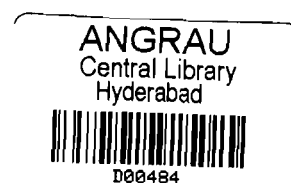


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Comparative Study of the
Utilization of Different Forms of Fertilizer Phosphorus by Rice Plant
in Typical Soils of Telengana Region, Andhra Pradesh

THESIS SUBMITTED TO THE ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN
PART FULFILMENT
OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE

BY
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RAJENDRANAGAR, HYDERABAD – A. P.

MARCH, 1965

C E R T I F I C A T E

This is to certify that the thesis entitled "Comparative study of the utilisation of different forms of fertiliser phosphorus by rice plant in typical soils of Telengana Region Andhra Pradesh" submitted in partial fulfilment for the award of M.Sc. Degree in Agriculture of the Andhra Pradesh Agricultural University, is a record of bonafide research work carried out by Shri M.A. Resak Khen during 1964-'65, the period of study and research at the College of Agriculture, A.P.A.U. Rajendranagar, under my supervision and that the thesis has not formed in whole or in part the basis for the award of any Degree, Diploma or the similar Degree and Distinction. The assistance and help received during the course of investigation have been specifically acknowledged by him.

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C O N T E N T S

	<u>Page</u>
ACKNOWLEDGEMENTS.	
I - Introduction.	1
II - Review of literature	3
III - Experimental procedures	20
IV - Results	29
V - Critical discussion	42
VI - Practical importance of the study	54
VII - Summary and conclusions	58
VIII - Bibliography	60

APPENDICES

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INTRODUCTION

Phosphorus is one of the major plant food nutrients essential for plant growth. According to Tamboli and Mishra (1963), Kriehnamurthy (1963), Ghosh (1963), Sirur (1963) and others, it is most limiting nutrient element in crop production. McKelvey et al (1953) called it the "bottleneck of the world's hunger". This is true for large parts of our country for most of Indian soils are generally low in available phosphorus. Senechelli (1961) is of the opinion that India is not over populated: it is rather under fertilized and chemical fertilizers offer the surest and the quickest way to increase food production.

Phosphates among the phosphatic fertilizers may be grouped into three main classes, based on solubility (1) water soluble (2) water-insoluble and (3) a mixture of both the forms in different proportions. The sum of chemically determined water-soluble and ammonium citrate soluble phosphates in a phosphatic fertilizer can be considered a valid measure of the nutrient value of such fertilizer. This sum is commonly termed "available phosphate" and very frequently is written simply as A.P.A. (Available phosphoric acid). All these soluble forms are ionized in which condition it is assimilated by plants and the entire phosphate fertilizer industry is based on the transformation of phosphates to ionizable forms.

Till recently India was producing superphosphate which contains phosphoric acid chiefly in water soluble monocalcium phosphate form. Due to shortage of sulphur and high cost for importing high quality rockphosphate, the fertilizer industry is shifting gradually towards the production of phosphatic fertilizers which avoid their use. As such several new types of fertilizers like dicalciumphosphate and fertilizer mixtures like ammonium phosphates and nitrophosphates are being manufactured. As these fertilizers have different grades of solubility their agronomic value in terms of solubility has got to

be evaluated for major crops of our country in different regions.

India's official policy is to become selfsufficient in food grains. As rice is the main food crop of Andhra Pradesh and the chief food grain of our country, boosting up its production means becoming more and more selfsufficient. Keeping in view its significance this crop is selected for the present study so that the problem would be of greater economic utility. A uniform dose of nitrogen as per the regional recommendation for this crop has been applied so that limitation of this nutrient should not interfere with phosphate availability.

The main objective of the present study is to evaluate the efficiency of utilization of nutrient phosphorus supplied in varying degrees of solubility. For this purpose a pot culture experiment with rice as a crop was undertaken using the two typical soils of Telengana Region of Andhra Pradesh (red chalk and black soil). In these experiments water-soluble phosphorus was supplied as superphosphate and the citrate-soluble form as dicalciumphosphate. These substances were used individually as well as in mixtures to provide varying degrees of water and citrate solubility.

Incidentally the use of both superphosphate and dicalciumphosphate has also provided an opportunity to assess and compare their relative agronomic efficiency.

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REVIEW OF LITERATURE

The task of reviewing the vast literature which has accumulated from a vast amount of laboratory, green house and field experiments throughout the world is formidable. However an attempt is made to wade into the heap of material to reach into the kernel of the matter.

Review of literature has been broadly classified into two parts. The first part deals with briefly the fundamental concept of availability and available forms, soil plant relationship with regard to phosphate fertilization and with restricted limitations of our current knowledge, the behaviour of phosphatic fertilizers when placed in soil. The properties of few important fertilizers and their performances on Indian soils are also discussed from the point of view of choice of phosphatic fertilizers of different solubilities. As nitrogen is the chief element in plant nutrition and has important role in phosphorus uptake and a nitrogenous fertilizer too is used in the experiment, this aspect is also reviewed briefly. The second part will review, within the scope of this survey (which is necessarily limited) many of the published data on experiments which have been conducted in India and elsewhere on the subject of efficiency of utilization by plants of the different forms of available phosphorus in fertilizers and the relative efficiency of dicalciumphosphate and superphosphate.

PART-I

According to De (1963) "one of the important reason for the existence of a large number of literature on the behaviour of phosphates in the realm of agriculture is its availability as effected by its fixation when applied to soils. Unquestionably it is this aspect of study that has filled up most of the cells of the ryotic honeycomb literature of phosphates". Available phosphorus is that form of phosphorus which plants can absorb. This includes both water and citrate soluble forms. The soils manifest great variations in quantity of available

P_2O_5 , which ranges from 0.1 to 21 mg. per 100 gr. of soil. The extremely clayey soils are poor in phosphate availability regardless of the fact that they contain a high total P_2O_5 . Results obtained so far by the Indian workers in the field of fixation and availability of P_2O_5 revealed, that only about 20% of the P_2O_5 added through phosphatic fertilizers is taken up by plants, the rest being fixed in the soil and for further economical yields fresh application of phosphate fertilizers are essential. Of the various factors present in the soils, clay minerals, various hydrous oxides especially iron and aluminium and lime are the important contributors in effecting the availability of phosphatic fertilizers.

According to Olsen (1953) alkaline calcareous soils which are rich in $CaCO_3$ have depressing effect on the absorption of phosphorus by plants, due to decreased solubility of phosphorus in soil and due to the tendency of $CaCO_3$ to maintain a high pH.

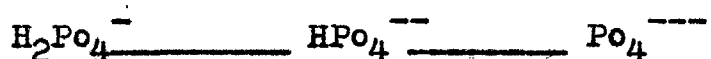
According to Arnon (1953) some investigators like Bingham tried to correlate the availability of phosphorus to plants in the displaced soil solution.

As experiments with rice are conducted under water-logged conditions, a study of the availability of phosphate in such soil is necessary as these conditions are not analogous to that of upland soil. Japanese work in this line revealed that phosphorus availability increases due to the reduction of iron from ferric to ferrous state. According to Ghosh (1956) the work conducted in this regard at Central Rice Research Institute, Cuttack gave similar results. Besides the intensity of standing water under water-logged conditions increased availability of phosphate.

According to Deen and Fried (1953) the absorption of phosphorus by plants is the result of a multiplicity of processes taking place in the plant, in the soil and at the root surfaces or interfacial boundaries and soil plant relationship depends upon the interdependence of these factors. When the

soil 'P' supply is a limiting factor in plant growth, increased doses of phosphate fertilizer added to the soil will result in the increased yield of dry matter.

According to Barbier (1959) the phosphorus compounds in soil all stem from orthophosphoric acid generally called phosphoric acid. This is a triacid, H_3PO_4 which forms with basis three kinds of phosphates, corresponding to the ions



In aqueous solutions it is supposed that each phosphate ion is continually passing from one form to the other, depending upon pH and the first two forms dominate in equal proportions at pH 7.0.

Plants absorb phosphates from soil solution in the form of HPO_4^{--} and $H_2PO_4^-$. Hydroxyl ions (OH⁻) formed by dissociation of water, successfully compete with the phosphatic ions in entering the plant roots and therefore the more abundant the concentration of hydroxyls, the less the uptake of phosphate. Under alkaline condition hydroxyl ions dominate and this is the reason why a given crop in alkaline soils may require say 300 lbs per acre of available phosphorus, whereas the same crop grown on an acid soil may require 30 lbs of P_2O_5 per acre (Seuchelli 1960).

According to Tisdale and Rucker (1964) the effectiveness of a phosphatic fertilizer for increasing crop yield is dependent primarily on three factors (1) the nature of the crop (2) the soil and climatic conditions under which the crop is grown (3) the chemical and the physical properties of the fertilizer used and the rate and method of application. A brief description of these factors and their relationship with the solubility aspect of phosphatic fertilizers are discussed below.

The factors associated with a crop and influence its response to different phosphatic fertilizers include (1) The nature of plant with due consideration to the type and extent

of root system (Plants with restricted root systems like potatoes and certain vegetables are responsive to application of highly water-soluble phosphates. (2) The time required for the plants to reach maturity (short duration and fast growing crops give greater response to water-soluble phosphates and vice versa).

The various factors which may effect crop response to different phosphates are:

(i) Soil texture - (It has pronounced effect on the degree of conversion of soluble phosphates to less soluble form.)

(ii) Soil reaction (pH) and amount of free calcium-carbonate present.

(iii) Amounts of hydroxides of iron and aluminium present.

(iv) Degree of phosphate saturation of soil (the effect of water-solubility of the fertilizer phosphorus becomes less pronounced if available phosphorus is already present in the soil to meet the minimum requirements).

(v) Temperature (low temperature lowers metabolic activity and reflects in poor root growth resulting in 'P' deficiency symptoms. High water solubility gives better performance).

(vi) Soil moisture - (with higher moisture content the movement of water-soluble phosphate out of granule is more)

The chemical and physical properties of the phosphatic fertilizers and their solubility aspect has been covered briefly in the following pages. Phosphates may be grouped in four classes based on their solubility.

(1) Water-solubles: This group consists of almost all completely water-soluble materials made up largely of compounds such as monocalciumphosphates and ammoniumphosphates.

(2) Citrate solubles; The specifications of citrate solutions vary among countries; in some countries like U.S.A.

it is neutral ammonium citrate solution; in other countries it is alkaline ammonium citrate solution; in still others, it is citric acid of usually 2% strength. It is important therefore to clearly state the particular solution that is used, since the degree of solubility of phosphate will vary with the kind of solution employed. Examples of this group are dicalciumphosphate and calcium metaphosphate.

(3) Citrate insolubles: This group will contain the phosphates known as apatites: unprocessed phosphate rock; hydroxyl apatite; tricalciumphosphate.

(4) Some investigators have set up a fourth group comprising, in a way, a sub-group of the solubility category; namely those solid mixed fertilizers, in which the phosphate is present largely as a mixture of ammoniumphosphate (water-soluble) and dicalciumphosphate (citrate-soluble).

Nutrient contents of the phosphatic fertilizers available in our country is given in the table below:

NUTRIENT CONTENTS OF PHOSPHATIC FERTILIZERS
(Expressed as percentages)

Fertilizer	Total P ₂ O ₅	Citrate soluble P ₂ O ₅	Water soluble P ₂ O ₅	Total N	Ammo cal N	Nit- rate N
1	2	3	4	5	6	7
Single superphosphate	16.5	16.5	16.0			
Triple superphosphate	40.0	40.0	40.0			
Dicalciumphosphate	34.0	34.0	Nil.			
Kotka phosphate	25.0	16.0	8.0			
Calcium metaphosphate	63.0	63.0	Nil			
Fused magnesiumphosphate.	22.5	19.0	Nil			
Defluorinated rock-phosphate (by calcination)	21.0	18.0	Nil			
Defluorinated rock-phosphate (by fusion)	28.1	22.3	Nil.			

Continued:

1	2	3	4	5	6	7
Rock phosphate	27.0- 35.0	1.5- 3.5	Nil.			
Basic slag (Bessemer)	15.0- 18.0	13.5- 16.5	Nil.			
Basic slag(Indian)	2.5- 7.5	2.0- 6.5	Nil.			
Mono-ammonium phosphate(Ammo.phos.A)	48.0	48.0	48.0	11.0	11.0	
Ammo.phos.B	20.0	20.0	20.0	16.0	16.0	
Ammonium phosphate-sulphate	20.0	20.0	20.0	16.0	16.0	
Nitro-phosphate (ODDA)	20.0	10.0	10.0	20.0	12.0	8.0
Nitrophosphate (PEC)	14.0	14.0	Nil	16.0	8.0	8.0
Bone-meal (raw)	20.0- 25.0	8.0	Nil	3.0- 4.0	Nil	Nil
Bone-meal(steamed)	22.0	16.0	Nil	1.0- 2.0	Nil	Nil
Ammoniated super-phosphate(ordinary)	14.0- 20.0-	13.0- 19.0	Nil	2.0- 5.0	Nil	Nil
Potassium metaphosphate.	60.1	57.0- 60.0	0.5- 3.0			

Source J.Soc.of Soil Sci.Volume II No.2 June 1963

Description of a few important single and mixed phosphatic fertilizers is given below:

Single superphosphate: It is the most widely used phosphatic fertilizer in India. It is manufactured largely by treating ground phosphate rock with almost equal weight of sulphuric acid which produces a brownish grey mixture containing monocalciumphosphate and calciumsulphate (Gypsum) in practically equal quantities. It has been found to be agronomically suitable for all field crops in all parts of the country, except in humid areas with acid soils. The

licenced capacity for production of superphosphate forms approximately 40% in terms of P_2O_5 of all phosphatic fertilizers (F.A.I. 1962-'63).

Dicalciumphosphate: It is usually produced by the action of HCl on natural rock phosphate. A recent method of manufacture developed at the TVA Labs consists of treating phosphate rock with HNO_3 . This yields calcium nitrate and phosphoric acid, which is then heated with ammonia to give dicalciumphosphate and further processed to recover the nitrate as ammonium nitrate. Although dicalciumphosphate is a citrate-soluble fertilizer, recent experiments have shown that it is equally effective on soils of acidic, neutral and alkaline reactions. It is normally equal or superior to monocalciumphosphate in acid and neutral soils and also for crops grown in alkaline soils provided their growth period is of sufficient length. Dicalciumphosphate possesses special properties. In the soil the rate of interconversion which lowers the fertilizing value is much slower. Besides it is neutral and remains a free flowing powder for a long time, the presence of fluoride does not effect the citrate solubility in storage (low grade phosphatic rock can be used) and being concentrated form renders economy in transport. A brief review of its agronomic trials is given in part-II. The licenced capacity of this fertilizer in India is 34,000 tons as on 31st July 1963 (F.A.I. 1962-'63).

Ammonium phosphate: It is usually manufactured by addition of ammonia to phosphoric acid in correct amounts necessary to secure the desired grade. Amophos is the trade name for commercial monoammoniumphosphate, either alone (Amophos 'A') or mixed with varying amounts of ammoniumsulphate (Amophos 'B') to give different 'N' to P_2O_5 ratios. Both these forms are slightly acidic to neutral in reaction and possess excellent physical properties. The production of ammoniumphosphate is increasing rapidly as the agronomic and

economic advantages of this material become more apparent. The present installed capacity in production is 3,350 tons of P_2O_5 and the total capacity including the licenced and yet to go on production would come to nearly 2,50,000 tons P_2O_5 representing about half of the total P_2O_5 to be produced in India (Raichandhri 1963).

Nitrophosphate: This fertilizer is obtained by the decomposition of rock phosphate by nitric acid either by ODDA process or FEC process. The citrate soluble phosphate in these fertilizers is in dicalciumphosphate form. Experiments with this fertilizer under Indian conditions are in progress. A very brief review of its agronomic trials is given in part II.

As fertilizer mixtures like smophos and nitrophosphate are gaining popularity it is expected that production in India as it is elsewhere will be mostly in the form of complex fertilizers.

Optimum response will not be obtained from an applied phosphatic fertilizer whether water-soluble or water-insoluble unless adequate quantities of the other plant food nutrients are present. According to Tamboli and Misra (1963) nitrogen is the primary limiting factor for crop production. Consequently nitrogen deficiency exerts a particularly marked effect on crop yields. Gericke et al in the year (1952) reported that cereal yields on soils adequately supplied with N and K increased as the content of easily soluble P_2O_5 increased. Increasing easily soluble P_2O_5 content from 0.4 mg. to over 8 mg. per 100 gr. of soil increased cereal yields by atleast 25%.

As there are no soil forming minerals containing nitrogen and most of our soils are poor in organic matter, the natural nitrogen reserve, supply of nitrogen in the form of inorganic or organic fertilizers is essential. This view has been confirmed by extensive trials in our country in which universal

response for nitrogen has been recorded and it is proved that deficiency of this nutrient determined the level of yield. According to Jacob (1960) practically the only combinations of nitrogen present in soil, or added to the soil, which are utilized by plant are ammonia and nitrate. In rice cultivation, fertilizers containing ammonia radicals have generally proved superior to those containing nitrates because there is danger of denitrification and consequent loss of 'N'. Among the ammonical nitrogenous fertilizers sulphate of ammonia has given better performance and is most extensively used.

Field trials have been carried out with dicalciumphosphate by the Indian Council of Agricultural Research; on non-acid soils at Delhi and on calcareous soils (36% CaCO_3) at Pusa (Bihar) using superphosphate for comparison. In Delhi dicalciumphosphate applied with ammoniumsulphate to rice crop increased the yield by 32 percent over ammoniumsulphate alone as against 24% with superphosphate Anonymous (1956).

Hegin in the year (1958) reported that addition of ammoniumsulphate with dicalciumphosphate had no appreciable effect on availability of 'P'.

According to Bixby et al (1964) the ammonium form of nitrogen as found in the complex fertilizers like ammonium-phosphates is not subject to immediate leaching as is the nitrate form. It is particularly suitable on soils subject to severe leaching conditions, such as sandy soils in high rainfall areas. Ammonia ~~and~~ nitrogen also may be preferred for use on calcareous soils as it is converted by bacteria into nitric acid which in turn lowers the soil pH.

Thus it may be concluded that nitrogen has an important role in the uptake of phosphate by plants and the ammonical form preferably as ammoniumsulphate is more suited to rice crop.

PART-II(A) EFFICIENCY OF UTILISATION OF DIFFERENT FORMS OF FERTILIZER PHOSPHORUS:

This review is based on the great volume of experimental work which has been performed by numerous workers over a period of years. References to the publications relating to this work are contained in bibliography. Summaries of some of the more significant findings on efficiency of available phosphorus in fertilizers is given below:

Wurston in the year (1948) reported that when 100 lbs per acre of water-soluble phosphate is added to a calcareous soil its availability is reduced in 24 hrs by 22-25 lbs per acre; after which a relatively constant level of availability is maintained. The availability of citrate-soluble form is much less, but it is subsequently available to succeeding crops. The so called P fixation in these soils is not as significant as in acid soils. Water-soluble phosphates are most advantageous as side dressings to growing crops.

Rogers in the year (1951) summarise the results of numerous field trials in which various nitrophosphates with varying degrees of water solubility were evaluated on generally acid soils, on crops like corn, small grains and cotton. Water solubility greater than 10 percent of the contained phosphate was not as important a factor in increasing yields of these three crops as under South-eastern U.S. conditions. Limited tests on alkaline soils revealed that nitrophosphates of low water solubility were less effective, than highly water-soluble concentrated superphosphate. It was also observed that water solubility probably was more important on soils extremely deficient in nitric phosphates.

Tromel in the year (1951) reported that except for appetite the different phosphates have practically the same fertilizing effect and water-soluble and insoluble P differ in re-

action velocity only. Phosphatic fertilizer is suitable if at equilibrium it releases an adequate concentration of phosphate ions in the soil solution. The degree of concentration of phosphate depends on the type of soil and the applied fertilizer.

Speer et al in the year (1951) conducted a pot culture experiment with 11 fertilizers labelled with P^{32} using Houston clay (pH 8.1) and a Sesquihenna sandy loam (pH 6.0). They concluded that yields generally were proportional to the degree of water-solubility of the phosphorus carrier on the alkaline Houston soil. However the differences due to water solubility were much less pronounced on the slightly acid Sesquihenna soils.

Martin et al in the year (1953) reported the results of pot culture experiment conducted with lettuce on some alkaline and acid California soils. On the acid soil growth was independent of water solubility of the phosphorus carrier, whereas the growth was proportional to the degree of water solubility in alkaline soils.

Bennett et al in the year (1954) summarises of five years study on the efficiency of different sources of phosphatic fertilizers on legumes and grasses. Most soluble forms of phosphatic fertilizers increased yields of dry matter significantly.

Strostks et al in the year (1955) reported that nitro-phosphates with less than 10 percent of their phosphorus content in a water soluble form were less effective than those with a higher degree of water solubility when judged on the basis of crop yields and phosphorus uptake.

Webb in the year (1955) reported the result of three years field trial showing the relative value of phosphatic fertilizers on maize. He concluded that the response to added fertilizer was greatly decreased if the fraction present in the water soluble form was less than 40 percent. Webb

also confirm by field and green house tests with oats, that water solubility of the contained phosphate was more important on alkaline than on acid soils.

Dement et al in the year (1956) reported on the basis of green house and field trials over a period of three years with several nitrophosphates on acid soils. It was concluded that with long season crops grown on acid soils, the degree of water solubility of the contained phosphorus was of minor importance. Where small grains, such as wheat or oats were to be used as forage crops, however, materials with a higher proportion of water soluble phosphorus were more effective in increasing yields.

Olsen et al in the year (1956) working on the availability of phosphate on small grains and clover summarised the result of five years field trial that high degree of water solubility in phosphatic fertilizers was much more effective than low degree of water solubility.

Barbier et al in the year (1957) reported that isotopic study on the solubility of phosphatic fertilizers indicate that the amount of 'P' dissolved from an excess of phosphate increase with the fixing capacity of soil colloids, explaining the greater efficiency of difficulty soluble phosphates in clay than in sandy soils.

Norland et al in the year (1957) conducted experiments with fertilizer containing varied percentages of water soluble 'P' on corn and vetch in green house pot tests with a chester soil limed to a pH of 6.5. Fertilizers used were laboratory prepared nitrophosphates adjusted to 5, 10, 20 and 40 percent water solubility and ammoniumphosphate and triple superphosphate of 100 and 92 percent water solubility respectively. They found that increasing proportions of water soluble 'P' resulted in significantly greater yield and 'P' uptake.

Scharpenseel and Concepcion in the year (1957) investigated the plant availability of phosphate fertilizers in tropical soils. Utilizing P^{32} they showed that reversion of 'P' in insoluble forms was rapid and no significant differences in the solubility of phosphates remained three weeks after application. The citric acid solubility of dicalcium phosphate tended to persist slightly longer than of water soluble phosphates. The 'P' uptake of rice and maize plants in the different soils indicated that water soluble phosphates are more suitable for low land soils rich in clay than the citric acid soluble dicalcium phosphate is, the latter being more effective in deep brown and red upland soils containing high levels of humus and sesquioxide.

Scharpenseel and Concepcion in the same year further studied on the availability to plants of phosphatic fertilizers. The Phillipine soils under study were (1) shallow heavy clay loams, moderate or low nutrients (2) low land soil rich in clay and silt, and (3) deep red brown upland soil rich in humus and sesquioxides. It was noticed that the decrease in 'P' soluble in citric acid in dicalcium phosphate was not very different from that of water soluble 'P' in superphosphate and monoammoniumphosphate although soils (2) and (3) maintained citric acid solubility rather longer than the water soluble 'P'. Analysis of rice and maize indicated that citric acid soluble 'P' was as available as or more available than water soluble 'P' type on (3) soils but less available than water-soluble form on type (1) soil.

Webb and Pesek in the year (1958) reported on the results of 20 field experiments conducted in Iowa on different silt loam and silt clay loam soils (pH.5.3-8) of low 'P' availabilities. Phosphatic fertilizers of 0-100% water solubility were applied in the hill to corn at planting time. As estimated by the yield response, there was a consistent increase in fertilizer efficiency with increasing water

Webb et al in the year (1961) conducted nine field experiments on oats with different phosphatic fertilizers ranging in 'P' solubility from 0-100%, on soils ranging in pH from 5.0 to 7.9. Soil reaction was the most important single factor influencing the effectiveness of the 'P' sources. Generally the degree of 'P' solubility assumed most importance in the calcareous soils while the effect of fertilizer placement was greatest on acid soils. In these out of five experiments located on calcareous soils there was a definite increase in yields with increasing water solubility of the 'P' sources.

Gunnarsson in the year (1961) studied the uptake of 'P' by plants both from water-soluble and citrate-soluble phosphatic fertilizers. He reported that in neutral or acid soils highly water soluble form was taken up most readily at the first cropping but at later harvests uptake of the less soluble phosphate increased.

Beaten et al in the year (1962) conducted an experiment on two calcareous Canadian soils using growth chamber techniques. They studied the effect of various phosphatic materials of differing water solubility on the phosphorus content of the roots and tops of alfalfa plants. They found that 'P' content of tissue increased by the use of highly water soluble phosphatic fertilizers as monoammonium and monocalciumphosphate.

Vogeler in the year (1962) reported that due to high content of hydroxides of iron and aluminium in tropical and sub-tropical soils, water soluble 'P' becomes rapidly fixed, necessitating very high applications of 'P' fertilizers. Water insoluble 'P' does not react with the soil complex hence high efficiency on these soils.

Mettingly in the year (1963) while giving an account of the recent work at Rathemsted and elsewhere on the agricultural value of citrate and water-soluble 'P' fertilizers

revealed that a few experiments on rapidly growing crops (cereals and radishes) suggest that early growth is approximately proportional to the amount of water-soluble phosphate the fertilizer contain.

Van Burg in the year (1963) reported the work carried out at Netherland on the agricultural value of phosphatic fertilizers especially nitrophosphates. For cereals and potatoes the highest yields were obtained with fertilizers containing the highest percentage of water-soluble phosphate. If fertilizers are applied each year in long term field experiments 50% water solubility was adequate for cereals and grass land.

(B) REVIEW OF WORK DONE ON THE RELATIVE EFFICIENCY OF DICALCIUMPHOSPHATE AND SUPERPHOSPHATE:

Most of scientists conducted experiments throughout the world to evaluate the relative efficiency of dicalcium-phosphate with superphosphate, the standard and most popular phosphatic fertilizer of the world. Under different soil and climatic conditions of experiment, different results have been obtained. In certain instances dicalciumphosphate proved superior to superphosphate, in some equal in efficiency and in some cases inferior to superphosphate. The literature on this subject is extensive and a number of references are given in the bibliography. A very brief account of the work is presented below.

Jacob and Rose (1940), Odland and Cox (1942), O'Brien and Obenshair (1942), Stanford and Nelson (1949), Prummel (1954), Popova (1954), Cooke(1955), Strostka and Hill (1955), Cooke(1956) Vithal Rao and Kishen Rao (1963) found dicalcium-phosphate more efficient than superphosphate agronomically.

Uliakov (1939), Karreker (1941), Hongland et al (1942) Robert et al (1942), Poulson and Studier (1945), William and

Reith (1948), Ritz and Lutz (1950), Ensminger (1950), Bureau et al (1953), Vander and Karlovesky (1953), Pierre and Norman (1953), Peterson et al (1953), Bell and Solomon (1955), Cooke (1956), Webb et al (1961), Cooke and Widdowson (1958), Rishi Iswara (1961), Mattingly (1963), reported that dicalciumphosphate was equally effective to superphosphate agronomically.

Niklos (1926), Green (1938), McGeorge (1939), William and Horrington (1939), Odland and Cox (1941), Dae (1944), O'Broin (1944), Ensminger and Cope (1947), Olson et al (1950) Speer et al (1952), Scharrer and Kubu (1952), Schmell et al (1952), Olson and Rhoads (1953), Bennett et al (1954) Schembel et al (1955), Simpson (1956) Rishi et al (1961) and Mattingly (1963) reported that dicalciumphosphate proved inferior to superphosphate agronomically.

EXPERIMENTAL PROCEDURES

(A) Potculture experiment: The experiment was conducted at College of Agriculture, Rajendranagar, Hyderabad.

(a) Programme of work:

(1) Analysis of chalks and Regur soils for mechanical chemical, total Hcl extract and exchangeable constituents. Besides for soil fertility, determination of pH, E.C; O.m; total N, Average P_2O_5 etc.

(2) Analysis of fertilizer material used for the experiment; superphosphate for water-soluble phosphate, dicalcium-phosphate for citrate soluble phosphate and sulphate of ammonia for ammonical nitrogen.

(3) Keeping standard dose of 45 lbs 'P' per acre dicalciumphosphate and superphosphate were used in the following different proportions.

P_1 100% Citrate soluble phosphate

P_2 75% citrate soluble + 25% water-soluble phosphate

P_3 50% " + 50% " "

P_4 25% " + 75% " "

P_5 100% water-soluble phosphate.

(4) Mixing fertilizer as per plan in three series of pots filled with measured soil.

- 1) Series I with crop to be grown to maturity
- ii) Series II with crop for analysis
- iii) Series III without crop for analysis (incubation study).

(5) Maintenance of 60 lbs N and 45 lbs P_2O_5 per acre. Application of total P_2O_5 and 50% N at the time of transplanting and the rest 50% N in two equal split doses at one month intervals.

(6) Maintenance of 1.5" water logging in all the three

series of pots. Transplantation at the rate of three seedlings per pot in series I and II.

(7) Recording growth data on the set of pots maintained in series I (Biometrical observations).

(8) Harvesting the set of plants in series II pots at three stages of sampling.

- i) At tillering
- ii) At flowering
- iii) At milking

Determination of total dry matter per plant and total P_2O_5 and nitrogen in plant tissues.

(9) Collecting soil samples from series II pots after final harvest of rice plants i.e. at third stage of sampling to determine total available and water-soluble P_2O_5 and total 'N'.

(10) Collection of soil samples from III series of pots (incubation study) at four stages of sampling to determine total, available and water-soluble P_2O_5 and total 'N'.

(11) Relating growth data with phosphate analysis as in above and working out recovery of added phosphate on dry weight basis. Preparation of graphs for percentage efficiency of each form of phosphate and working out yield per pot and relating it to growth and phosphate uptake.

(12) Discussing the practical significance of the problem while keeping in view the solubility aspect of the present day common phosphatic fertilizers and fertilizer mixtures.

(b) Plan of experiment: The plan of the experiment is described below (refer next page). There are five treatments with four replications i.e., 20 pots for each type of soil, chalks and regur. As there are three series in each type of soil (two series with plants and one without) altogether there are 120 pots (60 pots for each type of soil).

LAY-OUT FOR POT CULTURE EXPERIMENT FOR BOTH TYPES
OF SOILS CHALKA AND REGUR (Black soil)

Pot No.	Repliation	TREATMENTS		Series I	Series II	Series III
		45 lbs P ₂ O ₅ per acre	60 lbs 'N' per acre.			
1.	I	100% dicelciumphosphate	(NH ₄) ₂ SO ₄	With plants	With plants	Without plants
2.		75% dicelcium+25% super	"	(Main experi-	ts	(in-
3.		50% dicelcium+50% super	"	ments)	(Dumm-	cubs-
4.		25% dicelcium+75% super	"		ies for	tion
5.		100% Superphosphate	"		enly-	study)
6.	II	Same order as above	"		sis at	
7.					three	
8.					stages	
9.						
10.						
11.	III	Same order as above	"			
12.						
13.						
14.						
15.						
16.	IV	Same order as above	"			
17.						
18.						
19.						
20.						

(c) Fertilizer used: The nutrient percentages of the fertilizer used for the experiment were analysed before starting the investigation and actual quantity of each fertilizer required as per plan per pot on moisture free basis was calculated weighed accurately by sensitive balance and applied.

TABLE SHOWING ANALYSIS OF FERTILIZER MATERIAL USED FOR THE EXPERIMENT

Sl. No.	Fertilizer	Total N%	P ₂ O ₅ %		
			Total	Citrate soluble	Water soluble
1.	Single superphosphate	-	16.4	16.4	16.0
2.	Dicalciumphosphate	-	35.12	-	35.12
3.	Ammoniumsulphate	20.6	-	-	-

(d) Filling up pots: Earthen pots of 8" diameter made locally were used for the experiment. For filling soil in the pots typical regur and chalks soil from surface 6" of the barren field in the vicinity of the College was collected. The soil was thoroughly cleaned from stones, weeds etc., and the pots were filled at the rate of 7,000 gm. of soil per pot, three days before planting. The pots were moistened and thoroughly stirred up by hands to a depth of about 6", simulating puddling as under field conditions. No holes were provided in the pots in order to maintain standing water. The tap water was the source of irrigation which was tested and found to be of good quality and neutral in reaction. The fertilizer calculated as per the schedule was applied and mixed thoroughly by hand in each pot.

(e) Transplantation: 55 days old seedlings of H.R.35, the most popular long duration variety of the region, were transplanted at the rate of three seedlings per pot, on 15th August 1964.

(f) Interculture and after cultivation: The soil around the seedlings was stirred by the fingers once in two weeks till the time of primordial stage starting from one month after transplanting. Same operation was done to pots without plants simultaneously. The rest two split doses of ammoniumsulphate were applied at one month intervals i.e., on 15th September and 15th October 1964. Endrine was sprayed twice, at the time of top dressing with ammoniumsulphate, to avoid the incidence of borer.

(g) Observations (Biometrical): In the pots of the main experiment flowering dates were recorded. Average heights of the plants from ground upto tip of the largest leaf, average height of panicles and the number of effective tillers per pot basis were recorded before harvest. Plants were harvested per pot basis leaving a stubble of about 1½" to 2" from ground. The grain was harvested carefully in the envelopes. The grain and straw were weighed separately to constant weight after thorough sun drying. Weight of 100 seeds were also taken in all the treatments, for each replication.

(B) Soil and plant sampling for analysis:

(1) Soil sample - Representative samples of 250 cc. were collected from each pot by mixing the slurry. Samples were allowed to dry in open pans and passed through 2 mm seive and kept in tightly corked glass bottles having proper labels.

Individual plants from each pot of the dummies were collected at different stages. The plant samples were separately dried as rapidly as possible after keeping at temperature of 70°C in an electric oven so as to reduce the chemical and biological changes in these tender leaves to the minimum. The samples from final harvest (grain and straw) were not kept in oven but dried properly under sun. Weight of individual plant sample on moisture free basis was calculated to know the total dry matter produced at different stages of plant growth under different treatments. The individual samples

were then ground finely by electric sample grinder, passed through 40 mm seive and preserved carefully for analysis.

Sl. No.	Type of sample	Pot series No.	Sampling No.	Date of sampling	Stage at which sample was collected	Age of plant
1.	Soil sample (incubation study)	IIIrd	1st	1.10.64	45 days	-
			2nd	31.10.64	75 "	-
			3rd	25.11.64	100 "	-
			4th	15.12.64	120 "	-
		IInd (dummies)	1st	24.11.64	100 "	145 days
		Ist (main experiment)	1st	15.12.64	120 "	175 "
2.	Plant sample	IInd	1st	1.10.64	Tillering	90 "
			2nd	31.10.64	Flowering	120 "
			3rd	25.11.64	Milk	145 "
			Ist	15.12.64	Maturity (harvest)	175 "

(C) Statistical analysis: Changes in the available phosphate and nitrogen under different treatments at different stages and the uptake of phosphate and nitrogen by plants at different stages were analysed statistically by using Fishers method of analysis of variance. The 5% and 1% levels of 'F' test and 'T' test have been used to test the significance of findings. Where the difference was significant, the critical difference (C.D.) was calculated and the significance of one treatment over the other was compared.

(D) Description of the soils selected for the study: The soils under study are 'chalke' (red soil) 'regur' (Black soil) the typical soils predominant in Telengane Region of Andhra Pradesh. The soils were analysed before undertaking the study, description of which is given below:

Sl. No.	Soil constituents analysed	Chalke (Red soil)	Regur (Black soil)
1.	Moisture %	1.05	9.76
2.	Mechanical analysis		
	(i) Coarse fraction		
	Coarse sand %	55.7	15.2
	Fine sand %	12.3	7.4
	(ii) Fine fractions		
	Silt %	10.6	19.1
	Clay %	19.2	54.3
3.	pH	7.2	8.4
4.	Total 'N' %	0.0226	0.0315
5.	Organic carbon %	0.762	1.557
6.	Analysis of Hcl extract		
	CaO%	0.48	2.12
	MgO%	0.08	0.32
	AlO%	4.98	9.42
	FeO%	3.26	13.17
	Total P ₂ O ₅ %	0.107	0.157
	Sesquioxide %	10.15	26.5
7.	Citric acid extract p.p.m.		
	Available P ₂ O ₅	8.19	5.87
8.	Water-soluble salts P.P.H.T.		
	i) Acid radicles	* Nil.	* 5.568
	CO ₃ *		
	HCO ₃	50.251	58.519
	Cl	5.325	9.23
	SO ₄	Nil.	Nil.
	NO ₃	Nil.	Nil.
	ii) Basic radicles		
	CaO	2.03	3.621
	MgO	0.871	1.024
	iii) E.C.m.mhos /cm.	0.23	0.39
9.	Ionic exchange M.e per 100 gm.		
	i) C.E.C.	12.7	68.5
	ii) Exc. Ca	3.9	37.0
	iii) Mg.	0.9	13.7

The above analysis reveals that chelka soils are sandy loam in texture, quite porous and well drained due to high sand and low colloidal content. They have low base status and exchange capacity. They are fairly high in available P_2O_5 16.38 lbs per acre 'Olsen'. They are deficient in organic matter, poor in nitrogen, fairly low in water-soluble salts, Ca, Mg and Fe. and sesquioxides.

The black soils are clay loam, heavy in texture due to very high fine fraction and due to high colloidal content poor in drainage. They have high base status and exchange capacity. High in sesquioxide and water-soluble salts. They are rich in lime and total P_2O_5 , but they are poor in nitrogen and in available P_2O_5 (11.74 lbs per acre).

(E) Methods of chemical analysis:

(A) Fertilizer analysis - The nitrogen and phosphatic fertilizers were analysed by the standard methods as prescribed in Jackson.

(a) Nitrogen - Macro Kjeldhal method direct distillation in the known water extract.

(b) Available P_2O_5 :

(i) Water-soluble P_2O_5 estimation in the known water extract by volumetric ammoniummolybdate method (Femerton procedure).

(ii) Citrate-soluble P_2O_5 - Residue after water-soluble extract digested in neutral ammoniumcitrate solution and determined by volumetric ammoniummolybdate method.

(B) Soil analysis: As large number of samples were to be analysed, quick methods of estimation were followed.

(a) Available P_2O_5 - It was determined by Sodiumbicarbonate method of Olsen et al (1954) as prescribed by Jackson. 5 gm. soil was shaken for 30 mts. with 100 cc of 0.5 M $NaHCO_3$, adjusted to pH 8.5 and a spoon of activated charcoal. Filtered through Whatman No.40 10 cc aliquot taken and P_2O_5

determined Colorimetrically by molybdenum blue method and the result is expressed as p.p.m.

(b) Water-soluble P_2O_5 - Method of Bingham (1949) as prescribed by Chapman and Pratt August 1961 was followed. A 1:10 soil water mixture is shaken for 5 mts, then centrifuged at 20,000 r.p.m. for 20 mts. then phosphate determined by Molybdenum Blue method of Dickmen and Bray stated above.

(c) Total 'N' - It was estimated by Macro Kjeldhal method as described by Shenkeren 1958.

(C) Plant Analysis: As large number of samples were to be analysed, quick methods of estimation were followed.

(a) Total P_2O_5 - It was determined by Vanadomolybdate yellow method as prescribed by Chapman and Pratt 1961. 0.5 gm. of the grinded sample was taken, (except in the case of first two samplings in which case due to limited sample 0.25 gm. was taken), ashed with 2 cc. of $MgNO_3$ 40% and kept in muffle. Ash is dissolved in 2 N HNO_3 and made upto 100 cc. after filtering. In 10 cc. aliquot P_2O_5 is determined by above method and result is expressed as p.p.m. by help of standard curve

(b) Total 'N' - 0.1 to 0.2 gm. of the representative sample was taken and nitrogen estimated by Micro Kjeldhal method as prescribed by Piper 1950.

R E S U L T S

A brief description of the results obtained is given below:

(A) Observations (Biometrical)

(i) Flowering and maturity: Though in the case of chalka flowering started about four days earlier and the crop maturity too was about four days earlier, there was no marked difference due to solubility of 'P' on time of flowering.

(ii) Tillering and height measurements: From the data presented in the Table (1) (detailed tables in appendix 1 and 2), it is evident that tillering was poor in all the treatments but height was more conspicuous. Except for the height of panicle in black soils, the rest of the results are insignificant statistically. In general the tillering under black soil was lower than chalka.

(iii) Dry matter: Dry matter production at different stages of plant growth under different treatments is shown in the table (2). In both the soils the growth (production of dry matter) was more pronounced with the water-soluble 'P' in early stages of growth, whereas in the course of time and final stage dicalcium 'P' has given better performance especially in chalka and rather equal performance of both dicalcium and super 'P' was noticed in black soil. Histogram 1 showing this trend is enclosed.

(iv) Yield: The yield data of grain and straw is shown in the table (3). Except for grain yield in the black soil, the rest of the results are insignificant statistically. In general the grain yields were higher than the yields of straw. In chalka soil yield was in direct proportion to citrate-soluble 'P' in fertilizer though 75% citrate-soluble 'P' has given slightly better performance, the results are not statistically significant; whereas in case of black soil treatment with 25% and 100% water-soluble 'P' has given maximum grain yield and the results are statistically significant. Histogram 2 showing

the yield trend is enclosed. No variations are noted in the seed weights under different treatments.

(B) Analytical data:

(a) Plant:

(i) Uptake of P_2O_5 :- Results are shown in the table (4) (detailed tables in appendix 3A to 3D). It is noticed that the uptake was directly proportional to citrate-soluble 'P' in the fertilizer. Graph (1) representing this trend is enclosed. The results are statistically significant except for chalka at tillering stage and strew at final harvest in black soil.

(ii) Uptake of 'N' :- Results are shown in the table (5) (detailed tables in appendix 4A to 4D). There was no marked variation in the different treatments.

(b) Soil:

(i) Available P_2O_5 :- Results are shown in the table (6) (detailed tables in appendix 5A to 5F). Though there is a marked increase in the availability throughout the experiment, the effect of the treatments reveal that in chalka in the early stages the super 'P' was more available but in the later stages availability of dicalcium 'P' increased; whereas in black soil both the forms of 'P' were more or less in equal proportions. The results are statistically significant in case of dummies. Graph (2) showing this trend is enclosed.

(ii) Water-soluble P_2O_5 :- Results are shown in the table (7) (detailed tables in appendix 6A to 6F). Black soil has shown more water-soluble P_2O_5 content than chalka. It seems that in chalka intensity of water-soluble P_2O_5 was more pronounced under soils treated with greater proportions of citrate-soluble fertilizer, dicalciumphosphate. Any distinct trend is not visible in black soils. The results of main experiment pots are statistically significant. Graph (3) showing this trend is enclosed.

(iii) Total 'N' :- Results are showing the table (8) (detailed tables in appendix 7A to 7F). There is no marked variation due to 'N' content under different treatments.

MAIN EXPERIMENT POTS 5 Treatments & 4 Replications

D = Dicalcium phosphate (Citrate-Soluble 'P' water in soluble)

S = Super phosphate (Water-Soluble 'P')



CHALKA

BLACK SOIL

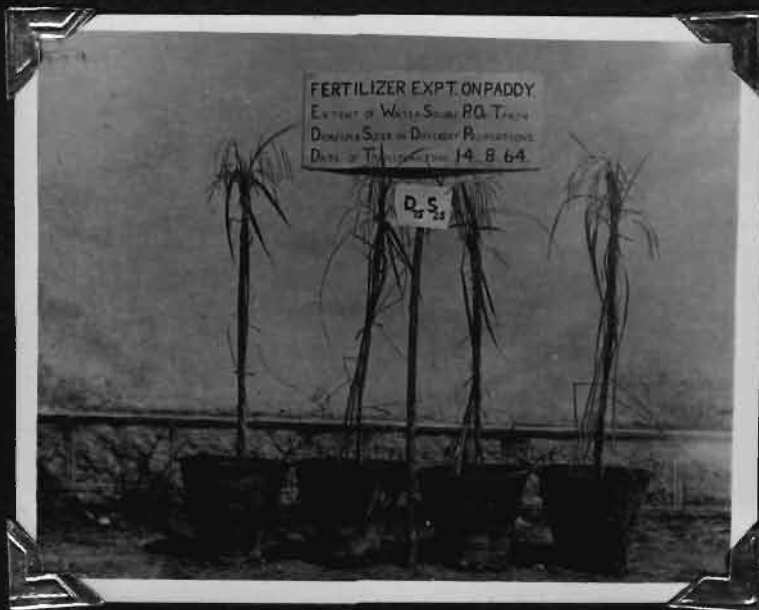




CHALKA
 Treatment P₁
 Dicalcium 'P' 100%.



CHALKA
 Treatment P₃ Dicalcium
 'P' 50% + Super 'P' 50%.



CHALKA
 Treatment P₂ Dicalcium
 'P' 75% + Super 'P' 25%.



CHALKA

*Treatment P₄ Dicalcium
'P' 25% + Super 'P' 75%.*



CHALKA

*Treatment P₅
Super 'P' 100%.*



BLACK SOIL

*Treatment P₂ Dicalcium
'P' 75% + Super 'P' 25%.*



BLACK SOIL

*Treatment P₃ Dicalcium
'P' 50% + Super 'P' 50%*



BLACK SOIL

*Treatment P₄ Dicalcium
'P' 25% + Super 'P' 75%*



BLACK SOIL

*Treatment P₅
Super 'P' 100%*

COMPARATIVE STUDY OF ALL THE TREATMENTS (P₁, P₂, P₃, P₄ & P₅)

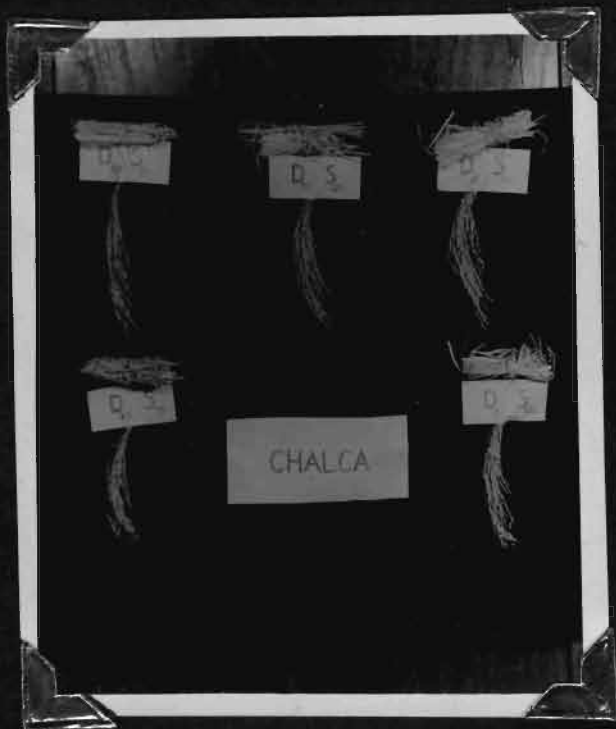


CHALKA

BLACK SOIL



YIELD PER POT (GRAIN & STRAW) UNDER DIFFERENT TREATMENTS



CHALKA

BLACK SOIL



LIST OF TABLES, HISTOGRAMS AND GRAPHS ENCLOSEDI. TABLES:

- 1) Dry matter production at different stages of plant growth.
- 2) Consolidated table for height of complete plant and panicle at harvest and the number of effective tillers.
- 3) Yield in grams per pot basis alongwith statistical analysis.
- 4) Consolidated table for total 'P' in plants.
- 5) Consolidated table for total 'N' in plants.
- 6) Consolidated table for available 'P' in soils.
- 7) Consolidated table for water-soluble 'P' in soils.
- 8) Consolidated table for total 'N' in soils.

N.B: FOR FURTHER DETAILS PLEASE REFER TO THE LIST OF DE-
TAILED TABLES PROVIDED WITH THE DATA IN THE APPENDIX.

II. HISTOGRAMS:

- 1) Yield of straw and grain.
- 2) Dry matter production at different stages of plant growth.
- 3) Fixation of 'P' under different treatments and its relation to yield.

III. GRAPHS:

- 1) Total 'P' in plants
- 2) Available 'P' in soils
- 3) Water-soluble 'P' in soils.

GUIDE TO TABLESI. Abbreviations

- (A) P₁ - 100% citrate-soluble phosphate
 P₂ - 75% citrate-soluble + 25% water-soluble phosphate
 P₃ - 50% " + 50% "
 P₄ - 25% " + 75% "
 P₅ - 100% water-soluble phosphate.
- (B) R - Replication.

II. Explanatory terms(A) Soil:

<u>Pot series</u> <u>No.</u>	<u>Sampling</u> <u>No.</u>	<u>Stage at which</u> <u>sample collected</u>	<u>Age of plant</u>
III (incubation study)	1st	45 days	
	2nd	75 "	
	3rd	100 "	
	4th	120 "	
II (dummies)	1st	100 "	145 days
I (Main expt.)	1st	120 "	175 "
		Tillering	90 "
		Flowering	120 "
		Milk	145 "
		Maturity	175 "

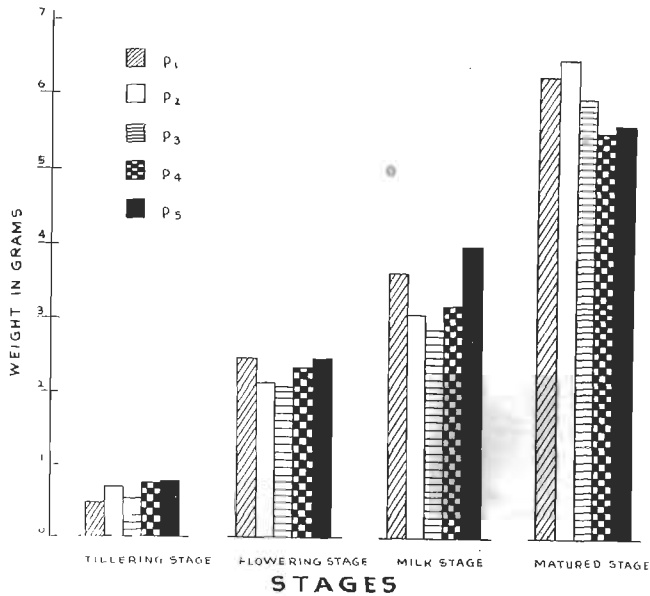
TABLE-I

Dry matter production at different stages of plant growth, under different treatments.
(Moisture free basis, in grams)

.....

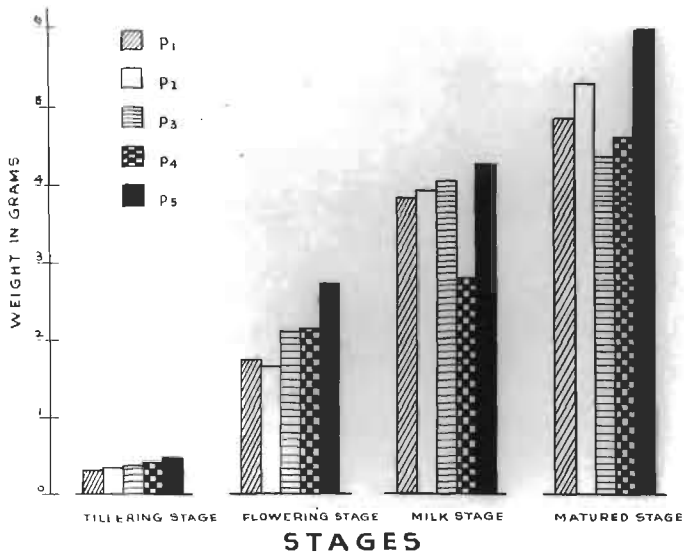
Soil type	Phosphorus material in various proportions	Whole plant weight at different sampling stages Average of four replications			
		Tillering stage	Flowering stage	Milk stage	Matured stage
Chalka	P ₁	0.4676	2.4484	3.6115	6.2341
	P ₂	0.4680	2.1032	3.0292	6.5407
	P ₃	0.5165	2.0565	2.8373	5.9529
	P ₄	0.7315	2.3195	3.1611	5.5043
	P ₅	0.7599	2.4436	3.9535	5.6228
Black soil	P ₁	0.2945	1.7542	3.8632	4.8735
	P ₂	0.3405	1.6729	3.9288	5.2934
	P ₃	0.3613	2.1065	4.0361	4.3386
	P ₄	0.4039	2.1617	2.7878	4.6038
	P ₅	0.4562	2.7503	4.2626	5.9869

CHALKA



HISTOGRAM 1. SHOWING WHOLE PLANT WEIGHT AT DIFFERENT SAMPLINGS AS INFLUENCED BY THE DEGREE OF SOLUBILITY OF THE APPLIED PHOSPHATE.

BLACK SOIL



HISTOGRAM 1. SHOWING WHOLE PLANT WEIGHT AT DIFFERENT SAMPLINGS AS INFLUENCED BY THE DEGREE OF SOLUBILITY OF THE APPLIED PHOSPHATE.

TABLE - II

Height of complete plant and panicle at harvest and
number of effective tillers, under different
treatments
(Average of four replications, per pot basis)

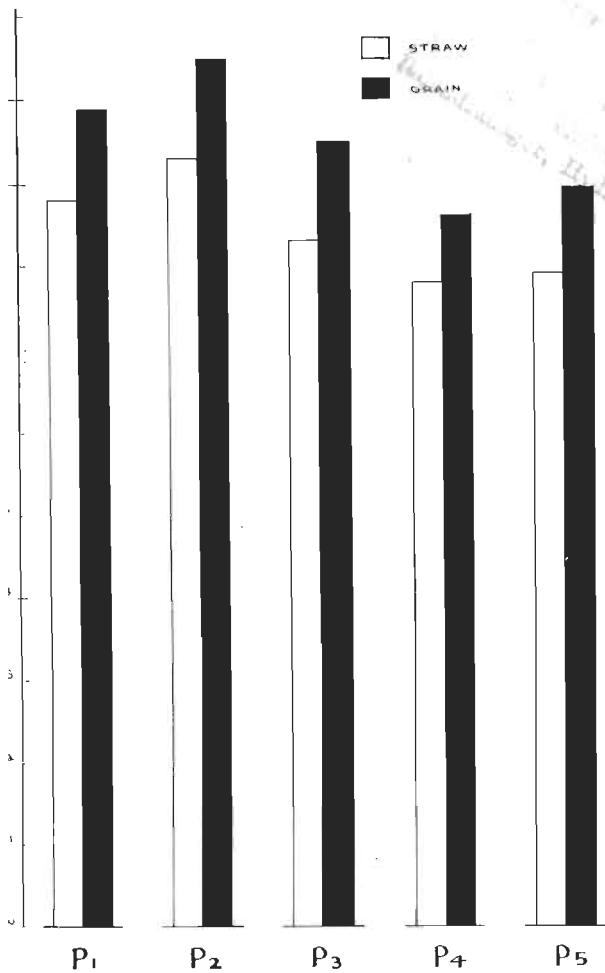
Soil type	Phosphorus material in various proportions	Average height measurements in cms.		No. of effec- tive tillers
		Whole plant	Panicle	
Chalke	P ₁	118.84	24.22	8.75
	P ₂	113.65	22.25	9.00
	P ₃	123.14	22.54	8.25
	P ₄	119.06	22.16	7.50
	P ₅	118.59	23.27	7.50
Black soil	P ₁	118.72	24.08	6.00
	P ₂	118.21	24.57	7.00
	P ₃	115.89	22.22	5.00
	P ₄	114.21	21.49	5.75
	P ₅	124.57	21.69	8.0

TABLE - III

Grain and straw yield per pot basis and weight of 100 grains
(Moisture free basis in grams)

Soil type	Phosphorus material in various proportions	GRAIN				Average Weight yield of 100 grains	
		R _I	R _{II}	R _{III}	R _{IV}		
Chalka	P ₁	10.9737	9.8149	10.6657	8.1273	9.8954	1.4896
	P ₂	10.5931	8.4547	11.7547	11.3823	10.5462	1.4518
	P ₃	11.4340	8.2269	8.4498	9.9119	9.5056	1.5054
	P ₄	9.6219	9.8272	7.8024	7.3701	8.6554	1.4203
	P ₅	9.2423	8.8842	7.5922	10.1666	8.9713	1.4915
Black soil	P ₁	7.4247	5.9336	8.9892	7.9034	7.5627	1.4800
	P ₂	9.9092	8.2374	7.0117	7.7668	8.2313	1.4332
	P ₃	7.0874	6.8617	5.7888	6.4365	6.5436	1.4855
	P ₄	7.6457	6.8822	7.0388	6.9398	7.1266	1.4415
	P ₅	11.5729	9.0682	8.2011	7.8063	9.1621	1.4511
				<u>STRAW</u>			
Chalka	P ₁	9.2991	8.6793	9.5037	7.7459	8.8070	
	P ₂	9.4982	7.3594	10.6771	9.8427	9.3443	
	P ₃	10.5146	7.2876	7.5033	8.1079	8.3530	
	P ₄	8.4097	8.4077	7.4677	7.1312	7.8541	
	P ₅	8.4850	7.5277	6.4991	9.0768	7.8972	
Black soil	P ₁	6.2287	6.0206	8.7042	7.2783	7.0580	
	P ₂	8.7823	7.4698	7.2903	8.0892	7.9079	
	P ₃	7.0278	7.7944	5.6070	5.4504	6.4722	
	P ₄	7.2304	6.4338	6.5353	6.5397	6.6848	
	P ₅	10.5639	8.4955	7.8705	7.2654	8.5238	

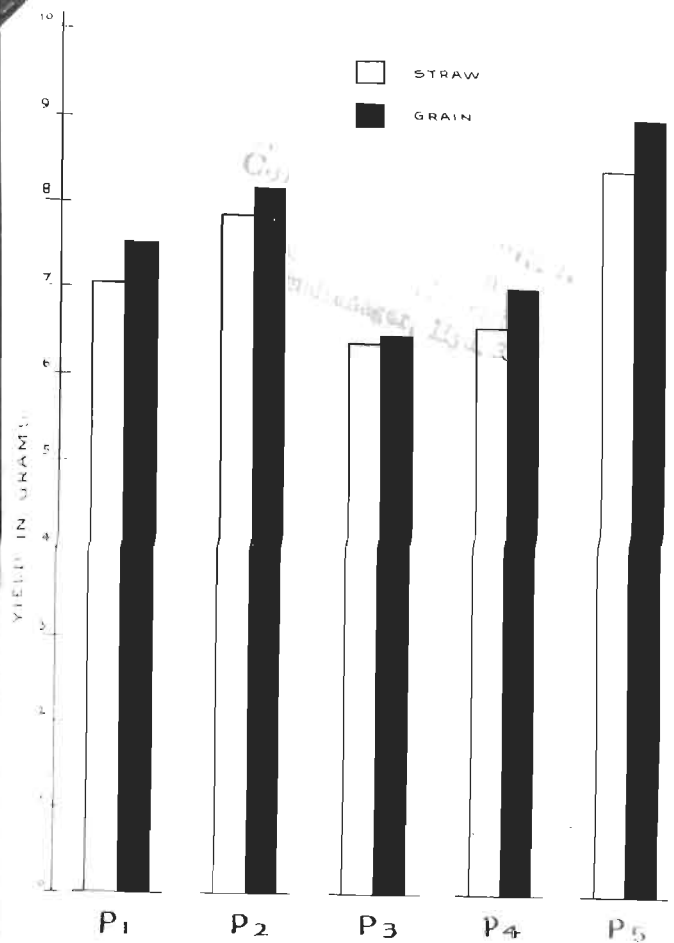
CHALKA



TREATMENTS

HISTOGRAM 2. SHOWING YIELD OF RICE PER POT BASES UNDER DIFFERENT TREATMENTS.

BLACK SOIL



TREATMENTS

HISTOGRAM 2. SHOWING YIELD OF RICE PER POT BASES UNDER DIFFERENT TREATMENTS.

STATISTICAL ANALYSIS OF YIELD

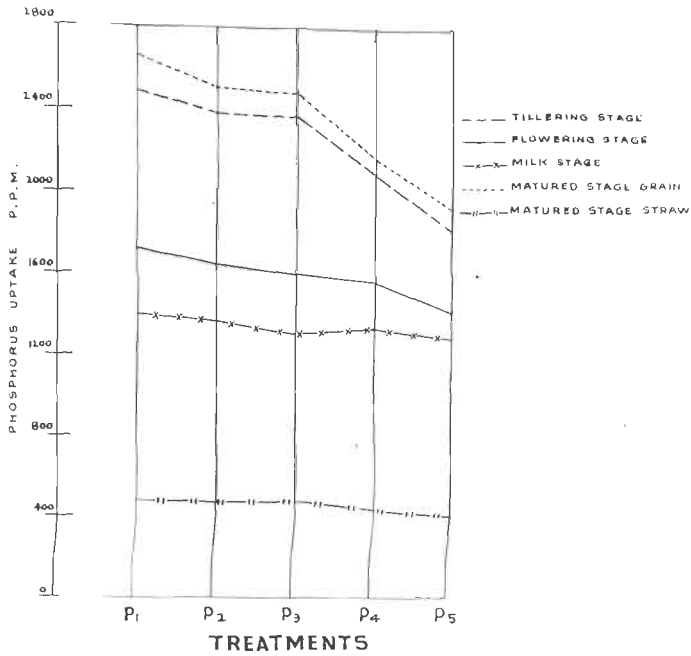
A.V. TABLE					SUMMARY OF RESULTS		
Due to	S.S.	D.F.	M.S.S.	F	Tr.	Mean yield	% G.M.
<u>GRAIN</u> <u>(CHALKA)</u>	B.S.S.	5.221	3		P ₂	10.5462	109.913
	Tr.S.S.	8.971	4	2.243	P ₁	9.8954	103.131
	Er.	20.934	12	1.745	P ₃	9.5056	99.155
	T.S.S.	35.126	19		P ₅	8.9713	93.615
					P ₄	8.6554	90.280
					G.M.	9.595	100.00
					S.E.M.	0.66	6.88
<u>GRAIN</u> <u>(BLACK SOIL)</u>	B.S.S.	6.712	3		P ₅	9.1621	118.603
	Tr.S.S.	16.412	4	4.103	P ₂	8.2313	106.554
	Er.	12.563	12	1.047	P ₁	7.5627	97.909
	T.S.S.	35.687	19		P ₄	7.1266	92.254
					P ₃	6.5436	84.717
					G.M.	7.725	100.000
					S.E.M.	0.51	6.602
					C.D.	1.57	20.32
Result significant at 5% level							
					P ₅	8.5238	116.223
<u>STRAW</u> <u>(CHALKA)</u>	B.S.S.	5.023	3		P ₂	9.3443	110.570
	Tr.S.S.	6.411	4	1.603	P ₁	8.8070	104.213
	Er.	14.529	12	1.211	P ₃	8.3530	98.840
	T.S.S.	25.963	19		P ₅	7.8972	93.447
					P ₄	7.8541	92.936
					G.M.	8.451	100.000
					S.E.M.	0.55	6.508
<u>STRAW</u> <u>(BLACK SOIL)</u>	B.S.S.	2.968	3		P ₅	8.5238	116.223
	Tr.S.S.	12.441	4	3.110	P ₂	7.9079	107.835
	Er1	51.042	12	4.254	P ₁	7.0580	96.236
	T.S.S.	66.451	19		P ₄	6.6848	91.148
					P ₃	6.4722	88.249
					G.M.	7.334	100.00
					S.E.M.	0.32	4.363

TABLE - IV

Total P_2O_5 ⁱⁿ plants at different stages of plant growth under different treatments
(Average of four replications at moisture free basis in p.p.m.)

Soil Phosphorus type material	in various proportions	Total P_2O_5 plants at different stages					
		Tillering stage	Flowering stage	Milk stage	Matured stage		
					Grain	Straw	Total
Chalks	P ₁	2510.64	1721.50	1402.08	2657.40	480.11	3137.51
	P ₂	2391.22	1646.66	1368.17	2509.10	468.44	2977.54
	P ₃	2378.49	1600.76	1303.51	2497.49	480.65	2978.14
	P ₄	2107.23	1573.21	1345.25	2172.00	440.89	2612.89
	P ₅	1823.53	1418.28	1293.02	1932.00	410.51	2342.51
Black soil.	P ₁	1452.64	1174.60	1137.78	2019.32	402.87	2422.19
	P ₂	1371.62	1189.92	1146.38	2121.95	425.18	2547.13
	P ₃	1367.54	1217.49	1066.86	2001.78	411.15	2412.93
	P ₄	1277.39	1177.45	1011.28	1937.75	406.85	2344.60
	P ₅	1229.79	1085.69	1024.63	1791.23	398.47	2189.70

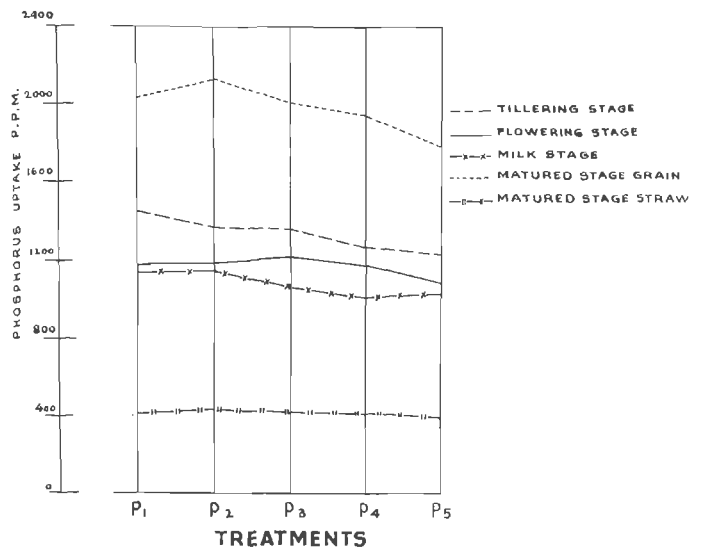
CHALKA



GRAPH 1. SHOWING PHOSPHORUS UPTAKE BY RICE PLANT AS INFLUENCED BY THE DEGREE OF SOLUBILITY OF THE APPLIED PHOSPHATE.

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BLACK SOIL



GRAPH 1. SHOWING PHOSPHORUS UPTAKE BY RICE PLANT AS INFLUENCED BY THE DEGREE OF SOLUBILITY OF THE APPLIED PHOSPHATE.

TABLE - V

Total 'N' in plants at different stages of plant growth under
different treatments
(Average of four replications at moisture free basis in percent)

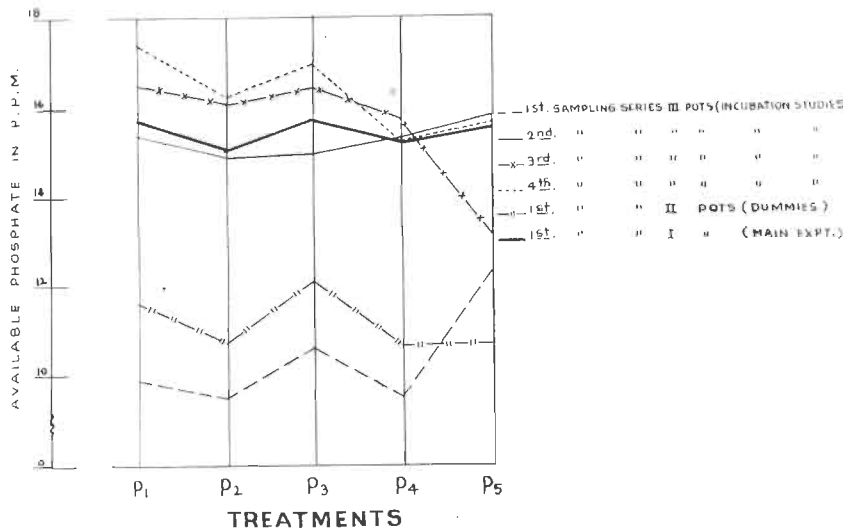
Soil Phosphorus type material in various proportions		Total 'N' in plants at different stages					
		Tillering stage	Flowering stage	Milk stage	Matured stage		
					Grain	Straw	Total
Chelke	P ₁	3.133	1.964	1.294	1.427	0.552	1.979
	P ₂	2.958	2.002	1.316	1.392	0.581	1.973
	P ₃	3.060	1.933	1.218	1.304	0.642	1.946
	P ₄	3.074	2.036	1.315	1.484	0.675	2.159
	P ₅	3.090	1.984	1.196	1.414	0.687	2.101
Black soil	P ₁	2.619	1.854	1.017	1.384	0.653	2.037
	P ₂	2.641	1.888	1.217	1.366	0.779	2.145
	P ₃	2.642	1.891	1.196	1.525	0.709	2.234
	P ₄	2.483	1.844	1.097	1.513	0.793	2.206
	P ₅	2.575	1.844	1.208	1.425	0.680	2.105

TABLE - VI

Available P_2O_5 in soil at different stages under different treatments
(Average of four replications on moisture free basis in p.p.m.)

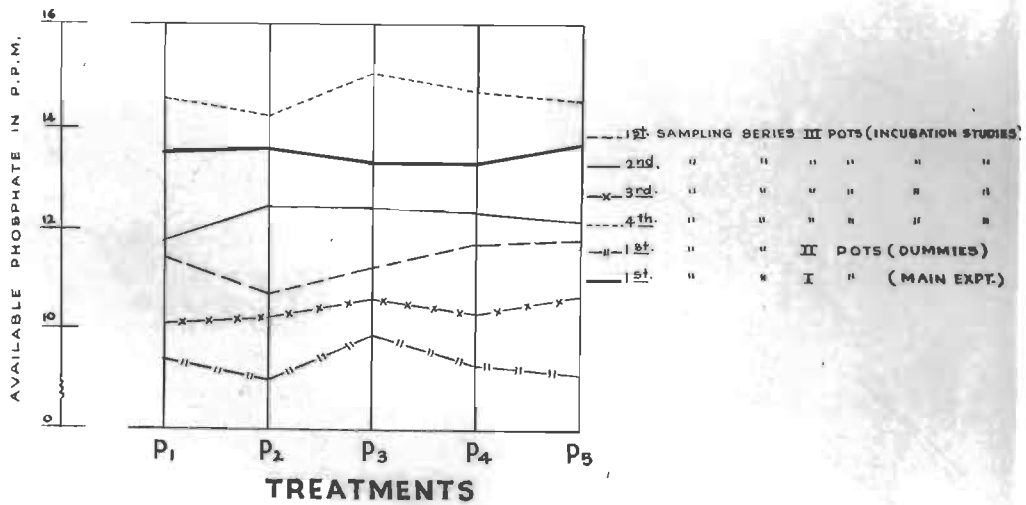
Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Series II pots (dummies) 1st sampling	Series I pots (main experiment) 1st sampling
		1st sampl- -ing	2nd sampl- -ing	3rd sampl- -ing	4th sampl- -ing		
Chelka	P ₁	9.94	15.34	16.53	17.45	11.62	15.69
	P ₂	9.49	14.89	16.12	16.30	10.75	15.02
	P ₃	10.62	14.91	16.45	16.95	12.07	15.84
	P ₄	9.52	15.32	15.78	15.30	10.65	15.31
	P ₅	12.27	15.81	13.12	15.59	10.72	15.59
Black soil	P ₁	11.42	11.73	10.11	14.62	9.39	13.47
	P ₂	10.68	12.43	10.22	14.25	9.01	13.56
	P ₃	11.19	12.42	10.58	15.10	9.93	13.31
	P ₄	11.70	12.35	10.32	14.74	9.32	13.33
	P ₅	11.82	12.21	10.65	14.55	9.13	13.66

CHALKA



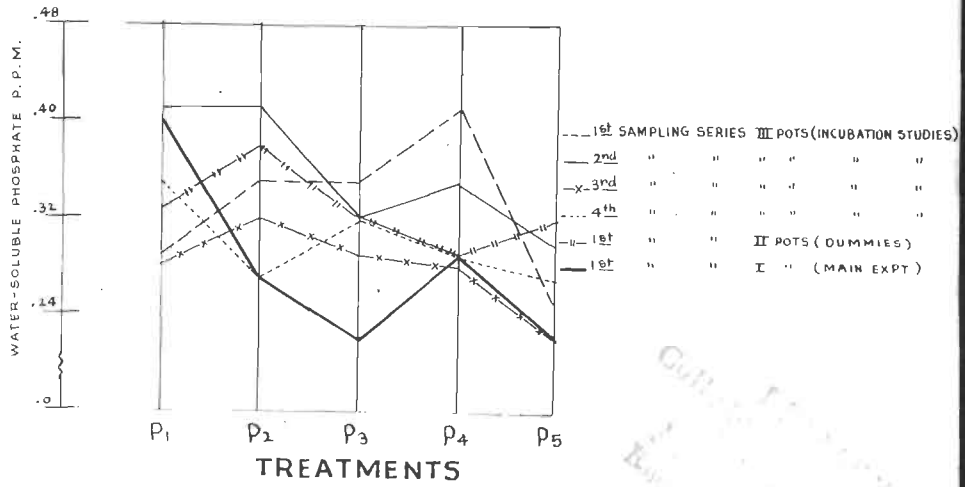
GRAPH 2. SHOWING THE CHANGES IN AVAILABLE PHOSPHORUS IN SOILS AS EFFECTED BY THE DEGREE OF SOLUBILITY OF THE APPLIED PHOSPHATE

BLACK SOIL



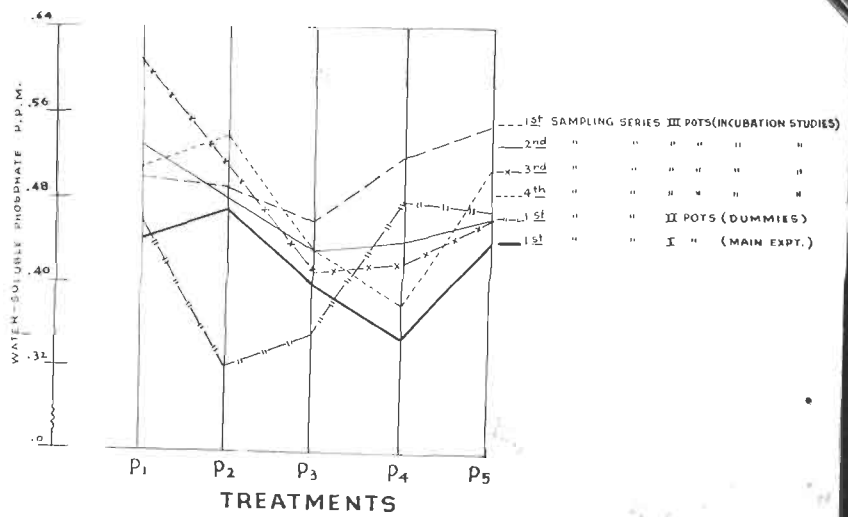
GRAPH 2. SHOWING THE CHANGES IN AVAILABLE PHOSPHORUS IN SOILS AS EFFECTED BY THE DEGREE OF SOLUBILITY OF THE APPLIED PHOSPHATE.

CHALKA



GRAPH 3. SHOWING THE CHANGES IN WATER-SOLUBLE PHOSPHORUS IN SOILS AS INFLUENCED BY THE DEGREE OF SOLUBILITY OF THE APPLIED PHOSPHATE.

BLACK SOIL



GRAPH 3. SHOWING THE CHANGES IN WATER-SOLUBLE PHOSPHORUS IN SOILS AS INFLUENCED BY THE DEGREE OF SOLUBILITY OF THE APPLIED PHOSPHATE.

TABLE - VIII

Total 'N' in soil at different stages under different treatments
(Average of four replications at moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Series II pots (dummies)	Series I pots (main experiment)
		1st samp- -ing	2nd sampl- -ing	3rd sampl- -ing	4th sampl- -ing	1st sampling	1st sampling
Chalke	P ₁	0.0518	0.0483	0.0525	0.0340	0.0382	0.0197
	P ₂	0.0517	0.0456	0.0526	0.0366	0.0376	0.0214
	P ₃	0.0511	0.0430	0.0553	0.0375	0.0429	0.0207
	P ₄	0.0476	0.0509	0.0542	0.0373	0.0377	0.0207
	P ₅	0.0535	0.0524	0.0502	0.0386	0.0425	0.0253
Black soil	P ₁	0.0598	0.0465	0.0467	0.0304	0.0342	0.0192
	P ₂	0.0582	0.0457	0.0447	0.0303	0.0341	0.0196
	P ₃	0.0591	0.0453	0.0479	0.0339	0.0368	0.0206
	P ₄	0.0571	0.0475	0.0468	0.0356	0.0317	0.0231
	P ₅	0.0596	0.0414	0.0504	0.0347	0.0308	0.0188

CRITICAL DISCUSSION

The primary purpose of fertilizers is to improve and increase the production of economic crops. It is believed that a plant absorbs phosphorus into its tissue in the form of its monobasic, ionic form H_2PO_4 . Further more a water-insoluble phosphatic material must be converted by chemical, thermal or biological means to a form that will release its phosphorus in the soil solution as ionic H_2PO_4 , before it can be considered a satisfactory carrier of nutrient phosphorus. It is for this reason that solubility of phosphates may become very important. Availability of phosphorus to plants is a function of the distribution and solubility of applied fertilizer and the phosphorus reaction products in the soil immediately surrounding the fertilizer granules.

Dicalciumphosphate dissolves very slowly in soil. Under some conditions octocalciumphosphate, a relatively new compound to fertilizer studies is formed and it is believed that this new solid phosphate is important in controlling the phosphorus composition and the pH condition of the liquid film which surrounds particles of the applied dicalciumphosphate. Plant roots are known to completely surround in very intimate fashion the fertilizer particle soil interface. The knowledge of just how the calciumphosphate types of compounds supply phosphorus and perhaps calcium to plants is quite incomplete. The above discussion gives some idea of the complex chemical reactions occurring in the root zone. The results obtained in this study can therefore be explained with this serious limitation in mind.

An examination of the market condition shows a large multiplicity of fertilizer mixtures supplying both water-soluble and citrate-soluble forms. It would be an impossible task to study the solubility performance of these products within the time limit available, hence this simplified experiment was devised to provide varying ranges of water and citrate solubility.

This approach is justified particularly by the results obtained by Lawton et al (1959) and Tromel (1951). Green house experiments conducted by Lawton et al using P^{32} labelled phosphatic fertilizers of wide range of solubility in comparison with commercial type mixed fertilizers revealed that there was no substantial difference in the behaviour between these two types of applications on yield of crops. Tromel's concept that any phosphate fertilizer which produces at equilibrium an adequate concentration of 'P' in soil solution is suitable for crop growth, is also kept in mind while judging the agronomic value of phosphatic fertilizers of different solubilities.

Keeping in view the complex behaviour of soil phosphorus under normal conditions and those obtaining under water-logged conditions involving rice culture where the relationship between water, soil and rice plant are so different in fertility studies, an attempt is made to explain the varying results obtained in the present study. For a proper understanding of the results, it is found necessary to classify the critical discussion under the following headings.

- (1) Solubility effect in relation to growth and yield.
- (2) Comparative study of the uptake of water-soluble and water-insoluble 'P' by plants.
- (3) The changes in available 'P' in soil during the entire study.
- (4) Comparative efficiency of dicalciumphosphate and superphosphate.
- (5) Comparative efficiency of phosphatic fertilizers in relation to their fixation assessed by working out recovery of added phosphate on dry weight basis.

(1) Solubility effect in relation to growth and yield:

It will be more appropriate to give a brief explanation with regard to observation on flowering, maturity and grain and straw yields in chalks and black soil.

The early flowering and maturity and high yield obtained in conformity with Speer (1951), can be attributed to higher uptake of P_2O_5 both from native and applied phosphates, whereas in the case of black soil which contains a higher percentage of colloids than chalks, the non-availability of soluble 'P' is more pronounced leading to more vegetative growth and delay in flowering and maturity. Incidentally it is clear that the inherent limitations met with in pot culture experimentation are probably responsible for higher grain yields than straw. (Mahinder Reddy 1960). In any case the higher yields of dry matter indicate the beneficial effect of 'P' applications.

Yield is the cumulative effect of several factors like growth, number of effective tillers, panicle length and number of grains per pot etc. But no significant correlation was obtained with regard to height in plant and panicle in the present study. The increased grain yields in the experiment clearly indicate the importance of the possible role of soluble 'P' in inducing increased tillering.

It is also found that in the early growth period the dry matter production was in proportion to the water-soluble 'P' in fertilizer. During the later stages of growth a better performance is found in chalks soils treated with citrate-soluble form than the black soil. In the early stages of plant growth the application of water-soluble 'P' will give a response to the young seedlings resulting in better root spread leading to high production of dry matter, whereas in advanced stages the plant has better root growth compared with seedling stage which enables it to obtain its requirements by coming in direct contact with the large soil surface as well as fertilizer granules. A doubt may be raised at this point that plants will have a set back if their growth is checked up in the early stage. It is evident in these studies that under the reducing conditions of water-logging, water-insoluble 'P'

is mobilised to become more available to meet the minimum requirements of normal plant growth in the earlier stages, though at a slower rate. The acidic nature of chalks, when compared to the black soil with higher pH, is responsible for the gradual solubility of dicalciumphosphate over a longer period rather than an immediate start by quick solution. Thus in the long run the gradual and steady solubility of dicalciumphosphate is superior to an immediate solubility as in the case of superphosphate (pH studies of the soil slurry immediately after collection for analysis at different stages of plant growth revealed that in chalks pH was ranging from 6.7 to 7.0 whereas in black soil it was between 7.0 to 7.4). These findings are in conformity with Ensminger (1959), Mattingly (1963) and are in accordance with the explanation given by Caldwell in the Minnesota soil series No.47.

Yield in chalk soils was more or less directly proportional to water-insoluble 'P' (although 75% water-insoluble 'P' has given slightly higher yield than 100% water-insoluble form, the result is statistically insignificant). Whereas in black soil 25% and 100% water solubility has given maximum yield and the results are statistically significant (Treatment with 100% water solubility was on par with 25% water solubility yet former has given higher yield than the later). With regard to this performance in the present study, the above discussion holds good. In addition to water-logging, soil colloids etc., pH played an important role in effectiveness of phosphatic fertilizers of different solubilities. This pH effect is in conformity with the findings of Webb et al (1961), who compared in his experiment different fertilizers ranging in 'P' solubility from 0 to 100% and concluded that soil reaction was the most important single factor influencing the effectiveness of 'P' sources. Besides the initial fairly high content of available P_2O_5 in chalks may also be responsible for the poor response of water-soluble 'P' in fertilizers (Tisdale and Rucker 1964). The findings of other workers referred below supported yield data obtained in these studies.

Speer et al (1951), Martin et al (1953) and Webb (1955) confirmed by field and green house tests that water solubility in phosphatic fertilizers was more important on alkaline soils than in acid soils. Archer and Thomas (1956) summarise that most of the workers and especially Olsen, Smith and Webb have shown that fertilizers containing a high proportion of water-soluble 'P' stimulated earlier growth but did not increase yield. Scherpenseel and Concepcion in the year (1957) revealed that the 'P' uptake of rice in the different soils indicated that water-soluble phosphates are more suitable for such low land soils which are rich in clay than the citric-acid soluble dicalciumphosphate.

(2) Comparative study of the uptake of water-soluble and water-insoluble 'P' by plants:

Uptake of phosphorus was maximum in the initial stages of plant growth. Nearly 50% of the total 'P' was absorbed when only about 20% of the total growth had occurred. This is followed by a period when the phosphorus absorbed remained practically constant. Then again very rapid uptake of phosphorus took place during seed formation. This trend is in conformity with the trend described by Olsen and Fried (1957) and findings of Seetha Rama Rao (1960).

It is revealed by the present experiment that uptake of P_2O_5 by rice crop was directly proportional to water-insoluble 'P' in fertilizers. These results are contradictory to findings of many workers who used dicalciumphosphate and superphosphate in their studies. Hall (1949); Dion (1949) and Blaster and McAuliffe in the same year reported that uptake was high from water-soluble 'P' in superphosphate. Some workers like Olsen (1950), Bennett et al (1954) and Norland et al (1957) revealed that both uptake and yield were higher in case of super 'P'.

In view of the above findings of the other workers and the contradictory results in the present study, the complexity

of the problem is evident. On the basis of the trend reported by Olsen, Bennet and Norland that high uptake is linked with high yield the present findings may be justified in case of chelks as the yield too was in proportion to uptake of water-insoluble 'P' whereas in case of black soil even though uptake of water insoluble 'P' is more the yield is high in treatments receiving more of water-soluble 'P'. The high uptake of 'P' from water-insoluble 'P' when compared with water-soluble 'P' in black soil may be due to very slow rate of conversion of dicalciumphosphate to tricalciumphosphate and other forms (Scharpenseel and Concepcion 1957), whereas water-soluble 'P' is immediately converted to other less soluble forms. No doubt in black soil the immediate conversion of monocalciumphosphate will be to a great extent into dicalciumphosphate, the immediate chemical reaction for this conversion may result in low uptake of 'P' from superphosphate. The seemingly contradictory results with reference to yield obtained in the black soil under both water-soluble and water-insoluble treatments and a higher uptake of 'P' under water-insoluble 'P' treatments may be due to some agronomic or physiological factors. The over all uptake is very poor as compared to chelks. This may be attributed to high pH resulting in increase in the concentration of hydroxyl ions, which compete with phosphate ions in the uptake by plants.

One more reason for over all high uptake of water-insoluble 'P' (dicalciumphosphate) may be due to increased nutritive value of dicalciumphosphate as resulted by increase in 'P' solubility in the presence of soluble salts and perhaps ammoniumsulphate may be playing an important role in this respect. Sterostka and Hill in the year 1955 measured the solubility of dicalciumphosphate in water and several salt solutions in green house test on lucerne. Salts such as ammoniumsulphate that increased the solubility of dicalciumphosphate with increasing ionic strength also gave the greatest crop responses.

The high uptake of dicalcium 'P' is also noticed by some other workers. Lawton et al (1956) reported that degree of solubility of 'P' had little effect on 'P' uptake and yield of crops, when powdered fertilizer was applied and same findings have been confirmed by Cook et al (1957). Gunnarsson (1961) reported that in pot experiment in a neutral and acid soil monocalciumphosphate was taken up most readily at first cropping but at later harvests uptake of the less soluble phosphates increased. Besides Singte et al in the year (1961) also found similar results as obtained in the present study while conducting an experiment on different soils including red and black soils.

Thus the above discussion reveals that there is peculiar behaviour of phosphate in relation to uptake and no single factor may be attributed to explain the high uptake of water-insoluble 'P' in relation to water-soluble 'P'

(3) Changes in the available 'P' in the soil during the entire study:

The gradual increase in availability throughout the experiment is mainly due to intensity of reducing conditions associated with flooding and increasing with time, leading to an increased release of soil phosphorus. Such results have been confirmed by Ghosh (1956). At Central Rice Research Institute, Cuttack it was noticed that phosphate extractable from Mergens reagent increased from 1.6 mg. to 4.1 mg. of P_2O_5 per 100 gram of soil in a period of seven days of water-logging.

In the present study it was also noticed that in chalks in the early stages the super 'P' was more available but in the later stages availability of dicalcium 'P' increased, whereas in black soil both the forms of 'P' were more or less equal in proportion. These results may also be contributed to reducing conditions prevailing during the study. These conditions favoured low fixation of water-soluble 'P' in clay complex,

reduced the chances of formation of unavailible ironphosphate compounds and also lowered the reversion of water-insoluble form of 'P' resulting in more or less higher availibility of both water-soluble and citrate-soluble 'P' in black soil. In chalks due to low colloidal content availability of water-soluble 'P' was not much effected especially in the early stages. Plant secretions, decomposition of algae developed in water-logging and the initial low pH of this soil favoured the increase in availability of citrate-soluble 'P' in advanced stages. These results are in confirmity with DeGues (1957) who reported similar trend while studying reducing conditions in wet rice growing.

In the present experiment an attempt was also made to correlate the water-soluble P_2O_5 content of the soil with the availibility to plant and yield of rice in different treatments. No doubt the application of fertilizer increased the water-soluble P_2O_5 content in the soil, the attainment of equilibrium was rapid in both the soils for all treatments. Crop plants were able to absorb phosphorus from extremely dilute solutions at rates sufficiently rapid to support maximal growth. It may be true that water-soluble phosphorus is the source of phosphorus for plants under natural conditions in soils and according to Arnon (1953) Bingham experiments provide support for the concept that phosphorus nutrition of plants grown in soils can be explained by the action of the water-soluble phosphorus without the necessity of invoking any auxiliary mechanism. The technique in this estimation was to use displaced soil solution for the chemical determination of the available phosphorus status in the soil. In the present study it is revealed that analyzing the soil solution does not give the true picture of the facts. Perhaps the concentration of phosphorus in close proximity to soil particles is considerably higher than that in soil solution hence correlation to availibility in different treatments could not be obtained. The results obtained re-

presented an equilibrium value and not a complete measure to judge available phosphate in soil. According to Arnon (1953) Parker, Pierre and Tidmore while analyzing productive soils found similar results in some instances. They concluded that water-soluble phosphorus as found in displaced soil solution could not by itself account for the phosphorus supply of crops. They evoked an additional mechanism, that of root soil contact, to explain 'P' absorption from soils.

High content of water-soluble 'P' in chalks under treatments having high citrate-soluble 'P' reveals that fixation of citrate soluble 'P' is not as quick as water-soluble 'P' in this soil due to reasons already stated above. Low pH of chalks further assisted in bringing into soil solution more of citrate-soluble 'P' while the black soil has not shown any distinct trend in the availability of either water-soluble 'P' or water-insoluble 'P'.

(4) Comparative efficiency of dicalciumphosphate and superphosphate:

In the present study while evaluating the efficiency of water-soluble and water-insoluble forms of phosphatic fertilizers an opportunity too was obtained to judge the efficiency of dicalciumphosphate and superphosphate, the two phosphatic materials used under the experiment. The study revealed that in general dicalciumphosphate was on par with superphosphate though slightly better performance is noted in chalks and superphosphate proved slightly better in black soil. This peculiar behaviour of dicalciumphosphate and superphosphate in two different soils one in chalks, the soil slurry of which at the root zone has shown an inclination towards acidity and the other the black soil which has shown an inclination towards alkalinity, may be explained in the light of the views of Tisdale and Rucker (1964). According to them when superphosphate is applied to the soil, water vapour moves rapidly into each granule. A solution is formed which is saturated with monocalciumphosphate and dicalciumphosphate dihydrate. A residual dicalciumphosphate remains



at the site of the original particle. The saturated solution that moves out of the granule is concentrated with respect to phosphorus and calcium and it is extremely acid (pH 1.8). This concentrated acid solution moves out in front reacting as it goes with different soil constituents. In soils inclined towards acidity, the reaction is largely with compounds of iron, aluminium and manganese, which are dissolved in the acid solution. In time, the phosphates of these three ions are precipitated. Whereas soils inclined towards alkalinity like calcareous soils, the moving phosphate front is precipitated as dicalcium phosphate on the surface of the particles of calcium carbonate. Further reversion to hydroxyapatite may occur. Phosphate ions also may react directly with calcium ions in the soil solution forming dicalcium phosphate and under some circumstances, small amounts of hydroxyapatite.

In case of dicalciumphosphate when applied to the soil no soil solution is formed and as a result dispersion of the reaction products into the soil surrounding the original fertilizer particle does not occur and reaction with the soil constituents proceeds slowly and availability to plants is reduced, especially in soils with alkaline reactions.

Though the behaviour of dicalciumphosphate and superphosphate in the present study is in conformity with the above findings, the results are not so distinct and sharp. The reducing conditions under water-logging have slightly changed the behaviour of these phosphatic materials. Within limitations it increased availability of both the forms of phosphates to a more or less appreciable extent and no outstanding distinction between the two forms was visible. In short it may be concluded that dicalciumphosphate was on par with superphosphate. Ritz and Lutz (1950) Ensminger (1950), Bureau et al (1953), Vander and Karlovsky (1953), Peterson et al (1953), Bell and Solomon (1955), Cooke (1956) who summarised results of 400 field experi-

-ments, Webb et al (1961) and Rishi and Iswaran (1961) who worked at I.A.R.I., New Delhi have all evaluated the efficiency of dicalciumphosphate with superphosphate on different crops in different soils and got similar results. This has also been confirmed in paddy soils, where water-logging causes reducing conditions, by Vithal Rao and Kishen Rao (1963) and by DeGues as explained in his latest book "means of increasing rice production".

(5) Comparative efficiency of phosphatic fertilizers in relation to their fixation by working out recovery of added phosphate on dry weight basis:

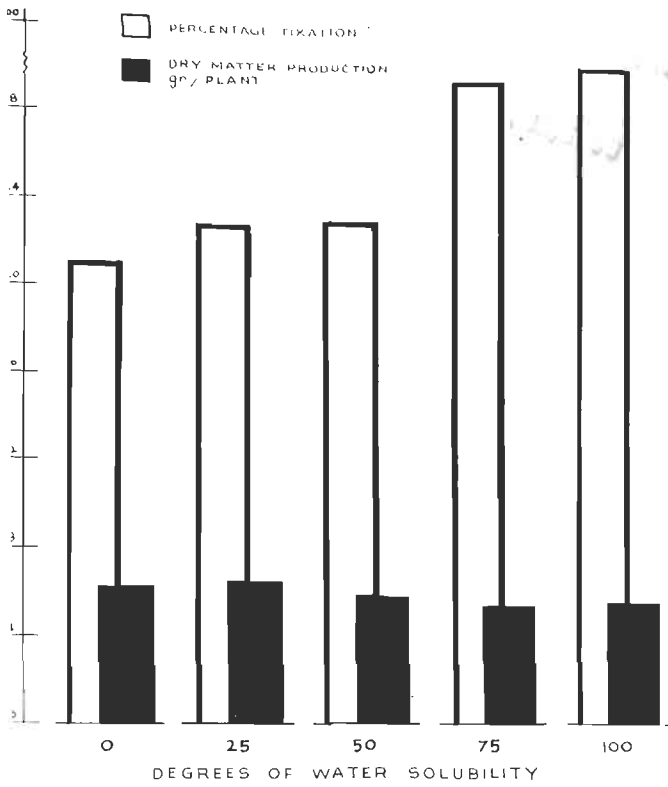
The results achieved in the present study regarding fixation of 'P' in relation to solubility and yield are shown in the following table.

(Results on moisture free basis in grams)

Soil type	Phosphorus material in various proportions.	'P' fixation in soil per pot basis				Percentage fixation.	Dry matter production per plant.
		Avail-able 'P' in soil at the start of expt.	Avail-able 'P' in soil at the end of expt.	Avail-able 'P' taken by plant	Avail-able 'P' fixed in expt.		
Chalka	P ₁	0.2057	0.1038	0.0584	0.0435	21.15	6.2341
	P ₂	"	0.0994	0.0592	0.0471	22.90	6.5407
	P ₃	"	0.1048	0.0532	0.0477	23.19	5.9529
	P ₄	"	0.1013	0.0431	0.0613	29.80	5.5043
	P ₅	"	0.1031	0.0395	0.0631	30.68	5.6228
Black soil	P ₁	0.1841	0.0704	0.0354	0.0783	42.53	4.8735
	P ₂	"	0.0708	0.0411	0.0722	39.22	5.2934
	P ₃	"	0.0695	0.0314	0.0832	45.19	4.3386
	P ₄	"	0.0696	0.0324	0.0821	44.60	4.6038
	P ₅	"	0.0714	0.0387	0.0741	40.25	5.9869

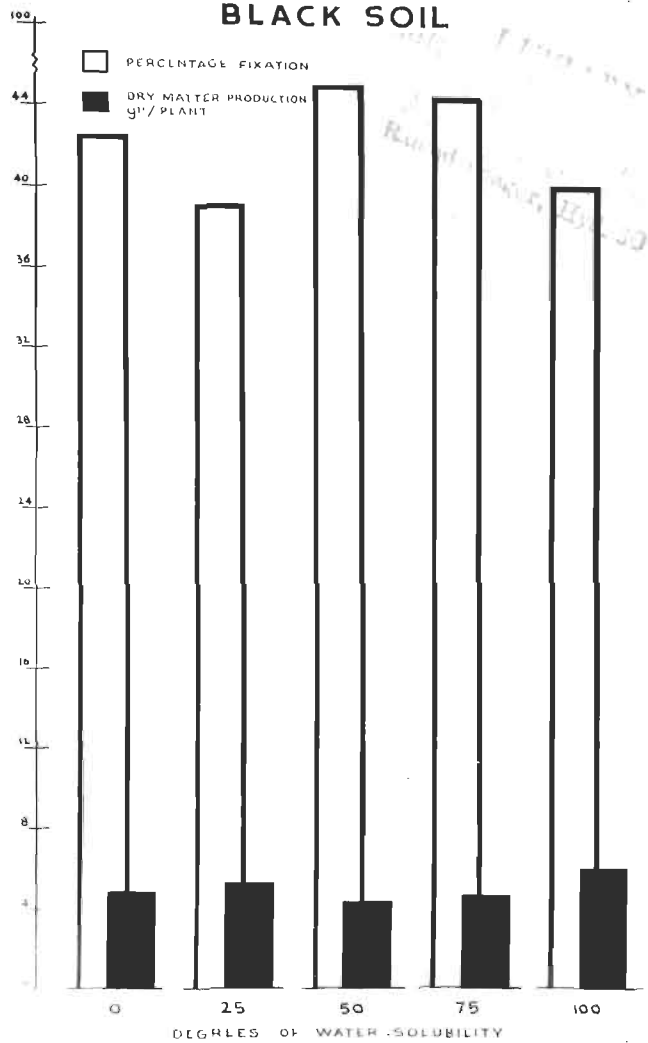
It is evident that in chalka fixation gradually increased with increase in water-soluble 'P' in the treatments, whereas yield was quite opposite to this trend. In black soil though yield has similar trend as in chalka, with regard

CHALKA



HISTOGRAM 3. SHOWING THE FIXATION OF 'P' UNDER DIFFERENT TREATMENTS AND ITS RELATION TO YIELD.

BLACK SOIL



HISTOGRAM 3. SHOWING THE FIXATION OF 'P' UNDER DIFFERENT TREATMENTS AND ITS RELATION TO YIELD.

to fixation, there was no marked distinction between the treatments. Treatments receiving 25% and 100% water-soluble 'P' from fertilizer phosphorus have given higher yield than the rest. Due to high colloidal content the over all fixation was high in black soil than chalke. Histogram 3 showing this trend is enclosed.

Thus present study has revealed that in chalke yield was inversely proportional to fixation i.e., indirectly to soluble 'P' content in fertilizer, phosphorus; whereas in black soil though there was similar trend of yield in relation to fixation, no definite relationship with solubility is visible.

PRACTICAL IMPORTANCE OF THE STUDY

This study is undertaken to judge the solubility of fertilizer phosphorus and to compare simultaneously the efficiency of the two phosphatic materials used for the experiment i.e., dicalciumphosphate and superphosphate. According to Caldwell (Minnesota soil series No.47) none will dispute the current widespread importance of solubility of fertilizer phosphorus. This interest can be attributed to a number of things among them, greater fertilizer use, competition for the fertilizer rupee, entry into the market of fertilizer mixtures having various grades of phosphate solubility, plus recent research indicating an advantage for water-soluble materials under some conditions.

Modern trend in farming is to reduce the crop unit cost of production which implies the use of high analysis fertilizers getting the highest production per man hour of labour. Low analysis materials such as ammoniumsulphate and single superphosphate should be discouraged and their use avoided wherever possible in the interest of more efficient and more profitable farming. Hence trend for using fertilizer mixtures containing concentrated phosphates chief among them comprising ammoniumphosphates and nitrophosphates is gaining favour. These new fertilizers comprise the majority tonnage of the fertilizer consumed in the advanced countries and in India too experimental evidence is favouring an expanded use of mixed fertilizers as a means of increasing food production of farm crops and maintaining the fertility of the soil. One of the resolutions recommended by the seminar of fertilizers and manures held in New Delhi during the World Agriculture Fair in January and February 1960, dealt with research into the relative efficiency of water-soluble and citrate-soluble phosphates when used on different soils and crops. The purpose of the recommended research was specifically to enable the Govt. to decide upon the type of mixed

fertilizer that should be produced in India. One factor militating against the production and use of more concentrated phosphate is the non recognition in the fertilizer law of our country, of citrate-soluble P_2O_5 as a satisfactory supplier of nutrient phosphorus. The modern trend in fertilizer technology is to prepare compounds by ammoniating superphosphate or phosphoric acid or acidulating phosphate-rock with nitric acid, yielding a complex mixture of nitrates and phosphates called nitrophosphates. According to Bixby (1961) in these processes some portion is converted from water-soluble to citrate-soluble form as in case of Amophos and in case of nitrophos though the phosphate component of the product of this reaction is in water-soluble monocalcium-phosphate form, the product is unsuitable for fertilizer use because the contained calciumnitrate causes it to be hygroscopic and also causes the monocalciumphosphate to be unstable. Thus water-soluble phosphate is largely converted to citrate-soluble phosphate, the dicalciumphosphate. Hence in the market fertilizer mixtures of varying proportions of water-soluble and citrate-soluble phosphorus are available. On the one hand largely water-soluble forms are available as Amophos A and B and on the other hand largely water-insoluble forms as nitrophos P.E.C. are manufactured. In between there are several proportions as Udda nitrosphos and different grades of Government of India fertilizer mixtures.

In this state of affair agricultural scientists of our country have to evaluate the present day phosphatic fertilizers in terms of solubility. To what extent must a fertilizer phosphorus be water-soluble when applied in a mixed fertilizer? How far may the water-solubility be reduced in the interest of economy before it causes decreases in the yield or quality of crop? Is there a significant difference between water-soluble and ammonium citrate-soluble phosphate in the production of farm crops? No doubt these questions have agitated

several agronomists and fertilizer manufacturers for many years and a vast amount of laboratory, green house and field experimentation throughout the world has been devoted to the elucidation of the multiple factors involved in the complex problems surrounding these questions, this field is rather new for our country as evidenced by the above discussion. Until a body of knowledge of the behaviour of the nutrients commonly present in materials used as fertilizers on different soil type and climatic conditions is built up locally in terms of chief food crops, the economic utility of the vast number of present day phosphatic fertilizers will not be achieved in its true sense and it will be a major handicap for self sufficiency of food grains in India. The present study is one of attempt in this line. Rice crop is taken as it is the chief food crop and the choice of a suitable phosphatic fertilizer for rice is a burning topic of the day.

For a long time only the water-soluble P_2O_5 i.e., the form of phosphoric acid in superphosphate was considered assimilable by plants. Hence superphosphate was the only phosphatic fertilizer manufactured and consumed in large scale, in our country, due to its suitability for soils of all kinds and simplicity in production. Comparing the production of phosphoric acid with the annual requirement, it is just a drop in the ocean. For the preparation of superphosphate sulphuric acid is required. The production of this acid is limited in this country as all the sulfur required for the purpose has to be imported. According to Patel (1953) due to the great demand of this acid in other industries only 20% of it is used for superphosphate production. Besides India has to depend on foreign countries for the supply of high grade phosphate rock; as the Indian apatite is of low grade and is unsuitable due to the presence of deleterious substances. Since the introduction of industrial processes for the production of dicalcium phosphate, which economises the use of sulphuric acid, its industrial

expansion is possible. Several desirable properties of this citrate-soluble phosphatic fertilizer, a brief description of which is given under review, enables it to compensate the demand of phosphatic fertilizers, not only in its pure state but also as an essential ingredient of common fertilizer mixtures like nitrophosphates and highly ammoniated super, hence this fertilizer is competing superphosphate. As such the comparative study of dicalciumphosphate and superphosphate for rice crop will be of great advantage both to the agronomists and to the cultivators.

The present study has given an incentive in this direction. It is concluded that in chalky yield of rice has increased in proportion to citrate-soluble 'P' in phosphatic fertilizer; whereas in black soil both water-soluble and citrate-soluble 'P' have given more or less equal results. It is also concluded that dicalciumphosphate is on par with superphosphate.

Thus in view of the above findings that citrate solubility is a blessing and not the curse, there is greater scope in our country for the popularity of new phosphatic fertilizers which are more economical. It may be worth while to suggest that field experiments have to be conducted to confirm these findings and if persistent results will be obtained, the Govt. of India may be approached to accept the concept that ammoniumcitrate soluble and water-soluble 'P' have equal manurial value.

SUMMARY AND CONCLUSIONS

The form of available P_2O_5 in fertilizers plays an important role in crop production. As such in the present study an attempt is made to evaluate in terms of crops response, the comparative fertilizing value of different proportions of water-soluble and water-insoluble 'P' so as to judge the single and mixed phosphatic fertilizers available in the country, on the basis of 'P' solubility. Rice crop is selected as it is the chief crop of Andhra Pradesh and the chief food grain of our country. A pot culture experiment is conducted on the typical soils of Telengana Region, the chalka and black soils. The recommended dose of 60 lbs 'N' per acre is applied as ammonium sulphate. The recommended dose of 45 lbs of P_2O_5 per acre is applied in the form of superphosphate and dicalcium phosphate in different proportions to provide different grades of solubility as required by the experimental plan. Both soil and plant samples were drawn from the experimental pots, at four stages of plant growth i.e., tillering, flowering, milk stage and maturity, to know the effect of solubility on the changes in available P_2O_5 and 'N' in the soil and uptake of the same by plants. Finally the yield in different treatments is compared to judge the efficiency. The following conclusions are drawn.

(1) High degree of water solubility gave a good response in the early stages of plant growth whereas in the later stages citrate-soluble 'P' has given better response in chalka and rather low response than water-soluble 'P' in black soil.

(2) The uptake of P_2O_5 by plants was greater for citrate-soluble 'P' throughout the experiment.

(3) In the early stages water-soluble 'P' has shown higher availability in soil whereas in the later stages citrate-soluble 'P' gave better performance. This trend was especially pronounced in chalka.

(4) The yield of rice has increased in proportion to the citrate-soluble 'P' in phosphatic fertilizers in chelka; whereas in black soil both citrate-soluble and water-soluble 'P' have given more or less equal yields.

(5) Dicalciumphosphate was on par with superphosphate.

(6) In chelka yield was inversely proportional to fixation i.e., indirectly to soluble 'P' content in fertilizer phosphorus; whereas in black soil though there was similar trend of yield in relation to fixation, no definite relationship with solubility is visible.

Thus in view of the above findings, it may be generalized within certain limitations, that citrate-solubility in phosphatic fertilizers is desirable in the interest of economy and production. The usefulness of dicalciumphosphate, as a 'P' carrier, as revealed in the studies, encourages its widespread agronomic use and its increased manufacture industrially as a supplement and one of the gradual substitute to superphosphate thereby ~~eliminating~~ eliminating use of scarce and costly sulphur.

BIBLIOGRAPHY

- Arnon, D.I. 1953 The physiology and Biochemistry of phosphorus in green plants. Agron. series vol. IV Chapt. I. Academic Press Inc.; N.Y. (1953)
- Archer, J.R; Thomas, R.P. 1956 Water-soluble phosphorus in fertilizers J. Agric. Food Chem. 4, 608-613
- Anonymous 1956 F.A.O. Report.
- Blester, R.E. and McAuliffe, C. 1949 Utilisation of 'P' from various fertilizer materials by orchard grass and Lendino clover. Soil Sci. 68: 145
- Bureau, M.F. et al 1953 The effect of 'P' fertilizer materials and soil 'P' level on the yield and 'P' uptake of soyabean. Agron. J. 45 (4): 150-154
- Bennett, O.L. et al 1954 A comparison of the efficiency of 18 sources of phosphate fertilizers on Houston black clay. Proc. Soil Sci. Soc. Amer. 18: 408-412 (1954)
- Bell, R.S. and Solomon, M. 1956 A field comparison of eight phosphate fertilizers. Agron. J. 48: 409-412
- Barbier, G 1959 Defenition of available phosphorus in soil. Fertilite No. 6 Jan. 1959.
- et al. 1957 The dissolution of difficulty soluble phosphates in soil, studied by means of isotopic dilution. Agro. Chemicals 1, 210-222 as reported in soils and fertilizers Abs. (1957).
- Bouldin, D.R. and Sample, E.C. 1959 Laboratory and green house studies with monocalcium, monoammonium and diammonium phosphates. Proc. Soil Sci. Soc. Amer. 23: 338-342 (1959)
- Beaton, J.D. et al 1962 The influence of soil moisture regime and phosphorus source on the response of alfalfa to phosphorus. Proc. Soil Sci. Soc. Amer. 26: 265-270 (1962).
- Bixby, D.W. et al 1964 Phosphatic fertilizers properties and processes. Sulphur Inst. Tech. Bull. No. 8 Feb. (1964)

- Cooke, G.W. 1955 Alternatives to superphosphate. J.Minist.Agric.62: 27-30.
- Cooke, R.L. et al 1957 Phosphorus solubility, particle size and placement as related to the uptake of fertilizer phosphorus and crop yields. Comm.Fertil.94, No.6, 41-43, 46-47. C.A.51.
- Chapman, Homer and Praft, Parker F. 1961 Analysis of soil, plant and water. Univ.Calif.Aug.1961.
- Caldwell, A.C. The solubility of fertilizer phosphates Univ.Minist.Inst.Agric.Soil Series No.47
- Daş, S. 1944 The manurial value of different mineral phosphates in calcareous soils. Ind.J.Agric.Sci.14: 269.
- Dion, H.G. et al 1949 The study of fertilizer uptake using dicalcium 'P'. The availability of 'P' carriers in calcareous soils. Sci.Agric.68:512 quoted from Proc.Soil Sci.Soc.Amer.19 (1955).
- Dean, L.A; Fried, M. 1953 Soil plant relationship in the phosphorus nutrition of plants. Agron.Series Vol.IV Chapt.II. Academic Press Inc., N.Y.(1953).
- Dement, J.P.; Seatz, L.F. 1956 Crop response to high alumine nitric-phosphate fertilizers. J.Agric.Food Chem.4:432-435 (1956).
- DeGeus, Ir.J.G. 1957 Reductive conditions in wet rice growing Their influence on the availability of plant nutrients, fertilizing and respiration of the roots. Stikstof, Dutch nitrogenous fertilizer review No.1, July(1957).
- De, S.K. 1963 India's contribution to the study of phosphate fixation by soils, clay minerals, hydrous oxides and lime. Journal of Ind.S.Soil Sci.Vol.II June(1963).
- DeGeus, F.G. Means of increasing rice production. Land bouwkundig Ingenieur Agronomist with Centraal Stikstof Verkoopkontoor n.v. The Hague Geneva.
- Ensminger, L.E and Cope, J.T. 1947 Effect of soil reaction on the efficiency of various phosphates for cotton and on

- loss of 'P' from erosion.
J.Amer.Soc.Agron.39: 1-11.
- Ensminger L.E. 1950 Response of crops to various phosphatic fertilizers.
Als.Agric.Expt.Ste.Bull.270.
- Preps,G.S. and Sterges,A.J. 1939 Effect of phosphate on nitrifying capacity of soils.
Soil Sci.47:115.
- Chedhe,T.R. and Kulkarni,A.N. 1963 Fertilizer statistics 1962-'63
Fertilizer Assoc. of India,New Delhi.
- Green,J.R. 1938 Phosphate investigation on irrigated crops.
Mont.Agric.Expt.Ste.Bull.356: 31.
- Gericke,S. and Zeschitz,E.V. 1952 Phosphoric acid content and soil productivity.
Phosphorsäure 12; 129-141 as reported in soils and fertilizers abstract, 631.85 (1952).
- Ghosh,R.L.M. et al 1956 Rice in India.
I.C.A.R. Publication.
- Gunnarsson,O. 1961 The uptake of phosphorus by plants from various phosphorus compounds.
K.Skogs Lantbruk Akad.Tidskr.Suppl.6, 26-35 (Sw.e.) as reported in soils and fertilizers Abst.225:221.18(1961).
- Hougland,G.V.C. 1942 Nutrient value of some new phosphatic materials used on potatoes.
Amer.Fert. 97 (7): 5-8
- Hell,N.S. et al 1949 Utilization of 'P' from various fertilizer materials.
Soil Sci.68:151.
- Hegin,J. 1958 Availability of dicalciumphosphate to plants when applied in various forms.
Plant and Soil 10: 101-113.
- et al 1961 Efficiency of phosphatic fertilizers of varying water solubility.
Canad.J.Soil Sci. 41: 68-80.
- Jacob,J.D. and Rose,W.H. 1940 Nutrient value of phosphorus in defluorinated phosphate, calciummetaphosphate, and other phosphatic materials as determined by growth of plants in pot experiment.

- J.Agric.Res.61(7): 539-560
- Jackson,M.L. 1949 Chemical and physiological methods of analysis.
- Jacob,A and Uexkull,H.V. 1960 Fertilizer use (Nutrition and manuring of tropical crops).
- Karraker,P.E. et al 1941 Green house tests of the availability of 'P' in certain phosphate fertilizers.
Ky.Agric.Expt.Sta.Bull.413:57-86.
- Krishna Murthy,C.H. 1963 Dose required to correct phosphorus deficiency in soil for rice.
et al J.Ind.Soc.Soil Sci.Vol.II June (1963)
- Lawton,K; et al 1956 Influence of particle size, water-solubility and placement of fertilizers on the nutrient value of phosphorus in mixed fertilizers.
Soil Sci.82; 465-476.
- 1959 Comparision of the availability to plants of phosphorus from mixed salt and commercial type fertilizers.
J.Agric.Food Chem.7: 112-114
- McGeorge,D.T. 1939 Factors influencing the availability of native soil 'P' and phosphate fertilizers in Arizone soils.
Ariz.Agric.Expt.Sta.Tech.Bull.82:295-331
- McKelvey,J.B. et al 1953 Domestic phosphate deposits.
Agron.Series Vol.IV Chapt.XI.Acad. Press Inc., N.Y.(1953)
- Martin,W.E. et al 1953 Effect of ammoniation on availability of phosphorus in superphosphates as indicated by plant response.
Soil Sci.75:41-49 (1953).
- Mahinder Reddy,K. 1960 Studies of phosphate placement techniques in black and red soils of Telengana - in respect of paddy. Thesis submitted for M.Sc.(Ag) College of Agriculture,O.U.
- Mettingly,G.E.G. 1963 The agricultural value of some water and citrate soluble fertilizers; an account of recent work at Rothamsted

- and elsewhere.
Proc.Ferti.Soc.Lond.75: 57-98(1963)
- Niklas,H. et al 1926 Further fertilizer experiments with super,basic slag,Rhenania phosphate and dicalciumphosphate on four different types of soils.
Landw. Jahrb.63:607-625 as reported in Amer.Chem.Soc.Abst.22:1008-1009.
- Norland,M.A. et al 1957 Influence of water-soluble phosphorus on agronomic quality of fertilizer mixtures containing two phosphatic compounds.
J.Agric. and Food Chem.5:217-219(1957)
- ----- 1958 Crop response to phosphate fertilizers as influenced by level of phosphorus solubility and time of placement prior to planting.
Proc.Soil Sci.Soc.Amer.22: 529-533(1958)
- Odlend,T.E. and Cox,T.R. 1942 Field experiments with phosphatic fertilizers.
R.I.Agric.Expt.Sta.Bull.281(1942).
- O'Brien,R.E. 1944 Field experiments with phosphatic fertilizers.
Va.Agric.Expt.Sta.Tech.Bull.364:26.
- O'Brien,R.L. and Obeushair,S.S. 1942 The effect of different phosphatic fertilizers on the yield, plant population and chemical composition of pasture herbage, on Dunmane and Emery soils.
Va.Agric.Expt.Sta.Tech.Bull.80
- Olsen,S.R. et al 1950 Utilisation of 'P' by various crops as effected by source of material and placement.
Colo.Agric.Expt.Sta.Tech.Bull.42:43
- Olsen,S.R. and Gardner,R. 1949 Utilisation of 'P' from various fertilizer materials,sugarbeet, wheat and barley in colorado.
Soil Sci. 68: 163.
- Olsen,S.R. 1953 Inorganic phosphorus in alkaline and calcareous soils.
Agron.Series Vol.IV Chapt.IV Acad. Press Inc., N.Y.(1953)

- Olsen, S.R. and Fried, M. 1957 Soil phosphorus and fertility. In 'soil' the 1957 year book of Agriculture U.S.D.A. Washington D.C.
- Olsen, R.A. and Rhodes, H.F. 1953 Commercial fertilizer for winter wheat in relation to the properties Nebraska soils. Nebraska Agric. Expt. Sta. Res. Bull. 172: 1 - 84.
- Olsen, R.A. et al 1956 Availability of phosphoric small grains and subsequent clover in relation to: 1. nature of soil and method of placement. Agron. J. 48: 106-111 (1956).
- Olsen, J.F. and Studier 1946 Studies on the fertilizer value of different phosphates. Zidasky Planteavl 50: 617 - 632 as reported in soils and fertilizers Abst. (1947)✓
- Patel, N.P. 1953 Studies on the precipitation of dicalcium phosphate on a pilot plant scale. J. Scienti. Indus. Res. 12(B): 373-377
- Peterson, H.B. et al 1953 A review of phosphatic fertilizer investigation in 15 Western states. U.S.D.A. Cir. No. 927 Washington D.C.
- Popova, I. 1954 New forms of phosphorus fertilizers on light saline Solonchaks. Khlopkovodstvo No. 10: 34-38 as reported in Soils and Fertilizers Abst. 167 (1955)
- Prummel, J. 1954 An experiment with 'P' fertilization on clay soil with high fixing power. Landbouwk Tijdschr 66(7): 448-457 as reported in biological Abst. 29: 17137 (1955)
- Robert, G. et al 1942 Field tests of relative effectiveness of different phosphates fertilizers. Ky. Agric. Expt. Sta. Bull. 420
- Ritz, O.I. and Lutz, J.A. 1950 Crop responses to 'P' fertilizer in Virginia. Va. Agric. Expt. Sta. Tech. Bull. 115

- Rogers, H.T. 1951 Crop response to nitrophosphate fertilizers. *Agron. J.* 43: 468-476 (1951)
- Raychoudhuri, S.P. 1963 On the choice of phosphatic fertilizers. *J. Ind. Soc. Soil Sci.* Vol. II June (1963).
- Rishi, A.K. and Iswaran, V. 1961 Fertilizer value of dicalcium phosphate. *Curr. Sci.* 30: 261-262.
- Stenford, G. and Nelson, L.B. 1949 Utilisation of 'P' from various fertilizer material. *Soil Sci.* 68: 157-161.
- Speer, R.J. et al 1951 Phosphate fertilizers for the Texas black lands: i. Relative availability of various phosphatic fertilizers. *Soil Sci.* 72: 459-464.
- Schmehl, W.R. et al 1952 Effect of type of 'P' material and method of application on 'P' uptake and yield of sugarbeets. *Proc. Amer. Soc. Sug. Beet Tech.* 153-158.
- Scherrer, K and Kuhu, H 1952 Leaching and depth effect of different 'P' fertilizers alone. *Ernahr. Dng.* 58 as reported in *Amer. Chem. Soc. Abst.* 47: 210 d.
- Strostka, R.W. et al 1955 Nutritive value of nitric phosphates produced from leached zone and land pebble phosphates determined in green house cultures. *J. Agric. Food Chem.* 3: 1022-1025 (1955)
- Schmehl, W.R. et al 1955 Availability of 'P' fertilizer materials in calcareous soils in Colorado. *Colo. Agric. Expt. Sta. Tech. Bull.* 58: 44
- Strostka, R.W. and Hill, W.L. 1955 Influence of soluble salts on the solubility of and plant response to dicalcium-phosphate. *Proc. Soil Sci. Soc. Amer.* 19: 193.
- Simpson, K 1956 Factors effecting the uptake of 'P' by crops in Scotland. *J. Sci. Food & Agric.* 7: 745-753.
- Scharpanseel, H.W. & Concepcion, J.S. 1957 Studies on the availability to plants of phosphorus fertilizers and their distribution in different strata of Phillipine soils. *Arenata J. Agric.* 4: 1-7

- Scharpenseel, H.W. & Concepcion, J.S. 1957 Investigation on the plant availability of some phosphate fertilizers and their distribution in the different layers of tropical soil types. Comparison of radioactive superphosphate $\text{NH}_4\text{H}_2\text{PO}_4$ and CaHPO_4 . Landw. Forsch. 10: 9-17. Arenal Inst. Agric. Manila, Philippines reported in Soils and Fertilizers Abst. 225: 145.7 (1957).
- Seetharama Rao, V. 1960 Uptake of nutrients by rice plant in relation to its growth. (Thesis submitted for M.Sc.(Ag)., College of Agriculture, Osmania University.
- Sauchelli, V. 1960 A report on fertilizer phosphate with special reference to the availability to plants April (1960).
- 1961 Evolution of phosphatic status in India. Report submitted in India phosphatic fertilizers Ltd., Jan. (1961).
- Shingte, A.K. et al 1961 Response to phosphatic fertilizers in a few typical soils. 1. Comparison of di-calcium phosphate and bone meal. Indian J. Agron. 5: 225-230 (Col. Agric. Poona)
- Sirur, S.S. 1963 Production and utilisation of phosphatic fertilizers in India. J. Ind. Soc. Soil Sci. Vol. II June (1963).
- Tromel, G. 1951 The chemical and technical principles of the production of phosphate fertilizers i. The solubility of different phosphates. Phosphorsäure. 12: 52-64 as reported in Soils and Fertilizers Abst. 631.85 (1952)
- Terman, G.L. 1958 Crop responses to commercial fertilizers in relation to granulation of water solubility of the phosphorus. Econ. Tech. Analysis Fertil. 37-54 as reported in Soils and Fertilizers Abst. 225: 220.36 (1958).
- Temboli, P.M. and Mishra, V.K. 1963 Phosphate requirement of soils of Madhya Pradesh. J. Ind. Soc. Soil Sci. Vol. II June (1963)
- Tisdale, S.L. and Rucker, D.L. 1964 Crop response of various phosphates. Sulphur Inst. Tech. Bull. No. 9 June (1964)

- Uliakov, I. 1939 Fixation of phosphates in different soils and phosphate availability to plants.
VIUAA 23:3-32 as reported in Soils and Fertilizers 4:81.
- Vander, E.F. and Karlovsky, J. 1953 Recent research work; phosphatic fertilizers.
N.Z.J.Agric.86:146
- Van Burg, P.F.J. 1963 The agricultural evaluation of nitro-phosphates with particular reference to direct and cumulative phosphate effects and to interaction between water-solubility and granule size.
Proc.Ferti.Soc.Lond.75:5-56(1963)
- Vithal Rao, T.M. & Kishan Rao, K. 1963 Correlation of available phosphoric acid in soil with grain yield and phosphorus uptake by rice.
J.Indian Soc.Soil Sci.Vol.II June (1963)
- Willis, W.D. and Herrington, F.M. 1939 A report of 'P' investigation in Montana
Mont.Agric.Expt.Sts.Bull.369.
- Wursten, J.L. 1948 Relative efficiency of some phosphatic fertilizers on calcareous soils.
Proc.Amer.Soc.Sug.Beet Tech.5:308-315 (1948)
- Webb, J.R. 1955 Significance of water solubility on phosphatic fertilizers.
Agric.Chem.10:44-46 (1955)
- et al 1961 An evaluation of phosphate fertilizers applied broadcast on calcareous soils for corn.
Proc.Soil.Sci.Soc.Amer.25:232-236.
- et al 1961 An evaluation of phosphorus fertilizers varying in water solubility.iii.oat fertilization.
Proc.Soil.Sci.Soc.Amer.25:222-226.
- Webb, J.R. and Pesek, J.T. 1958 An evaluation of phosphorus fertilizers varying in water solubility i.Hill applications for corn.
Proc.Soil.Sci.Soc.Amer.22:533-538.
- William, E.J. and Reith, J.W.S. 1948 The relative efficiencies of phosphatic fertilizers.
Emp.J.Expt.Agric.16:1-13.

LIST OF TABLES IN APPENDIX

- 1) Height of complete plant and panicle at harvest alongwith statistical analysis.
- 2) Number of effective tillers.
- 3) Total P_2O_5 in plants alongwith statistical analysis
 - 3 - A. At tillering stage
 - 3 - B. At flowering stage
 - 3 - C. At milk stage
 - 3 - D. At matured stage (harvest).
- 4) Total 'N' in plants.
 - 4 - A. At tillering stage
 - 4 - B. At flowering stage
 - 4 - C. At milk stage
 - 4 - D. At matured stage (harvest)
- 5) Available P_2O_5 in soils alongwith statistical analysis
 - (i) In series III pots (incubation study)
 - 5 - A. At 1st sampling
 - 5 - B. At 2nd sampling
 - 5 - C. At 3rd sampling
 - 5 - D. At 4th sampling
 - (ii) In series II pots (dummies)
 - 5 - E. At 1st sampling
 - (iii) In series I pots (main experiment)
 - 5 - F. At 1st sampling
- 6) Water-soluble P_2O_5 in soils alongwith statistical analysis
 - (i) In series III pots (Incubation studies)
 - 6 - A. At 1st sampling
 - 6 - B. At 2nd sampling
 - 6 - C. At 3rd sampling
 - 6 - D. At 4th sampling
 - (ii) In series II pots (dummies)
 - 6 - E. At 1st sampling
 - (iii) In series I pots (main experiment)
 - 6 - F. At 1st sampling.

7) Total 'N' in soils

- (i) In series III pots (Incubation studies)
 - 7 - A. At 1st sampling
 - 7 - B. At 2nd sampling
 - 7 - C. At 3rd sampling
 - 7 - D. At 4th sampling
- (ii) In series II pots (dummies)
 - 7 - E. At 1st sampling
- (iii) In series I pots (main experiment)
 - 7 - F. At 1st sampling.

GUIDE TO TABLES IN APPENDIX

I. Abbreviations

- (A) P₁ - 100% citrate-soluble phosphate
- P₂ - 75% citrate-soluble + 25% water-soluble phosphate
- P₃ - 50% " + 50% "
- P₄ - 25% " + 75% "
- P₅ - 100% water-soluble phosphate

- (B) R - Replication.

II. Explanatory terms

(A) Soil:

Pot series No.	Sampling No.	Stage at which sample collected	Age of plant
IIIrd (incubation study)	1st	45 days	
	2nd	75 "	
	3rd	100 "	
	4th	120 "	
IIInd (dummies)	1st	100 "	145 days
Ist (Main expt.)	1st	120 "	175 "

(B) Plant:

Tillering	90	"
Flowering	120	"
Milk	145	"
Maturity	175	"

APPENDIX TABLE - 1

Height of complete plant and panicle at harvest under
different treatments
(Average height per pot in cms.)

Soil Phosphorus type material in various proportions		HEIGHT OF WHOLE PLANT				Average
		R _I	R _I	R _{III}	R _{IV}	
CHALKA	P ₁	127.00	112.77	130.80	104.77	118.84
	P ₂	102.87	118.11	113.60	120.01	113.65
	P ₃	130.81	120.65	121.28	119.81	123.14
	P ₄	123.19	121.92	111.76	119.38	119.06
	P ₅	130.81	107.31	116.84	119.38	118.59
BLACK SOIL	P ₁	109.98	121.92	128.70	114.30	118.72
	P ₂	113.03	119.38	126.13	114.30	118.21
	P ₃	115.57	119.38	118.11	110.49	115.89
	P ₄	116.84	109.22	118.11	112.65	114.21
	P ₅	130.81	128.70	124.46	114.30	124.57
		<u>LENGTH OF PANICLE</u>				
CHALKA	P ₁	24.76	24.51	26.67	20.95	24.22
	P ₂	20.32	22.60	21.84	24.13	22.25
	P ₃	26.67	20.95	22.86	19.68	22.54
	P ₄	22.86	22.60	22.86	20.32	22.16
	P ₅	24.13	19.81	23.87	25.27	23.27
BLACK SOIL	P ₁	22.68	23.49	26.03	24.13	24.08
	P ₂	24.63	25.40	24.23	24.00	24.57
	P ₃	22.22	21.59	23.36	21.71	22.22
	P ₄	20.82	22.52	20.95	21.65	21.49
	P ₅	27.30	24.38	22.22	22.86	21.69

STATISTICAL ANALYSIS(PLANT HEIGHT)

		<u>A.V.TABLE</u>				<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F	Tr.	Mean height	% G.M	
<u>CHALKA</u>	B.S.S.	142.84		3		P ₁	24.22	105.86
	Tr.S.S.	181.48		4	45.37	P ₅	23.27	101.70
	Er.	916.60		12	76.38	P ₃	22.54	98.54
	T.S.S.	1240.92		19		P ₂	22.25	97.25
						P ₄	22.16	96.85
						G.M.	22.88	100.00
						S.E.M.	4.369	19.09
<u>BLACK SOIL</u>	B.S.S.	260.56		3		P ₂	24.57	105.45
	Tr.S.S.	248.23		4	62.06	P ₁	24.08	103.35
	Er.	308.72		12	25.73	P ₃	22.22	95.36
	T.S.S.	817.51		19		P ₅	21.69	93.09
						P ₄	21.49	92.23
						G.M.	23.30	100.00
						S.E.M.	2.536	10.88

PANICLE LENGTH

<u>CHALKA</u>	B.S.S.	12.88		3		P ₃	123.14	108.35
	Tr.S.S.	12.09		4	3.02	P ₄	119.06	104.76
	Er.	61.22		12	5.10	P ₁	118.84	104.57
	T.S.S.	86.19		19		P ₅	118.59	104.35
						P ₂	113.65	100.00
						G.M.	113.65	100.00
						S.E.M.	1.129	0.993
<u>BLACK SOIL</u>	B.S.S.	1.36		3		P ₅	124.57	105.30
	Tr.S.S.	29.86		4	7.47	P ₁	118.72	100.36
	Er.	36.02		12	3.00	P ₂	118.21	99.92
	T.S.S.	67.24		19		P ₃	115.89	97.96
						P ₄	114.21	96.54
						G.M.	118.30	100.00
						S.E.M.	0.866	0.73

APPENDIX TABLE - 2

Number of effective tillers under different treatments

Soil Phospho- type rus ma- terial in ve- rious propor- tions.	EFFECTIVE TILLERS										
	R _I		R _{II}		R _{III}		R _{IV}		Average		
	Per pot	Av/Pl.	Per pot	Av/Pl.	Per pot	Av/Pl.	Per pot	Av/Pl.	Per pot.	Av/Pl.	
<u>CHALKA</u>	P ₁	9	3.0	8	2.66	10	3.33	8	2.66	8.75	2.91
	P ₂	9	3.0	7	2.33	10	3.33	10	3.33	9.0	3.00
	P ₃	10	3.33	6	2.0	8	2.66	9	3.0	8.25	2.75
	P ₄	8	2.66	9	3.0	7	2.33	6	2.0	7.50	2.50
	P ₅	7	2.33	8	2.66	6	2.0	9	3.0	7.50	2.50
<u>BLACK SOIL</u>	P ₁	6	2.0	4	1.33	8	2.66	6	2.0	6.0	2.0
	P ₂	9	3.0	7	2.33	6	2.0	6	2.0	7.0	2.33
	P ₃	5	1.66	6	2.0	4	1.33	5	1.66	5.0	1.66
	P ₄	6	2.0	6	2.0	5	1.66	6	2.0	5.75	1.92
	P ₅	10	3.33	9	3.0	7	2.33	6	2.0	8.0	2.67

N.B: Av/Pl. = Average per plant.

APPENDIX TABLE-3(A)

Total P₂O₅ in plants at tillering stage under different treatments
(Moisture free basis in p.p.m.)

Soil type	Phosphorus level in various proportion	TILLERING STAGE				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chalko	P ₁	2576.61	2524.74	2448.86	2492.34	2510.64
	P ₂	2474.71	2305.70	2350.24	2434.26	2391.22
	P ₃	2336.91	2287.18	2413.54	2476.35	2378.49
	P ₄	2097.50	2033.98	2106.11	2191.33	2107.23
	P ₅	1737.28	1838.90	1915.77	1802.20	1823.53
Black soil	P ₁	1450.80	1507.75	1461.36	1390.67	1452.64
	P ₂	1428.90	1355.73	1317.22	1384.63	1371.62
	P ₃	1368.70	1441.56	1359.03	1300.86	1367.54
	P ₄	1220.84	1272.10	1324.18	1292.42	1277.39
	P ₅	1247.56	1214.74	1160.97	1295.87	1229.79

STATISTICAL ANALYSIS

	Due to	A.V. TABLE				SUMMARY RESULTS		
		S.S.	D.F.	M.S.S.	F	Tr.	Mean 'P'	% G.M.
CHALKA	B.S.S.	16788.94	3			P ₁	2510.64	111.97
	Tr.S.S.	1225502.87	4	306375.72	1.33	P ₂	2391.22	106.65
	Er.	2759673.40	12	229964.45		P ₃	2378.49	106.08
	T.S.S.	4001965.21	19			P ₄	2107.23	93.98
						P ₅	1823.53	81.33
				G.M.		2242.22	100.00	
				S.E.M.	239.76	10.69		
BLACK SOIL	B.S.S.	3163.16	3			P ₁	1452.64	108.43
	Tr.S.S.	122816.88	4	30704.22	10.54	P ₂	1371.62	102.30
	Er.	34956.31	12	2913.03		P ₃	1367.54	102.08
	T.S.S.	160936.35	19			P ₄	1277.39	95.33
						P ₅	1229.79	91.81
				G.M.		1339.79	100.00	
				S.E.M.	26.96	2.01		
				C.D.	83.04	6.20		

Results significant at both 5% & 1% level

P₁ P₂ P₃ P₄ P₅

APPENDIX TABLE-3(B)

Total P₂O₅ in plants at flowering stage under different treatments
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	FLOWERING STAGE				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	1783.10	1653.91	1703.19	1745.80	1721.5
	P ₂	1714.72	1639.05	1592.26	1640.62	1646.66
	P ₃	1659.05	1610.29	1542.52	1591.17	1600.76
	P ₄	1517.26	1545.27	1640.62	1589.69	1573.21
	P ₅	1381.05	1395.45	1436.30	1460.30	1418.28
BLACK SOIL	P ₁	1198.24	1153.95	1120.01	1226.19	1174.60
	P ₂	1248.67	1179.91	1138.68	1192.41	1189.92
	P ₃	1230.90	1210.35	1168.24	1260.47	1217.49
	P ₄	1180.95	1170.00	1233.22	1125.61	1177.45
	P ₅	1117.90	1081.70	1095.32	1047.82	1085.69

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>						<u>SUMMARY RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F	Tr.	Mean 'P'	% G.M.	
CHALKA B.S.S.	5888.38	3			P ₁	1721.50	108.13	
Tr.S.S.	201537.04	4	50384.26	19.64	P ₂	1646.66	103.49	
Er.	30782.01	12	2565.17		P ₃	1600.76	100.49	
T.S.S.	238208.43	19			P ₄	1573.21	99.32	
Results significant at both 5% & 1% level						P ₅	1418.28	89.28
					G.M.	1592.08	100.00	
					S.E.M.	25.32	1.59	
					C.D.	77.98	4.89	
BLACK SOIL B.S.S.	5656.72	3			P ₃	1217.49	104.15	
Tr.S.S.	38424.95	4	9606.24	5.46	P ₂	1189.92	101.97	
Er.	21104.54	12	1758.88		P ₄	1177.45	100.72	
T.S.S.	65186.21	19			P ₁	1174.60	100.56	
Results significant at both 5% & 1% level						P ₅	1085.69	92.95
					G.M.	1169.02	100.00	
					S.E.M.	20.95	1.79	
					C.D.	64.53	5.52	

APPENDIX TABLE-3(C)

Total P₂O₅ in plants at milk stage under different treatments
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	MILK STAGE				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	1410.74	1347.84	1377.83	1465.25	1402.08
	P ₂	1388.13	1317.35	1350.92	1416.31	1368.17
	P ₃	1240.56	1336.56	1348.22	1288.73	1303.51
	P ₄	1310.72	1327.32	1377.44	1365.53	1345.25
	P ₅	1350.47	1239.16	1281.12	1301.34	1293.02
BLACK SOIL	P ₁	1147.52	1095.98	1119.80	1187.85	1137.78
	P ₂	1188.41	1150.47	1085.37	1161.27	1146.38
	P ₃	1087.55	1056.18	1103.64	1020.10	1066.86
	P ₄	1069.68	998.32	950.44	1026.68	1011.28
	P ₅	953.66	1036.03	1079.17	1029.66	1024.63

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>						<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F	Tr.	Mean 'P'	% G.M.	
CHALKA B.S.S.	7508.48	3			P ₁	1402.08	104.42	
Tr.S.S.	50723.29	4	12680.82	35.21	P ₂	1368.17	101.89	
Er.	4321.48	12	360.12		P ₄	1345.25	100.18	
T.S.S.	61885.00	19			P ₃	1303.51	97.08	
Results significant at both 5% & 1% level						P ₅	1293.02	96.29
					G.M.	1342.77	100.00	
					S.E.M.	9.49	0.71	
					C.D.	29.23	2.18	
BLACK SOIL B.S.S.	2157.87	3			P ₂	1146.38	106.40	
Tr.S.S.	62861.79	4	15715.45	67.34	P ₁	1137.78	105.60	
Er.	28006.85	12	2333.90		P ₃	1066.86	99.02	
T.S.S.	93026.51	19			P ₅	1024.63	95.10	
Results significant at both 5% & 1% level.						P ₄	1011.28	93.86
					G.M.	1077.40	100.00	
					S.E.M.	24.16	2.24	
					C.D.	74.41	6.91	

APPENDIX TABLE-3(D)

Total P₂O₅ in plants at matured stage (Grain and straw
at harvest) under different treatments.
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Matured stage GRAIN				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chelka	P ₁	2746.68	2555.30	2610.71	2716.92	2657.40
	P ₂	2415.90	2594.89	2556.25	2469.34	2509.10
	P ₃	2567.30	2422.58	2535.49	2464.58	2497.49
	P ₄	2089.86	2238.62	2205.72	2153.82	2172.00
	P ₅	1843.92	1975.08	2017.52	1891.50	1932.00
Black soil.	P ₁	1955.98	1984.40	2088.70	2048.21	2019.32
	P ₂	2046.51	2155.41	2199.87	2086.01	2121.95
	P ₃	1930.00	2058.05	1990.45	2025.81	2001.78
	P ₄	1878.46	1995.48	1951.92	1925.14	1937.75
	P ₅	1714.07	1832.71	1867.75	1750.37	1791.23
		<u>Matured stage STRAW</u>				
Chelka	P ₁	466.31	459.63	496.65	497.86	480.11
	P ₂	445.50	514.18	453.43	460.65	468.44
	P ₃	477.69	501.22	494.51	449.19	480.65
	P ₄	469.41	414.12	432.56	447.45	440.89
	P ₅	402.17	418.90	388.29	432.68	410.51
Black soil.	P ₁	428.55	396.27	374.52	412.12	402.87
	P ₂	448.99	401.24	418.23	432.24	425.18
	P ₃	387.31	412.16	434.37	410.74	411.15
	P ₄	436.38	396.38	382.63	412.01	406.85
	P ₅	481.52	365.58	396.49	350.28	398.47

STATISTICAL ANALYSIS OF TOTAL P₂O₅ IN PLANTS
(Matured stage Grain and Straw)

		A.V. TABLE				SUMMARY OF RESULTS		
Due to		S.S.	D.F.	M.S.S.	F	Tr.	Mean 'P' %	G.M.
<u>GRAIN</u> <u>(CHALKA)</u>	B.S.S.	8198.27	3			P ₁	2657.40	112.91
	Tr.S.S.	1391965.99	4	347991.50	52.197	P ₂	2509.10	106.61
	Er.	80002.42	12	6666.868		P ₃	2497.49	106.11
	T.S.S.	1480166.68	19			P ₄	2172.00	92.28
						P ₅	1932.00	82.09
Results significant at both 5% and 1% level						G.M.	2353.60	100.00
						S.E.M.	40.78	1.733
						C.D.	125.60	5.34
		<u>P₁</u>	<u>P₂</u>	<u>P₃</u>	<u>P₄</u>	<u>P₅</u>		
<u>GRAIN</u> <u>BLACK</u> <u>SOIL</u>	B.S.S.	39368.6	3			P ₂	2121.95	107.48
	Tr.S.S.	237587.74	4	59396.94	41.65	P ₁	2019.32	102.28
	Er.	17114.37	12	1426.20		P ₃	2001.78	101.39
	T.S.S.	294071.71	19			P ₄	1937.75	98.15
						P ₅	1791.23	90.72
Results significant at both 5% and 1% level						G.M.	1974.27	100.00
						S.E.M.	18.88	0.96
						C.D.	58.15	2.95
		<u>P₂</u>	<u>P₁</u>	<u>P₃</u>	<u>P₄</u>	<u>P₅</u>		
<u>STRAW</u> <u>(CHALKA)</u>	B.S.S.	282.53	3			P ₃	480.65	105.38
	Tr.S.S.	14565.78	4	3641.20	5.327	P ₁	480.11	105.26
	Er.	8201.61	12	683.47		P ₂	468.44	102.70
	T.S.S.	23049.92	19			P ₄	440.89	96.67
						P ₅	410.51	90.00
Results significant at 5% level.						G.M.	456.12	100.00
						S.E.M.	13.07	2.87
						C.D.	40.25	8.83
		<u>P₃</u>	<u>P₁</u>	<u>P₂</u>	<u>P₄</u>	<u>P₅</u>		
<u>STRAW</u> <u>BLACK</u> <u>SOIL</u>	B.S.S.	5324.37	3			P ₂	425.18	103.98
	Tr.S.S.	1677.50	4	419.38	0.48	P ₃	411.15	100.55
	Er.	10514.87	12	876.24		P ₄	406.85	99.51
	T.S.S.	17516.74	19			P ₁	402.87	98.62
						P ₅	398.47	97.45
						G.M.	408.90	100.00
						S.E.M.	14.80	3.62

APPENDIX TABLE-4(A)

Total 'N' in plants at tillering stage under different
treatments
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Tillering stage				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	3.245	3.176	2.988	3.124	3.133
	P ₂	3.120	2.796	3.044	2.872	2.958
	P ₃	2.953	3.124	3.167	2.996	3.060
	P ₄	2.973	3.064	3.169	3.088	3.074
	P ₅	3.025	3.003	3.177	3.156	3.090
BLACK SOIL	P ₁	2.723	2.544	2.695	2.516	2.619
	P ₂	2.534	2.604	2.747	2.678	2.641
	P ₃	2.751	2.576	2.533	2.709	2.642
	P ₄	2.581	2.385	2.503	2.462	2.483
	P ₅	2.677	2.609	2.472	2.541	2.575

APPENDIX TABLE-4(B)

Total 'N' in plants at flowering stage under different
treatments
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Flowering stage				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	2.037	1.943	1.891	1.986	1.964
	P ₂	2.075	1.957	1.929	2.045	2.002
	P ₃	1.865	1.982	2.003	1.883	1.933
	P ₄	2.093	2.013	1.984	2.055	2.036
	P ₅	1.905	1.951	2.071	2.010	1.984
BLACK SOIL	P ₁	1.784	1.907	1.921	1.802	1.854
	P ₂	1.805	1.927	1.971	1.850	1.888
	P ₃	1.813	1.944	1.840	1.967	1.891
	P ₄	1.913	1.871	1.776	1.817	1.844
	P ₅	1.775	1.871	1.913	1.817	1.844

APPENDIX TABLE-4(C)

Total 'N' in plants at milk stage under different
treatments
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Milk stage				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	1.242	1.315	1.348	1.272	1.294
	P ₂	1.366	1.295	1.267	1.337	1.316
	P ₃	1.165	1.249	1.271	1.185	1.218
	P ₄	1.244	1.347	1.371	1.299	1.315
	P ₅	1.140	1.212	1.252	1.178	1.196
BLACK SOIL	P ₁	1.065	0.967	0.983	1.052	1.017
	P ₂	1.287	1.144	1.193	1.243	1.217
	P ₃	1.153	1.215	1.178	1.238	1.196
	P ₄	1.133	1.060	1.109	1.084	1.097
	P ₅	1.249	1.224	1.192	1.167	1.208

APPENDIX TABLE-4(D)

Total 'N' in plants at matured stage (Grain and Straw)
under different treatments
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Matured stage Grain				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	1.514	1.341	1.459	1.394	1.427
	P ₂	1.311	1.477	1.350	1.430	1.392
	P ₃	1.404	1.209	1.381	1.221	1.304
	P ₄	1.555	1.411	1.456	1.512	1.484
	P ₅	1.480	1.347	1.457	1.373	1.414
BLACK SOIL	P ₁	1.282	1.459	1.484	1.312	1.384
	P ₂	1.478	1.400	1.255	1.330	1.366
	P ₃	1.455	1.542	1.590	1.515	1.525
	P ₄	1.586	1.555	1.442	1.470	1.513
	P ₅	1.519	1.483	1.332	1.364	1.425
		<u>Matured stage Straw</u>				
CHALKA	P ₁	0.492	0.520	0.610	0.586	0.552
	P ₂	0.623	0.598	0.540	0.564	0.581
	P ₃	0.689	0.653	0.592	0.634	0.642
	P ₄	0.704	0.669	0.645	0.683	0.675
	P ₅	0.718	0.674	0.702	0.654	0.687
BLACK SOIL	P ₁	0.695	0.612	0.673	0.632	0.653
	P ₂	0.816	0.741	0.762	0.795	0.779
	P ₃	0.734	0.679	0.694	0.729	0.709
	P ₄	0.808	0.776	0.784	0.802	0.793
	P ₅	0.702	0.657	0.691	0.668	0.680

APPENDIX TABLE-5(A)

Available P₂O₅ in soils under different treatment incubation
study 1st sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chelka	P ₁	8.99	11.04	10.14	9.60	9.94
	P ₂	9.41	10.57	8.78	9.22	9.49
	P ₃	11.76	9.57	9.97	11.17	10.62
	P ₄	9.20	10.63	8.62	9.61	9.52
	P ₅	13.02	11.62	12.42	12.00	12.27
Black soil.	P ₁	11.73	11.03	12.63	10.30	11.42
	P ₂	10.37	11.72	9.90	10.74	10.68
	P ₃	11.29	12.09	10.40	10.97	11.19
	P ₄	11.75	11.77	11.55	11.74	11.70
	P ₅	10.79	12.08	12.66	11.74	11.82

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>						<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F.	Tr.	Mean Av. 'P'	% G.M.	
Chelka. B.S.S.	1.305	3			P ₅	12.25	118.09	
Tr.S.S.	21.327	4	5.332	7.05	P ₃	10.62	102.38	
Er.	9.072	12	0.756		P ₁	9.94	95.82	
T.S.S.	31.704	19			P ₄	9.52	91.77	
Results significant at both 5% & 1% level.						P ₂	9.49	91.48
					G.M.	10.37	100.00	
					S.E.M.	0.43	4.15	
					C.D.	1.32	12.72	
Black soil.	B.S.S.	1.232	3		P ₅	11.82	104.02	
	Tr.S.S.	3.277	4	0.819	1.42	P ₄	11.70	102.96
	Er.	6.890	12	0.574		P ₁	11.42	100.50
	T.S.S.	11.399	19			P ₃	11.19	98.47
						P ₂	10.68	93.98
					G.M.	11.36	100.00	
					S.E.M.	0.38	3.34	

Mean Av. 'P': = Mean available P₂O₅

APPENDIX TABLE-5(B)

Available P₂O₅ in soils under different treatments incubation
study 2nd sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		P _I	P _{II}	P _{III}	P _{IV}	
Chalka	P ₁	15.12	14.76	16.53	14.93	15.34
	P ₂	15.98	14.18	14.41	14.97	14.89
	P ₃	13.95	15.56	14.98	15.16	14.91
	P ₄	14.42	15.59	15.01	16.26	15.32
	P ₅	15.15	16.55	16.37	15.16	15.81
Black soil	P ₁	10.91	11.70	12.45	11.84	11.73
	P ₂	12.57	11.64	13.50	12.01	12.43
	P ₃	12.74	11.98	13.30	11.66	12.42
	P ₄	12.10	13.11	12.49	11.79	12.35
	P ₅	12.73	11.31	12.79	11.99	12.21

STATISTICAL ANALYSIS

		<u>A.V. TABLE</u>				<u>SUMMARY OF RESULTS</u>		
Due to		S.S.	D.F.	M.S.S.	F	Tr.	Mean Av. 'P'	% G.M.
Chalka	B.S.S.	0.793	3			P ₅	15.81	103.67
	Tr.S.S.	2.280	4	0.570	0.84	P ₁	15.34	100.58
	Er.	8.098	12	0.675		P ₄	15.32	100.45
	T.S.S.		11.171	19		P ₃	14.91	97.76
					P ₂	14.89	97.63	
					G.M.	15.25	100.00	
					S.E.M.	0.40	2.62	
Black soil	B.S.S.	3.376	3			P ₂	12.43	101.68
	Tr.S.S.	1.408	4	0.352	1.08	P ₃	12.42	101.59
	Er.	3.377	12	0.323		P ₄	12.35	101.02
	T.S.S.		8.661	19		P ₅	12.25	100.21
					P ₁	11.73	95.95	
					G.M.	12.23	100.00	
					S.E.M.	0.29	2.37	
Mean Av. 'P': Mean available P ₂ O ₅								

APPENDIX TABLE-5(C)

Available P_2O_5 in soils under different treatment incubation study 3rd sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chalka.	P ₁	17.19	17.35	15.61	15.97	16.53
	P ₂	17.21	15.83	15.41	16.03	16.12
	P ₃	16.16	16.62	17.39	15.62	16.45
	P ₄	16.16	15.38	16.38	15.18	15.78
	P ₅	12.35	13.97	12.77	13.37	13.12
Black soil.	P ₁	9.43	10.93	10.22	9.84	10.11
	P ₂	9.91	10.30	10.28	10.47	10.22
	P ₃	10.23	11.59	10.61	9.89	10.58
	P ₄	10.87	9.83	9.99	10.57	10.32
	P ₅	9.84	10.54	11.29	10.91	10.65

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>					<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F.	Tr.	Mean	% G.M.
					Av. 'P'		
Chalka. B.S.S.	1.212	3			P ₁	16.53	105.96
Tr.S.S.	32.238	4	8.059	13.69	P ₃	16.45	105.44
Er.	7.050	12	0.588		P ₂	16.12	103.33
T.S.S.	40.500	19			P ₄	15.78	101.15
Results significant at both 5% & 1% level.					P ₅	13.12	84.10
					G.M.	15.60	100.00
					S.E.M.	0.38	2.44
					C.D.	1.17	7.50
Black soil. B.S.S.	0.915	3			P ₅	10.65	113.42
Tr.S.S.	0.839	4	0.210	0.64	P ₃	10.58	101.89
Er.	3.950	12	0.329		P ₄	10.32	99.38
T.S.S.	5.704	19			P ₂	10.22	98.42
					P ₁	10.11	97.36
					G.M.	10.38	100.00
					S.E.M.	0.29	2.79
Mean Av. 'P' := Mean available P_2O_5							

APPENDIX TABLE-5(D)

Available P₂O₅ in soils under different treatments incubation
study 4th sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus materiel in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chalka.	P ₁	18.37	17.62	16.99	16.80	17.45
	P ₂	16.81	15.59	15.43	17.38	16.30
	P ₃	17.58	16.01	16.79	17.40	16.95
	P ₄	15.21	16.19	14.58	15.20	15.30
	P ₅	15.96	15.62	15.77	14.99	15.59
Black soil.	P ₁	15.97	14.40	13.47	14.65	14.62
	P ₂	13.71	14.13	14.38	14.79	14.25
	P ₃	14.06	15.03	15.42	15.88	15.10
	P ₄	15.79	13.62	14.72	14.84	14.74
	P ₅	15.50	14.87	13.45	14.38	14.55

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>					<u>SUMMARY OF RESULTS</u>			
Due to	S.S.	D.F.	M.S.S.	F.	Tr.	Mean	% G.M.	
					Av. 'P'			
Chalka. B.S.S.	1.988	3			P ₁	17.45	106.98	
Tr.S.S.	12.989	4	3.247	6.98	P ₃	16.95	103.92	
Er.	5.576	12	0.465		P ₂	16.30	99.94	
T.S.S.	20.553	19			P ₅	15.59	95.58	
Results significant at both 5% & 1% level.					P ₄	15.30	93.80	
					G.M.	16.31	100.00	
					S.E.M.	0.34	2.08	
					C.D.	1.05	6.44	
Black soil.	B.S.S.	1.910	3		P ₃	15.10	103.07	
	Tr.S.S.	1.510	4	0.378	0.55	P ₄	14.74	100.62
	Er.	8.307	12	0.692		P ₁	14.62	89.64
	T.S.S.	11.727	19			P ₅	14.55	99.32
					P ₂	14.25	97.27	
Mean Av. 'P': = Mean available P ₂ O ₅					G.M.	14.65	100.00	
					S.E.M.	0.415	2.83	

APPENDIX TABLE-5(E)

Available P₂O₅ in soils under different treatments dummy pots
1st sampling
 (Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series II pots (dummies)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chalke	P ₁	12.56	11.17	12.14	10.59	11.62
	P ₂	9.99	11.01	10.58	11.40	10.75
	P ₃	12.82	11.23	10.28	13.45	12.07
	P ₄	11.99	11.20	9.81	9.59	10.65
	P ₅	11.22	9.83	10.99	10.83	10.72
Black soil.	P ₁	9.66	8.75	10.22	8.93	9.39
	P ₂	9.18	9.60	8.27	9.00	9.01
	P ₃	8.77	8.83	9.15	8.98	8.93
	P ₄	9.24	8.55	9.45	10.02	9.32
	P ₅	8.33	9.44	9.47	9.29	9.13

STATISTICAL ANALYSIS

		<u>A.V. TABLE</u>				<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F.	Tr.	Mean Av. 'P'	% G.M.	
Chalke. B.S.S.	2.3663	3			P ₃	12.07	108.16	
Tr.S.S.	6.663	4	1.666	1.811	P ₁	11.62	104.13	
Er.	11.041	12	0.920		P ₂	10.75	96.33	
T.S.S.	20.070	19			P ₅	10.72	95.52	
					P ₄	10.65	95.43	
					G.M.	11.16	100.00	
					S.E.M.	0.49	4.39	
Black soil. B.S.S.	0.307	3			P ₁	9.39	102.51	
Tr.S.S.	0.605	4	0.151	0.45	P ₄	9.32	101.75	
Er.	4.070	12	0.339		P ₅	9.13	99.67	
T.S.S.	4.982	19			P ₂	9.01	98.36	
					P ₃	8.93	97.49	
					G.M.	9.16	100.00	
					S.E.M.	0.29	3.17	
Mean Av. 'P': = Mean available P ₂ O ₅								

APPENDIX TABLE-5(F)

Available P₂O₅ in soils under different treatment main
experiment pots 1st sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series I pots (main experiment)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chelka	P ₁	16.40	15.57	14.98	15.81	15.69
	P ₂	13.56	15.95	14.79	15.78	15.02
	P ₃	16.79	16.00	15.39	15.20	15.84
	P ₄	15.23	16.20	14.62	15.19	15.31
	P ₅	15.98	15.60	15.79	14.98	15.59
Black soil.	P ₁	12.67	13.34	14.35	13.53	13.47
	P ₂	12.57	13.39	13.77	14.49	13.56
	P ₃	14.12	12.57	13.16	13.37	13.31
	P ₄	12.55	14.09	13.54	13.15	13.33
	P ₅	12.73	13.90	14.56	13.45	13.66

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>					<u>SUMMARY OF RESULTS</u>		
Due to	S.E.	D.F.	M.S.S.	F.	Tr.	Mean Av. 'P'	% G.M.
Chalke. B.S.S.	1.506	3			P ₃	15.84	102.26
Tr.S.S.	1.715	4	0.429	0.79	P ₁	15.69	102.39
Er.	6.552	12	0.546		P ₅	15.59	100.65
T.S.S.	9.773	19			P ₄	15.31	98.84
					P ₂	15.02	96.97
					G.M.	15.49	100.00
					S.E.M.	0.37	2.39
Black soil. B.S.S.	2.375	3			P ₅	13.66	101.41
Tr.S.S.	0.357	4	0.089	0.20	P ₂	13.56	100.67
Er.	5.247	12	0.437		P ₁	13.47	100.00
T.S.S.	7.979	19			P ₄	13.33	98.96
					P ₃	13.31	98.81
					G.M.	13.47	100.00
					S.E.M.	0.33	2.45

Mean Av. 'P': = Mean available P₂O₅

APPENDIX TABLE-6(A)

Water-soluble P_2O_5 in soils under different treatments
incubation study 1st sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chelka	P ₁	0.3479	0.2862	0.2224	0.2851	0.2854
	P ₂	0.4126	0.3789	0.2843	0.3176	0.3484
	P ₃	0.3158	0.3476	0.3790	0.3475	0.3475
	P ₄	0.4438	0.4129	0.3807	0.4121	0.4124
	P ₅	0.3489	0.1904	0.1586	0.3169	0.2537
Black soil.	P ₁	0.5804	0.5037	0.4931	0.4079	0.4963
	P ₂	0.4699	0.5069	0.4357	0.5279	0.4851
	P ₃	0.4908	0.4063	0.4337	0.5211	0.4625
	P ₄	0.5236	0.5830	0.5224	0.4648	0.5235
	P ₅	0.5795	0.6095	0.5231	0.4941	0.5516

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>						<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F.	Tr.	Mean	% G.M.	
					W.S. 'P'			
Chelka. B.S.S.	0.0201	3			P ₄	0.4124	125.21	
Tr.S.S.	0.0609	4	0.0152	0.96	P ₂	0.3484	105.77	
Er.	0.1891	12	0.0158		P ₃	0.3475	105.49	
T.S.S.	0.1081	19			P ₁	0.2854	86.86	
					P ₅	0.2537	77.02	
					G.M.	0.3294	100.00	
					S.E.M.	0.06277	19.05	
Black soil. B.S.S.	0.0093	3			P ₅	0.5516	109.47	
Tr.S.S.	0.0189	4	0.0047	1.68	P ₄	0.5235	103.89	
Er.	0.033	12	0.0028		P ₁	0.4963	98.50	
T.S.S.	0.0613	19			P ₂	0.4851	96.29	
					P ₃	0.4625	91.82	
					G.M.	0.5039	100.00	
					S.E.M.	0.0264	5.239	

Mean W.S. 'P' := Mean water-soluble P_2O_5

APPENDIX TABLE-6(B)

Water-soluble P₂O₅ in soils under different treatments
incubation study 2nd sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		P _I	P _{II}	P _{III}	P _{IV}	
Chalko	P ₁	0.4727	0.4105	0.3469	0.4100	0.4100
	P ₂	0.4430	0.4737	0.3798	0.3477	0.4111
	P ₃	0.3788	0.3192	0.2471	0.3160	0.3153
	P ₄	0.4119	0.3164	0.2853	0.3767	0.3478
	P ₅	0.2526	0.3159	0.2530	0.3793	0.3002
Black soil	P ₁	0.5473	0.5500	0.5799	0.4619	0.5348
	P ₂	0.4908	0.4610	0.5201	0.4326	0.4761
	P ₃	0.4614	0.4890	0.4037	0.3751	0.4323
	P ₄	0.4649	0.4325	0.4070	0.4369	0.4353
	P ₅	0.5186	0.4915	0.4341	0.4032	0.4619

STATISTICAL ANALYSIS

A.V. TABLE						SUMMARY OF RESULTS		
Due to	S.S.	D.F.	M.S.S.	F	Tr.	Mean	% G.M.	
						U.S. 'P'		
Chalko. B.S.S.	0.0218	3			P ₂	0.4111	115.23	
Tr.S.S.	0.0431	4	0.0108	5.14	P ₁	0.4100	114.92	
Er.	0.0247	12	0.0021		P ₄	0.3478	97.49	
T.S.S.	0.0896	19			P ₃	0.3153	88.40	
Result significant at 5% level.						P ₅	0.3002	84.17
					G.M.	0.3568	100.00	
					S.E.M.	0.02291	6.42	
					C.D.	0.0706	19.78	
Black soil. B.S.S.	0.0105	3			P ₁	0.5348	117.20	
Tr.S.S.	0.2446	4	0.0612	38.25	P ₂	0.4761	104.34	
Er.	0.0187	12	0.0016		P ₅	0.4619	101.22	
T.S.S.	0.2738	19			P ₄	0.4353	95.40	
Results significant at both 5% & 1% level.						P ₃	0.4323	94.74
					G.M.	0.4563	100.00	
					S.E.M.	0.02	4.38	
					C.D.	0.0616	13.49	
Mean U.S. 'P': Mean water soluble P ₂ O ₅								

APPENDIX TABLE-6(C)

Water-soluble P₂O₅ in soils under different treatments
incubation study 3rd sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chalka.	P ₁	0.3484	0.2528	0.2218	0.3162	0.2848
	P ₂	0.3168	0.3808	0.3171	0.2539	0.3172
	P ₃	0.2528	0.2219	0.3484	0.3171	0.2851
	P ₄	0.3160	0.2849	0.2530	0.2848	0.2847
	P ₅	0.1894	0.2213	0.2527	0.2214	0.2212
Black soil.	P ₁	0.6321	0.6062	0.5207	0.6636	0.6057
	P ₂	0.5232	0.6118	0.4667	0.4372	0.5097
	P ₃	0.4051	0.4365	0.3477	0.4352	0.4061
	P ₄	0.4019	0.4325	0.3742	0.4616	0.4176
	P ₅	0.5196	0.4317	0.4039	0.4903	0.4614

STATISTICAL ANALYSIS

Due to	<u>A.V. TABLE</u>				<u>SUMMARY OF RESULTS</u>			
	S.S.	D.F.	M.S.S.	F.	Tr.	Mean	% G.M.	
6 6 6						<u>WVS. 'P'</u>		
Chalka. B.S.S.	0.0003	3			P ₂	0.3172	113.84	
Tr.S.S.	0.0195	4	0.0049	1.88	P ₃	0.2851	102.33	
Er.	0.0310	12	0.0026		P ₁	0.2848	102.23	
T.S.S.	0.0508	19			P ₄	0.2847	102.20	
					P ₅	0.2212	97.40	
					G.M.	0.2786	100.00	
					S.E.M.	0.0255	9.152	
Black soil. B.S.S.	0.0222	3			P ₁	0.6057	126.16	
Tr.S.S.	0.1055	4	0.0264	12.48	P ₂	0.5097	106.17	
Er.	0.0256	12	0.0021		P ₅	0.4614	96.10	
T.S.S.	0.1503	19			P ₄	0.4176	86.98	
Results significant at both 5% & 1% level.					P ₃	0.4061	84.59	
	<u>P₁</u>	<u>P₂</u>	<u>P₅</u>	<u>P₄</u>	<u>P₃</u>	G.M.	0.4801	100.00
						S.E.M.	0.02291	4.77
Mean W.S. 'P': Mean water-soluble P ₂ O ₅						C.D.	0.0706	14.71

APPENDIX TABLE-6(D)

Water-soluble P₂O₅ in soils under different treatments
incubation study 4th sampling
(Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chalko	P ₁	0.3163	0.4120	0.3798	0.2852	0.3483
	P ₂	0.3168	0.2531	0.2219	0.2848	0.2692
	P ₃	0.3797	0.2853	0.2532	0.3485	0.3167
	P ₄	0.3169	0.2850	0.2530	0.2853	0.2851
	P ₅	0.2212	0.2855	0.2531	0.3166	0.2691
Chalko	P ₁	0.5233	0.6135	0.4671	0.4409	0.5112
	P ₂	0.5866	0.4943	0.6115	0.4682	0.5402
	P ₃	0.4689	0.4407	0.3531	0.4387	0.4254
	P ₄	0.4072	0.3203	0.3500	0.4410	0.3796
	P ₅	0.5247	0.5117	0.4959	0.4957	0.5070

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>					<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F.	Tr.	Mean	% G.M.
						W.S. 'P'	
Chalko. B.S.S.	0.0044	3			P ₁	0.3483	117.00
Tr.S.S.	0.0188	4	0.0047	2.30	P ₃	0.3167	106.38
Er.	0.0245	12	0.00204		P ₄	0.2851	95.77
T.S.S.	0.0477				P ₂	0.2692	90.43
					P ₅	0.2691	90.39
					G.M.	0.2977	100.00
					S.E.M.	0.0258	8.66
Bleek soil. B.S.S.	0.0071	3			P ₂	0.5402	114.28
Tr.S.S.	0.0724	4	0.0181	5.34	P ₁	0.5112	108.14
Er.	0.0412	12	0.0034		P ₅	0.5070	107.26
T.S.S.	0.1207	19			P ₃	0.4254	89.99
					P ₄	0.3796	80.30
					G.M.	0.4727	100.00
					S.E.M.	0.02915	6.16
					C.D.	0.0898	18.99

Result significant at 5% level.

P ₂	P ₁	P ₅	P ₃	P ₄
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Mean W.S. 'P': Mean water-soluble P₂O₅

APPENDIX TABLE-6(E)

Water-soluble P₂O₅ in soils under different treatments
 dummy pots 1st sampling
 (Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series II pots (dummies)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
Chalka	P ₁	0.3157	0.3477	0.2838	0.3798	0.3318
	P ₂	0.4116	0.3806	0.3476	0.3805	0.3801
	P ₃	0.2536	0.3178	0.3162	0.3817	0.3173
	P ₄	0.2533	0.3486	0.3172	0.2215	0.2852
	P ₅	0.3808	0.3493	0.2533	0.2860	0.3174
Black soil.	P ₁	0.4907	0.4055	0.5222	0.4370	0.4639
	P ₂	0.2881	0.3770	0.4074	0.3178	0.3226
	P ₃	0.4067	0.3793	0.2907	0.3207	0.3494
	P ₄	0.5222	0.4357	0.4666	0.4940	0.4796
	P ₅	0.4063	0.4941	0.4373	0.5233	0.4653

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>						<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.F.	M.S.S.	F.	Tr.	Mean W.S. 'P'	% G.M.	
Chelka.	B.S.S.	0.0052	3			P ₂	0.3801	116.31
	Tr.S.S.	0.0191	4	0.0048	1.92	P ₁	0.3318	101.53
	Er.	0.0297	12	0.0025		P ₅	0.3174	97.15
	T.S.S.	0.0540	19			P ₃	0.3173	97.10
						P ₄	0.2852	87.27
					G.M.	0.3268	100.00	
					S.E.M.	0.0236	7.22	
Black soil	B.S.S.	0.0001	3			P ₄	0.4796	113.89
	Tr.S.S.	0.0040	4	0.0010	1.15	P ₅	0.4653	110.50
	Er.	0.01042	12	0.00087		P ₁	0.4639	110.16
	T.S.S.	0.1083	19			P ₃	0.3494	82.97
						P ₂	0.3226	76.61
					G.M.	0.4211	100.00	
					S.E.M.	0.01475	3.50	
Mean W.S. 'P': Mean water-soluble P ₂ O ₅								

APPENDIX TABLE-6(F)

Water-soluble P₂O₅ in soils under different treatments
 main experiment pots 1st sampling
 (Moisture free basis in p.p.m.)

Soil type	Phosphorus material in various proportions	Series I pots (main experiment)				Average
		P _I	P _{II}	P _{III}	P _{IV}	
Chalke	P ₁	0.3801	0.4112	0.3482	0.4437	0.3958
	P ₂	0.2527	0.3158	0.2848	0.2214	0.2687
	P ₃	0.1899	0.2218	0.2530	0.2218	0.2216
	P ₄	0.2540	0.2219	0.3172	0.3484	0.2854
	P ₅	0.2530	0.2218	0.1900	0.2215	0.2216
Black soil	P ₁	0.4652	0.3812	0.4079	0.4979	0.4381
	P ₂	0.4098	0.4421	0.5236	0.4998	0.4688
	P ₃	0.4068	0.3518	0.4397	0.3823	0.3952
	P ₄	0.4088	0.2940	0.3229	0.3813	0.3518
	P ₅	0.5037	0.4112	0.3844	0.4668	0.4415

STATISTICAL ANALYSIS

<u>A.V. TABLE</u>						<u>SUMMARY OF RESULTS</u>		
Due to	S.S.	D.D.	M.S.S.	F.	Tr.	Mean W.S.'P'	% G.M.	
Chalke. B.S.S.	0.0016	3			P ₁	0.3958	142.07	
Tr.S.S.	0.0814	4	0.0204	13.33	P ₄	0.2854	102.44	
Er.	0.0218	12	0.0018		P ₂	0.2687	96.45	
T.S.S.	0.1048	19			P ₃	0.2216	79.62	
Results significant at both 5% & 1% level.						P ₅	0.2216	79.62
					G.M.	0.2786	100.00	
					S.E.M.	0.02121	10.00	
					C.D.	0.0653	23.43	
Black soil.	B.S.S.	0.0147	3		P ₂	0.4688	111.89	
	Tr.S.S.	0.0337	4	0.0084	4.42	P ₅	0.4415	105.34
	Er.	0.0229	12	0.0019		P ₁	0.4381	104.53
	T.S.S.	0.0713	19			P ₃	0.3952	94.30
Result significant at 5% level.						P ₄	0.3518	83.94
					G.M.	0.4191	100.00	
					S.E.M.	0.02179	5.20	
					C.D.	0.0671	16.01	
Mean W.S.'F': Mean water-soluble P ₂ O ₅								

APPENDIX TABLE-7(A)

Total 'N' in soil under different treatments incubation
study 1st sampling
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Series III pot (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	0.0628	0.0406	0.0486	0.0550	0.0518
	P ₂	0.0611	0.0422	0.0562	0.0472	0.0517
	P ₃	0.0419	0.0604	0.0535	0.0487	0.0511
	P ₄	0.0387	0.0564	0.0506	0.0445	0.0476
	P ₅	0.0632	0.0438	0.0567	0.0502	0.0535
BLACK SOIL	P ₁	0.0691	0.0506	0.0647	0.0549	0.0598
	P ₂	0.0486	0.0672	0.0608	0.0560	0.0582
	P ₃	0.0687	0.0495	0.0546	0.0636	0.0591
	P ₄	0.0617	0.0507	0.0618	0.0542	0.0571
	P ₅	0.0513	0.0674	0.0627	0.0570	0.0596

APPENDIX TABLE-7(B)

Total 'N' in soil under different treatments incubation
study 2nd sampling
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	0.0563	0.0403	0.0515	0.0451	0.0483
	P ₂	0.0386	0.0525	0.0505	0.0409	0.0456
	P ₃	0.0472	0.0382	0.0462	0.0402	0.0430
	P ₄	0.0595	0.0417	0.0535	0.0487	0.0509
	P ₅	0.0571	0.0476	0.0553	0.0495	0.0524
BLACK SOIL	P ₁	0.0528	0.0402	0.0498	0.0432	0.0465
	P ₂	0.0511	0.0407	0.0491	0.0417	0.0457
	P ₃	0.0507	0.0403	0.0423	0.0477	0.0453
	P ₄	0.0405	0.0545	0.0515	0.0435	0.0475
	P ₅	0.0376	0.0450	0.0440	0.0390	0.0414

APPENDIX TABLE-7(C)

Total 'N' in soil under different treatments incubation
study 3rd sampling
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	0.0566	0.0484	0.0551	0.0499	0.0525
	P ₂	0.0563	0.0489	0.0544	0.0508	0.0526
	P ₃	0.0603	0.0503	0.0583	0.0521	0.0553
	P ₄	0.0565	0.0519	0.0560	0.0524	0.0542
	P ₅	0.0551	0.0453	0.0530	0.0474	0.0502
BLACK SOIL	P ₁	0.0519	0.0415	0.0502	0.0432	0.0467
	P ₂	0.0483	0.0411	0.0467	0.0427	0.0447
	P ₃	0.0517	0.0459	0.0506	0.0432	0.0479
	P ₄	0.0416	0.0520	0.0434	0.0502	0.0468
	P ₅	0.0567	0.0441	0.0533	0.0475	0.0504

APPENDIX TABLE-7(D)

Total 'N' in soil under different treatments incubation
study 4th sampling
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Series III pots (incubation study)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	0.0358	0.0319	0.0353	0.0330	0.0340
	P ₂	0.0398	0.0335	0.0384	0.0347	0.0366
	P ₃	0.0401	0.0344	0.0397	0.0356	0.0375
	P ₄	0.0435	0.0362	0.0375	0.0420	0.0373
	P ₅	0.0412	0.0359	0.0408	0.0363	0.0386
BLACK SOIL	P ₁	0.0283	0.0326	0.0316	0.0289	0.0304
	P ₂	0.0328	0.0277	0.0316	0.0291	0.0303
	P ₃	0.0368	0.0309	0.0361	0.0318	0.0339
	P ₄	0.0314	0.0397	0.0383	0.0328	0.0356
	P ₅	0.0386	0.0307	0.0373	0.0320	0.0347

APPENDIX TABLE-7(E)

Total 'N' in soil under different treatments dummy pots
1st sampling
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Series II pots (dummies)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	0.0443	0.0321	0.0416	0.0348	0.0382
	P ₂	0.0421	0.0331	0.0401	0.0351	0.0376
	P ₃	0.0474	0.0434	0.0441	0.0367	0.0429
	P ₄	0.0442	0.0312	0.0409	0.0345	0.0377
	P ₅	0.0449	0.0401	0.0441	0.0409	0.0425
BLACK SOIL	P ₁	0.0373	0.0311	0.0369	0.0315	0.0342
	P ₂	0.0379	0.0303	0.0359	0.0323	0.0341
	P ₃	0.0420	0.0316	0.0396	0.0340	0.0368
	P ₄	0.0337	0.0297	0.0331	0.0303	0.0317
	P ₅	0.0326	0.0290	0.0317	0.0299	0.0308

APPENDIX TABLE-7(F)

Total 'N' in soil under different treatments main
experiment pot 1st sampling
(Moisture free basis in percent)

Soil type	Phosphorus material in various proportions	Series I pots (main experiment)				Average
		R _I	R _{II}	R _{III}	R _{IV}	
CHALKA	P ₁	0.0258	0.0137	0.0229	0.0164	0.0197
	P ₂	0.0234	0.0195	0.0229	0.0198	0.0214
	P ₃	0.0225	0.0188	0.0216	0.0197	0.0207
	P ₄	0.0227	0.0186	0.0222	0.0191	0.0207
	P ₅	0.0280	0.0221	0.0279	0.0232	0.0253
BLACK SOIL	P ₁	0.0206	0.0177	0.0202	0.0183	0.0192
	P ₂	0.0217	0.0174	0.0212	0.0179	0.0196
	P ₃	0.0238	0.0175	0.0228	0.0183	0.0206
	P ₄	0.0271	0.0202	0.0256	0.0196	0.0231
	P ₅	0.0202	0.0173	0.0196	0.0179	0.0188