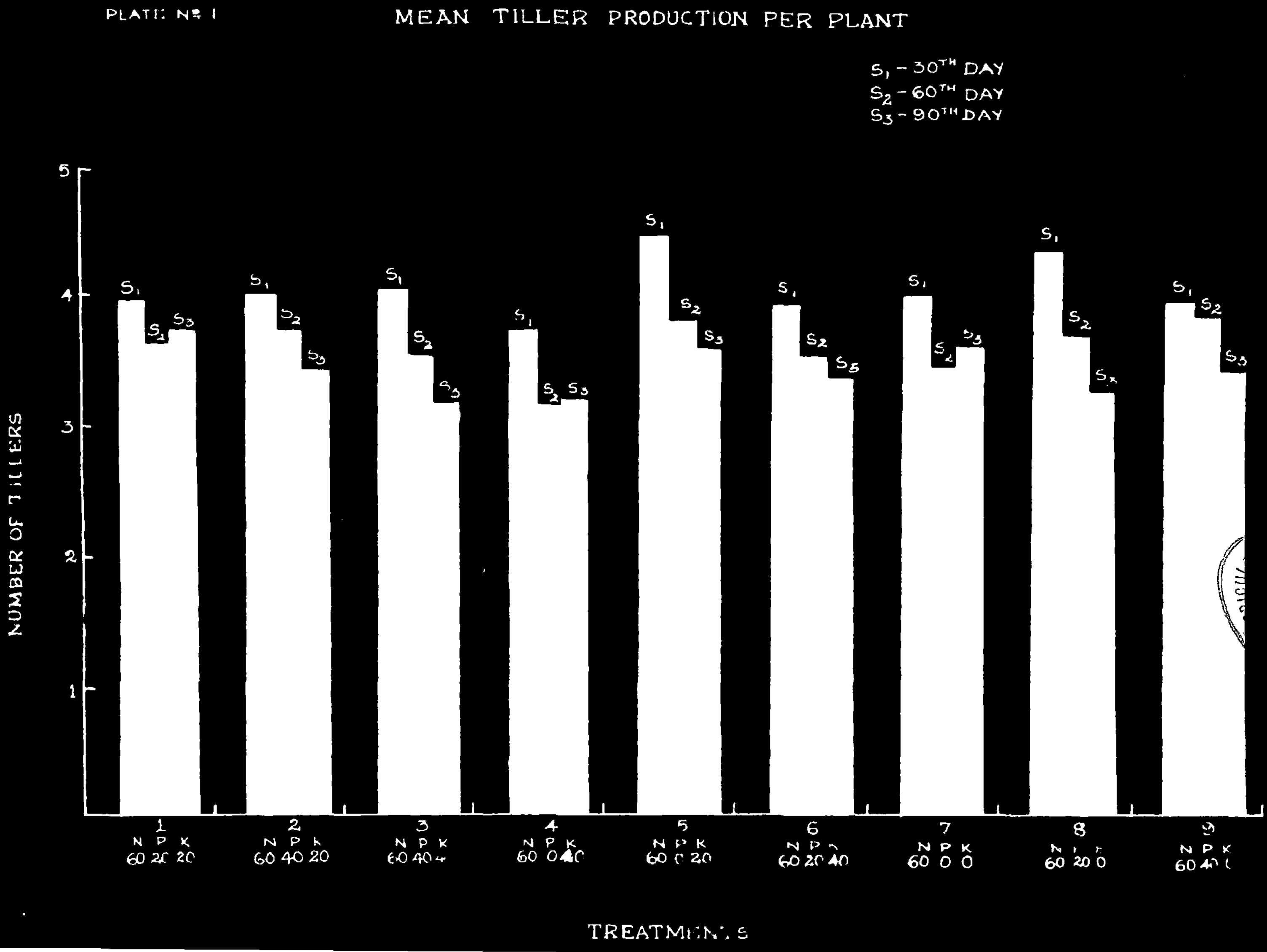

MEAN TILLER PRODUCTION PER PLANT
S1 - 30TH DAY
S2 - 60TH DAY
S3 - 90TH DAY
NUMBER OF TILLERS
5
4
3
2
1
S1 S2 S3
1 N P K 60 20 20
2 N P K 60 40 20
3 N P K 60 40
4 N P K 60 0 40
5 N P K 60 0 20
6 N P K 60 20 40
7 N P K 60 0 0
8 N P K 60 20 0
9 N P K 60 40
TREATMENTS

PLATE II Height of Plant

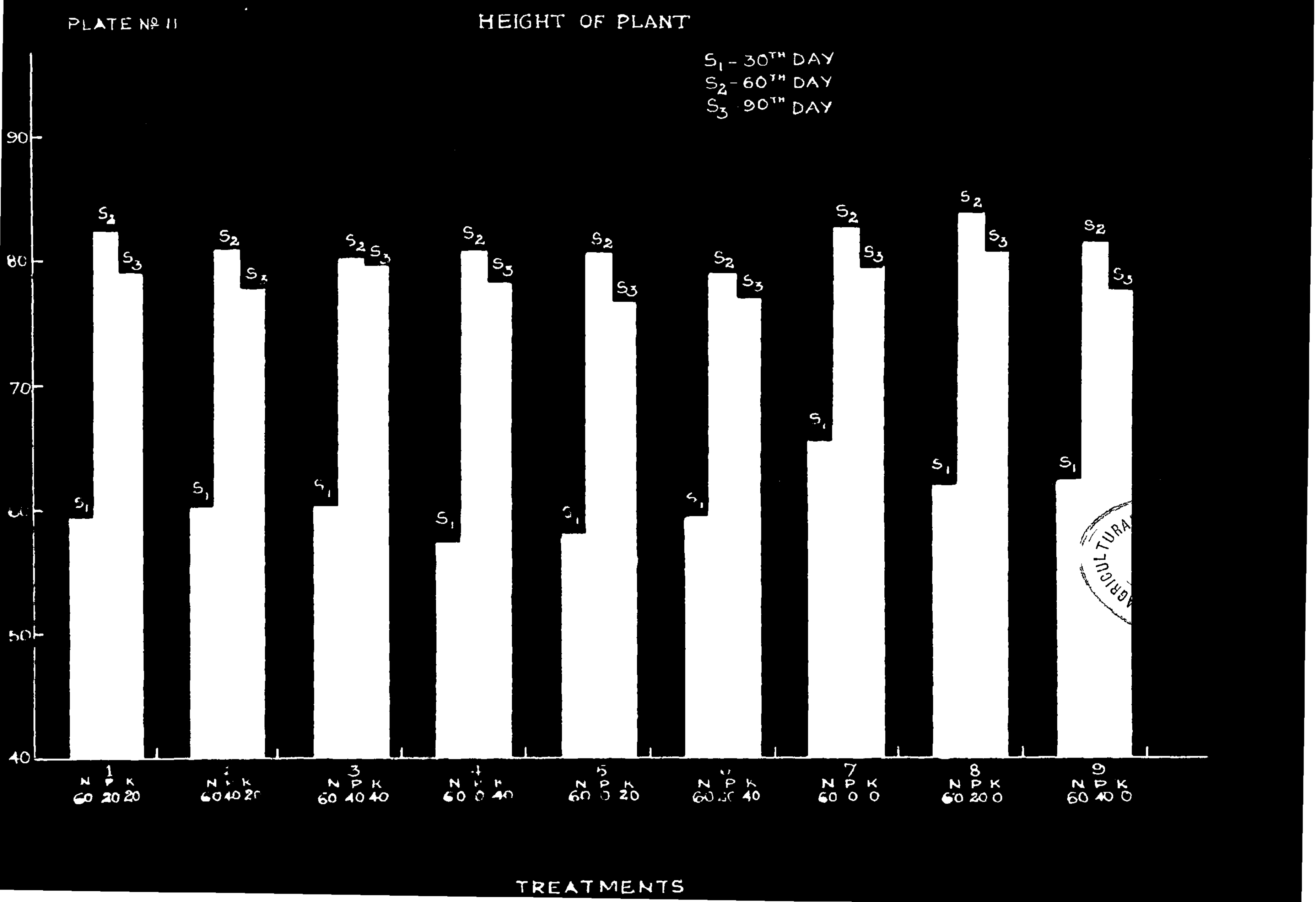


PLATE No 11
HEIGHT OF PLANT
S1 - 30TH DAY
S2 - 60TH DAY
S3 - 90TH DAY
TREATMENTS

PLATE III Straw yield

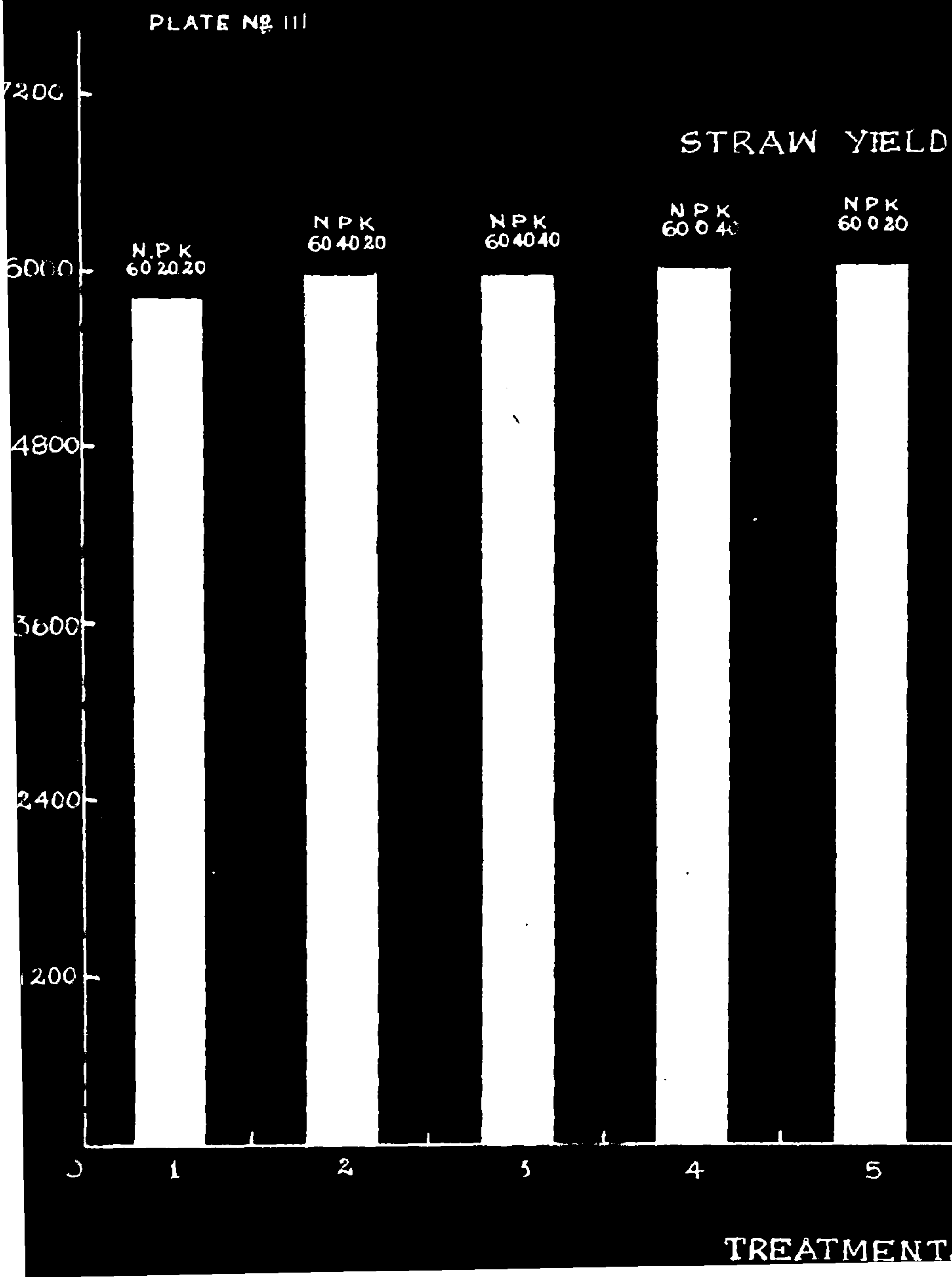
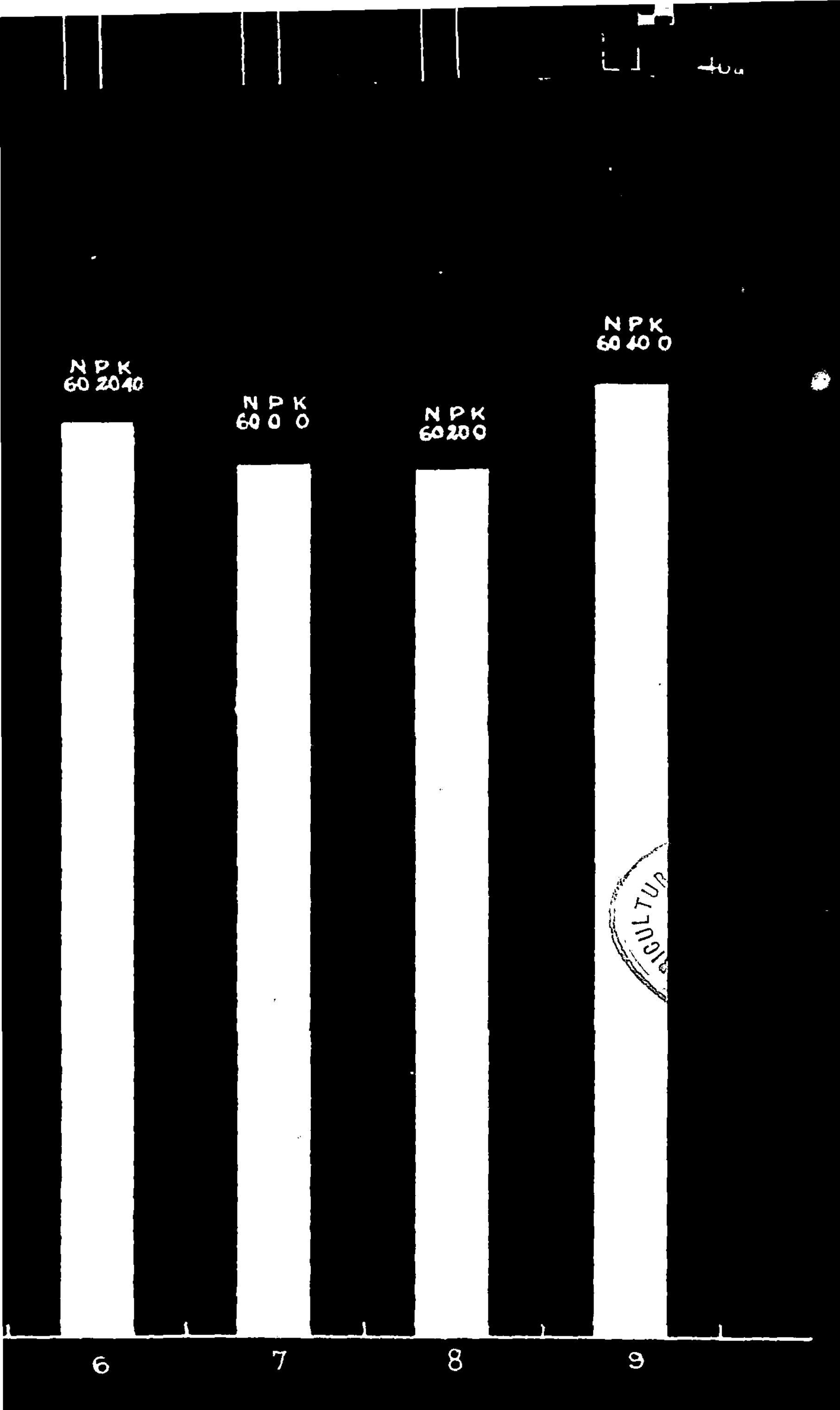


PLATE No. III
STRAW YIELD
7200
6000
4800
3600
2400
1200
0
N.P.K
60 20 20
N P K
60 40 20
N P K
60 40 40
N P K
60 0 40
N P K
60 0 20
1
2
3
4
5
TREATMENT



S

PLATE IV Grain yield

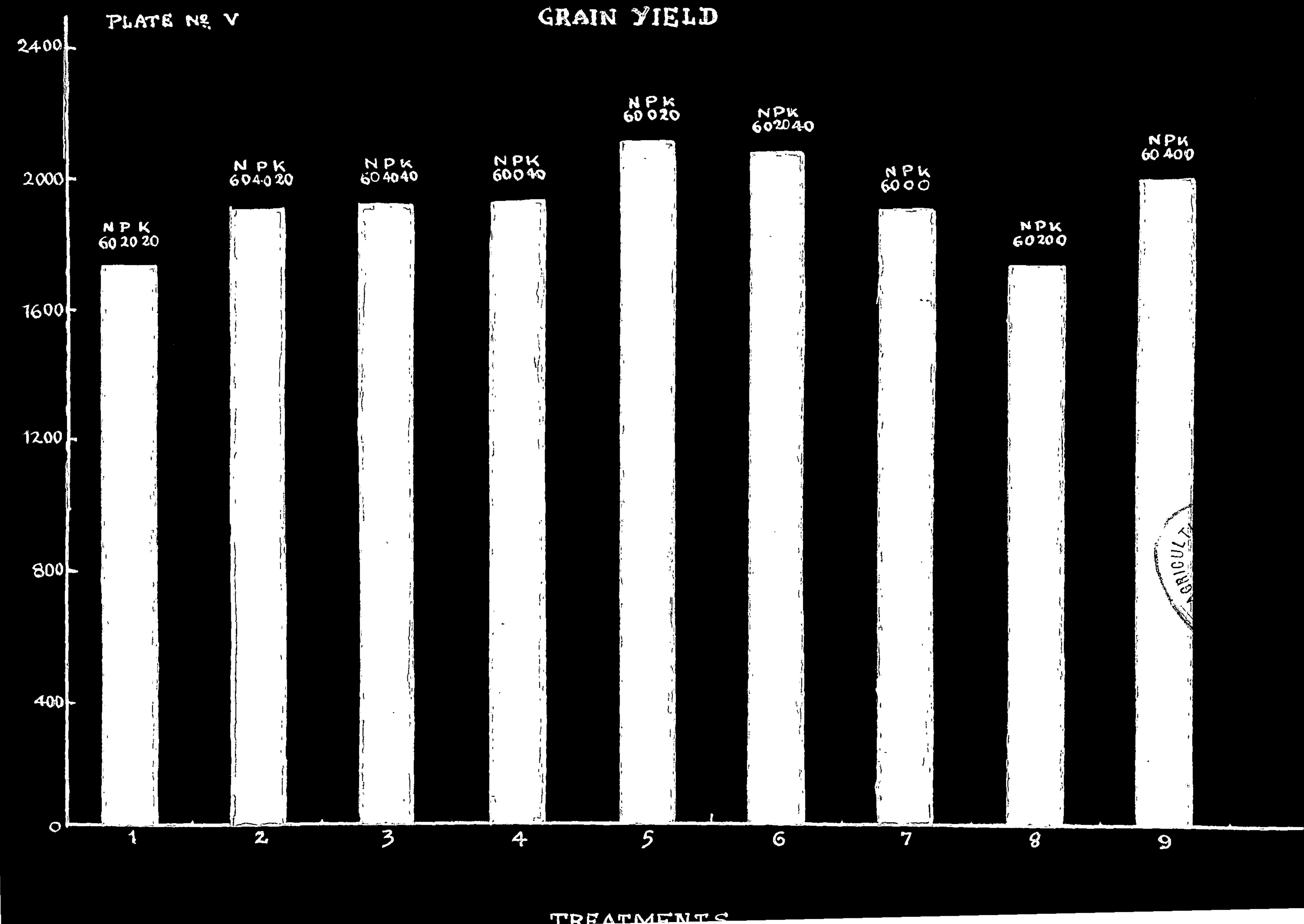


PLATE No. V
GRAIN YIELD
2400
2000
1600
1200
800
400
0
N P K 60 20 20
N P K 60 40 20
N P K 60 40 40
N P K 60 0 40
N P K 60 0 20
N P K 60 20 40
N P K 60 0 0
N P K 60 20 0
N P K 60 40 0
1
2
3
4
5
6
7
8
9
TREATMENTS

PLATE V   Grain Analysis

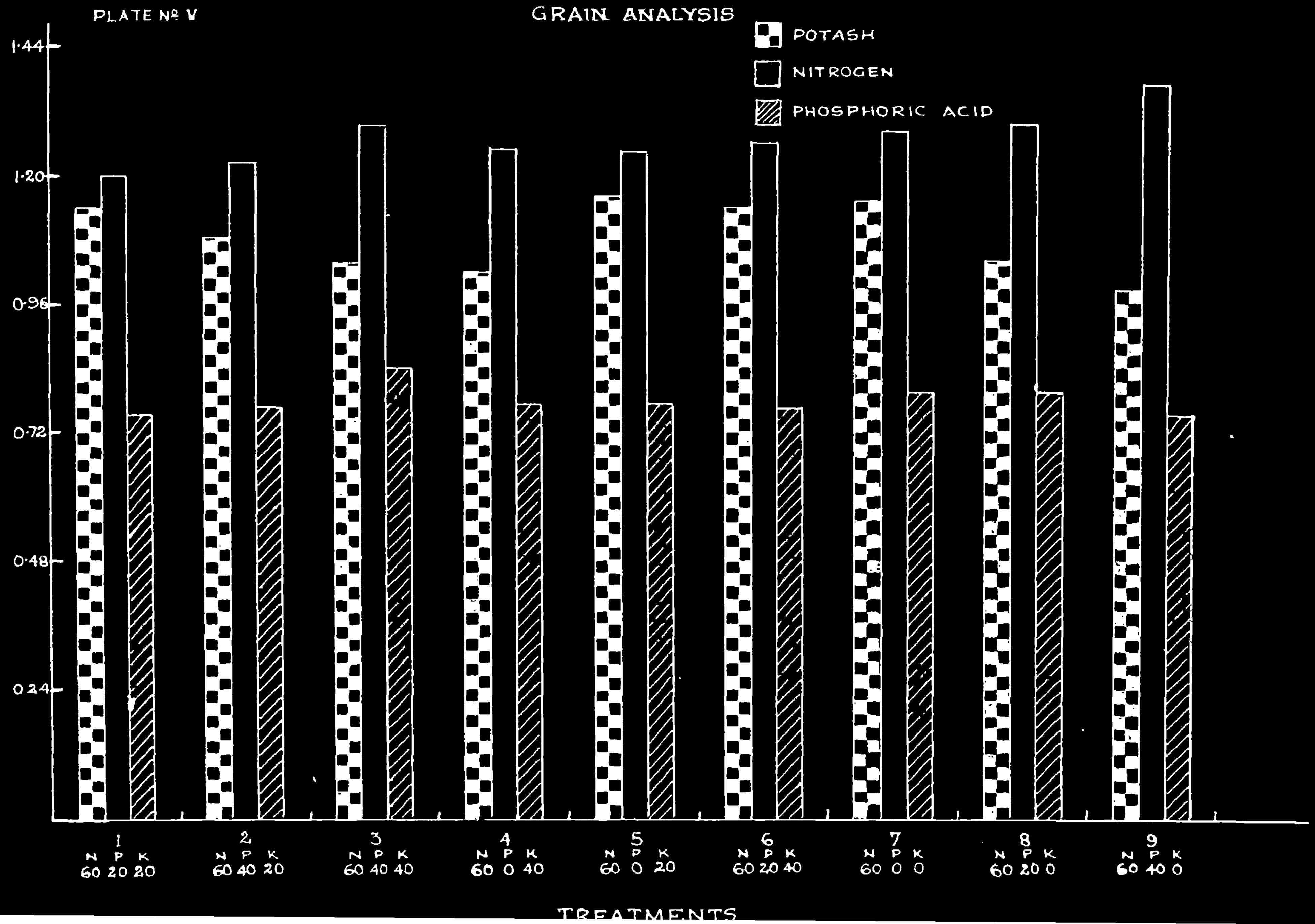


PLATE Nº V
GRAIN ANALYSIS
POTASH
NITROGEN
PHOSPHORIC ACID
1·44
1·20
0·96
0·72
0·48
0·24
1 N P K 60 20 20
2 N P K 60 40 20
3 N P K 60 40 40
4 N P K 60 0 40
5 N P K 60 0 20
6 N P K 60 20 40
7 N P K 60 0 0
8 N P K 60 20 0
9 N P K 60 40 0
TREATMENTS

PLATE VI P X K Interaction on Grain yield

P×K INTERACTION ON GRAIN YIELD

PLATE Nº VI

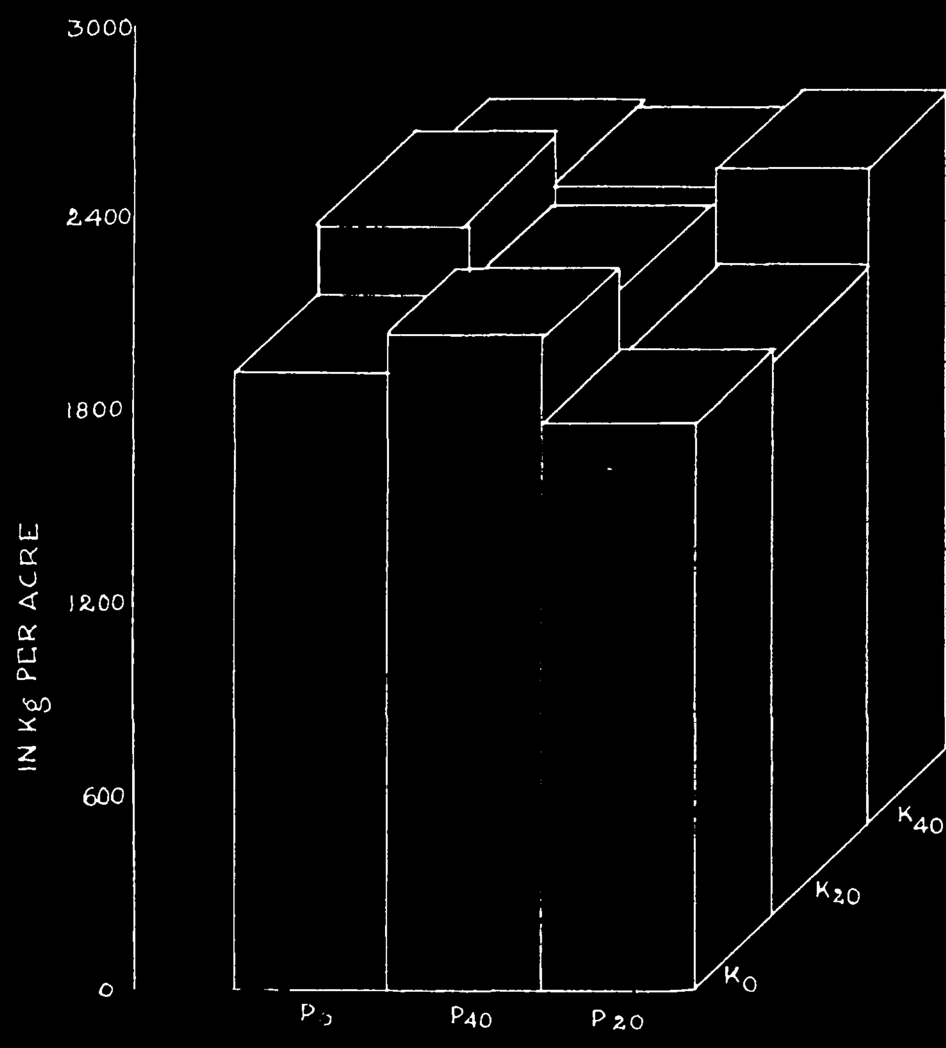
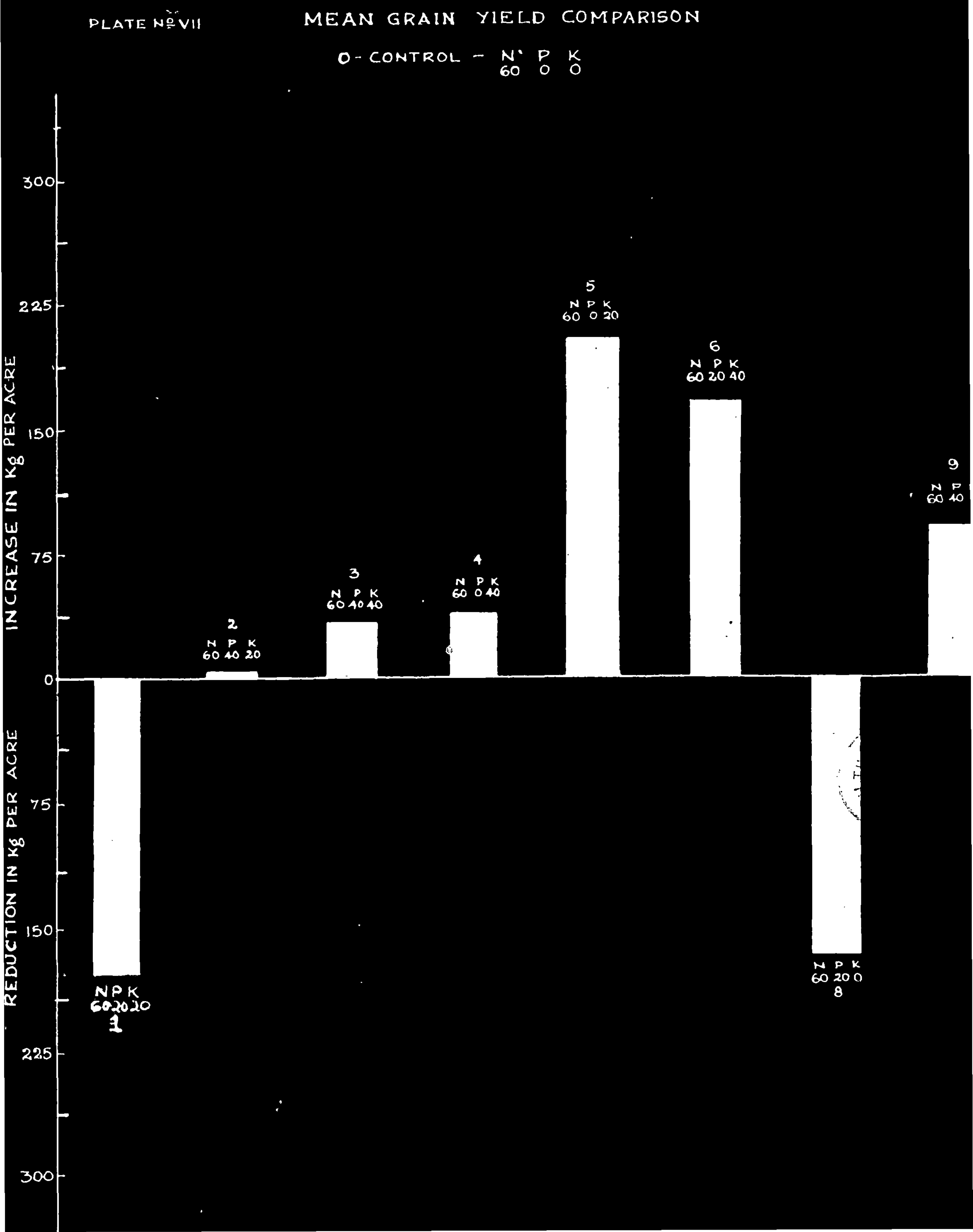


PLATE VII Mean Grain yield comparison

PLATE No. VII



MEAN GRAIN YIELD COMPARISON
O - CONTROL - N 60 P 0 K 0
INCREASE IN Kg PER ACRE
REDUCTION IN Kg PER ACRE
300
225
150
75
0
75
150
225
300
NPK 60 20 20 1
2 N P K 60 40 20
3 N P K 60 40 40
4 N P K 60 0 40
5 N P K 60 0 20
6 N P K 60 20 40
N P K 60 20 0 8
9 N P 60 40

PLATE VIII Regression of Grain yield (Y) on straw yield (X)

PLATE No. VIII

REGRESSION OF GRAIN YIELD (Y) ON STRAW YIELD (X)

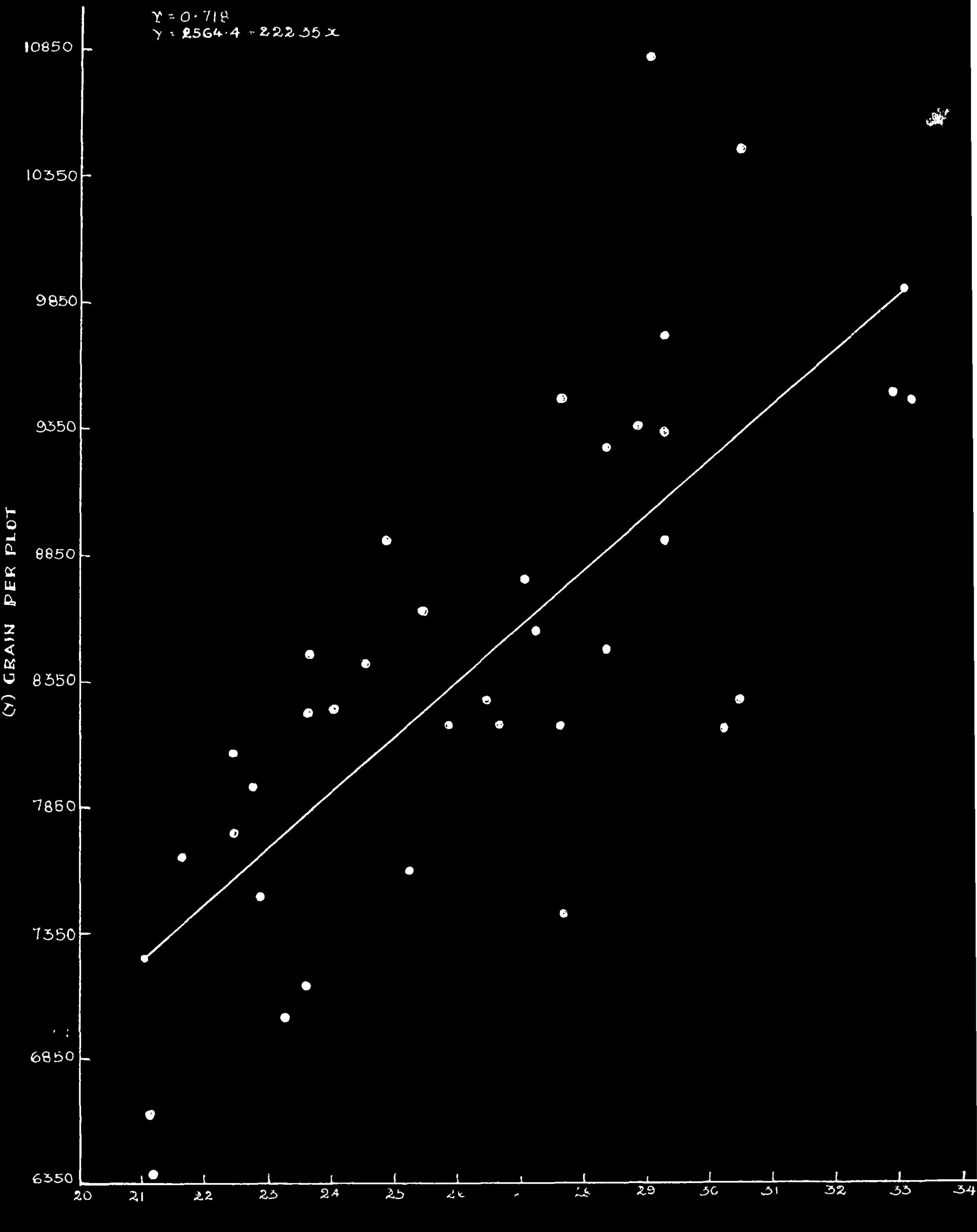
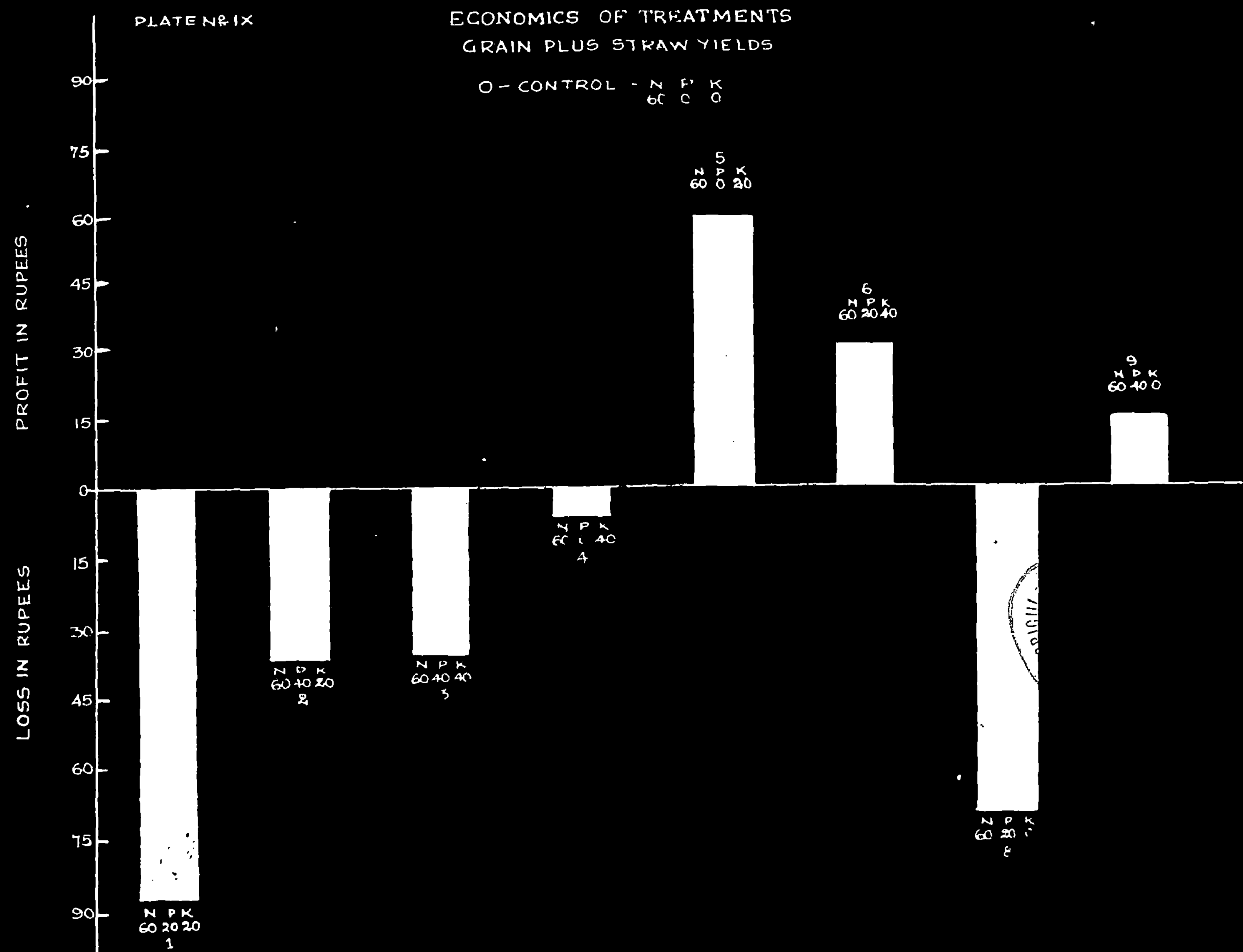


PLATE IX Economics of Treatments

PLATE No. IX



ECONOMICS OF TREATMENTS
GRAIN PLUS STRAW YIELDS
O – CONTROL – N P K 60 0 0
PROFIT IN RUPEES
LOSS IN RUPEES
90
75
60
45
30
15
0
15
30
45
60
75
90
N P K 60 20 20 1
N P K 60 40 20 2
N P K 60 40 40 3
N P K 4
5 N P K 60 0 20
6 N P K 60 20 40
N P K 60 20
9 N P K 60 40 0