RELATIVE EFFICIENCY OF RICE VARIETIES FOR ABSORPTION AND UTILIZATION OF SOIL AND FERTILIZER PHOSPHORUS

By

MASHAR VELAPURATH

THESIS

submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1986

DECLARATION

I hereby declare that this thesis entitled "Relative efficiency of rice varieties for absorption and utilization of soil and fertiliser phosphorus" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

(MASHAR VELAPURATH)

Vellanikkara,
14th August 1986.

CERTIFICATE

Certified that this thesis entitled "Relative efficiency of rice varieties for absorption and utilization of soil and fertiliser phosphorus" is a record of research work done independently by Sri. Mashar Velapurath, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship, or associateship to him.

(Dr.(Mrs.) P. PADMAJA)
Chairman,
Advisory Committee,
Professor, Project Co-ordinator
(Soils & Agronomy)

Vellanikkara,
August 1986.

Approved by:

Chairman

Dr. (Mrs.) P. PADMAJA

Members

1. Dr. P. A. Wahid

2. Dr. N. P. Chinnamma

3. Dr. R. VIKRAMAN NAIR

to my parents

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude to Dr. (Mrs.) P. Padmaja, Professor, Project Co-ordinator (Soils & Agronomy), College of Horticulture, Vellanikkara for her valuable guidance, keen interest and constructive criticism throughout the course of investigation as well as in the preparation of manuscript.

No less has been the help, guidance and suggestions I received during the conduct of the experiment and preparation of the manuscript from the members of my advisory committee, Prof. P.N. Pisharody, Associate Director, Directorate of Research, Kerala Agricultural University; Dr. A.I.Jose, Professor & Head, Department of Soil Science & Agricultural Chemistry, College of Horticulture, Vellanikkara and Dr. R. Vikraman Nair, Professor of Agronomy, College of Horticulture, Vellanikkara.

I am specially thankful to Dr. P.A. Wahid, Professor, Radio-tracer Laboratory, Vellanikkara for his expert guidance and sincere help during the conduct of radio-tracer experiment.

My sincere thanks are due to Dr. C. Sreedharan, Professor and Head, Department of Agronomy, College of Horticulture, Vellanikkara for useful suggestions and encouragements during the course of the experiment. I wish to place on record my thanks to the staff of the Department of Soil Science & Agricultural Chemistry for the co-operation and help.

I owe a great debt to the large number of friends for the help rendered by them. Special mention should be made to Sri.K.S. Anilkumar, Smt. Stella Jacob and Smt. Prema, D., post-graduate students of the Department of Soil Science & Agricultural Chemistry, College of Horticulture. I am indebted to my parents for their constant encouragement and help. The award of research fellowship by the Kerala Agricultural University is gratefully acknowledged.

(NASHAR VELAPURATH)

CONTENTS

Table No. LIST OF TABLES

Introduction

INTRODUCTION

Phosphorus is recognised universally as an essential ingredient for successful crop production. It is all the more important in India where about 98 per cent of the soils are reported to be low to medium in available P status. The economic use of inorganic P carriers is highly essential since fertiliser P is a costly input, as most of the raw materials for the manufacture are to be imported. There is also the problem of fixation of applied P in most of the Indian soils especially in acid soils.

P utilisation by a single crop rarely exceeds twenty per cent. The availability of fixed P depends on soil characteristics, crop species and also on the variety of crops. Phosphatic fertilisers applied to one crop exhibit residual effect on the succeeding crop also. The magnitude of residual effect depends upon the rate and kind of phosphatic fertilizer used, the cropping and management systems followed, the type of soil and nature of crop species as well as the variety of the crop.

Research so far conducted on efficient utilisation of P indicated that P management should be tackled in a different way by considering crop-soil-fertiliser complex as a whole rather than individually. Selection of crop varieties in different situations should also be made based on the capacity of utilisation of applied fertiliser as well as soil P.

Tracer techniques are useful to identify varieties which are fertiliser responsive and those which utilise soil P efficiently. Karappadam soil in Kuttanad area is reported to have high P fixing capacity. Under such a situation the extent of uptake of the applied P is to be assessed. The differential uptake of P by the popular rice varieties of Kuttanad from the two sources has not been investigated so far. Moreover, such studies in rice are rare in India and practically nil in Kerala.

Different rice varieties of the same duration grown under identical fertility conditions, help to understand their relative potential for giving maximum grain and straw yield. The root distribution pattern at the flowering stage of each variety will give an idea regarding the foraging capacity of the roots of each variety to utilise soil P. Based on the above two studies the varieties can be phased properly or time of application of fertilizer P can be so adjusted in rice-rice cropping sequence for the efficient utilization of fertilizer and soil P.

Solution culture experiment with graded levels of soluble P will also help to find out the P requirement of varieties for maximum grain and straw yield. Hence the present investigation was taken up with the following objectives:

1. To generate research data on the relative efficiency of rice varieties popular in Kuttanad for utilization of soil and fertilizer P by using radio-tracer technique;

2. To identify varieties which give reasonably high grain and straw yield at the recommended dose of P supply as per package of practices recommendations of the Kerala Agricultural University for the respective varieties in Karappadam soil of Kuttanad;

3. To identify varieties which are inherently P deficiency tolerant or with low P requirement;

4. To study the relationship between P absorbed from the two sources viz. soil and fertiliser, in the early stages of growth in grain as well as straw yield;

5. To study the response of different varieties to graded levels of soluble P in the root medium using solution culture experiment; and

6. To assess the relationship between root distribution pattern of rice varieties and their foraging capacity for native P.

Review of Literature

REVIEW OF LITERATURE

Rice unlike other crops of tropical and subtropical origin is managed in a special way by virtue of its capacity for growth in anaerobic soil. The release of fixed P into the soil solution as a result of reduction following submergence cannot fully satisfy the requirement of P of modern varieties of rice in some soils. However, it is now known that rice varieties vary in their requirement for P, tolerance to P deficiency and capacity for absorption and utilisation of soil and fertilizer P. In this chapter an attempt has been made to review the results of research conducted so far on this aspect.

a) Response of rice to phosphorus application

Significant positive response in grain yield to P application was reported by several workers (Ratna and Fernando, 1954; Mukherjee, 1955; Yates, 1959; Rao, 1965 and Rao, 1975). Peterson (1968) obtained a response to as much as 150 kg P_2O_5/ha. Linear response to 30-90 kg P_2O_5/ha has been reported by several workers (Naphade, 1969; Dev et al., 1970; Singh and Varma, 1971 and Thenabadu, 1979). The response to each kilogram depended upon initial P status of the soil and was lowest on soils with high level of P (Dev et al., 1970). Khalid et al. (1979) concluded that soils with high P sorption under reduced conditions were more likely to give higher response to applied P. This positive response to P application was obtained in soils which are deficient in soil P.

It is generally believed that most of the Indian soils are adequately supplied with P because response to phosphate manuring had not been observed uniformly. Even on the same soil, wet rice generally shows lower response to P than upland rice. Low response of P in rice soils indicate that either the need of the rice crop is lower than that of other crops or rice has access to sources of soil P that are unavailable to other crops (Mitsui, 1960).

Sethi (1940) indicated that there was no response to P applied singly or in combination from his review of five years field experiments in Indian soils. Govin and Chand (1959) while reviewing the results of manurial experiments conducted at the various research stations in India indicated an erratic response to the application of P fertilizers. Mahapatra (1961) also did not get any response to P for eight indica rice varieties during the Kharif season in Orissa. Davide (1964) concluded that unless a soil is deficient in P, yield response to phosphate fertilizer in field experiments could not be obtained. Potty (1964) while reviewing the fertilizer experiments at the various research stations in Kerala reported no response to applied P fertilizers. Nair and Pisharody (1970) observed no increase in rice yield by increasing P application from the experiments conducted in waterlogged lateritic sandy loam soils of Kerala for thirtyfive years. Sasidhar and Sadanandan (1973) reported that application upto 60 kg P_2O_5/ha did not increase yield of rice cv. Rohini. Sadanandan and Sasidhar (1976) concluded that increasing rate of applied P had no significant effect on yield of grain and straw, number of filled grains per panicle and number of productive tillers per plant in the cv. Triveni. Gupta and Singh (1977) attributed the poor response of rice to applied P fertilizers to increase in available P following flooding.

b) Differential response of rice varieties to phosphorus

It is commonly known that the crop response to fertilizer vary not only with the nature of the crop but also with the genotype of each crop. A crop species or its variety which gives the highest yield under one set of field condition does not necessarily give highest yield under all conditions. Although considerable research have been carried out in India to evaluate response to P, little attention has so far been paid to the causes of such differences.

The All India Co-ordinated Agronomic Experiment conducted in lateritic soils at Mangalore (Anon., 1970a) showed that MTU-20 and Jaya did respond better to P than IR-8 irrespective of the source of P. Such differences among the rice varieties in their response to applied P were also reported by Kansal et al. (1974) and Gupta and Manchanda (1975). They stated that modern dwarf varieties should receive additional P fertilisers. Rao (1975) also observed that varietal response to P was highly variable and in general rabi rice responded better than Kharif. Kiasulu (1983) showed that grain yield of OS-6 and ITA-116 were higher than those of ITA-117 and ITA-122 with and without P application. Reddy et al. (1984) studied the response of low land rabi rice to applied P with six rice varieties and five levels of P. All the treatments with added P gave higher grain yield than the control. The highest mean grain yield was recorded by IR-50 which was significantly superior to all other varieties.

c) Phosphorus uptake and utilisation by rice at various stages of growth

Dabin (1951) showed that maximum utilization of P occurred at tillering stage. About 80 per cent of P was absorbed before flower emergence and most of it was translocated to panicle (Kasai and Asada, 1959; Rao, 1965; Ramanathan and Krishnamoorthy, 1973; Khumbar and Sonar, 1979). Kasai and Asada (1959) also observed that 60-80 per cent of P absorbed before flowering was translocated to the grain and this resulted in decreased accumulation of P in the roots upto flowering. However, accumulation of P increased in root after flowering particularly at high P level. It was also observed that rate of uptake of absorbed P increased until ripening, indicating that P absorption continued even after flowering. Naphade (1969) obtained a significant positive correlation between grain yield and total uptake of P. Several workers reported that uptake of P increased with increasing rate of application (Varma, 1971; Pathak et al., 1972 and Bhushan and Singh, 1979). Qiu and Wan (1982) from a solution culture study found that P uptake increased rapidly during early growth stage but was low in the later stages. They also noticed that when P was excluded from the culture solution tillering did not take place during the growth period.

Pathak et al. (1972) showed that plant content of P decreased with age, uptake and content of P were higher in grain than in straw. Kothandaraman et al. (1976) found that maximum grain content of P (0.27%) was obtained at 180 kg P_2O_5/ha in the cv. IR-20. Rai and Murty (1976) observed that P content increased from 14 to 42 days after planting. Shiga and Yamaguchi (1976) found that greatest panicle number and grain yield were associated with plant P_2O_5 concentration of 0.6-0.7 per cent at maximum tillering stage. According to them the level of soil P for highest yield varied from 22-40 mg P_2O_5/100 g of soil according to the nature of soil. Chang (1976) was of opinion that excessive use of P did not depress rice yield unlike N, but P content of plants increased with increase in supply.

d) Varietal efficiency in phosphorus absorption

Datta (1967) observed maximum P uptake by TN1 followed by Chang and Taiwan-3. Koyama and Chammek (1971) from a trial using two rice cv. Dawk Mali-3 and Muey Naung-62-M showed that the absorption of P by former variety was higher than that of latter. A similiar observation was made by Koyama and Snitwongse (1971). Ramanathan and Krishnamoorthy (1973) observed significantly greater uptake of P by the rice variety IR-8 than IR-20 and IR-22. Weeraratne (1974) studied the uptake of P at the first and third month after sowing in modern rice varieties like IR-5, H-4 and H-8 and in local varieties such as Pachaperumal, Herath Banda and Suda Ratawi. He observed that the rate of P uptake increased from first to third month after sowing and was higher in modern varieties than in local varieties. Devasia et al. (1976) studied the content of P in the straw of eleven rice varieties of Kerala and found that P content ranged from 0.21 to 0.54 per cent. Khumbar and Sonar (1979) reported a higher uptake of P by upland rice cultivars than low land cultivars. Srivastava et al. (1984) screened salt tolerant varieties IR-54, IR-45-63-52-151-3-6, IR-9975-5-1, IR-146-32-22-3, IR-1961-131-1-2, M-242 and Pokkali for P uptake in sodic soils. Pokkali yielded the maximum followed by IR-4563-52-151-3-6. IR-54 yielded the least. They found that higher yielding varieties had comparatively higher uptake and translocation of P from source to sink.

e) Varietal efficiency in absorption of soil and fertiliser phosphorus

It has been observed by many workers that the total P and fertiliser P uptake increased with increasing rate of applied P.

Increasing rate of fertilizer P reduced the uptake of soil P by rice (Verma et al., 1959; Maung Mya Thaung, 1960 and Nagarajah and Mookashekhara, 1962). Datta and Datta (1963) reported a highly significant exponential inverse relationship between log 'A' value (available soil P) and percentage yield response. Rao and Srinivasan (1978) obtained higher paddy yield from two Assam dwarf cultivars RPA-5824 and RPA-5929 than three standards viz. Jaya, Tella Hamsa and Cauvery, when grown without applied P or at low rate of P supply. Nath and Borah (1979) observed that the plant P content was higher in soils having both native and applied P than in a soil having only native P. Paddy grain and straw yield increased with increasing P rates but decreased the uptake of soil P (Sinha et al., 1980 and Rastogi et al.,1981). Chaudhary and Uppal (1981) observed that the P accumulation was 4.2, 4.4 and 6.4 mg/pot upto tillering, and 32.7, 30.7 and 38.5 mg/pot from tillering to maturity in rice cultivars IR-8, Jaya and J-351 respectively without added P indicating variation among rice varieties for the absorption of soil P.

Nagarajah and Mookashekhara (1962) investigated utilization of fertilizer P by rice and found it as 0.52-2.36 per cent during the first five weeks of growth period. De Datta et al. (1966) reported that the percentage of plant P derived from applied P ranged from 8 to 27 per cent and was generally unaffected by rate of applied N. Szepes and Kiss (1967) obtained most significant ^{32}P uptake at tillering, which decreased markedly by the time of panicle emergence and flowering. The ^{32}P uptake again approached the initial value at ripening. Dev et al. (1971) reported that the plants were capable of absorbing P from fertilizer more effectively upto maximum tillering than at later stages of growth.

Datta and Datta (1963) obtained a highly significant relationship between percentage yield response and percentage uptake of fertiliser P. Dev et al. (1971) recorded varietal differences to P response in rice using ^{32}P tracer technique. They concluded that IR-8 and Jaya are less efficient in utilising fertiliser phosphorus as compared to culture-95 and IR-62288. Osa et al. (1971) also reported significant varietal variation in P uptake. Varieties varied in total fertiliser P uptake but the percentage of P in the plant derived from the fertiliser did not differ in any of the different treatments tried.

Shukla and Choudhary (1976) observed the rice variety IR-8 to be more responsive to P application than T(N)1 and Jhona-349. Rao et al. (1978) noticed seasonal variation in varietal differences in P uptake by rice. Tella Hamsa, MTU-8002, Mashuri and RNR-12329 showed higher percentage of P derived from fertiliser in Kharif while RP-414 and Sona showed the same trend in rabi at 60 kg P_2O_5/ha level. Kiazulu (1983) found that external P requirements were 0.03 ppm for

ITA-117, 0.06 ppm for OS-6 and ITA-122 and 0.12 for ITA-116.

f) Varietal requirement of phosphorus

Singh et al. (1972) obtained the highest yield of 4.13 t/ha in the variety Bala and 3.78 t/ha in N-22 by application of 40 kg P_2O_5 and 20 kg P_2O_5/ha respectively indicating the differential requirement of P for rice varieties for the expression of their yield potential. Rao et al. (1974) in their studies on the effect of levels and time of application of P to IR-8 found that 40 kg P_2O_5/ha applied at planting was optimum for maximum yield. Khatua et al. (1976) suggested application of 30 kg P_2O_5/ha in Kharif and 60 kg P_2O_5/ha in rabi season for the cultivar IR-8. Choudhary and Mian (1978) found that application of 45 kg P_2O_5/ha gave maximum grain yield, number of tillers per plant and panicle weight in the rice variety Dharial. Patel (1978) compared the performance of the new variety Patel-85 with Jaya and IR-8 and found that the former yielded 8.32 t/ha when 60 kg P_2O_5 was applied which was much higher than the yield of other varieties. Choudhary and Uppal (1981) observed that application of 60 kg P_2O_5/ha as a single dose at puddling was best for IR-8 and Jaya but cultivar J-351 responded best to half the dose applied at puddling and the other half at tillering.

g) Roots of the rice plants and its capacity for phosphorus absorption

The mechanisms governing the rate of nutrient movement through soil to roots as well as surface area of feeder roots account for soil nutrient availability in a particular crop and varieties of the same crop. Besides these, the plant roots can change pH, salt content and ionic composition of the rhizosphere. These changes directly or indirectly affect the plant availability of nutrients including P.

Two third of the root system of rice was found in the upper most 5 cm of the soil, and over 95 per cent in the first 5 cm (Anon., 1951). Mori (1954) measured root activity of rice by the number and length of regenerating roots and found it was the greatest at the maximum tillering stage and decreased at heading stage. Fuji (1957) reported that tenth node produced the maximum number of roots (23 Nos.) and these had the maximum basal diameter of 1.36 cm in rice where as in wheat there were uniformly three roots per node and these roots attained maximum basal diameter (1.26 cm) at the sixth node. Pelerants (1958) studied the roots of upland rice and arrived at following inferences. (a) Fourty per cent of roots of cultivar R-55 were formed during the first sixty days of growth and the remaining sixty per cent between sixtieth and ninetieth days and thereafter there was no increase in root length or weight. (b) Root growth were compared in three soils and found that in sandy soil the root weight was double of that in clayey soil, the root hairs were however more developed in clayey soil and (c) Varietal difference in root development was observed between R-55, E-12 and E-411. Fuji (1959) reported that under low land condition rice roots were less branched and shorter lived than under upland condition.

Tanaka (1959) showed that P uptake by rice roots was increased with increasing pH of the culture solution. When P concentration was very low, as in the soil solution, the suitability of root environment for metabolism was more important than P concentration for P uptake. Tang Van Hai and Lau De Lout (1966) found that P uptake of excised rice roots was directly proportional to P concentration in the nutrient medium upto about 7.0 ppm. Positive relationship was observed between root CEC and nutrient uptake by several workers (Kanwar, 1970; Kansal et al., 1974 and Oza et al., 1977).

Root activity and rooting pattern of crops have been found to influence nutrient uptake by crops. Singh et al. (1971) showed that the rooting pattern of wheat varieties caused differential uptake of native and applied P. Wakhaloo et al. (1973) also found good relationship between root activity and P uptake by cotton varieties. Similar relations for barley and maize crops were also obtained by Oza et al. (1976). Kamath et al. (1974) reported that the root system of maize cultivars which were tested under normal and adverse soil conditions, showed a shift in the rooting system towards shallow and compactness.

According to Ramamoorthy and Bisan (1971) the energy requirement for the absorption of phosphorus by wheat from Fe-P and solid-P was less than that from Ca-P. Rice has a greater capacity than wheat for extracting P from Ca-P.

It was suggested that a genetical control over the absorption of P exists and it was mainly due to additive gene action (Oomen et al., 1972; Reddy and Rao, 1976 and Oza et al., 1977). Subbiah and Oza (1973) emphasized that selection of crop plants and their varieties for efficient absorption of specific plant nutrient was very important. The varietal difference for nutrient uptake can be exploited for breeding varieties suited for different agroclimatic conditions.

Bole (1973) related the influence of root hairs of wheat in utilisation of soil P and found that root hair density was fourtyfive hairs/mm for low P absorption capacity whereas it was sixty for high P. Rape roots virtually devoid of root hairs took up 2-6 times as much soil P/unit length of root as wheat with hairs.

Kumaraswamy et al. (1977) from a field experiment using ^{32}P injection technique in rice found that 55-75 per cent of roots were in the soil zone at 10 cm lateral distance and 16 cm depth from the base of the plant. Variation in percentage root distribution in the soil zone 10 cm (laterally) x 16 cm (depth) was observed between cultivars but distribution in the 15 x 24 cm zone was similar. Sanzo et al. (1980) examined root growth of rice cultivars IR-880 and Naylamp at the beginning of maximum tillering and during the flowering stages. The root systems of both cultivars did not extend below 40 cm. Maximum root growth occurred during maximum tillering stage. Root volume and dry matter production increased until flowering. The root distribution pattern of some wheat varieties using ^{32}P tagged fertiliser was studied by Dev et al. (1980). They found that dwarf varieties like Kalyan Sona, WG-357 and WG-377 have more compact and shallow rooting systems whereas tall variety C-306 has a deeper spreading system.

An attempt was made to quantify the effect of nodal root production on tillering and P uptake from various soils in wheat by Woodruff (1980). The nodal root number produced per plant was found to be highly correlated with tiller number. Delaying nodal root establishment beyond mid tillering lead either to a reduced production of tillers or a reduced survival of tillers. This effect was more marked under conditions of low soil P with fertiliser P banded on the surface soil, suggesting an improved P uptake efficiency of nodal roots over seminal roots alone. Veen and Boone (1981) reported that increasing P levels increased fresh weight of root and root diameter. Socorro (1982) studied the effect of P on root growth of rice. According to him higher rates of P positively increased length, volume, absorption area and dry matter accumulation.

Singh et al. (1981) reported that rice varieties varied greatly in the vertical and lateral development of roots. Cultivars PH-465, PH-612, IET-2970, IET-3372, IET-4011 and Cauvery had deeper and less spreading root system. Row and Venkateswaralu (1983) from the studies conducted in root boxes showed that the potential root system in rice in terms of length, volume, weight and thickness was greater in tall cultivars such as Lalnakanda-41 and MTU-17 and Rasi (dwarf) while IR-20 had a relatively shallow root system. The dwarf plants concentrated much in 'A' zone while the proportion of distribution was relatively balanced in tall types. Kwak et al. (1983) observed differences in rooting ability among thirteen rice varieties. The varieties Fujisaka-5, P-33, G-19 and KT-31-1 showed good rooting ability. Pillai et al. (1984) reported that root system of IET-5854 and IET-1444 was more extensive than those of other cultivars.

Differences in root activity of many modern varieties of crops have been established in recent times. Such variations in the rooting pattern of cultivars can be exploited for an efficient use of applied and native P by suitable manipulation of cultural practices.

h) Varietal resistance to phosphorus deficiency

P deficiency limits rice yields on Andosols, Oxisols, Vertisols, Histosols and acid sulphate soils. Some of these soils are deficient in available P, others convert phosphatic fertilisers to highly unavailable forms. P deficiency in rice lands is wide spread in Asia (Tanaka and Yoshida, 1970; Goswami, 1975 and Kowaguchi and Kyuma, 1977).

It was observed that cultivars differed markedly in their resistance to injury caused by P deficiency (Anon., 1970). The varietal difference in susceptibility to P deficiency was reported for the first time in 1971 (Anon., 1971). Of the ten varieties studied IR-8 was severely injured by P deficiency while IR-5 and H-4 grew well on a P deficient soil. The resisting power of rice varieties to P deficiency was tested in the same year and found that out of ninety eight varieties tested, IR-5, IR-22, H-4 and IR-400-5-12 were most resistant to P deficiency while IR-8, Daun, IR-498-42-1, IR-626-1-112 and IR-878 and D-220-3 were least resistant. In the following year (Anon., 1972) fiftytwo varieties were screened in outdoor concrete tanks and their tolerance to P deficiency was assessed by comparing their grain yields with and without P fertiliser. The varieties were graded according to their degree of tolerance. Among the most tolerant were cultivars IR-4-11, IR-26, IR-1632-93-2, IR-2035-290-2 and among the most susceptible were IR-1529-680-3, IR-2031-724-2, IR-2061-628-1 and IR-2071-625-1.

Turner et al. (1978) reported that American rice varieties Nato, Starbonnet, Lebonnet and Labelia were as tolerant as or more tolerant than three varieties of IR series. Mahadevappa et al. (1979) reported that IR-34, BR-51-91-6 and IR-5105-93-2-2 could be regarded as tolerant to soil deficient in P. They also observed that tolerance to P deficiency contributed 0.5-0.8 tonnes at yield levels of 2.5-4.0 t/ha in these varieties. It was also found that tolerant cultivars maintained higher yields under mild P stress conditions.

Among five genotypes tested at three levels of P, the yield depression from P_0 plots was only 11 per cent over three seasons, and all the five genotypes were consistently tolerant in all seasons (Ponnamperuma, 1979). In one season the overall reduction in panicle number in P_0 in relation to other treatments was 6 per cent. Straw weight reduction was 10 per cent. These genotypes differed in various degrees in their depression of both panicle number and straw weight. Also P removed through grain by tolerant varieties was high, where as that removed through straw was relatively low.

IR-42, was found to be tolerant to P deficiency and the same variety showed marked response to moderate P application (Ponnamperuma, 1979). This variety was reported to exploit soil P and utilise fertilizer P as well as other nutrients more efficiently.

Fageria and Filho (1981) reported that rice cultivars differed in their P requirements and their capacity to extract P from the soil. About one hundred and sixty seven upland rice cultivars were screened for tolerance to soil P deficiency under field condition. They confirmed the existence of varietal tolerance to P deficiency and the cultivars were classified into four groups viz., non-responsive efficient (NRE), responsive efficient (RE), responsive inefficient (RIE) and non-responsive inefficient (NRIE). The most desirable cultivars from the point of view of tolerance to low level of P were those belonging to NRE and RE.

Eight rice cultivars were compared for their tolerance to low P conditions in a field trial by Pillai et al. (1984) and found that IET-5854, a long duration variety and IET-1444, a short duration variety showed the best performance in terms of growth, drymatter production, tillering, and grain yield at zero and moderate levels of P application.

It has been observed that the efficient users of both soil and fertilizer P are varieties with growth duration exceeding one hundred and twenty days. Varieties that mature in less than one hundred and thirteen days are poor users (Anon., 1984). However, most early varieties respond better to phosphatic fertilizers.

Materials and Methods

MATERIALS AND METHODS

A series of pot culture experiments was conducted to study differential response of popular rice varieties to soil and applied fertiliser P.

a) Soil characteristics

Karappadam soil of Moncompu which belongs to the order Inceptisol was used for the study. The soil was sampled to plough layer depth (15 cm), air dried under shade and sieved through 2 mm sieve. The soil was analysed for physical properties like particle size distribution, apparent and absolute specific gravities and chemical properties like total HCl extractable and exchangeable nutrients. Electro-chemical characteristics like pH and conductivity of the soil were also studied.

b) Rice varieties

Five short duration and eleven medium duration varieties were selected for various experiments. Details of the varieties used are as follows:

Sl.No.	Varieties	Duration (days)	Grain characteristics
I. SHORT DURATION			
1	Rohini	75-110	White, long, bold
2	Jyothi	110-125	Red, long, bold
3	Annapoorna	90-100	Red, short, bold
4	Triveni	95-105	White, long, bold
5	IR-36	100-105	White, medium, slender

II. MEDIUM DURATION

1	Jaya	120-125	White, long, bold
2	IR-8	125-135	White, long, bold
3	Sabari	100-135	Red, long, bold
4	Bharathi	115-125	Red, long, bold
5	Mashuri	125-145	White, fine rice
6	IR-20	120-145	White, long, bold
7	Mo-4 (Bhadra)	125-130	Red, short, bold
8	Mo-6 (Pavizham)	115-118	Red, short, bold
9	Mo-7 (Karthika)	115-120	Red, long, bold
10	H-4	125-145	Red, long, bold
11	IR-42	130-145	White, medium grained

c) Evaluation of rice varieties for their capacity to absorb and utilise soil and fertiliser phosphorus

The experiment was designed to evaluate the varieties for their capacity to utilise the two major sources of P, viz. soil and fertiliser.

Plastic buckets of four litre capacity lined with well washed polythene sheets were used for the experiment. Three kilogram of 2 mm sieved air dried soil was taken in each pot. The soil in the pots was kept waterlogged for two to three weeks before planting. Two seedlings of each variety were planted in a pot. Short duration varieties were replicated four times whereas medium duration varieties were replicated thrice. The different varieties were supplied with N, P_2O_5 and K_2O as per the package of practices recommendations of

KAU (Anon., 1982). Short duration varieties were given N, P_2O_5 and K_2O at the rate of 70:35:35 kg/ha, medium duration varieties at 90:45:45 kg/ha and Mashuri and H-4 at 70:45:45 kg/ha respectively. Urea (46% N), ^{32}P labelled superphosphate (16% water soluble P_2O_5) and muriate of potash (60% K_2O) were used to supply N, P_2O_5 and K_2O. Calcium carbonate was used as the liming material. N and K_2O were applied in two equal split doses whereas P_2O_5 was applied as one single basal dose before planting. Calcium carbonate was applied at the rate of 350 kg/ha two to three weeks before planting and 250 kg/ha a month after. The pots were arranged in CRD.

The pots were regularly irrigated with deionised water so as to maintain the level of water 5 cm above the soil surface. One plant was removed on the 30th and 60th day of planting from each pot. The harvested plants were dried in a hot air oven at 75°C and dry weight recorded. The dried plant samples were then used for the determination of total P content as well as for radioassay. From the analytical data obtained the amounts of P derived from fertiliser and soil were computed.

d) <u>Growth and yield characteristics under identical fertility conditions</u>

The experiment was designed to study the differential behaviour of rice varieties under identical soil fertility conditions.

Fifteen kilograms of 2 mm sieved, air dried Karappadam soil was filled in each pot and was kept flooded for fifteen days before application of fertilizers and planting. N, P_2O_5, K_2O and lime were applied as per package of practices recommendations of KAU (Anon., 1982). There were four replications for the five short duration varieties and three replications for the eleven medium duration varieties. Four hills of two seedlings each were planted in a pot. The pots were arranged in CRD.

Plant characters like height, number of total and productive tillers were recorded a week before harvest. Plants were harvested at maturity, washed and dried at 75°C in a hot air oven. After drying, weight of straw, grain and thousand grains were recorded. Fertility percentage of each variety was recorded from grain weight, thousand grain weight and chaff number. Concentration of P in grain and straw was analysed and total P uptake computed using dry weight of grain and straw.

e) <u>Foraging capacity of root system of rice varieties for soil and fertiliser phosphorus</u>

A pot culture study was conducted to study the root distribution pattern of different varieties under identical fertility conditions and to examine the relationship between root distribution and utilisation of applied fertilizer and soil P.

Fifteen kilogram of air dried, sieved soil was filled in each pot and kept submerged for fifteen days before planting. The same fertiliser schedule was adopted for different varieties as in the previous experiment. A single seedling of each variety was planted in a pot. Four replications were kept for short duration varieties and three for medium duration varieties.

Plant height and total number of tillers were recorded when 75 per cent of tillers of each variety flowered. At this stage, plants along with the soil were uprooted from the pots. The adhering soil particles were washed off using jet of water. After thorough washing, the plants along with their root system were dried in a hot air oven at 75°C. Total weight of roots, weight and volume of thick and thin roots were recorded.

f) <u>Response of different varieties of rice at increasing levels of phosphorus supply</u>: <u>Solution culture experiment</u>

A solution culture experiment was conducted to study performance of the above mentioned varieties at graded levels of P supply.

Plastic pots of four litre capacity were used for the experiment with waxed bamboo basket. Well washed gravel was kept on the basket to give anchorage to the seedlings. Eighteen day old seedlings were planted in the basket so that the roots hang down and touch culture solution in the pot. Two seedlings were planted in each basket.

Same varieties as in above experiments were used. Graded levels of P were 0, 1, 2, 4, 5 and 10 ppm. Each treatment was replicated twice. The pots were arranged in CRD factorial design.

The culture solution used in the experiment had the following composition.

Chemical	Concentration
NH_4NO_3 to supply	50 ppm N
KCl to supply	20 ppm K
$CaCl_2$ to supply	20 ppm Ca
$MgCl_2$ 6 H_2O to supply	20 ppm Mg
FeEDTA to supply	2 ppm Fe
$NaSiO_3$ to supply	2 ppm Si

Micro-nutrients (Mn, Zn, Cu, B and Mo) were applied according to the formulation of Johnson et al. (1957). P was applied as $NaH_2PO_4 \cdot 2H_2O$ as per treatments. The initial pH of culture solution was adjusted to 4.8-5.2 with normal H_2SO_4 by employing bromocresol green indicator. Sulphuric acid also served as a source of sulphur to plants.

The culture solution was changed once in a week. At the time of changing, the basket supporting plants was removed and the roots were washed with a jet of tap water. After thorough washing of pots, the nutrient solution was renewed.

After one month, one seedling from each pot was removed.

Shoot portion of these seedlings was dried in a hot air oven at 75°C and analysed for P. The other plant was kept upto harvest.

Flowering duration was recorded when 75 per cent of tillers flowered. Plant height, number of total and productive tillers were recorded one week before harvest. At maturity, plants were removed along with their root system, washed thoroughly, dried in a hot air oven at 75°C, shoot and root weights were recorded. Earhead measurements and grain weights were also recorded. Fertility percentage was computed from fertile and total grain number.

ANALYTICAL TECHNIQUES

A. Methods used for soil analysis

Soil samples were drawn from the bulk brought for pot culture studies by the method of quartering, air dried under shade, sieved through 2 mm sieve and used for different physical, electro-chemical and chemical determinations.

1. Physical properties

a) Particle size distribution

Mechanical analysis of the soil was carried out by Robinson's international pippette method, after reduction of organic matter with 6 per cent H_2O_2 as described by Piper (1942). Soil was classified into textural group using I.S.S.S. system.

b) Single value constant

The apparent and absolute specific gravities, water holding capacity, and pore space were determined using Keen Raczkowski method (Piper, 1942).

2. Electrochemical properties

a) Soil reaction (pH)

pH of the soil was determined using Elico pH meter with glass electrode in a 1:2.5 soil water suspension.

b) Electrical conductivity

Electrical conductivity of saturation extract was determined as described by Hesse (1971).

3. Chemical parameters

a) Organic carbon

Organic carbon was estimated by Walkley and Black's rapid titration method (Walkley and Black, 1934).

b) Total nitrogen

Total nitrogen was determined by the macro Kjeldahl method (Jackson, 1958).

c) Total phosphorus

The soil was fused with sodium carbonate and the fusion cake was extracted with HCl. The P was estimated from an aliquot of fusion extract by chlorostannous reduced molybdo-phosphoric blue colour method in HCl acid system (Jackson, 1958).

d) Total potassium

Total potassium was determined in the leachate after removal of sesquioxides from fusion extract using an 'EEL' flame photometer (Jackson, 1958).

e) Total calcium and magnesium

From an aliquot of the fusion extract, total calcium and magnesium were also determined (Jackson, 1958).

f) Total sesquioxides

Total sesquioxides were determined gravimetrically after precipitation with ammonium hydroxide, from an aliquot of fusion extract (Jackson, 1958).

g) Total silica

Total silica in the soil was estimated gravimetrically by the method suggested by Jackson (1958).

h) Available nitrogen

Available nitrogen in the soil was determined by the alkaline permanganate method described by Subbiah and Asija (1956).

i) Available phosphorus

Bray No.1 available P was extracted in dilute acid fluoride solution (0.03 N NH_4F and 0.025 N HCl) (Bray and Kurtz, 1945). P from the extract was determined colorimetrically by chlorostannous reduced molybdo-phosphoric blue colour method in hydrochloric acid system (Jackson, 1958).

Olsen's available P was determined by the method of Olsen et al. (1954) in alkaline extractant (0.5 N $NaHCO_3$ at pH 8.5) as described by Jackson (1958).

j) Cation exchange capacity

The cation exchange capacity of the soil was determined by leaching the soil with neutral normal ammonium acetate solution and estimating the NH_4^+— N adsorbed by distillation using MgO (Peech et al., 1947).

k) Available potassium

Available potassium in the soil was determined from ammonium acetate extract using 'EEL' flame photometer (Jackson, 1958).

l) Available calcium and magnesium

From the ammonium acetate extract, calcium and magnesium were also determined by the versenate titration method (Cheng and Bray, 1951).

B. Methods used for plant analysis

1. Total phosphorus

P contents in the grain and straw were determined. The procedure involved wet digestion of oven dried (75°C) and finely ground samples with 1:1 perchloric-nitric acid mixture and determination of total P in the digest colorimetrically by the vanadomolybdate yellow colour method (Jackson, 1958).

2. Radioassay of plant samples

For the determination of ^{32}P activity in the plant samples, the method developed by Wahid et al. (1985) was followed. The method is based on the determination of ^{32}P activity by Carenkov counting technique. Briefly, the procedure involves wet digestion of oven dried (75°C) and finely cut plant samples with 1:1 perchloric-nitric acid mixture and determination of radioactivity in the digest. One gram plant sample was weighed into 250 ml conical flask followed by addition of 15 ml diacid mixture (complete sample was taken for the plant harvested on the 30th day after planting). Flask with its contents was then heated on a hot plate at a low temperature until initial frothing subsided. The digestion was continued at increased temperature until the digest became clear and its volume reduced to 2-3 ml. The flask with its contents was then cooled and the colourless digest was quantitatively transferred into a 20 ml glass scintillation counting vial with distilled water upto a final volume of 20 ml by repeated washings of the flask. The radio-activity was determined after 4 h by Carenkov counting technique in a microprocessor controlled liquid scintillation system (Rackbeta of LKB Wallac, Finland) adopting channel settings and the programme recommended for tritium counting by liquid scintillation technique.

a) Specific activity determination

Specific activity of ^{32}P in the plant samples was estimated as follows. After the radioassay of the sample, an aliquot of the plant digest was removed from scintillation vial for the determination of total P by the vanadomolybdate method (Jackson, 1958). The specific activity of the ^{32}P in the sample was then calculated as the ratio of ^{32}P content per unit weight of P and expressed as cpm/mg P.

$$\text{Specific activity (cpm/mg P)} = \frac{\text{cpm per gram of dry matter}}{\text{milligram P per gram of dry matter}}$$

From the specific activity, percentages of P derived from fertiliser and soil were calculated as shown below.

$$\text{Percentage P derived from fertiliser} = \frac{\text{Specific activity of the plant (cpm/mg P)}}{\text{Specific activity of the fertiliser (cpm/mg P)}} \times 100$$

$$\text{Percentage P derived from soil} = 100 - \text{percentage P derived from fertiliser}$$

After that, amounts of P derived from fertiliser and soil were computed from the above value using total P uptake.

$$\text{Amount of P derived from fertiliser by the plant} = \frac{\text{Total P uptake} \times \text{percentage P derived from fertiliser}}{100}$$

$$\text{Amount of P derived from soil by the plant} = \frac{\text{Total P uptake} \times \text{percentage P derived from soil}}{100}$$

'A' value was also calculated based on the formula

$$\frac{\text{Percentage P derived from soil}}{\text{Percentage P derived from fertiliser}} \times \text{Rate of application } (\mu g\ P/g\ soil)$$

Results

RESULTS

A series of pot culture studies was carried out in Karappadam soil (Inceptisols) of Kuttanad to evaluate the efficiency of popular rice varieties to utilise soil and applied fertiliser P and to study their relative tolerance to P deficiency.

Pot culture study was carried out using five short duration and eleven medium duration varieties to compare their relative performance under recommended rate of nutrient supply as per the package of practices recommendations of the Kerala Agricultural University (Anon., 1982) for those varieties. A set of pots with the same treatments was utilised for root studies at the flowering stage of the varieties.

Comparative efficiency of all the varieties was evaluated for utilisation of soil and fertiliser P using ^{32}P tagged superphosphate as the source of the nutrient.

A solution culture experiment was carried out using graded levels of P to study the requirement of different varieties for the expression of maximum yield potential.

The results obtained from various investigations are presented in this chapter.

A. Analysis of soil

a) Physical characteristics
(Table 1a)

The data on particle size distribution indicated that

Karappadam soil collected from Moncompu was clayey in texture, the clay content being 49.82 per cent. Organic matter content was high (3.20 per cent). Apparent and absolute specific gravities of the soil were 1.29 and 2.40 respectively. Maximum water holding capacity and percentage pore space were found to be 35.40 and 46.92 respectively.

b) Electrochemical and chemical characteristics (Table 1b)

The soil was found to have an acidic pH of 5.60 in the dry state which was raised to 7.2 on submergence. The soil recorded an electrical conductivity of 1.10 mmhos/cm in the saturation extract.

The total content of nitrogen, phosphorus, potassium, calcium and magnesium were 0.218, 0.109, 0.135, 0.43 and 0.14 per cent respectively. The sesquioxides and silica were found to be 20.15 and 53.24 per cent each. The soil has a cation exchange capacity of 27.23 me/100 g soil. Available nitrogen and potassium were estimated as 600 and 125 kg/ha. Available P status of the dry and wet soil was found to vary widely and it ranged from 11.66 to 17.00 kg/ha with Bray No.1 while the olsen values were 18.72 and 16.66 kg/ha respectively. Available calcium and magnesium were 0.23 and 0.03 me/100 g soil.

Table 1. Characteristics of the karappadam soil

a) Physical properties

Sl.No.	Particulars	
1	Particle size distribution	
	1. Coarse sand (%)	10.40
	2. Fine sand (%)	19.53
	3. Silt (%)	16.55
	4. Clay (%)	49.82
	Organic matter (%)	3.20
	Textural classification	Clayey
2	Apparent specific gravity	1.29
3	Absolute specific gravity	2.40
4	Maximum water holding capacity(%)	35.40
5	Pore space (%)	46.92

Table 1 (continued)

b) Electrochemical and chemical properties

Sl.No.	Particulars	
I	Electrochemical	
1(a)	pH (dry soil)	5.600
(b)	pH (submerged soil)	7.200
2	Electrical conductivity of the saturation extract (m.mhos/cm)	1.100
II	Chemical	
1	Organic carbon (%)	1.860
2	Total N (%)	0.218
3	Total P (%)	0.109
4	Total K (%)	0.135
5	Total Ca(%)	0.430
6	Total Mg(%)	0.140
7	Total sesquioxides (%)	20.150
8	Total SiO_2 (%)	53.240
9	Available N (kg/ha)	600.00
10	Available P (kg/ha)	
	a) Dry soil - Bray No.1	11.66
	Olsen	18.72
	b) Wet soil - Bray No.1	17.00
	Olsen	16.66
11	Cation exchange capacity (me/100 g)	27.23
12	Available K (kg/ha)	125.00
13	Available Ca (me/100 g)	0.23
14	Available Mg (me/100 g)	0.03

B. Evaluation of rice varieties for their capacity to utilise soil and fertiliser phosphorus

a) Short duration varieties

Data on dry weight of straw, P uptake, amount of P derived from fertiliser, and that from soil, and 'A' value at thirty and sixty days after planting for short duration varieties are presented in Table 2. Analysis of variance table is presented in Appendix I.

a.1. Dry weight of straw

a.1.1. At 30 DAP (Days after planting)

Data on dry weight of straw at 30 DAP indicated significant difference between different short duration varieties at this stage. Rohini recorded the highest dry matter yield (0.61 g/plant) which was on par with Annapoorna and Triveni. The lowest dry matter yield was given by Jyothi (0.34 g/plant) and was on par with IR-36, but were inferior to the above three varieties.

a.1.2. At 60 DAP

Varietal difference in dry matter yield was significant at this stage also. Jyothi which has recorded the lowest dry matter at 30 DAP outyielded all the other varieties at this stage (6.48 g/plant) where as Rohini which has recorded the highest straw yield at 30 DAP yielded very low at this stage (4.30 g/plant). IR-36 behaved in the same pattern as at 30 DAP.

Table 2. Evaluation of rice varieties for their capacity to absorb and utilise soil and fertiliser phosphorus

A. Short duration varieties

Sl. No.	Varieties	At 30 DAP					At 60 DAP				
		Dry matter (g/ plant)	Uptake of P (mg/ plant)	APDFF (mg/ plant)	APDFS (mg/ plant)	'A' value (µg P/g soil)	Dry matter (g/ plant)	Uptake of P (mg/ plant)	APDFF (mg/ plant)	APDFS (mg/ plant)	'A' value (µg P/g soil)
1	Rohini	0.61	1.61	0.37	1.24	23.02	4.30	8.59	0.92	7.67	57.92
2	Jyothi	0.34	0.99	0.28	0.71	17.68	6.48	17.02	1.38	15.64	79.74
3	Annapoorna	0.59	1.89	0.44	1.45	24.30	5.54	15.77	1.76	14.01	54.53
4	Triveni	0.55	1.60	0.53	1.07	14.78	6.33	17.81	1.26	16.55	89.06
5	IR-36	0.38	0.83	0.32	0.51	10.95	4.07	10.54	1.57	8.97	39.37
	CD (5%)	0.1185	0.0949	0.0601	0.0940	4.2441	0.9970	0.8314	0.0659	0.8622	0.1049
	CD (1%)	0.1639	0.1312	0.0832	0.1312	5.8692	1.3787	1.1499	0.0991	1.1923	1.2084
	SEm ±	0.3930	0.0314	0.0200	0.0315	1.9916	0.3308	0.2759	0.2190	0.2861	3.8033

APDFF - Amount of phosphorus derived from fertiliser

APDFS - Amount of phosphorus derived from soil

a.2. Uptake of phosphorus

a.2.1. At 30 DAP

Significant difference in the uptake of P was observed between different short duration varieties. Annapoorna recorded maximum P uptake (1.89 g/plant) which was significantly higher than all other varieties Rohini and Triveni followed Annapoorna in total P uptake. Jyothi and IR-36 recorded very low uptake at this stage and were on par at 1 per cent level but significantly different at 5 per cent level.

Amount of P derived from fertiliser at this stage was also found to differ significantly between varieties. Triveni removed maximum fertiliser P (0.53 mg/plant) followed by Annapoorna. Both these varieties were equally efficient in the utilisation of fertiliser P. IR-36 and Jyothi removed significantly lower amount of fertiliser P (0.32 and 0.28 mg/plant respectively).

Among the different short duration varieties Annapoorna extracted significantly higher quantity of soil P (1.45 mg/plant) followed by Rohini. Jyothi and IR-36 removed comparatively lower quantity of soil P (0.71 and 0.51 mg/plant respectively).

a.2.2. At 60 DAP

At the 60th day Triveni and Jyothi recorded significantly higher uptake of P when compared to other varieties

(17.81 and 17.02 mg/plant respectively) and were statistically on par. Annapoorna followed the above varieties in this character. IR-36 which has recorded very low uptake at 30 DAP, behaved in the similar manner at this stage also. Rohini also has a very low uptake which was on par with IR-36.

P removed from fertiliser as well as that from native P during this period also showed significant difference among the varieties. Annapoorna utilised the largest quantity of P from fertiliser (1.76 mg/plant) which was significantly superior to all the other varieties. The lowest quantity of fertiliser P was taken up by Rohini (0.92 mg/plant). Triveni extracted more soil P at this stage (16.55 mg/plant) followed by Jyothi (15.64 mg/plant) and were on par at 1 per cent level but significantly different at 5 per cent level. Both Rohini and IR-36 were least efficient in the extraction of native P.

a.3. <u>'A' value</u>

a.3.1. <u>At 30 DAP</u>

Significant difference among short duration varieties were observed in 'A' value. Annapoorna recorded the highest (24.30 μg P/g soil) followed by Rohini (23.02 μg P/g soil) and were statistically on par. Triveni and IR-36 showed comparatively lower 'A' value. This result was more or less in confirmation with those of soil P extraction.

a.3.2. <u>At 60 DAP</u>

At 60th day Triveni recorded the highest 'A' value (89.06 µg P/g soil) followed by Jyothi (79.74 µg P/g soil). They were on par at 1 per cent level but significantly different at 5 per cent level. Both Rohini and Annapoorna showed lower values. The lowest 'A' value was recorded by IR-36 (39.37 µg P/g soil).

b. <u>Medium duration varieties</u>

Table 3 presents data on dry weight of straw, P uptake, amount of P derived from fertiliser, amount of P derived from soil and 'A' value at thirty and sixty days after planting for medium duration varieties. Analysis of variance table is presented in Appendix II.

b.4. <u>Dry weight of straw</u>

b.4.1. <u>At 30 DAP</u>

Dry weight of straw at 30 DAP varied significantly between different medium duration varieties. IR-8 recorded the highest dry matter production at this stage (0.83 g/plant) which was significantly superior to all the other varieties. Dry matter yield of Jaya was found to be next to IR-8 (0.58 g/plant) which is followed by Mo-6, Mo-4 and Sabari. The lowest dry weight of straw was recorded by Mashuri (0.15 g/plant).

Table 3. Evaluation of rice varieties for their capacity to absorb and utilise soil and fertiliser phosphorus

B. Medium duration varieties

Sl. No.	Varieties	Means of observations									
		At 30 DAP					At 60 DAP				
		Dry matter (g/ plant)	Uptake of P (g/ plant)	APDFF (mg/ plant)	APDFS (mg/ plant)	'A' value (µg P/g soil)	Dry matter (g/ plant)	Uptake of P (mg/ plant)	APDFF (mg/ plant)	APDFS (mg/ plant)	'A' value (µg P/g soil)
1	Jaya	0.58	1.62	0.57	1.05	16.40	6.33	14.67	1.51	13.16	82.59
2	IR-8	0.83	2.16	0.70	1.45	18.67	8.70	16.08	1.85	14.23	67.91
3	Sabari	0.35	0.86	0.24	0.62	22.69	3.30	6.34	1.24	5.10	36.24
4	Bharathi	0.23	0.63	0.16	0.47	25.98	2.45	5.70	1.49	4.21	24.89
5	Mashuri	0.15	0.51	0.22	0.29	11.61	1.20	2.75	0.65	2.10	28.67
6	IR-20	0.26	1.07	0.45	0.62	12.32	3.57	9.62	1.28	8.34	57.86
7	Mo-4	0.38	1.12	0.37	0.75	17.90	6.30	10.38	1.24	9.64	69.01
8	Mo-6	0.48	1.03	0.33	0.70	19.05	8.17	11.09	1.40	9.69	61.07
9	Mo-7	0.31	0.92	0.26	0.66	22.33	3.57	7.67	1.41	6.26	39.31
10	H-4	0.23	0.58	0.20	0.38	17.03	3.63	6.91	0.66	6.25	83.37
11	IR-42	0.16	0.57	0.15	0.42	24.21	3.27	7.26	1.04	6.22	52.72
	CD (5%)	0.0891	0.1333	0.0813	0.0775	4.7248	0.7714	0.6282	0.0834	0.6171	7.4141
	CD (1%)	0.1211	0.1812	0.1105	0.1054	6.4220	1.0485	0.8539	0.1133	0.8388	10.0773
	SEm ±	0.0304	0.0454	0.0277	0.0264	1.6109	0.2030	0.2142	0.0284	0.2104	2.5278

APDFF - Amount of phosphorus derived from fertilizer

APDFS - Amount of phosphorus derived from soil

b.4.2. <u>At 60 DAP</u>

On the 60th day of planting also IR-8 recorded the highest dry weight (8.7 g/plant) followed by Mo-6 (8.17 g/plant) which were on par with each other. All the other varieties were significantly inferior to the above two varieties. Jaya and Mo-4 closely followed these varieties and were on par. Here again Mashuri was the lowest in dry matter production (1.2 g/plant).

b.5. <u>Uptake of phosphorus</u>

b.5.1. <u>At 30 DAP</u>

P uptake at 30 days after planting followed the same pattern as dry matter production at 30 DAP (Table 3). IR-8 recorded the highest P uptake (2.16 mg P/plant) followed by Jaya (1.62 mg/plant), but was inferior to IR-8. Mo-4, IR-20 and Mo-6 followed the above varieties, but all these were inferior to Jaya in total P uptake. P requirements of Mashuri, M-4 and IR-42 were very low at this stage of growth among medium duration varieties, and were statistically on par with each other in P uptake.

Uptake of fertiliser P was found to be maximum for IR-8 (0.70 mg/plant) and was significantly superior to all the other varieties, followed by Jaya (0.57 mg/plant). So IR-8 and Jaya were found to be efficient in utilising soluble fertiliser P. All the other varieties were inferior to the above two varieties in utilising fertiliser P. IR-20, Mo-4 and Mo-6 followed IR-8 and Jaya in this respect. IR-42, Bharathi and Mashuri utilised comparatively smaller amount of P from fertiliser.

Data on soil P uptake also showed that IR-8 took up maximum amount of P from soil (1.45 mg/plant), which was significantly higher when compared to all the other varieties. Jaya followed IR-8 in soil P uptake (1.05 mg/plant). Mashuri utilised soil P almost as efficiently as fertiliser P. All the other varieties utilised soil P more efficiently than fertiliser P at this stage.

b.5.2. <u>At 60 DAP</u>

Data on P uptake at 60 DAP showed that the highest uptake was recorded by IR-8 (16.08 mg/plant) followed by Jaya (14.66 mg/plant), but differed significantly as the dry matter yield of these two varieties at this stage. Mo-6, Mo-4 and IR-20 followed these two varieties in P uptake. Uptake of Mashuri was the lowest (2.75 mg/plant) among medium duration varieties. H-4 and IR-42 also recorded very low uptake suggesting their low requirement of P at this stage.

IR-8 recorded significantly higher P from fertiliser (1.85 mg/plant), followed by Jaya (1.51 mg/plant) but significantly superior to Jaya and all the other varieties. So these two varieties can be considered as efficient users of soluble fertiliser P as if at 30 DAP. Mashuri, H-4 and IR-42 utilised comparatively smaller quantity of fertiliser P, confirming the low requirement for these three varieties.

Quantity of P taken up from soil by different medium duration varieties (Table 3) also showed similar trend as at 30 DAP. IR-8 took up significantly higher quantity of P from soil (14.23 mg/plant) followed by Jaya (13.16 mg/plant). Mashuri recorded the lowest P uptake from soil (2.1 mg/plant) among different medium duration varieties. Here also most of the varieties utilised soil P more efficiently than fertilizer P.

b.6. <u>'A' value</u>

b.6.1. <u>At 30 DAP</u>

Data on 'A' value at 30 DAP showed that varieties differ significantly. The highest 'A' value was recorded by Bharathi (25.98 µg P/g soil) followed by IR-42, Mo-7 and Sabari and all these were found to be on par. The lowest 'A' value was recorded by Mashuri (11.61 µg P/g soil).

b.6.2. <u>At 60 DAP</u>

The greatest 'A' value was observed in the case of H-4 at 60 DAP (83.37 µg P/g soil) followed by Jaya (82.59 µg P/g soil) but were on par. Mo-4 and IR-8 followed the above two varieties and were statistically on par. The lowest 'A' value was recorded by Bharathi (24.89 µg P/g soil) which has recorded the highest at 30 DAP.

C. <u>Yield and growth characteristics under identical fertility conditions</u>

a. <u>Short duration varieties</u>

Data on height of plants, number of productive tillers, dry weight of grain and straw, thousand grain weight, fertility percentage and P uptake of different short duration varieties grown in Karappadam soil with recommended doses of fertilisers were presented in Table 4. Appendix III presents abstract of analysis of variance table of the experiment.

a.1. <u>Height of plants</u>

Plant height differed significantly among different short duration varieties. Rohini recorded the highest plant height (98.6 cm) which is significantly superior to all the other varieties followed by Triveni (91.3 cm). IR-36 appeared to be the shortest among the short duration varieties (79.2 cm).

a.2. <u>Number of productive tillers</u>

Significant variation was observed between varieties in their number of productive tillers. Jyothi, Annapoorna and IR-36 recorded comparatively higher number of productive tillers. The lowest was recorded by Triveni.

a.3. <u>Dry weight of grain</u>

Significant difference in grain yield was recorded by different short duration varieties. Maximum dry weight of grain was recorded by IR-36 (103 g/pot) and was significantly superior to all the other varieties. Triveni and Rohini followed IR-36 in this character and were statistically on par. Annapoorna recorded the lowest grain yield (73 g/pot).

Table 4. Yield and growth characteristics under identical fertility conditions

A. Short duration varieties

Sl. No.	Varieties	Means of observations						
		Height of the plant (cm)	Number of productive tillers	Dry weight			Fertility percentage	P uptake (mg/pot)
				Grain (g/pot)	Straw (g/pot)	1000 grain (g)		
1	Rohini	95.6	10.5	92.00	83.00	28.69	86.80	723.45
2	Jyothi	83.5	12.0	79.25	92.00	29.98	88.03	722.70
3	Annapoorna	84.5	11.8	73.00	67.25	23.54	84.63	532.58
4	Triveni	91.3	10.0	92.75	66.75	22.38	86.40	622.93
5	IR-36	79.2	11.8	103.00	66.50	22.87	92.60	735.65
	CD at 5% level	2.603	0.9919	6.3514	4.5622	0.4623	3.1102	92.3906
	CD at 1% level	3.1258	1.3718	8.7835	6.3092	0.6394	4.3012	127.7687
	SEm ±	0.750	0.3291	1.5138	2.1075	0.1534	1.0320	30.6570

a.4. Dry weight of straw

Jyothi recorded the highest dry weight of straw (92 g/pot) followed by Rohini (83 g/pot). IR-36 and Triveni which produced higher grain yield showed very low straw yield (66.5 and 66.8 g/pot respectively) and were on par with each other.

a.5. Thousand grain weight

Data indicated that difference in thousand grain weight was highly significant. Jyothi and Rohini recorded significantly higher thousand grain weight over other varieties. (29.98 and 28.69 g respectively).

a.6. Fertility percentage

Fertility percentage data showed that it was significantly higher for IR-36 (92.6%). All the other varieties were inferior to IR-36 in this character. The lowest fertility percentage was recorded by Annapoorna (34.8%).

a.7. Phosphorus uptake

IR-36 recorded the highest P uptake (735.65 mg/pot) followed by Rohini and Jyothi, and all the three varieties were statistically on par in P uptake. Annapoorna took up the lowest amount of P (532.88 mg/pot).

b. Medium duration varieties

Data on height of plants, number of productive tillers, dry weight of grain, straw and thousand grain, fertility percentage and P uptake of medium duration varieties grown in Karappadam soil with recommended doses of fertiliser are presented in Table 5. Appendix IV presents abstract of analysis of variance table of this experiment.

b.8. Height of plants

Significant difference in plant height was observed among different medium duration varieties. The highest plant height was recorded by H-4 (150.2 cm), which was significantly superior to all the other varieties. Mashuri (117.1 cm) followed H-4 in this character. Mo-7 and IR-42 followed H-4 and Mashuri. Mo-4 appeared to be the shortest among different medium duration varieties (90.0 cm).

b.9. Number of productive tillers

Number of productive tillers differed significantly. H-4, Mo-4, IR-42 and Sabari recorded comparatively higher number of productive tillers. The lowest number of productive tillers was recorded by Mashuri.

b.10. Dry weight of grain

Grain yield differed significantly among different medium duration varieties. IR-8 recorded the highest yield (132.33 g/pot) which was significantly superior to all the other varieties at 5 per cent level. IR-42, Bharathi and Jaya yielded next to IR-8. All the other varieties were inferior to the above four varieties in grain yield and

Table 5. Yield and growth characteristics under identical fertility conditions

B. Medium duration varieties

Sl. No.	Varieties	Means of observations						
		Height of the plant (cm)	Number of productive tillers	Dry weight			Fertility percentage	P uptake (mg/pot)
				Grain (g/pot)	Straw (g/pot)	1000 grain (g)		
1	Jaya	91.3	11.0	114.67	82.00	27.43	83.17	986.57
2	IR-8	96.0	11.7	132.33	88.67	28.75	85.27	866.37
3	Sabari	96.2	13.3	98.67	81.00	31.06	86.03	725.00
4	Bharathi	99.9	12.0	121.00	61.67	23.06	87.93	927.60
5	Mashuri	117.1	10.0	104.67	97.00	17.06	96.27	760.57
6	IR-20	94.2	12.3	99.00	85.00	19.79	84.83	434.77
7	Mo-4	90.0	14.0	105.67	75.67	27.59	85.17	1132.23
8	Mo-6	98.7	12.7	97.67	80.00	25.06	87.10	925.03
9	Mo-7	101.5	11.3	104.67	69.00	27.66	89.80	662.33
10	H-4	150.2	14.3	95.33	139.00	25.36	86.07	1299.03
11	IR-42	101.4	14.0	122.67	99.00	19.28	88.03	965.27
	CD (5%)	6.2797	1.0212	7.8104	7.4692	1.0080	4.0463	71.0427
	CD (1%)	8.5354	1.3880	10.6160	10.1522	1.3701	5.4998	96.5619
	SEm ±	2.1410	0.3482	2.6629	2.5465	0.3437	1.3796	24.2212

found to be on par at 1 per cent level of significance. The grain yield of H-4 was found to be the lowest (95.33 g/pot).

b.11. Dry weight of straw

Varieties differed significantly among themselves in the dry weight of straw production. H-4 recorded the highest straw yield (139 g/pot) which was significantly superior to all other varieties. IR-42, Mashuri and IR-8 followed H-4 in straw yield and were found to be statistically on par with each other. Bharathi recorded the lowest straw yield (61.67 g/pot).

b.12. Thousand grain weight

Thousand grain weight of different varieties varied significantly. The highest weight was recorded by Sabari (31.06 g) which was significantly superior to all other varieties. IR-8, Mo-7, Mo-4 and Jaya followed Sabari in this factor and did not differ significantly at 1% level. The lowest value was recorded by Mashuri (17.06 g).

b.13. Fertility percentage

Fertility percentage was significantly higher for Mashuri (96.3%) when compared to other varieties. Mo-7, IR-42, Bharathi and Mo-6 followed Mashuri and were found on par with each other in this character. The lowest value was recorded by Jaya (83.17%).

b.14. Phosphorus uptake

Significant differences was observed between various medium duration varieties in P uptake. H-4 recorded significantly higher uptake over other varieties (1299.03 mg/pot). Mo-4 followed H-4 in this character but was significantly lower than H-4. Jaya, IR-42 and Mo-6 followed Mo-4 but recorded significantly lower uptake than Mo-4 and were found to be on par among themselves.

D. Response of different varieties of rice at increasing levels of phosphorus supply (solution culture)

a. Short duration varieties

a.1. Dry weight of straw

a.1.1. At 30 DAP

Data on the dry weight of straw of short duration varieties at different levels of P supply are presented in Table 6. Appendix V(a) presents abstract of analysis of variance table.

Different short duration varieties differed significantly only at 5% level of significance in dry weight of straw at 30 DAP. Averaged over varieties different levels of P supply differed significantly at 1 per cent level. But interaction effect of variety-level of P was found to be insignificant.

Among the varieties Jyothi recorded the highest straw yield (471.2 mg/plant) followed by Triveni (448.7 mg/plant).

Table 6. Dry weight of straw at 30 DAP for short duration varieties (mg/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)						
		0	1	2	4	5	10	Mean
1	Rohini	150.0	474.0	516.0	555.0	478.0	422.0	432.56
2	Jyothi	126.0	579.0	489.0	689.5	569.5	574.0	471.17
3	Annapoorna	99.0	411.0	407.0	564.0	428.0	373.0	380.33
4	Triveni	123.0	723.0	541.0	391.5	402.0	511.5	448.67
5	IR-36	96.0	421.0	359.5	558.5	320.5	392.5	341.33
	Mean	118.8	521.6	462.6	551.7	439.6	394.6	

	F	CD (5%)	CD (1%)
Between varieties	Sig.	92.438	124.49
Between levels	Sig.	101.261	130.37
Interaction	NS	-	-

Rohini and Annapoorna followed the above two varieties in this character and all these four varieties were found to be on par among themselves. IR-36 recorded the lowest straw yield (341.33 mg/plant) which was inferior to all the other varieties.

Among the different levels of P, 4 ppm recorded the highest dry weight of straw (551.7 mg/plant) followed by 1 ppm (521.6 mg/plant) but were statistically on par. The lowest straw yield was recorded at 0 ppm level (118.8 mg/plant). In general straw weight showed sharp decrease after 4 ppm concentration of P in the root medium.

4.1.2. <u>At harvest</u>

Table 7 presents data on the dry weight of straw of short duration varieties at harvest. Abstract of analysis of variance table is given in Appendix V(a).

The different short duration varieties did not differ significantly in straw yield at different levels of P supply. But straw yield at different level as well as variety-level of P interaction were found to differ significantly.

Straw yield of varieties were not significant at different levels of P supply. Annapoorna recorded the highest mean straw yield of (4.44 g/plant). The lowest was recorded by Jyothi.

Data on straw yield at different levels of P supply

Table 7. Dry weight of straw at harvest for short duration varieties (g/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)						Mean
		0	1	2	4	5	10	
1	Rohini	2.17	3.41	6.17	6.57	4.54	3.49	4.31
2	Jyothi	4.65	5.33	3.00	3.48	2.91	4.13	3.92
3	Annapoorna	0.85	2.87	4.50	13.62	1.91	2.86	4.44
4	Triveni	0.33	3.10	8.20	3.74	6.00	3.78	4.19
5	IR-36	0.23	3.86	6.04	4.91	7.43	4.35	4.25
	Mean	1.64	3.72	5.58	6.37	4.29	3.72	-

	F	CD (5%)	CD (1%)
Between varieties	NS	-	-
Between levels	Sig.	1.099	1.479
Interaction	Sig.	2.456	3.308

showed that short duration varieties increased their straw weight upto 4 ppm level of P and decreased thereafter. The highest mean straw yield was recorded at 4 ppm P level (6.37 g/plant) followed by 2 ppm P (5.58 g/plant), but were found to be on par. The lowest straw yield was at 0 ppm level (1.64 g/plant).

Among the variety-level interaction Annapoorna at 4 ppm P recorded the highest straw yield (13.62 g/plant) which is significantly superior to all other treatment combinations. Triveni at 2 ppm level followed the above (8.2 g/plant). The lowest straw yield was given by IR-36 at 0 ppm P (0.23 g/plant).

a.2. Dry weight of roots

a.2.1. At 30 DAP

Data on dry weight of roots of different short duration varieties at different levels of P supply at 30 DAP are given in Table 8. Appendix V(a) presents abstract of analysis of variance table.

Different varieties as well as levels of P supply showed high significant difference in dry weight of roots. But their interaction effect did not differ significantly.

Among the varieties Jyothi recorded the highest dry weight of roots averaged over different levels of P supply (90 mg/plant), followed by Triveni (83.42 mg/plant) which

Table 8. Dry weight of roots at 30 DAP for short duration varieties (mg/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)						Mean
		0	1	2	4	5	10	
1	Rohini	58.5	75.5	76.0	88.0	68.0	54.5	70.83
2	Jyothi	65.0	127.5	73.5	119.5	102.5	52.0	90.00
3	Annapoorna	38.0	73.5	62.5	98.5	66.5	56.0	65.831
4	Triveni	56.5	125.5	91.0	93.0	63.0	71.5	83.42
5	IR-36	39.5	78.0	64.0	103.0	52.5	39.0	62.67
	Mean	51.5	96.0	73.4	100.4	70.5	54.6	

	F	CD (5%)	CD (1%)
Between varieties	Sig.	14.559	19.607
Between levels	Sig.	15.949	21.478
Interaction	NS	-	-

were on par and superior to all other varieties. IR-36 produced the smallest root system at this stage (62.67 mg/plant).

The greatest root production was found to be at 4 ppm level averaged over different varieties (100.4 mg/plant) followed by 1 ppm and were on par. The lowest weight was recorded at 0 ppm level.

Though interaction effect is insignificant the highest dry weight of roots at 30 DAP was recorded by Jyothi at 1 ppm (127.5 g/plant).

a.2.2. <u>At harvest</u>

Data about dry weight of roots at harvest is presented in Table 9. Abstract of analysis of variance table is presented in Appendix V(a).

Different varieties as well as interaction did not differ significantly. Dry weight of root at different levels only differed significantly.

The highest root production was observed at 1 ppm (1.08 g/plant) followed by 4 ppm (0.9 g/plant) and were on par. The lowest was at 0 ppm level (0.16 g/plant).

a.3. <u>Dry weight of grain</u>

Table 10 presents data on dry weight of grain of different short duration varieties at different levels of P supply. Abstract of analysis table is presented in Appendix V(b). Rice plants did not flower at 0 ppm level and hence that treatment was omitted in the statistical analysis.

Table 9. Dry weight of roots at harvest for short duration varieties (g/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)						Mean
		0	1	2	4	5	10	
1	Rohini	0.110	0.630	0.640	0.940	0.504	0.875	0.613
2	Jyothi	0.245	1.420	1.150	0.910	0.580	0.785	0.853
3	Annapoorna	0.171	0.701	0.590	0.641	0.535	0.481	0.520
4	Triveni	0.151	1.640	0.620	0.891	0.310	0.726	0.621
5	IR-36	0.140	0.991	0.610	1.145	0.490	0.610	0.663
	Mean	0.160	1.081	0.72	0.90	0.48	0.690	

	F	CD (5%)	CD (1%)
Between varieties	NS	-	-
Between levels	Sig.	0.260	0.351
Interaction	NS	-	-

Table 10. Dry weight of grain for short duration varieties (g/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)					Mean
		1	2	4	5	10	
1	Rohini	3.68	3.09	3.12	2.53	2.32	2.95
2	Jyothi	3.09	4.99	3.87	0.99	2.180	3.02
3	Annapoorna	4.35	2.11	2.58	2.28	2.63	2.85
4	Triveni	4.08	3.54	3.84	1.04	2.83	3.07
5	IR-36	2.67	3.18	3.24	1.66	2.54	2.31
	Mean	3.57	3.18	3.24	1.66	2.54	

	F	CD(5%)	CD (1%)
Between varieties	NS	-	-
Between levels	Sig.	0.922	1.247
Interaction	NS	-	-

Different short duration varieties did not differ significantly in grain production. However, Triveni recorded the highest yield (3.07 g/plant) followed by Jyothi. IR-36 recorded the lowest grain yield.

Various levels of P influenced the grain yield significantly. The greatest yield was obtained at 1 ppm (3.57 g/plant) followed by 4 ppm (3.24 g/plant) and were on par, but superior to other levels.

Interaction effect did not differ significantly. However Jyothi at 2 ppm recorded the highest grain yield (4.99 g/plant).

a.4. Phosphorus uptake

a.4.1. At 30 DAP

Table 11 presents data on P uptake of different short duration varieties at different levels of P supply. Abstract of analysis of variance table is presented in Appendix V(b). P uptake at 0 ppm level of P was nil or trace and hence that treatment was omitted in the statistical analysis.

Different varieties as well as levels of P supply influenced P uptake significantly, but their interaction did not show any difference.

Uptake of P by Jyothi (3.3 mg/plant) was the highest, followed by Triveni (3.13 mg/plant) and were statistically on par. The lowest P uptake was recorded by IR-36 (2.16 mg/plant) averaged over different levels of P supply.

Table 11. Phosphorus uptake at 30 DAP by short duration varieties (mg/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)					Mean
		1	2	4	5	10	
1	Rohini	1.51	2.92	3.33	3.83	3.02	2.92
2	Jyothi	1.43	2.49	4.90	4.24	3.46	3.30
3	Annapoorna	0.81	1.80	3.92	2.75	2.24	2.36
4	Triveni	1.91	2.77	4.03	3.29	3.65	3.13
5	IR-36	0.81	1.99	4.00	2.24	1.74	2.16
	Mean	1.30	2.40	4.04	3.27	2.82	-

	F	CD (5%)	CD (1%)
Between varieties	Sig.	0.737	0.997
Between levels	Sig.	0.737	0.997
Interaction	NS	-	-

Uptake at different levels of P showed that the greatest amount of P was taken up at 4 ppm (4.04 mg/plant) followed by 5 ppm level (3.27 mg/plant), but the former was superior to all other levels. The lowest uptake was at 1 ppm. In general, P uptake increased upto a level of 4 ppm and decreased gradually thereafter.

a.2.3. At harvest

Data on P uptake at harvest by different short duration varieties at different levels of P supply are given in Table 12. Appendix V(b) presents table on abstract of analysis of variance.

The data indicated that different varieties as well as variety-level interactions did not differ significantly in P uptake where as the level of P supply influenced P uptake significantly.

The highest uptake was recorded at 4 ppm (54.46 mg/plant) averaged over different varieties. The 10 ppm level followed 4 ppm in this character (53.58 mg/plant) and was on par with the former. All other treatments were inferior to the above. The lowest uptake was at 1 ppm level of P (16.63 mg/plant).

Eventhough the interaction effect was not significant, the highest uptake was recorded by Annapoorna at 4 ppm (81.22 mg/plant).

Table 12. Phosphorus uptake at harvest by short duration varieties (mg/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)					Mean
		1	2	4	5	10	
1	Rohini	19.75	33.80	45.50	47.38	48.21	38.97
2	Jyothi	10.65	35.37	29.63	25.99	68.37	34.69
3	Annapoorna	15.68	26.05	81.22	19.03	44.19	37.23
4	Triveni	19.92	45.78	50.60	35.70	60.40	42.45
5	IR-36	16.98	36.55	55.37	42.64	46.75	39.60
	Mean	16.63	35.51	54.46	32.77	53.58	

	F	CD (5%)	CD (1%)
Between varieties	NS	-	-
Between levels	Sig.	12.145	16.43
Interaction	NS	-	-

b. Medium duration varieties

b.5. Dry weight of straw

b.5.1. At 30 DAP

Data on dry weight of straw of different medium duration varieties at different levels of P supply at 30 DAP is presented in Table 13. Appendix VI(a) presents table of abstract of analysis of variance.

Different medium duration varieties as well as levels of P supply differed significantly in straw yield, but their interaction effect is not significant.

Among the varieties, Mo-4 recorded the highest (437.3 mg/plant) averaged over different levels followed by Sabari and Jaya, but these three varieties were on par. The lowest straw yield was recorded by IR-20 (253.8 mg/plant).

Data on different levels showed that the straw yield increased sharply from 0 to 1 ppm and decreased gradually at still higher concentrations. The highest straw yield was recorded at 1 ppm (597.7 mg/plant) which was significantly superior to all other levels. The lowest was at 0 ppm level.

b.5.2. At harvest

Table 14 presents data on dry weight of straw of different medium duration varieties at different levels of P supply. Abstract of analysis of variance table is given in Appendix VI(a).

Table 13. Dry weight of straw at 30 DAP for medium duration varieties (mg/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)						
		0	1	2	4	5	10	Mean
1	Jaya	160.5	408.0	421.5	690.5	404.5	362.5	407.9
2	IR-8	194.0	662.0	383.5	227.5	451.0	349.0	377.8
3	Sabari	128.5	785.5	637.0	367.0	390.0	381.5	431.6
4	Bharathi	167.0	590.5	384.0	339.0	324.0	265.0	344.9
5	Mashuri	725.0	631.0	436.0	353.5	264.5	195.0	325.4
6	IR-20	149.0	460.5	220.5	224.5	201.5	267.0	253.8
7	Mo-4	211.0	717.0	476.0	434.5	325.5	457.5	437.3
8	Mo-6	169.0	693.0	319.0	257.0	454.0	326.0	369.7
9	Mo-7	146.5	458.5	468.0	337.5	350.5	233.5	337.9
10	H-4	218.0	690.5	476.5	376.5	377.5	332.0	398.3
11	IR-42	202.5	559.5	430.0	213.5	328.0	256.5	531.7
	Mean	165.3	597.7	413.5	347.4	351.9	311.6	

	F	CD (5%)	CD (1%)
Between varieties	Sig.	79.103	104.942
Between levels	Sig.	58.422	77.505
Interaction	NS	-	-

Table 14. Dry weight of straw at harvest for medium duration varieties (g/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)						Mean
		0	1	2	4	5	10	
1	Jaya	0.31	5.99	7.37	11.05	6.90	4.81	6.07
2	IR-8	1.28	5.95	4.39	3.1	1.95	6.34	3.92
3	Sabari	0.26	8.01	9.09	9.58	5.72	6.30	6.49
4	Bharathi	0.39	10.06	8.95	6.81	5.61	5.49	6.22
5	Mashuri	0.22	11.13	8.49	6.29	8.61	3.75	6.41
6	IR-20	0.33	4.29	6.65	4.38	5.12	3.15	3.98
7	Mo-4	0.94	10.55	8.85	8.47	8.14	10.83	7.96
8	Mo-6	0.85	10.14	2.79	4.18	2.88	6.75	4.60
9	Mo-7	0.32	4.30	8.94	7.61	7.57	3.05	5.30
10	H-4	1.31	12.98	10.14	3.31	8.86	3.58	6.61
11	IR-42	0.20	3.63	8.11	3.10	3.49	6.39	4.15
	Mean	0.58	7.91	7.66	6.12	5.89	5.49	-

	F	CD (5%)	CD (1%)
Between varieties	Sig.	0.862	1.145
Between levels	Sig.	0.637	0.846
Interaction	Sig.	2.115	2.810

The different medium duration varieties, levels of P supply and variety-level interactions were found significant.

Among the varieties Mo-4 recorded the highest dry weight of straw (7.96 g/plant). All other varieties were inferior to Mo-4 at this stage. H-4, Sabari, Mashuri, Bharathi and Jaya followed Mo-4 in this character and they were found to be on par among themselves. The lowest straw yield was given by IR-8 (3.92 g/plant).

The highest straw yield was obtained at 1 ppm (7.91 g/plant) followed by 2 ppm level (7.66 g/plant) but were on par with each other and was significantly superior to all other treatments. The lowest straw yield was recorded at 0 ppm level.

Variety-level interaction data showed that H-4 at 1 ppm yielded the highest straw of 12.98 g/plant, but was on par with Mashuri at 1 ppm (11.13 g/plant).

In general, the dry weight of straw increased sharply from 0 to 1 ppm level. Different varieties differed in the degree of increase in straw weight with levels of P. IR-8, Bharathi, Mashuri, Mo-4, Mo-6 and H-4 recorded an increase upto 1 ppm and a gradual decrease with increase in concentration, where as Jaya, Sabari, IR-20, Mo-7 and IR-42 increased their straw weight upto 2 ppm.

b.6. Dry weight of roots

b.6.1. At 30 DAP

Data on dry weight of roots at 30 DAP are presented in Table 15. Appendix VI(a) presents table on abstract of analysis of variance.

Different medium duration varieties, levels of P supply and their interaction differed significantly.

Among the varieties Mo-4 produced the highest root dry weight (97.3 mg/plant) and is significantly superior to all other varieties. Sabari, IR-8 and Jaya followed Mo-4 in this character. The lowest root weight was recorded by Mashuri (64.0 mg/plant).

The greatest root production was found to be at 1 ppm (132.1 mg/plant) which is significantly superior to all other levels. The lowest was at 0 ppm. In general root production increased sharply upto a level of 1 ppm and a gradual decrease was noticed thereafter.

The highest root weight at 30 DAP was produced by Mo-4 at 1 ppm (168 mg/plant) followed by IR-8 at the same level (156.5 mg/plant) and were statistically on par. The lowest weight was recorded by Mashuri at 0 ppm (27 mg/plant).

b.6.2. At harvest

Data on dry weight of roots at harvest of different medium duration varieties at different levels of P supply

Table 15. Dry weight of roots at 30 DAP for medium duration varieties (mg/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)						Mean
		0	1	2	4	5	10	
1	Jaya	59.5	80.5	71.0	12.90	65.5	94.5	83.3
2	IR-8	60.5	156.5	89.5	60.5	70.0	67.0	84.0
3	Sabari	49.0	163.5	100.0	64.0	75.5	57.5	84.9
4	Bharathi	52.0	120.5	76.5	65.5	59.0	36.0	68.3
5	Mashuri	27.0	130.5	70.0	69.5	44.0	43.0	64.0
6	IR-20	51.5	152.0	64.5	34.5	36.5	63.0	67.0
7	Mo-4	75.0	168.0	74.0	115.0	67.0	84.0	97.3
8	Mo-6	70.0	128.0	47.5	57.5	79.5	52.0	72.4
9	Mo-7	49.0	101.5	73.0	76.5	60.0	38.5	66.3
10	H-4	37.5	108.5	85.0	71.0	91.0	78.0	78.5
11	IR-42	52.5	143.5	88.5	48.0	45.0	44.0	70.3
	Mean	53.0	132.1	76.3	71.9	63.0	59.8	-

	F	CD (5%)	CD (1%)
Between varieties	Sig.	12.237	16.234
Between levels	Sig.	9.038	11.989
Interaction	Sig.	29.974	39.764

are presented in Table 16. Abstract of analysis of variance table is given in Appendix VI(a).

Different medium duration varieties, levels of P and their interaction were found to be significant.

Among the varieties Mashuri recorded the highest root weight (1.3 g/plant) followed by Mo-6 and Mo-7, which were on par. The lowest root production was by Mo-7 (0.53 g/plant).

The highest root weight was recorded at 1 ppm (1.87 g/plant) followed by 2 ppm (1.42 g/plant). The lowest root weight was at 0 ppm. The root system increased sharply at 1 ppm level and decreased at still higher concentration.

IR-20 at 1 ppm recorded the highest root dry weight (2.98 g/plant) followed by Mashuri (2.94 g/plant) and were on par. The lowest was recorded by Bharathi at 0 ppm (0.11 g/plant).

b.7. Dry weight of grain

Table 17 presents data on grain yield of medium duration varieties at different levels of P supply. Abstract of analysis of variance table is presented in Appendix VI(b).

Different medium duration varieties, levels of P and their interaction differed significantly.

The highest yield was recorded by Mo-4 (3.89 g/plant) followed by IR-8, M-4 and Sabari and these varieties were found to be on par. Mo-7 yielded the least (1.57 g/plant).

Table 16. Dry weight of roots at harvest for medium duration varieties (g/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)						Mean
		0	1	2	4	5	10	
1	Jaya	0.44	1.93	0.83	0.87	2.44	0.71	1.14
2	IR-8	0.15	1.73	1.49	0.75	0.92	0.66	0.95
3	Sabari	0.16	1.49	1.07	1.40	1.98	0.71	1.13
4	Bharathi	0.11	2.46	0.86	0.50	0.61	0.49	0.84
5	Mashuri	0.17	1.39	2.94	2.05	1.05	0.22	1.30
6	IR-20	0.13	2.98	1.30	0.62	0.75	0.35	1.02
7	Mo-4	0.15	1.75	1.46	1.34	1.58	0.95	1.20
8	Mo-6	2.45	1.90	0.68	2.16	1.05	1.22	1.24
9	Mo-7	0.14	0.38	0.77	0.31	0.69	0.41	0.53
10	H-4	0.13	2.14	2.91	2.16	1.93	0.34	1.58
11	IR-42	0.14	2.4	1.27	0.99	0.91	0.59	1.05
	Mean	0.20	1.87	1.42	1.19	1.25	0.60	-

	F	CD (5%)	CD (1%)
Between varieties	Sig.	0.255	0.338
Between levels	Sig	0.188	0.250
Interaction	Sig.	0.624	0.828

Table 17. Dry weight of grain for medium duration varieties (g/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)					Mean
		1	2	4	5	10	
1	Jaya	4.27	1.31	3.08	2.04	4.35	3.01
2	IR-8	4.92	4.95	2.94	3.64	2.43	3.77
3	Sabari	5.03	4.46	3.93	2.53	1.62	3.51
4	Bharathi	7.81	2.28	0.64	2.38	1.09	2.84
5	Mashuri	7.81	3.37	4.84	0.89	0.14	3.41
6	IR-20	3.96	2.15	1.87	2.07	1.51	2.31
7	Mo-4	5.49	4.49	4.56	2.37	2.56	3.89
8	Mo-6	5.03	1.16	3.79	2.12	1.60	2.74
9	Mo-7	2.58	1.17	0.98	1.51	1.6	1.57
10	H-4	6.41	5.47	2.82	2.08	1.24	3.60
11	IR-42	5.23	2.64	1.76	3.08	2.19	2.98
	Mean	5.32	3.04	2.84	2.25	1.85	-

	F	CD (5%)	CD (1%)
Between varieties	Sig.	0.512	0.678
Between levels	Sig.	0.34	0.457
Interaction	Sig.	1.144	1.517

Among the different levels of P, grain yield at 1 ppm was found to be the greatest and was significantly superior to others. The yield at 2 ppm followed 1 ppm. The lowest yield was recorded at 10 ppm level. In general, with increase in concentration of P after 1 ppm, grain yield gradually decreased.

Bharathi and Mashuri at 1 ppm recorded the highest yield (7.81 g/plant for both) followed by H-4 (6.41 g/plant) and Mo-4 (5.49 g/plant) at the same level of P. The lowest yield was given by Mashuri at 10 ppm (0.14 g/plant) followed by Bharathi (1.09 g/plant). In general, though Mashuri and Bharathi yielded the highest at 1 ppm, with increase in concentration the reduction in yield was drastic for these varieties, while significant difference in yield was not observed in Mo-4 between 1 and 4 ppm. The yield of IR-8 and H-4 were on par at 1 and 2 ppm.

b.8. <u>Phosphorus uptake</u>

b.8.1. <u>At 30 DAP</u>

Data on P uptake by different medium duration varieties at different levels of P supply are given in Table 18. Appendix VI(b) presents abstract of analysis of variance table.

Significant difference in P uptake was found between varieties, levels of P and their interaction at 30 DAP.

Table 18. Phosphorus uptake at 30 DAP by medium duration varieties (mg/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)					Mean
		1	2	4	5	10	
1	Jaya	0.81	1.51	3.65	2.65	4.14	2.55
2	IR-8	1.12	1.72	2.24	3.20	2.00	2.06
3	Sabari	1.67	2.49	3.00	1.99	2.16	2.26
4	Bharathi	1.35	1.51	2.51	1.91	1.59	1.69
5	Mashuri	1.75	1.91	2.38	1.66	1.12	1.76
6	IR-20	0.97	1.55	1.97	2.75	1.68	1.79
7	Mo-4	1.57	2.13	3.11	2.41	3.20	2.48
8	Mo-6	1.04	1.59	2.17	2.93	2.13	1.97
9	Mo-7	1.78	1.88	2.32	3.22	1.08	2.06
10	H-4	1.59	2.15	2.75	2.49	2.07	2.21
11	IR-42	1.38	1.82	1.65	1.99	1.43	1.66
	Mean	1.37	1.84	2.48	2.47	2.05	-

	F	CD (5%)	CD (1%)
Between varieties	Sig.	0.351	0.465
Between levels	Sig.	0.237	0.314
Interaction	Sig.	0.785	1.041

Maximum uptake of P was recorded by Jaya (2.55 mg/plant) followed by Mo-4, Sabari and IR-4 and were on par. These four varieties were superior to all other varieties significantly. The lowest P uptake was recorded by IR-42 (1.66 mg/plant).

Data on different levels showed that P uptake increased upto 4 ppm. The highest P uptake was recorded at 4 ppm P (2.48 mg/plant).

Among interaction of varieties and levels, Jaya at 4 ppm P (3.65 mg/plant) recorded the highest. Mo-7 at 5 ppm recorded second highest (3.22 mg/plant). Mo-4 at 10 ppm and IR-8 at 5 ppm followed the above varieties and were on par. The lowest P uptake was by Jaya at 1 ppm (0.81 mg/plant).

b.8.2. <u>At harvest</u>

Data on the P uptake by different medium duration varieties are presented in Table 19. Abstract of analysis of variance table is given in Appendix VI(b).

The different medium duration varieties, levels of P and their interaction effect varied significantly in P uptake.

Among the different varieties Mo-4 recorded the highest P uptake (73.49 mg P/plant) followed by Jaya (60.38 mg P/plant). Sabari is next to Jaya in P uptake but were on par. IR-42 recorded the lowest uptake of 37.34 mg P/plant.

Table 19. Phosphorus uptake at harvest by medium duration varieties (mg/plant)

Sl. No.	Varieties	Levels of phosphorus (ppm)					Mean
		1	2	4	5	10	
1	Jaya	25.94	31.77	107.44	55.23	81.39	60.35
2	IR-8	24.18	30.38	52.98	42.78	87.28	43.53
3	Sabari	23.25	50.85	69.85	42.04	76.16	52.43
4	Bharathi	22.17	69.50	40.90	39.91	57.10	41.99
5	Mashuri	47.86	37.17	54.16	62.26	7.55	41.80
6	IR-20	19.57	34.73	32.67	37.07	48.41	34.49
7	Mo-4	40.62	51.69	82.34	59.98	132.83	73.49
8	Mo-6	31.12	18.90	61.06	25.54	80.60	43.45
9	Mo-7	17.39	25.04	58.72	64.60	41.12	41.46
10	H-4	52.99	70.40	30.91	43.23	47.50	49.01
11	IR-42	8.36	37.10	24.77	41.30	75.15	37.34
	Mean	28.50	39.88	54.16	46.69	66.83	-

	F	CD (5%)	CD (1%)
Between varieties	Sig.	10.477	13.954
Between levels	Sig.	7.063	9.407
Interaction	Sig.	23.627	31.201

The highest uptake was observed at 10 ppm level (66.83 mg P/plant) which was superior to all other treatments. The lowest uptake was at 1 ppm level.

Variety-level interaction data showed that uptake of P by Mo-4 at 10 ppm level was the greatest (132.83 mg P/plant) followed by Jaya at 4 ppm (107.44 mg P/plant) but was significant only at 5 per cent level. IR-8 at 10 ppm took 87.28 mg P/plant and was found to be on par with Jaya at 4 ppm. The lowest uptake was recorded by Mashuri at 10 ppm (7.55 mg P/plant).

In general uptake of P by medium duration varieties increased upto a certain concentration of P in the root medium. Jaya, Sabari, and Mo-4 increased their uptake upto 4 ppm. Bharathi, IR-20, H-4 and IR-42 increased upto 2 ppm. Uptake of Mo-7 showed an increasing trend till 5 ppm whereas P uptake of Mo-6 and Mashuri increased only upto 1 ppm.

Discussion

DISCUSSION

Pot culture studies using soil and culture solutions were conducted in Karappadam soil (Inceptisol) of Moncompu to evaluate popular rice varieties for their efficiency to utilise native soil P and applied soluble fertiliser P and for their capacity to P deficiency tolerance. Basic information on the effect of P absorbed at different stages of growth on dry matter production, grain and straw yield was collected. Root characteristics of different varieties and their relationship with utilisation of soluble fertiliser P as well as insoluble native P were also investigated.

A. Evaluation of rice varieties to utilise soil and fertiliser phosphorus during early stage of growth

a. Phosphorus uptake

Studies using ^{32}P tagged superphosphate revealed that P uptake was maximum for Annapoorna at 30 DAP where as it was minimum for IR-36. Jyothi and Triveni recorded highest P uptake at 60 DAP and Rohini the lowest. P uptake of IR-36 was very low at this stage also (Table 2).

Among medium duration varieties, P uptake values of Mashuri, IR-42, H-4 and Bharathi were found to be low at 30 DAP and the same trend was shown at 60 DAP also. IR-8 recorded the highest P uptake followed by Jaya at both the stages (Table 3).

P uptake of all the varieties at 60 DAP was higher than at 30 DAP.

Thus conspicuous difference in the uptake of P was observed between varieties of almost the same duration. Similar observations were made by Datta (1967) and Koyama and Chamock (1971). Ramanathan and Krishnamoorthy (1973) observed significantly higher uptake of P by the rice variety IR-8 when compared to IR-20 and IR-22. In the present study also uptake of IR-8 was significantly higher than IR-20 (Table 3). P uptake of IR-42 was low at both the stages. This variety was reported to have low nutrient requirement (Ponnamperuma, 1979).

b. Utilisation of fertiliser phosphorus

Fertiliser P uptake expressed as percentage to total uptake was found to range from 23.0 to 39.3 and 7.2 to 14.9 per cent for short duration varieties at 30 and 60 DAP, respectively. For medium duration varieties, it was found to range from 25.4 to 43.1 and 9.6 to 26.1 at those stages. De Datta et al. (1966) reported that percentage P derived from fertiliser varied from 8 to 27 per cent among different rice varieties.

Uptake of P derived from fertilizer was also found to decrease with increase in age of the crop. Szepes and Kiss (1967) obtained significantly higher P uptake at tillering which decreased markedly by the time of panicle emergence and flowering. It again approached the initial value at ripening. Dev et al. (1971) reported that rice plants are capable of absorbing P from fertiliser more effectively upto maximum tillering than at later stages.

Among short duration varieties, IR-36 and Triveni were found to utilise 39.3 and 33.1 per cent respectively of the total uptake from fertiliser P at 30 DAP. At 60 DAP also IR-36 utilised maximum P from applied P source (14.9%) (Table 20). This variety though having low P requirement was found to utilise major part from soluble applied P fertiliser indicating its fertiliser responsiveness.

Among medium duration varieties, Mashuri and IR-20 were found efficient users of fertiliser P (43.1 and 42.1 per cent, respectively) at 30 DAP. Percentage utilization of fertiliser P in Bharathi and Mashuri was found to be higher (26.1 and 23.6 per cent) than in other varieties at 60 DAP (Table 21). IR-8, Jaya, Mo-4, Mo-6 and H-4 were found moderate in utilizing fertiliser P at 30 DAP but most of these varieties were found comparatively inefficient in utilizing this source by 60 DAP. Dev et al. (1971) recorded varietal difference in P uptake using ^{32}P tracer technique. They observed that IR-8 and Jaya were less efficient in utilising fertiliser P when compared to culture-95 and IR-622288. Contrary to the above observation Oza et al. (1972) reported significant varietal difference in P uptake

Table 20. Phosphorus derived from fertiliser and soil expressed as percentage to total P uptake in short duration varieties (mean)

Sl. No.	Varieties	At 30 DAP		At 60 DAP	
		PPDF	PPDS	PPDF	PPDS
1	Rohini	23.0	77.0	10.7	89.3
2	Jyothi	28.3	71.7	8.1	91.9
3	Annapoorna	23.3	76.7	11.2	88.8
4	Triveni	33.1	66.9	7.2	92.8
5	IR-36	39.3	60.7	14.9	85.1

PPDF - Percentage phosphorus derived from fertiliser

PPDS - Percentage phosphorus derived from soil

Table 21. Phosphorus derived from fertiliser and soil expressed as percentage to total P uptake in medium duration varieties (mean)

Sl. No.	Varieties	At 30 DAP		At 60 DAP	
		PPDF	PPDS	PPDF	PPDS
1	Jaya	35.2	64.8	10.3	89.7
2	IR-8	32.6	67.4	11.5	88.5
3	Sabari	27.9	72.1	19.6	80.4
4	Bharathi	25.4	74.6	26.1	73.9
5	Mashuri	43.1	56.9	23.6	76.4
6	IR-20	42.1	57.9	13.3	86.7
7	Mo-4	33.0	67.0	11.4	88.6
8	Mo-6	32.0	68.0	12.6	87.4
9	Mo-7	28.3	71.7	18.4	81.6
10	H-4	34.5	65.5	9.6	90.4
11	IR-42	26.3	73.7	14.3	85.7

PPDF - Percentage phosphorus derived from fertiliser

PPDS - Percentage phosphorus derived from soil but no difference in percentage P derived from the fertilizer in any of the treatments tried.

c. Utilisation of native phosphorus

Rohini and Annapoorna were found to be efficient in extracting soil P among short duration varieties at 30 DAP (77.0 and 76.7 per cent, respectively) whereas the highest extraction of native P was shown by Triveni and Jyothi at 60 DAP (92.8 and 91.8 per cent) (Table 20).

Among medium duration varieties, Bharathi and IR-42 were observed to be most efficient in utilising soil P at 30 DAP. Mashuri and IR-20 were least efficient. At 60 DAP H-4, Jaya, IR-8, Mo-4 and Mo-6 were comparatively efficient users whereas Bharathi and Mashuri were observed to be least efficient at both the stages. IR-42 was found to be moderate in using P from both the sources at the two stages (Table 21). Chaudhary and Uppal (1981) noticed variation in absorption of soil P and accumulation of P between varieties like IR-8, Jaya and J-35, without added P.

'A' values were found to vary with varieties, duration of the crop and also with the age of the crop. 'A' values of short duration varieties were found to range from 10.95 to 23.02 and 39.37 to 89.06 µg per g of soil at 30 and 60 DAP respectively.

In medium duration varieties it was found to range from 11.61 to 25.98 and 28.67 to 83.57 µg P per g of soil at

30 and 60 DAP, respectively. 'A' value increased with increase in age of the crop in both short and medium duration varieties. Higher 'A' value at later stages might be due to higher foraging capacity of the roots. Kalra and Soper (1968) also made similar observation in their studies with soyabean, flax, oat and rape.

It was also found that uptake of native P from soil was much higher than that from soluble fertiliser for all the varieties at both the stages. Motsara and Datta (1971) observed increased soil available P due to reduction on flooding and consequently higher uptake of soil P by rice.

d. Relationship between dry matter yield and phosphorus uptake

Relationships between dry matter yield at 30 and 60 DAP and P uptake from different sources are presented in Table 22.

Irrespective of the duration of the varieties dry matter production at both the stages showed significant relationship with soil as well as fertiliser P uptake, but better relationship was observed with soil P. Dry matter at 60 DAP showed significant relationship with P uptake at 30 DAP also.

B. Utilisation of soil and fertiliser phosphorus in the early stages and its relationship with growth and yield of rice

a. Short duration varieties

Among short duration varieties maximum grain yield per pot was recorded by IR-36 (103 g/pot) (Table 4). Larger number

Table 22. Relationship between dry matter and P uptake from soil and fertiliser at 30 and 60 DAP (coefficients of correlation)

Factors correlated	'r' values
1. Dry matter at 30 DAP vs	
a) P uptake from fertiliser at 30 DAP	0.8213**
b) P uptake from soil at 30 DAP	0.8011**
2. Dry matter at 60 DAP vs	
a) P uptake from fertilizer at 60 DAP	0.5427**
b) P uptake from soil at 60 DAP	0.7965**
c) Total P uptake at 30 DAP	0.6560**

** Significant at 0.01 level

of productive tillers and higher percentage of fertile grains per panicle might have contributed to higher grain production. Tracer studies indicated clearly (Table 2) that IR-36 was the most efficient among the different short duration varieties tried in utilizing fertiliser P followed by Triveni whereas Rohini utilized more of soil P at 30 DAP. Basic studies on P nutrition conducted by different workers with tall indica as well as modern varieties indicated that partial efficiency of P in rice was at its greatest during early stages of growth and the P absorbed during these stages upto two to four weeks after planting only was utilized efficiently for grain production.

Triveni and Rohini followed IR-36 in grain production. Triveni absorbed higher percentage of fertiliser P whereas Rohini absorbed higher percentage of soil P at 30 DAP which might have contributed to higher grain production. Higher P uptake of Jyothi and Triveni at 60 DAP and thereafter was reflected in higher straw weight of those varieties.

b. Medium duration varieties

IR-8 recorded maximum grain weight per pot of 132.33 g (Table 5) and moderately high straw weight among medium duration varieties. Uptake of P at 30 DAP was maximum for this variety which might have contributed to higher grain yield (Table 3). The higher straw production might be due to higher P uptake at later stages.

IR-42 and Bharathi were on par in grain yield and were the next best. Both these varieties were found to have low P requirement. Mashuri, though recorded moderate grain and straw yields was found to have very low P requirement when compared to all the other varieties.

Varietal difference in susceptibility to P deficiency was reported for the first time in 1971 at IRRI. Out of the ten varieties studied, IR-8 was found severely injured by P deficiency while H-4 and IR-5 have grown well in a P deficient soil (Anon., 1971). In the present study also, uptake of IR-8 in the initial stages of growth was higher than all the other varieties. P uptake of this variety from both the sources was moderate indicating the fertiliser responsive nature of the variety or its preference for high fertility conditions of soil (Table 3).

Uptake of H-4 in the early stages which will account for the increased grain yield was lower but total uptake was the highest. Total P uptake might have contributed for more number of tillers and plant height. The increased straw yield recorded by the variety might be due to the large number of tillers and higher plant height.

Comparatively lower uptake of P in the initial stages of growth of Bharathi and IR-42 indicated varietal tolerance to P deficiency due to low P requirement inherent to the variety. Ponnamperuma (1979) reported that IR-42 was found to be tolerant to P deficiency. Both these varieties recorded high grain yield (Table 5) indicating their response to P application.

Mashuri and IR-20 obtained a major part of their P requirement from applied fertiliser source (Table 21). The grain yield of both varieties was lower. It might be due to lower total P uptake during initial stages of growth.

Total P uptake showed significant and positive relationship with total number of tillers, productive tillers, height of plants, dry weight of grain and straw (Table 23).

C. Phosphorus requirements of varieties for maximum yield

a. Short duration varieties

Results of solution culture experiment indicated that there is variation among varieties in dry weight of straw, grain, root and P uptake at various stages of growth.

Jyothi which has recorded maximum dry weight of straw at 1 ppm concentration of P in the root medium (Table 7) was found to require 2 ppm P for the expression of maximum grain yield potential (Table 10). A perusal of Table 4 indicated that this variety recorded maximum straw yield among the different short duration varieties tried. Rohini and Triveni required 4 and 5 ppm P respectively, for giving maximum straw yield (Table 7) whereas these varieties required only 1 ppm P for maximum grain yield. Results presented in

Table 23. Relationship between P uptake and yield attributing characters

Sl. No.	Yield attributing characters	Coefficients of correlation (r)
(a)	Total number of tillers	0.3589**
(b)	Number of productive tillers	0.5547**
(c)	Height at harvest	0.5429**
(d)	Dry weight of straw	0.5404**
(e)	Dry weight of grain	0.3934**
(f)	Length of earhead	-0.1463
(g)	1000 grain weight	0.1789
(h)	Fertility percentage	-0.1294

** Significant at 0.01 level

Table 4 revealed that both these varieties recorded high grain yield but their straw yield was comparatively lower.

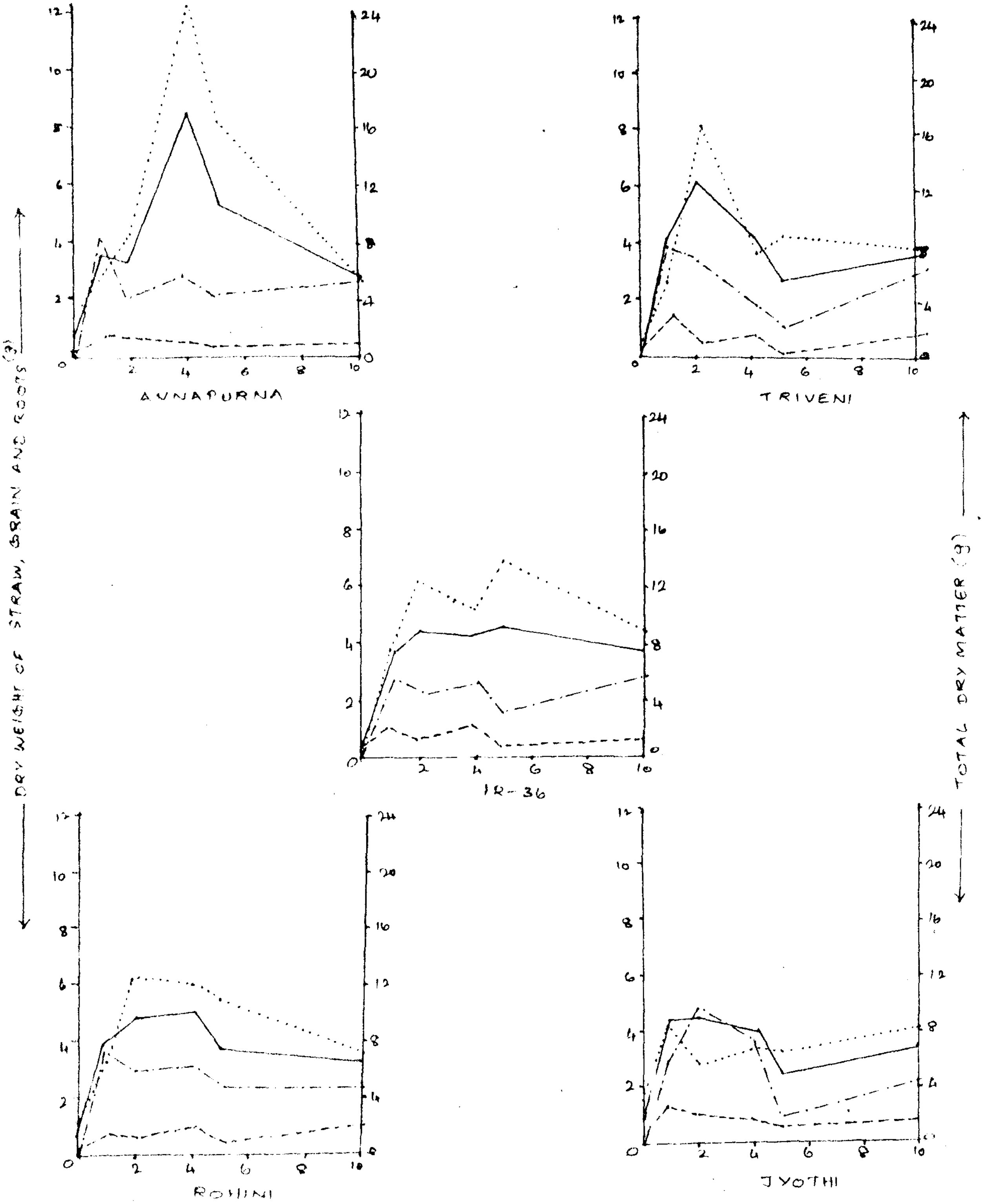
Karappadom soil with high P fixing capacity of 77.8 per cent (Madhusudhanan and Padmaja, 1983) might have fixed most of the applied P reducing the soluble form. Varieties like Jyothi, which required higher concentration of soluble P for maximum grain production have recorded low grain yield at recommended rate of P supply due to fixation of soluble P in Karappadam soil. Rohini and Triveni which have recorded the highest grain yield at 1 ppm level in the solution culture (Table 10, Fig.1) have also recorded high grain yield (Table 4) at the recommended dose of P supply.

The data thus indicated that at the recommended rate of P supply, available soil P was sufficient for the expression of maximum grain yield potential for Rohini and Triveni and not sufficient for Jyothi. At that level of available P supply Jyothi could yield maximum straw but was not sufficient for the other varieties.

IR-36 has recorded maximum grain yield and maximum straw yield at recommended dose of P supply (35 kg P_2O_5/ha) in soil culture (Table 4). The solution culture experiment showed that there was a quantum jump from 1 ppm to 2 ppm in grain weight beyond which the increase was marginal, indicating that this variety does not require more than 2 ppm P for grain yield whereas for maximum straw production 5 ppm

FIG (1):

EFFECTS OF LEVELS OF PHOSPHORUS ON DRY WEIGHT OF GRAIN, STRAW, ROOT AND TOTAL DRYMATTER PRODUCTION IN SHORT DURATION VARIETIES.



CONC. OF P (ppm) in the culture solution

- - - - DRY WEIGHT OF ROOTS
-·-·-· " " " GRAINS
——— TOTAL DRY MATTER
······· DRY WEIGHT OF STRAW

SCALE: X axis : 1 cm = 2 ppm P
Y axis : 1 cm = 2 g
Y' axis : 1 cm = 4 g

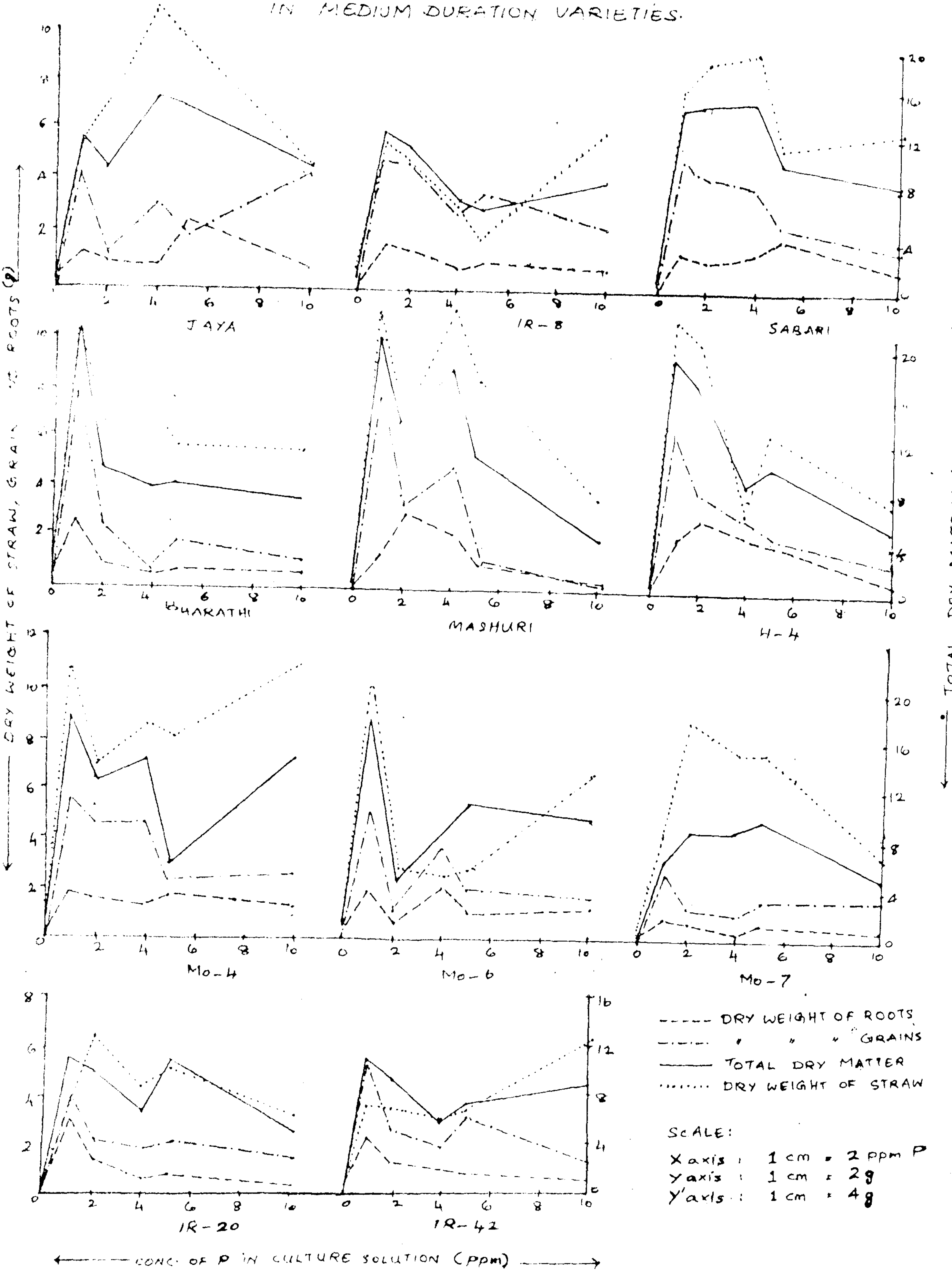
P was required which was not usually obtained under soil culture.

b. Medium duration varieties

Most of the medium duration varieties required only 1 ppm P for maximum grain and straw yield except for Jaya which required 4 ppm P for maximum straw production (Table 14 and 17, Fig.2). In Karappadam soil it is difficult to obtain such high concentration of water soluble P on fertiliser application and hence the variety has given very poor straw yield. P uptakes of Mashuri, H-4, IR-42 and Bharathi were comparatively lower (Table 3). Among these varieties, Mashuri was the lowest in P requirement in early stages but the variety utilised maximum fertiliser P indicating the fertiliser responsive nature of the variety. Soil P forms the better source for the other varieties. High grain and straw yields with low P requirement in the initial stages appeared to be an expression of varietal tolerance to P deficiency in IR-42 (Table 5). Bharathi required only small quantity of P for maximum grain yield. The low straw yield produced by the variety appeared to be a varietal character. H-4 required only 1 ppm P for maximum grain and straw yields (Table 14 and 17, Fig.2). The low grain yield might be a varietal character. Height of plant and number of tillers might have contributed for the high straw yield for the variety (Table 5).

FIG. 2):

EFFECT OF LEVELS OF PHOSPHORUS ON DRY WEIGHT OF GRAIN, STRAW, ROOT AND TOTAL DRY MATTER PRODUCTION IN MEDIUM DURATION VARIETIES.



Uptake of Mo-4 and Mo-6 was medium in the early stages. But both these varieties were inferior to IR-8, IR-42, Bharathi and Jaya in grain production (Table 5).

Total P uptake showed significant relationship with dry weight of grain, dry weight of straw and root volume at 1 and 10 ppm levels of P supply. Correlation of dry weight of grain and root volume was significant at 1 ppm but not at 10 ppm level of P supply (Table 24).

D. Root distribution pattern and phosphorus uptake

Data collected on root distribution pattern of short duration rice varieties at the flowering stage, revealed that Triveni which has recorded the highest 'A' value at 60 DAP as well as the highest soil P uptake, recorded maximum dry weight and volume (Table 25, Plate I). Specific area exposed by root per unit area is directly related to nutrient absorption especially that of sparingly soluble soil P. Jyothi followed Triveni in this character. 'A' value at 60 DAP also showed similar relationship (Table 2).

Among medium duration varieties H-4, Mo-4, Jaya, IR-42 and Mo-6 were found to have good root system with higher proportion of thinner roots when compared to other varieties (Table 26, Plate II). 'A' value at 60 DAP was not found to have much relation with root characteristics of medium duration varieties (Table 3).

Table 24. Relationship between total P uptake, dry weight of straw, grain and root volume (Solution culture)

Sl. No.	Factors correlated	Coefficients of correlation (r)	
		At 1 ppm level	At 10 ppm level
1	Total P uptake vs		
	a) Dry weight of straw	0.8626**	0.8316**
	b) Dry weight of grain	0.6165**	0.4779**
	c) Root volume	0.3593*	0.6742**
2	Dry weight of grain vs		
	a) Root volume	0.6288**	0.2425

** Significant at 0.01 level

* Significant at 0.05 level

Table 25. Dry weight and volume of thick and thin roots of short duration varieties (mean)

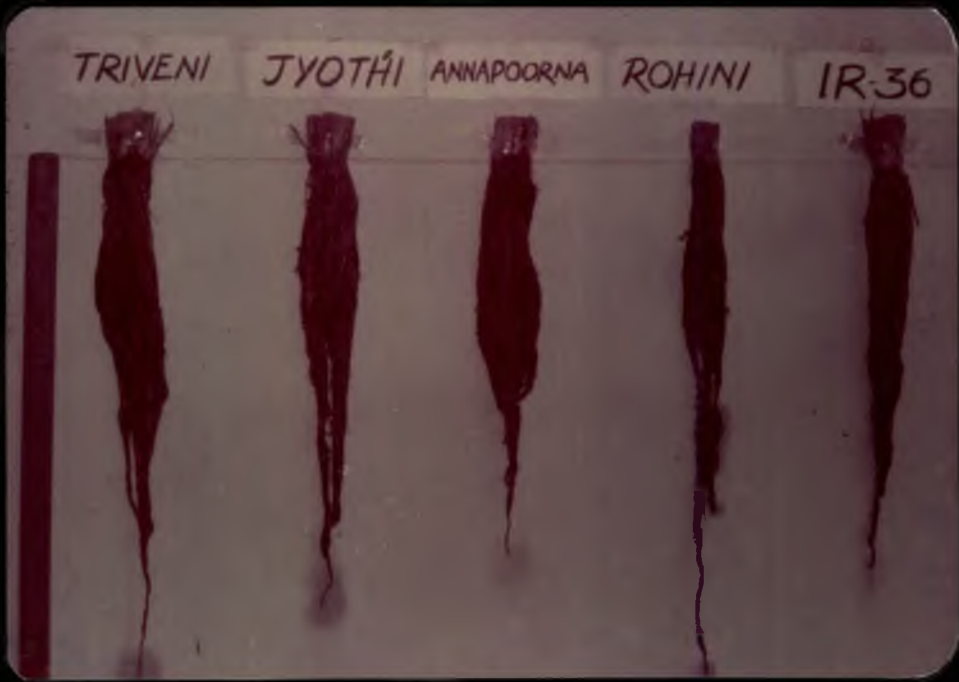
Sl. No.	Varieties	Length (cm)	Dry weight (g)			Volume (cm^3)		
			Thick	Thin	Total	Thick	Thin	Total
1	Rohini	49.3	2.57	1.51	4.08	13.50	4.50	18.00
2	Jyothi	51.7	3.00	1.78	4.78	15.00	6.00	21.00
3	Annapoorna	46.1	2.53	1.88	4.41	10.75	7.00	17.75
4	Triveni	44.4	2.99	1.81	4.80	12.00	6.50	18.50
5	IR-36	42.6	2.35	1.58	3.93	11.50	3.50	15.00

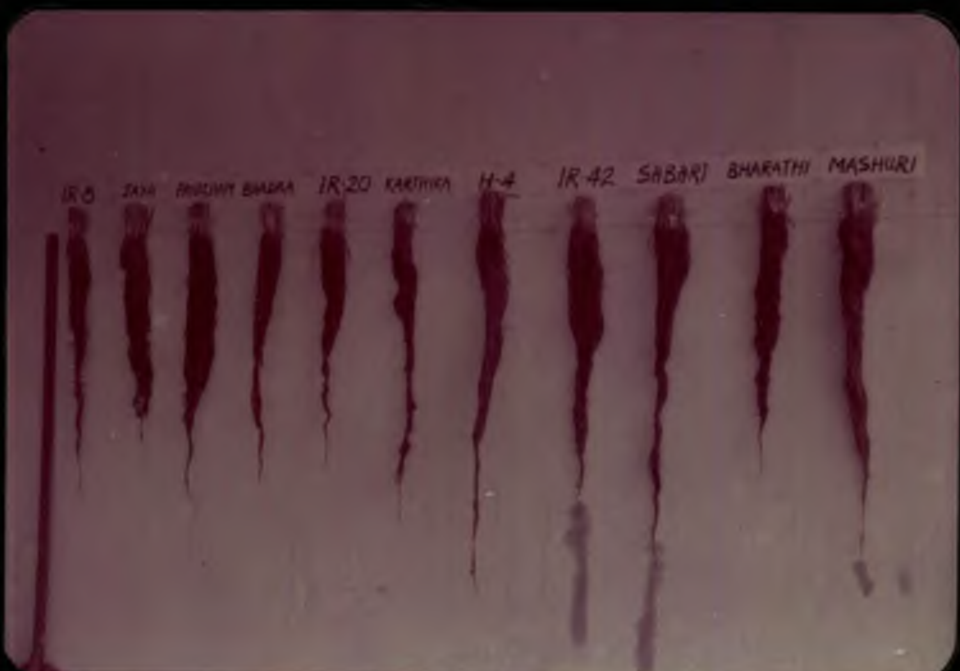
Table 26. Dry weight and volume of thick and thin roots of medium duration varieties (mean)

Sl. No.	Varieties	Length (cm)	Dry weight (g)			Volume (cm^3)		
			Thick	Thin	Total	Thick	Thin	Total
1	Jaya	33.4	4.03	2.24	6.27	20.00	5.75	25.75
2	IR-8	49.4	2.89	1.22	4.11	12.00	7.25	19.25
3	Sabari	46.3	4.79	1.94	6.73	20.00	7.50	27.50
4	Bharathi	24.5	2.24	1.60	3.84	9.75	6.50	16.25
5	Mashuri	48.8	3.96	2.40	6.36	20.50	8.25	28.75
6	IR-20	35.8	4.48	2.55	7.03	14.25	8.50	22.75
7	Mo-4	43.1	2.91	2.03	4.94	14.50	9.50	24.00
8	Mo-6	40.7	4.76	1.61	6.37	16.00	7.00	23.00
9	Mo-7	26.3	2.31	0.80	3.11	11.50	2.75	14.25
10	H-4	77.1	4.50	2.81	7.31	20.25	10.50	30.75
11	IR-42	63.4	4.62	3.01	7.63	20.25	11.75	32.00

Plate I. Rooting pattern of short duration varieties

Plate II. Rooting pattern of medium duration varieties


TRIVENI
JYOTHI
ANNAPOORNA
ROHINI
IR-36


IR 8
IR-20
KARTHIKA
H-4
IR 42
SABARI
BHARATHI
MASHURI

Summary

SUMMARY

Varietal efficiency for soil and fertiliser P utilisation was evaluated in Karappadam soil collected from RARS, Moncompu having high P fixing capacity. Performance of five short duration and eleven medium duration varieties was assessed at recommended dose of N, P, K and lime as per the package of practices recommendations of KAU (Anon., 1992). Radio-tracer studies were conducted using ^{32}P tagged superphosphate to determine P uptake from fertilizer and soil P and 'A' values at two stages in the early growth period. Grain and straw yield potential of the different varieties at graded levels of soluble P were also assessed in the solution culture experiment. The root distribution pattern of the different varieties with regard to their total, thick and thin root weight and their respective volumes was also studied. Grain and straw yield produced by the different varieties was related with total P requirement, relative response to applied fertilizer and soil P and other characters which contribute to high grain and straw yield. An attempt was made to identify varieties which give proportionately high grain and straw yield at higher level of P supply, varieties which can utilise soil as well as fertilizer P efficiently The important results obtained and conclusions drawn are summarised below:

1. IR-36 was having a low root weight and volume. P absorbed by this variety at 30 DAP was efficiently utilised for grain production. Total P uptake was minimum for this variety but percentage utilization from fertilizer P was maximum as evidenced from the tracer studies.

This variety therefore can be grown in soils which are poor in available P with a basal dressing of a small dose of fertiliser containing water soluble P.

2. Triveni and Rohini were found to have low P requirements in the initial stages. Rohini utilised native P at the early stages whereas Triveni responded better to applied P fertiliser in the early stages and utilised soil P in the later stages. The variety was also found to develop good root system by this stage.

Rohini was found to utilise native P more efficiently and it can be grown successfully either in a soil rich in native P or it can follow fertiliser responsive variety in the cropping sequence.

Triveni can be grown in a soil medium to rich in P status with a small basal dose of water soluble P carrier. Triveni gave good grain and straw yield under such conditions.

3. Jyothi was found to utilise both soil and fertiliser P efficiently. But this variety requires higher level of soluble P for giving maximum grain yield but low level for

good straw yield. The variety is suited for soils with low P fixing capacity.

4. Among medium duration varieties uptake of P was highest for IR-8. Moderately high utilization of P from both the sources contributed for higher uptake in the initial stages of growth which has resulted in high grain yield for the variety.

5. IR-42 and Bharathi were having low P requirement in the initial stages which is an exhibition of varietal tolerance for P deficiency. Both these varieties were found efficient users of native P.

These varieties are suitable for soils having medium P status or can be grown succeeding fertilizer responsive variety in the cropping sequence.

6. Mashuri was having the lowest P requirement but utilized fertilizer P more efficiently. Therefore it can be grown in soils of poor P status with a basal dressing of small dose of soluble fertilizer P.

7. H-4 with low P requirement in the initial stages was moderate in the utilization of soil and fertilizer P. The low P requirement is an indication of P deficiency tolerance but high 'A' values at 60 DAP and total uptake at harvest indicates its capacity to utilise native P at later stages of growth, and thereby showing its potential for high straw yield in soils with high P status.

8. Jaya can be grown in soils with moderate amount of soil P and application of P fertilisers is a common practice. The variety is capable of giving more straw yield at high levels of P than the recommended dose.

Phosphate management of rice should take into consideration the nutrient status of soil, P requirement of the variety, relative efficiency of the varieties to feed on soil and fertiliser P. Rice cvs. for rice-rice cropping sequence should be so selected to reduce wastage of costly fertiliser and utilise soil sources efficiently. Fertiliser application should be confined to only those varieties which are fertiliser responsive. Residual effect of fertiliser should be better exploited by growing variety which can utilise soil P, succeeding a fertiliser responsive variety.

References

REFERENCES

Anonymous (1951). The root system of plants. Agronomico campinas. 30(3): 1-3.

Anonymous (1970a). Annual Report. All India Co-ordinated Agronomical Experiments. 1969-70. UAS. Bangalore.

Anonymous (1970b). Varietal resistance to soil problems. Annual Report. International Rice Research Institute. Philippines. p. 117.

Anonymous,(1971). Varietal resistance to injurious soils. Annual Report. International Rice Research Institute. Philippines. p. 39-43.

Anonymous (1972). Varietal resistance to injurious soils. Annual Report. International Rice Research Institute. Philippines. p. 116.

Anonymous (1982). Rice (Oryza sativa). Package of Practices Recommendations. Extension Division, Kerala Agricultural University, Trichur.

Anonymous (1984). Adverse soil tolerance, efficient use of P and Zn. Res. Highlights. International Rice Research Institute. Philippines. p. 8.

Bhushan, L.S. and Singh, G. (1979). Yield and nutrient uptake by rainfed direct sown rice as affected by N and P fertilization. Fert. News. 24(3): 25-27.

Bole, J.B. (1973). Influence of root hairs in supplying soil phosphorus to wheat. Can. J. Soil Sci., 53(2): 169-175.

Bray, R.H. and Kurtz, L.T. (1945). Determining total organic and available forms of phosphate in soils. Soil Sci., 59: 39-45.

Chang, S.C. (1976). Phosphorus in submerged soils and P nutrition and fertilisation of rice. The Fertility of Paddy Soils and Fertiliser Application for Rice. ASPAC Publication, Taiwan, p. 93-116.

Cheng, K.L. and Bray, R.H. (1951). Determination of calcium and magnesium in soils and plant materials. Soil Sci., 72: 449-458.

Choudhary, M.L. and Uppal, A.K. (1981). Accumulation of phosphorus by three varieties of rice and its relationship to phosphate fertilisation. Indian J. agric. Res., 15(3):145-148.

Choudhary, S.U. and Mian, M.H. (1970). Effect of phosphatic fertilisers on rice yields. Thai. J. agric. Sci., 2(2): 111-119.

Dabin, B. (1951). Manurial nutrition of rice. Agron. Trop., 6: 507-513.

*Datta, N.P. (1967). J. Indian Soc. Soil Sci., 22: 258.

Datta, N.P. and Datta, N.R. (1963). Radio-tracer studies on crop responses in rice and wheat to phosphate applied to different types of soils. Indian J. agric. Sci., 33: 55-70.

*Datta, N.R. and Datta, N.P. (1963). J. Indian Soc. Soil Sci., 11: 117.

Davide, C. (1964). The time and methods of phosphatic fertiliser application. Mineral Nutrition of Rice Plants, p. 108.

De Datta, S.K., Moomaw, J.C., Racho, V.V. and Simsiman, G.V. (1966). Phosphorus supplying capacity of lowland rice soils. Proc. Soil Sci. Soc. Am., 30(5): 613-617.

Devasia, P.A., Thomas, C.T. and Nandakumaran, M. (1976). Studies on the chemical composition of certain hybrid varieties of paddy straw. Kerala J. Vet. Sci., 7(2): 101-107.

Dev, G., Randhawa, N.S. and Nayyar, K.L. (1970). Response of high yielding varieties of rice (TN 1 and IR-8) to graded dose of phosphate. J. Res., PAU, 7(4): 449-453.

Dev, G., Saggar, S., Singh, R. and Sioju, B.S. (1980). Root distribution pattern of some wheat varieties in mid-brown soil under rainfed conditions. J. Nucl. Agric. Biol., 9(3): 89-90.

Dev, G., Singh, A. and Bohl, G.S. (1971). Efficiency of four high yielding varieties of paddy for absorption of fertiliser phosphorus. Proc. Symp. Radiation and Radio-isotopes in Soil Studies and Plant Nutrition, Hebbal, p. 369-376.

Fageria, N.K. and Filho, S.M.P. (1981). Screening rice cultivars for higher efficiency in phosphorus absorption. Pesquisa Agropecuaria, 6(2): 146-151.

Fuji, Y. (1957). Physiological and morphological differences in the roots according to nodes. Succession in rice and wheat plants. Proc. Crop. Sci. Soc., Japan, 26(2): 156-158.

Fuji, Y. (1959). Development of roots on successive nodes of rice plants. Proc. Crop Sci. Soc., Japan, 28(1): 15-16.

Goswami, N.N. (1975). Phosphorus deficient rice soils of India. Fert. News, 20(9): 25-29.

Gowin, L. and Chand, T.R. (1959). NPK experiments on paddy. Fert. News, 4(5): 8-9.

Gupta, A.P. and Manchanda, M.L. (1975). Response to phosphorus fertilisation of different varieties of paddy with respect to dry matter and yield. Riso, 24(1):45-58.

Gupta, R.K. and Singh, T.A. (1977). Inter-relationship among labile P kinetics, phosphate potential and fertiliser response of rice in sub-Himalayan soil. Agrochimica, 22: 123-133.

Hesse, P.R. (1971). A Textbook of Soil Chemical Analysis. William Clowes and Sons Ltd., London, p. 702.

Jackson, M.L. (1958). Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., p. 498.

Johnson, C.M., Stout, P.R., Broyer, T.C., Carlton, A.B. (1957). Comparative chlorine requirements of different plant species. Pl. Soil, 8: 337-353.

Kalra, Y.P. and Soper, R.J. (1968): Agron. J. 60: 209

Kamath, M.B., Goswami, N.N., Oza, A.M., Davide, M.S. and Bhimsen (1974). Proc. Symp. Use of Radiation and Radioisotopes in Studies of Plant Productivity, Pantnagar, p. 621.

Kansal, B.D., Bhumbla, D.R. and Kanwar, J.S. (1974). Variation in fertiliser response of different varieties of wheat and rice. Indian J. agric. Sci., 44(1): 55-59.

*Kanwar, J.S. (1970). Bull. Indian Soc. Soil Sci., 8: 115.

Kasai, Z. and Asada, K. (1959). Translocation of mineral elements in the higher plants: Part 10 - Behaviour of phosphorus absorbed at each stage of growth in the ripening of rice plant. J. Sci. Soil, Tokyo, 30: 479-482.

Khalid, R.A., Patrick, W.H. and Peterson, F.J. (1979). Relationship between rice yields and soil phosphorus evaluated under aerobic and anaerobic conditions. Soil Sci. Plant Nut., 25(2): 155-164.

Khatua, K.B., Choudhary, S.C., Panda, M. and Mishra, A. (1976). N, P and K requirements of high yielding rice. Indian J. Agron., 21(4): 425-520.

Khumbar, D.D. and Sonar, K.R. (1979). Performance of rice grain under upland conditions. Dry matter accumulation and N P K uptake. Maharashtra agric. Univ., 4(2):183-187.

Kiasulu, J.S. (1983). Differential response of four upland rice cultivars to phosphorus fertilization on an Alfisol and Ultisol in south western and south eastern Nigeria. Diss. Abstr. int., 44(6): 677.

Kothandaraman, G.V., Krishnaswamy, R. and Krishnamoorthy, K.K. (1976). Studies on the quality of IR-20 rice as influenced by fertilization. Madras agric. J., 63(6): 346-348.

Kowaguchi, K. and Kyuma, K. (1977). Paddy Soils of Tropical Asia - Their Material Nature and Fertility. University Press, Hawaii, p. 258.

*Koyama, T. and Chammeck, C. (1971). Soil Sci. Pl. Nut., 17: 115-126.

*Koyama, T. and Snitwongse, P. (1971). Soil Sci. Pl. Nut., 17: 186-194.

Kumaraswamy, K., Natarajan, C.P., Subramanion, T.L., Balasubramanian, S. and Krishnamoorthy, K.K. (1977). Studies on the root distribution of rice varieties using ^{32}P plant injection technique. Madras agric. J., 64(5): 285-289.

Kwak, T.S., Ham, Y.S. and Vergara, B.S. (1983). Studies on the screening method of rooting ability under low water temperature. Crop, 25: 67-71.

Madhusudhanan, K. and Padmaja, P. (1983). Phosphorus fixing capacity of major rice soils of Kerala. *Agric. Res. J. Kerala*. p. 63-65.

Mahadevappa, M., Ikehashi, H. and Ponnamperuma, F.N. (1979). The contribution of varietal tolerance for problem soils to yield stability in rice. *Res. Paper Series. International Rice Research Institute. Philippines*. **43**: 15.

Mahapatra, I.C. (1961). Phosphate needs of rice crop. *Indian J. Agron*., **5**(4): 219-224.

Maung Mya Thaung (1960). Relative absorption of phosphorus by rice plants from native and additive sources using radio-active P as a tracer. *Soil Sci*., **90**: 284-289.

Mitsui, S. (1960). *Inorganic Nutrition, Fertilisation and Soil Amelioration for Lowland Rice*. 4th Edition, Yokendo Press, Tokyo, p. 107.

Mori, T. (1954). Studies on the ecological characters of rice root. (2) The relation between top growth and rooting activity of rice plants. *Bull. Inst. agric. Res., Tohoku*. **6**(2): 63-72.

*Motsara, M.R. and Datta, N.P. (1971). *J. Indian Soc. Soil Sci*., **19**: 107-113.

Mukherjee, H.N. (1955). *Rice in India*. Indian Council of Agricultural Research, New Delhi, p. 196.

Nagarajah, S. and Weerasekhara, D.A. (1962). Uptake and utilisation of fertiliser phosphorus by rice from some rice soils of Ceylon as determined by radio-active ^{32}P. *Trop. Agricst*., **18**: 23-29.

Nair, R.R. and Pisharady, P.N. (1970). Response of rice to phosphate manuring in a waterlogged lateritic sandy loam soils of Kerala. Agric. Res. J. Kerala. 8(1): 6-13.

Naphode, J.D. (1969). Influence of phosphate applications to various soils, on the response of rice and P uptake at different stages of plant growth. Riso. 18: 37-42.

Nath, A.K. and Borah, D.K. (1979). The plant availability and yield potential of native and applied fixed phosphates as affected by pH and moisture regime of soils. Indian J. agric. Chem., 2(12): 145-150.

Olsen, S.L., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A. Circ., p. 939.

*Oomen, P.K., Oza, A.M. and Subbiah, B.V. (1972). Indian J. agric. Sci., 42: 370.

Oza, A.M., Kamath, M.B., Goswami, N.N., Davide, M.S. and Singh, S. (1977). Improving crop and animal productivity. Oxford and IBH Publishing Co., New Delhi, p. 361.

*Oza, A.M., Singh, M., Verma, N.S. and Khanna, P.K. (1976). J. Nucl. Agric. Biol., 5: 79.

Oza, A.M., Velmaloo, S. and Subbiah, B.V. (1971). Relative efficiency of different rice varieties to take up soil and fertiliser phosphorus. Proc. Symp. Radiation and Radio-isotopes in Soil Studies and Plant Nutrition, Hebbal, p. 377-385.

Patel, J.P. (1978). Relative performance of some latest varieties of rice and their yield attributing characters. Curr. Res., 7(6): 106-107.

Pathak, A.S., Krishna, A.S. and Tiwari, K.N. (1972). Studies on chemical composition, yield and nutrient uptake of high yielding rice varieties in relation to fertility levels. Indian J. agric. Res., 6(4): 263-266.

Peach, M., Alexander, L.T., Dean, L.A. and Reed, J.F. (1947). Methods of soil analysis for soil fertility investigations. U.S.D.A. Cir., p. 757.

Pelerents, C. (1958). A study of the root system of upland rice under natural conditions. Bull. agric. Cong., Belgium, 49: 269-289.

Peterson, F.J. (1968). Rice fertilization. Rice J., 71: p. 53.

Pillai, G.K., Krishnamoorthy, K. and Ramaprasad, A.S. (1984). Studies on varietal tolerance of rice varieties to phosphorus deficiency. Fert. Agric., 87: 17-20.

Piper, C.S. (1942). Soil and Plant Analysis. University of Adelaide, p. 368.

Ponnamperuma, F.N. (1979). IR-42: A rice type for small farmers of south and south east Asia. Res. Paper Series, International Rice Research Institute, Philippines, 44: p. 4.

Potty, N.S. (1964). Studies on the response curves of major nutrients on rice in Kerala. M.Sc.(Ag) Thesis submitted to the University of Kerala.

Qui, J.Z. and Wan, C.B. (1982). Phosphate absorption by rice at different growth stages. Jiangsu agric. Sci., 8: 27-33.

Rai, R.S.V. and Murty, K.S. (1976). The uptake of nutrients in relation to growth period of late duration indica rice varieties. Indian J. Plant Physiol., 19(2): 229-235.

*Ramamoorthy, B. and Bisen, D.C. (1971). Proc. Int. Symp. Soil Fert. Eval., New Delhi, 1: p. 63.

Ramanathan, K.M., Krishnamoorthy, K.K. (1973). Influence of variability in soils, varieties and fertiliser levels, on the uptake of nutrients in relation to growth of paddy. Plant Soil, 22(4): 24-30.

Rao, G.T.K., Kolandaisamy, S., Seshadri, P. and Sankaran, S. (1974). Madras agric. J., 61: 255-274.

*Rao, R.G. (1965). Andhra agric. J., 14: p. 85.

*Rao, S.I.V. (1975). Bull. Tech., APAU, Hyderabad, 1: 14-15.

Rao, S.I.V., Raju, S.A. and Sathe, A. (1978). Improving Crop and Animal Productivity. Oxford and IBH Publishing Co., New Delhi, p. 400.

Rao, U.P. and Srinivasan, T.C. (1978). Evaluation of Assam dwarf's suitability under low P and N conditions. Madras agric. J., 65(9): 626-627.

Rastogi, A.K., Mahajan, J.P. and Sinha, S.B. (1981). Phosphorus utilisation by three rice varieties at different stages of growth in a vertisol. J. Biol. Agric. Biol., 10(2): 48-50.

Ratna, C.M.F. and Fernando, L.M. (1983). Studies on the fertiliser response of rice (1) Direct, residual and cumulative effects of various phosphatic fertilizers. Trop. Agric., 110(3): 179-189.

*Reddy, P.R. and Rao, M. (1976). J. Nucl. Agric. Biol., 5: p. 49.

Reddy, S.S., Rao, M.P. and Reddy, V.G. (1984). Response of rice cultivars to phosphorus. Newsletter, International Rice Research Institute, Philippines, 9(2): p. 5.

Row, K.S. and Venkateswaralu, B. (1983). Root characteristics as influenced by soil type and compaction for moisture stress conditions in rice. Indian J. Plant Physiol., 26(3): 241-249.

Sadanandan, N. and Sasidhar, V.K. (1976). Studies on the response of rice variety, Triveni to phosphorus application. Agric. Res. J. Kerala, 14(2): 175-177.

Sanzo, M.R., Chibas, S.J. and Socorro, R.M. (1980). Root growth of rice at different phases of its vegetative cycle. Desarolia radiculas dol., 7(1): 133-139.

Sasidhar, V.K. and Sadanandan, N. (1973). The effect of different levels of phosphorus on the yield of rice variety Rohini in Vellayani. Agric. Res. J. Kerala, 9(2): 92-93.

Sethi, R.L. (1940). Manuring of Rice in India. Indian Council of Agricultural Research, p. 38.

Shiga, A. and Yamaguchi, Y. (1976). Effect of P fertility of soil and phosphate application on rice culture in cool region. Res. Bull. Hokkaido Nat. agric. Exp. Station, 116: 139-155.

Shukla, V.C. and Choudhary, M.L. (1976). Fert. News, 21(3): 17.

Singh, M., Oza, A.M. and Khanna, P.K. (1971). Proc. Symp. Radiation and Radioisotopes in Soil Studies and Plant Nutrition, Bangalore, p. 387.

Singh, M. and Varma, S.C. (1971). Effect of different rates of N and P application on the yield and yield attributing characters of T(N) 1 rice. Indian J. Agron., 16(3): 257-260.

Singh, S.P., Lal, K.B., Ram, R.S. and Srivastava, C.P. (1981). Studies on the root distribution pattern in paddy cultivars. Indian J. agric. Chem., 14(1): 155-161.

Singh, V., Nishad, M.S. and Prasad, S. (1972). Response of paddy varieties to levels of fertility. Indian J. agric. Res., 6(4): 289-290.

Sinha, S.P., Rastogi, A.K. and Mahajan, J.P. (1980). Uptake of fertilizer phosphorus by three rice varieties in a vertisol. J. Nucl. Agric. Biol., 9(4): 139-140.

Socorro, Q.M. (1982). Effect of mineral fertilizers on the development of the root system of rice. Centro Agricola, 9(1): 23-29.

Srivastava, O.P., Singh, B. and Pathak, A.N. (1984). Varietal differences in phosphorus uptake of rice on sodic soils. Newsletter, International Rice Research Institute, Philippines, 9(3): p.11.

Subbiah, B.V. and Asija, G.L.A. (1956). A rapid procedure of the estimation of available nitrogen in soils. Current Sci., 25: 259-260.

Subbiah, B.V. and Oza, A.M. (1973). Proc. Symp. Use of Isotopes and Radiation in Agriculture and Animal Husbandry Research, New Delhi, p. 616.

Szopos, J. and Kiss, I.S. (1967). The uptake of ^{32}P and its incorporation into phosphate fraction of the rice leaf in response to various levels of nitrogen. Novenytermeles, 16(1): 73-78.

Tanaka, A. (1959). Nutrient supplying power of the soil solution judged from the growth of rice plants grown under waterlogged conditions. Soil Sci. Plant. Nut., 2(1): p. 38.

Tanaka, A. and Yoshida, S. (1970). Nutritional disorders of the rice plant in Asia. International Rice Research Institute, Philippines, p. 51.

Tang Van Hai and Lau De Lout, H. (1966). Phosphate uptake by rice roots. Ann. Phys. Veg. Paris, 8: 13-24.

Thenabadu, M.W. (1979). Fertiliser studies with improved high yielding varieties of rice in the dryzone of Sri Lanka. J. Nat. agric. Soc. Ceylon, 16: 1-10.

Turner, F.T., Bollich, C.N. and Scotte, T.E. (1978). Phosphorus efficient varieties. Newsletter, International Rice Research Institute, Philippines, 3(3): 13-14.

Varma, S.C. (1971). Effect of N and P application on the dry matter accumulation and uptake, translocation and recovery of nutrient by T(N)1. J. Sci. Res., 22(1):11-19.

Veen, B.W. and Boone, F.R. (1981). The influence of mechanical resistance and phosphate supply on morphology and formation of crown roots. Plant Soil, 63(1): 77-81.

Verma, R.D., Dainty, J. and Simpson, K. (1959). Studies on the uptake of phosphorus from ^{32}P labelled superphosphate by crops. J. Sci. Food Agric., 10: 100-107.

Wahid, P.A., Kamalam, N.V. and Sankar, S.J. (1985). Determination of ^{32}P in wet digested plant leaves by Cerenkov counting. Int. J. Appl. Rad. Isot., 36: 323-324.

Wakhaloo, S., Osa, A.M. and Singh, M. (1973). Newsletter, ISNA. 2: p. 24.

Walkley, A. and Black, T.A. (1934). An examination of the Degtjareff method for determination of soil organic matter and a proposed modification of the chromic acid titration. Soil Sci., 37: 29-38.

Weeraratne, C.S. (1974). Phosphorus, iron and manganese uptake of some low and high yielding rice varieties. J. Nat. agric. Soc. Ceylon, 11(12): 40-44.

Woodruff, D.R. (1980). Influence of nodal root production on wheat yields under conditions of limited soil water and phosphorus supply. Queensland J. Agric. Animal Sci., 37(1): 53-62.

Yates, (1959). An exploratory analysis of a large set of 3 x 3 x 3 fertilizer trials in India. Emp. J. Exp. Agric., p. 17.

* Originals not seen

Appendices

APPENDIX -I

A. SHORT DURATION VARIETIES

Abstract of analysis of variance table for dry weight of straw, uptake of P, amount of P, derived from soil and fertilizer and A value at 30 and 60 DAP respectively

Source	df	Mean square									
		At 30 DAP					At 60 DAP				
		Dry weight of straw	Uptake of P	APDFF	APDFS	A value	Dry weight of straw	Uptake of P	APDFF	APDFS	A value
Variety	4	0.066**	0.807**	0.039**	0.590**	124.888**	5.017**	68.010**	0.412**	64.191**	1608.934**
Error	15	0.006	0.004	0.002	0.004	7.933	0.438	0.304	0.002	0.327	28.931

** Significant at 0.01 level

APDFF- Amount of phosphorus derived from fertiliser

APDFS- Amount of phosphorus derived from soil

APPENDIX -II

B. MEDIUM DURATION VARIETIES

Abstract of analysis of variance table for dry weight of straw, uptake of P, amount of P derived from soil and fertilizer and A value at 30 and 60 DAP respectively

Source	df	Mean square									
		At 30 DAP					At 60 DAP				
		Dry weight of straw	Uptake of P	APDFF	APDFS	'A' value	Dry weight of straw	Uptake of P	APDFF	APDFS	'A' value
Variety	10	0.124**	0.741**	0.092**	0.329	64.831**	17.443**	47.004**	0.306**	41.164**	1253.226**
Error	22	0.003	0.006	0.002	0.002	7.785	0.208	0.138	0.002	0.133	19.169

** Significant at 0.01 level

APDFF - Amount of phosphorus derived from fertilizer

APDFS - Amount of phosphorus derived from soil

APPENDIX -III

A. SHORT DURATION VARIETIES

Abstract of analysis of variance table for height of the plant, number of productive tillers dry weight of grain, straw and 1000 grain, fertility percentage and P uptake

Source	df	Mean square						
		Height of the plant	Number of productive tillers	Dry weight			Fertility percentage	P uptake
				Grain	Straw	1000 grain		
Variety	4	171.906**	3.175**	565.125**	553.324**	50.74**	36.020**	31013.00**
Error	15	2.250	0.433	9.167	17.767	0.094	4.260	3759.40

** Significant at 0.01 level

APPENDIX -IV

B. MEDIUM DURATION VARIETIES

Abstract of analysis of variance table for height of the plant, number of productive tillers, dry weight of grain, straw and 1000 grain, fertility percentage and P uptake

Source	df	Mean square						
		Height of the plant	Number of productive tillers	Dry weight			Fertility percentage	P uptake
				Grain	Straw	1000 grain		
Variety	10	880.916**	5.806**	443.206**	1247.673**	58.97**	36.766**	165406.599**
Error	22	13.751	0.364	21.273	19.455	0.354	5.71	1760.00

APPENDIX -V

A. SHORT DURATION VARIETIES

Abstract of analysis of variance for

a) Dry weight of straw and roots

Mean square

Source	df	Dry weight of straw		Dry weight of roots	
		At 30 DAP	At harvest	At 30 DAP	At harvest
Variety	4	33677.3*	0.827	1663.1**	0.180
Levels	5	242143.6**	27.707**	4150.4**	1.03**
Interaction	20	13122.2	11.397**	344.1	0.0920
Error	30	12295.3	1.447	305.0	0.0813

b) Dry weight of grain and P uptake

Mean square

Source	df	Dry weight of grain	P uptake	
			At 30 DAP	At harvest
Variety	4	0.930	2.577**	2505.3
Levels	4	5.706	10.420**	83.4**
Interaction	16	1.178	0.400	299.0
Error	25	1.001	0.640	173.8

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX -VI

B. MEDIUM DURATION VARIETIES

Abstract of analysis of variance table for

a) Dry weight of straw and roots

Source	df	Mean square			
		Dry weight of straw		Dry weight of roots	
		At 30 DAP	At harvest	At 30 DAP	At harvest
Variety	10	35189.6**	20.75**	1297.3**	0.879**
Level	5	438791.6**	154.73**	18149.9**	7.915**
Interaction	50	14160.0	9.46**	765.7**	0.584**
Error	66	9423.6	1.12	225.5	0.0977

(b) Dry weight of grain and P uptake

Source	df	Mean square		
		Dry weight of grain	P uptake	
			At 30 DAP	At harvest
Variety	10	4.781**	0.958**	1270.55**
Level	4	40.144**	4.840**	4605.95**
Interaction	40	3.098**	0.590**	790.94**
Error	55	0.323	0.152	136.66

* Significant at 0.05 level

** Significant at 0.01 level

RELATIVE EFFICIENCY OF RICE VARIETIES FOR ABSORPTION AND UTILIZATION OF SOIL AND FERTILIZER PHOSPHORUS

By

MASHAR VELAPURATH

ABSTRACT OF A THESIS

submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1986

ABSTRACT

Relative efficiency of rice varieties for absorption and utilisation of soil and fertiliser phosphorus

An investigation was carried out at the College of Horticulture, Vellanikkara, Trichur, during the year 1984-'85 to study the efficiency of popular modern rice varieties of Kerala for absorption and utilisation of soil and fertiliser P as well as for their capacity to P deficiency tolerance.

A series of pot culture experiments was conducted using five short duration (Rohini, Jyothi, Annapoorna, Triveni and IR-36) and eleven medium duration (Jaya, IR-8, Sabari, Bharathi, Mashuri, IR-20, Mo-4, Mo-6, Mo-7, H-4 and IR-42) rice varieties in Karappadam soil of Kuttanad region of Kerala.

The first pot culture trial involves evaluation of the above varieties for their capacity to utilise soil and applied fertiliser P using ^{32}P labelled superphosphate. The experiment was carried out in CRD.

The relative performance of all the varieties as well as their root distribution pattern were compared from another pot culture trial under identical fertility conditions. Fertilisers and lime were applied as per the package of practices recommendations of the Kerala Agricultural University. The experiment was designed in CRD.

An attempt was also made to study the P requirement of each variety for the expression of maximum grain and straw yield from a solution culture trial. Solution containing all the macro and micronutrients was used for the experiment. The treatments consisted of combinations of different varieties and different levels of P supply. The various levels of P used were 0, 1, 2, 4, 5, and 10 ppm. The experiment was conducted in CRD factorial design.

The results indicated that cv. IR-36 was having a very low P requirement for the expression of maximum yield potential among short duration varieties and that it responded well to applied fertiliser P, indicating its fertiliser responsive nature as well as tolerance to P deficiency.

Triveni and Rohini were also having low requirements, but they differed in their dependence on the source of P to meet the requirement. Rohini was capable of utilizing native soil P efficiently while a good response to applied P was observed in the cv. Triveni.

Jyothi utilised both the sources of P viz. soil and fertiliser; efficiently but was found to have a higher requirement for giving maximum grain yield.

Among the medium duration varieties cv. Mashuri has the lowest requirement and majority of its requirement was met from the fertilizer revealing its P deficiency tolerance nature and responsiveness to applied fertilizer P.

Cv. IR-42 and Bharathi were found to be tolerant to P deficiency due to their capacity to utilise native soil P efficiently and low requirements of P.

Cv. IR-4 was also having low requirement and it utilized both the sources efficiently. But this was not very much reflected on the grain yield.

Cv. IR-8 and Jaya had comparatively higher requirements and it reflected well on the grain yield. But these varieties yielded poor at lower levels indicating its susceptibility to P deficiency.