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GENOTYPIC DIFFERENCES IN PHOSPHATE NUTRITION OF RICE (*ORYZA SATIVA* L.)

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Abstract

GENOTYPIC DIFFERENCES IN PHOSPHATE NUTRITION OF RICE (*ORYZA SATIVA* L.)

Phosphate uptake and use by five genotypes of paddy rice were studied at five phosphate levels in pot studies for 49 days. For all five P levels there were marked genotypic differences in shoot growth, plant dry weight, root/shoot ratios, phosphate uptake and translocation, P content of roots and shoots, and phosphorus use efficiency of shoots (PUE, g shoot mg P^{-1} in shoot). There were significant genotypic differences in root weight (4 P levels) and in uptake/mg root (all P levels). These latter may have resulted from differences in root weight/root length conversion, root hair development or uptake characteristics, factors which were not studied specifically. Differences between genotypes and P levels in the percentage translocation were partly explicable by differences in P uptake/plant ($r = 0.72$) but especially by differences in root/shoot ratios ($r = 0.89$). Differences in PUE were largely a factor of P percentage of the tops ($r = 0.94$) but significant differences between genotypes were shown as a function of % P. Differences in net photosynthesis rates were largely, but not entirely, due to differences in P % of the shoots. Key factors in P uptake and use and genotypic differences are root growth, uptake/mg root, root/shoot ratios and PUE.

1. INTRODUCTION

Differences in nutrient relations between genotypes within a species are well known [1,2,3]. Two possible major components of such differences are the uptake of the nutrient from soil and physiological differences in use of the nutrient in the plant. The former is determined by root dynamics and/or the physiology of nutrient uptake by the root. The components of the latter, collectively defined as physiological nutrient use efficiency (g dry matter/mg absorbed nutrient) include transloction of the nutrient to shoots (and its dynamics), effects on net photosynthesis and eventually the distribution of assimilates from leaf to other plant parts. This paper exmamines some of these components with five genotypes of rice (*Oryza sativa* L.) varying in their ability to grow in phosphate deficient soils. Their behaviour at 5 levels of phosphate was examined.

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2. MATERIALS AND METHODS

2.1. Genotypes

Five genotypes were: Lalka Motka, Pokkali, IR-9884-543-IE-PI (subsequently referred to as IR-9844), IR-42 and Khao Dawk Mali 105 (subsequently referred to as KDM-105). All varieties were kindly supplied by the International Rice Research Institute, Los Banos, the Philippines.

Earlier studies using 25 genotypes had indicated the first three to perform well in a soil with a moderate application of phosphate while the last two performed poorly.

2.2. Soils and plant growth

Plants were grown in pots in 1.0 kg of a 1:1 mixture of sand and a soil from Weschel, Eastern Austria, with the composition pH 6.5, total N 0.3%, available P 7.9 ppm (Bray 1) and 7.8% organic matter. Urea was added to give 60 ppm N, potassium chloride to give 50 ppm K, and a micro nutrient mixture containing Boron, Zinc, Copper and Molybdenum. Phosphorus additions of 0, 20 ppm, 40 ppm, 80 ppm and 120 ppm were made by thoroughly mixing potassium dihydrogen phosphate with the soil before potting. The soil had little phosphate fixing ability.

The pots were watered daily with de-ionized water to field capacity to simulate paddy conditions. The plants were grown in a glasshouse with approximately 10,000 lux 12 hr day, with mean day and night temperatures of 28°C and 20°C, respectively; relative humidity varied between 60 and 70%.

Four replicate pots each with two plants were employed for each of the 5 genotypes at each of the 5 phosphate levels, and the plants were harvested after 49 days growth.

2.3. Measurements

(i) After harvesting the shoots, the roots were removed from the pots using a water jet and subsequently washed throughly in tap water and finally in distilled water. The shoot and the root samples were then dried to constant weight in an oven at 70°C before recording the dry weights. The plant samples were then ground, digested with a 2:1 mixture of nitric and perchloric acid and analysed for P using a colorimeter. This enabled the calculation of root/shoot ratios, total P uptake, % P translocated to the shoots and phosphorus use efficiency in the shoots (g shoot d.m./mg P in the shoots).

(ii) Measurement of net photosynthetic rates: The net photosynthetic rate of the youngest fully expanded leaf was measured on each of three replicate plants in each treatment. The measurements were made using an Infra Red Gas Analyser (IRGA) fitted with a Parkinson leaf chamber (Analytical Development Company, Hoddesdon, Herts, England).

3. RESULTS

3.1. Plant growth experiment

3.1.1. Shoot weight

Table I, indicaes Lalka Motka and Pokkali to have significantly greater shoot growth than IR-9884 and IR-42 at all P levels and KDM 105 at most P levels. Pokkali had 60% more shoot growth than IR-42 at 0 added P (control) and 27% more at 120 ppm. Pokkali was significantly better than Lalka Motka only at 120 ppm, having 13.6% greater shoot weight.

Within all genotypes, growth at 20 ppm was significantly greater than in the control soil but, with the exception of IR-42 there was no significant difference between 20 ppm and higher P additions. The growth of IR-42 increased throughout the range of P additions but significant differences from 20 ppm occurred only at 120 ppm added phosphate.

3.1.2. *Root weight*

Root dry weight (Table I) behaved differently from shoot dry weight. There were no significant differences between 5 P levels with Pokkali and KDM- 105; but with Lalka Motka and IR-9884 root growth was significantly greater by some 38% and 26% respectively at 20 ppm than at 0 added P; root growth at other levels being equivalent to that at 20 ppm. By contrast, root growth of IR-42 increased by 55% up to 40 ppm and a significant decline occurred between 80 ppm and 120 ppm. Interesting differences occurred between genotypes: in contrast to shoot growth, at 0 added P root growth of Lalka Motka was 33% less than that of Pokkali (significant at $P = 0.01$) and root growth of IR-42 was significantly less than that of IR-9884 (33% less). Root growth of IR-42 tended to be less than that of all other genotypes at 20 ppm and above (significantly so at 20 ppm).

3.1.2. *Whole plant*

Pokkali was significantly greater than all other genotypes in whole plant dry weight (Table I) at 0 added P and was the greatest at all P levels, being consistently significantly greater than IR-42 and KDM-105 at 20 ppm and above.

3.1.3. *Root/shoot (R/S) ratios*

Root/shoot ratios decreased with all genotypes up to 20 ppm but little beyond that. Significant differences occurred between genotypes (Fig. 1) at all P levels IR-9884 being consistently greater than all other genotypes and Lalka Motka being consistently smaller. At 0 added P, the R/S ratio of Lalka Motka was 40% less than that of IR-9884 and at 40 ppm it was 30% less.

3.1.4. *P content of shoots and roots*

Not surprisingly, total P and % P of shoots and roots (Table II) increased with increasing P application. Few generaliites can be drawn between genotypes in P content and %P of shoots, except that the P content tended to mimic shoot growth although that of IR-9884 IR-42 was disproportionally higher than shoot growth and at least in O P and 20 ppm P the % P in the shoot of Lalka Motka and Pokkali (the highest shoot growth) was consistently lower than that of other genotypes. Suprisingly, KDM-105, an intermediate performer had significantly higher % P in shoots than other genotypes at 0, 20 and 40 ppm added P.

The P content of the roots of IR-9884 with poor shoot growth was consistently higher than all other genotypes and that of IR-42 - another with poor shoot growth - had consistently lower P content in the roots. At 0 P, Lalka Motka and Pokkali (high shoot growth) had significantly lower % P in the shoots.

3.1.5. *Total P uptake*

The total P uptake (Table II) of IR-42 was significantly lower than that of all other genotypes at all P levels, among which no significant differences occurred at each P level. The P content of IR-42 was usually some 25% lower than that of Pokkali. The total P uptake increased continually with increases in P applied for each genotype.

TABLE I. THE INFLUENCE OF P LEVELS ON SHOOT, ROOT AND TOTAL DRY MATTER YIELD OF RICE

Genotype	Plant part	P Level					LSD 5%
		Control	20 ppm	40 ppm	80 ppm	120 ppm	
Lalka Mokta	Shoot	3.70	5.54	5.58	5.35	5.37	0.71
	Root	1.68	2.31	2.31	2.25	2.12	0.35
	Total	5.38	7.85	7.89	7.59	7.49	0.53
Pokkali	Shoot	4.37	5.81	5.83	5.89	6.12	1.10
	Root	2.50	2.53	2.41	2.70	2.64	0.90
	Total	6.87	8.34	8.24	8.59	8.75	0.91
IR-9884	Shoot	2.84	4.25	4.56	4.30	4.68	0.51
	Root	2.11	2.67	2.70	2.42	2.50	0.46
	Total	4.95	6.93	7.24	6.72	7.18	0.49
IR-42	Shoot	2.71	3.85	4.34	4.42	4.82	0.62
	Root	1.39	1.68	2.16	2.39	1.94	0.34
	Total	4.11	5.53	6.49	6.82	6.76	0.48
KDM-105	Shoot	3.13	4.17	3.70	4.83	4.52	1.01
	Root	1.94	2.11	1.74	2.27	2.09	0.61
	Total	5.07	6.27	5.44	7.10	6.60	0.80

TABLE II. GENOTYPIC DIFFERENCES IN P UPTAKE (SHOOTS, ROOTS AND TOTAL) AND %P (IN PARENTHESES) OF RICE AT DIFFERENT P LEVELS

Genotype	Plant part	P Level					LSD 5%
		Control	20 ppm	40 ppm	80 ppm	120 ppm	
Laika Mokta	Shoot	4.96 (0.14)	10.57 (0.19)	13.78 (0.25)	15.74 (0.29)	17.42 (0.32)	1.7 (0.018)
	Root	1.37 (0.08)	2.24 (0.09)	2.61 (0.12)	3.01 (0.11)	3.19 (0.15)	0.62 (0.021)
	Total	6.33	12.81	16.39	18.75	20.61	1.15
Pokkali	Shoot	5.78 (0.13)	10.41 (0.18)	13.20 (0.23)	14.82 (0.25)	16.76 (0.27)	2.5 (0.022)
	Root	2.02 (0.08)	2.44 (0.10)	2.68 (0.11)	3.30 (0.12)	3.85 (0.15)	1.02 (0.013)
	Total	7.80	12.85	15.88	18.12	20.60	1.75
IR-9884	Shoot	4.81 (0.17)	8.90 (0.21)	11.81 (0.26)	12.67 (0.29)	14.50 (0.31)	1.66 (0.215)
	Root	2.14 (0.10)	2.85 (0.11)	2.98 (0.12)	3.34 (0.14)	4.04 (0.15)	0.60 (0.015)
	Total	6.95	11.78	14.79	16.06	18.54	1.13
IR-42	Shoot	4.41 (0.16)	8.10 (0.21)	10.23 (0.22)	10.99 (0.24)	13.07 (0.25)	1.26 (0.014)
	Root	1.36 (0.10)	1.76 (0.10)	2.39 (0.11)	2.58 (0.13)	3.22 (0.13)	0.68 (0.017)
	Total	5.77	9.89	13.62	13.57	16.29	0.97
KDM-105	Shoot	5.19 (0.17)	9.54 (0.23)	11.24 (0.30)	14.97 (0.31)	17.55 (0.39)	3.4 (0.041)
	Root	2.03 (0.10)	2.68 (0.13)	2.29 (0.13)	2.88 (0.13)	25 (0.13)	0.81 (0.02)
	Total	7.22	12.55	13.53	17.85	20.80	2.20

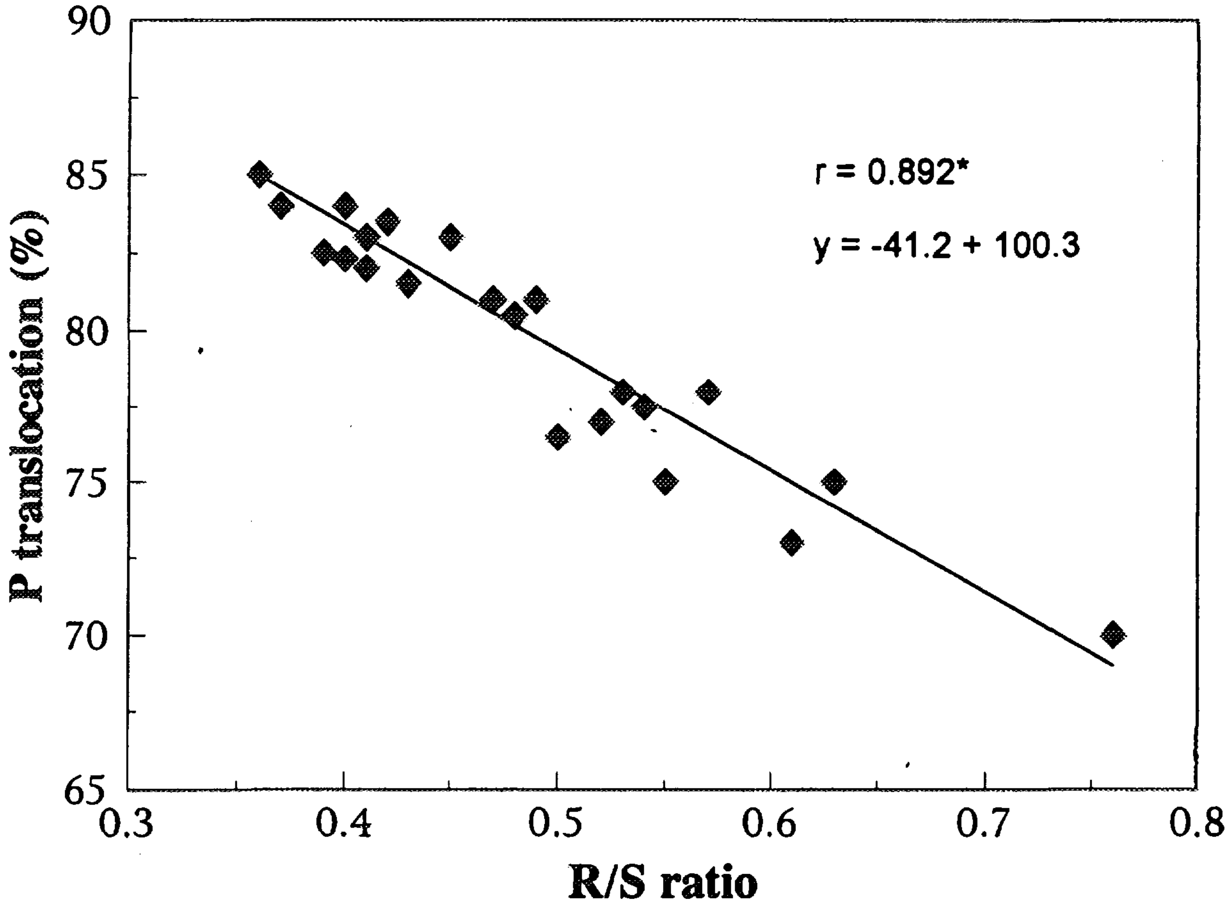

Fig. 1. The relationship between R/S ratio and % P translocation to shoot in rice.

3.1.6. P uptake efficiency

The P uptake efficiency (mg P uptake g $^{-1}$ root dry matter) is given in Appendix Table XXXVI. Across P levels, all genotypes had significantly greater P uptake/mg root at 20 ppm and greater again at 40 ppm (80 ppm in the case of IR-42). However, for Pokkali, IR-9884 and IR-42 the P uptake mg $^{-1}$ root changed little in the P levels 40, 80 and 120 ppm. By contrast P uptake mg $^{-1}$ root of Lalka Motka continually increased over all five P/levels.

At 0 P, with the exception of IR-42 which had significantly higher uptake than Pokkali and IR-9884, there was little differece between the other 4 genotypes. At 120 ppm IR-9884 was significantly lower than all other genotypes and at 40, 80 and 120 ppm IR-9884 and IR-42 were consistently lower than the other 3 genotypes, often significantly so. At 20 to 120 ppm Lalka Motka and KDM-105 were consistently higher.

3.1.7. % P translocated to shoots

The % P translocated to the shoots (Appendix Table XXXVII) shows significant increases in each genotype between 0 and 20 ppm, but no difference beyond 40 ppm.

Interestingly, at each P level significant differences occured between various genotypes with IR-9884 consistently translocating less to the shoot. Only moderately good correlation (r = 0.723, y = 0.623x + 71.2) was obtained between % P translocated and total P uptake (Fig. 1) with no significant differences in the slope between the genotypes, possibly due to there being only 5 points for each genotype. On the other hand there was a high correlation (r = 0.892*) between % P translocated and R/S ratio (Fig. 1). The relationships for the 5 genotypes were not significantly different: IR-9884 had significantly higher R/S ratios than all other genotypes at all P levels.

3.1.8. Phosphate Use Efficiency

As expected PUE (Table III) of the shoot decreased with increasing P levels and increasing %P. Genotypic difference apparently occurred between genotypes, but this was largely due to differences in % P in the shoots.

However, while PUE was highly (negatively) correlated (r = 0.940*, y = -1.97x + 0.917) with % P in the shoots for all genotypes considered together (Fig. 2), the slope of the relationship

TABLE III. GENOTYPIC DIFFERENCES IN PHOSPHATE USE EFFICIENY OF RICE AT DIFFERENT P LEVELS

Genotype	P Level					LSD at 5%
	Control	20 ppm	40 ppm	80 ppm	120 ppm	
	g dry matter yield in shoot mg P $^{-1}$ in shoot					
Lalka Mokta	0.75	0.53	0.40	0.43	0.31	0.05
Pokkali	0.75	0.56	0.44	0.39	0.36	0.07
IR-9884	0.59	0.48	0.38	0.34	0.32	0.03
IR-42	0.61	0.47	0.42	0.40	0.36	0.02
KDM-105	0.60	0.43	0.33	0.32	0.26	0.04
LSD at 5%	0.08	0.03	0.03	0.03	0.02	

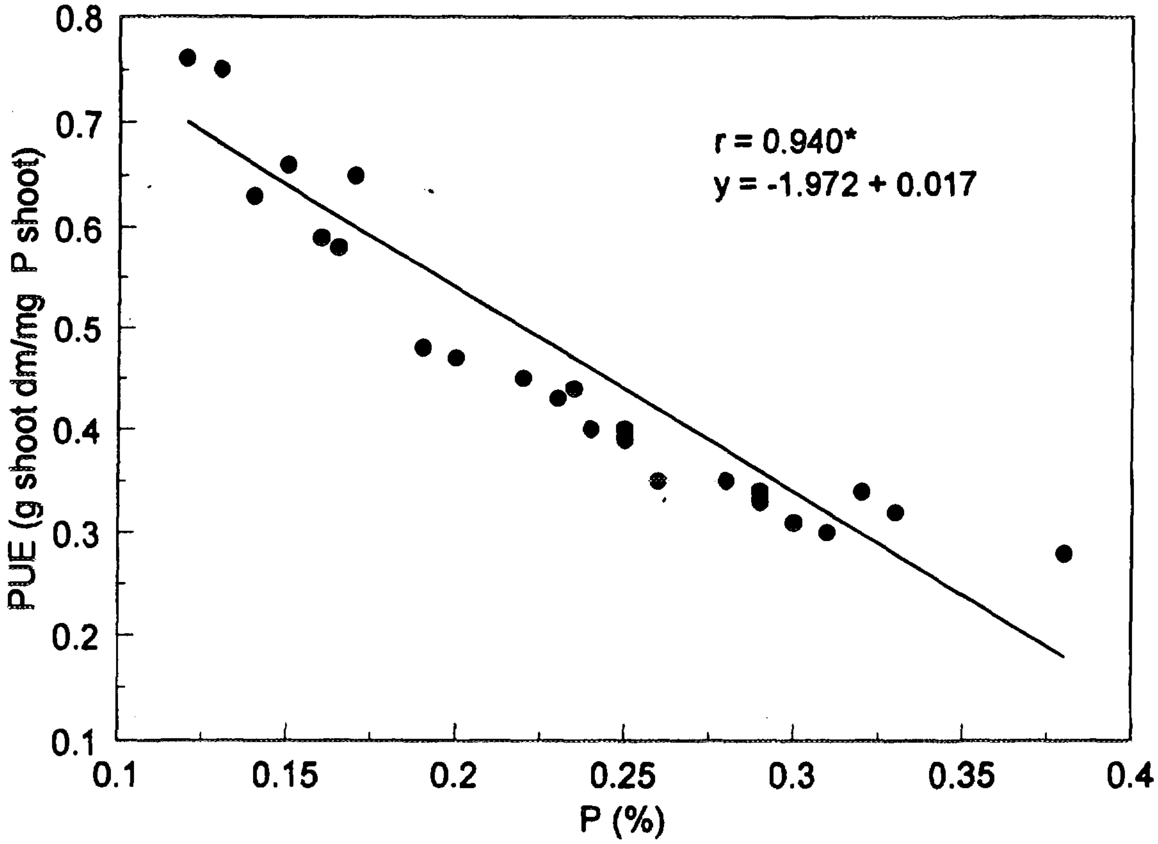

Fig. 2. The correlation between % P and phosphate use efficiency in rice.

for IR-42 ($y = -2.88x + 1.05$) was significantly different from that for IR-9884 and KDM-105 ($y = -1.89x + 0.89$ and $y = -1.54x + 0.82$, respectively). IR-42 had greater PUE, especially at the higher %P.

3.1.9. Net photosynthesis rate

Despite apparent large genotype differences in net photosynthetic rates (NPR) across P levels (Appendix Table XXXVIII), many of these disappeared when NPR was examined as a function of shoot P %. However, some significant differences were recorded between genotypes at the same shoot P level. For example, Table 8 indicates genotypes paired for the same % P but with significant differences in NPR.

However, these data are at the lower % P levels which may be sensitive to small changes in % P and errors are involved in assuming the % P of the shoot is identical to that of the leaf measured for NPR.

Generally, NPR was at a maximum at 0.26-0.30 % P and a feature of the data is the relatively uniform NPR of Lalka Motka through a concentration range of 0.135 to 0.324 % P.

4. DISCUSSION

The data clearly show genotypic differences in shoot and root growth, not only in phosphate deficient soil but also under phosphate sufficiency. The fact that the rankings were the same under both the phosphate sufficient and phosphate deficient conditions indicates basic differences in growth potential which are still expressed under phosphate deficient conditions. Of particular interest is IR-42 which achieved full growth potential only with a higher level of P than other genotypes. This is probably a reflection of the lower root development of that genotype under the test condition limiting phosphate uptake.

Root growth differences between genotypes did not always correspond with shoot growth differences. The lack of correspondence between genotypes in root growth and shoot growth is further indicated in R/S ratios. Of particular note was the consistently high root/shoot ratio of IR-9884 over all P applications. This was, no doubt, an important factor in the consistently lower translocation of P to the shoot by this genotype.

Full growth potential in all genotypes except KDM-105 was achieved at shoot P level of 0.23-0.26%. With KDM-105 it appeared to be closer to 0.30%, and this may be related to a consistently lower phosphorus use efficiency than other genotypes with equal or greater shoot P contents.

When P uptake was calculated g^{-1} root, at 0 P, uptake was not significantly different between all genotypes with the exception of IR-42 which was significantly greater than that of two others. At all other P levels, differences between other genotypes in this characteristic were generally small, with the exception of Lalka Motka and KDM-105 at 80 ppm and 120 ppm which were significantly larger than the other 3 genotypes. High correlations between phosphate uptake and root length in low phosphate soils have been obtained by other workers which do not hold so well in high phosphate soils [4].

Root length is particularly important for poorly diffusing ions such as phosphate when supply, not uptake ability, is limited. Root weight/root length coversions may differ between genotypes and phosphate because of differences in root diameter and percentages of 1°, 2° and 3° lateral limiter levels [5]. Such factors and possible differences in root hair growth may have been important in differences between genotypes in uptake mg $^{-1}$ root and require further study. Nevertheless, it may be that at higher P levels, supply of phosphate to the root is less limiting and differences in uptake potential of the root become more important [6], this leading to a lowering of correlation between root length and uptake of phosphate. The probable importance of physiological differences in phosphate uptake ability in medium to higher phosphate soils has been indicated by Nielsen and Schjørring [3] and Römer et al [4].

The amounts of nutrient transported to the shoot are all important for shoot growth and photo-assimilation. Genotypes differed in this at all P/levels. These, however, are not likely to reflect basic differences in physiology for translocation appears to be determined by root/shoot ratio and total P uptake. Genotype IR-9884 had consistently higher root/shoot ratios and lowered % translocations. Similarly, there was increasing translocations with increased P uptake.

This study has also indicated some genotypic differences in phosphate use efficiency within the shoots and these may or may not be related to possible differences in NPR vs %P - a factor which needs to be examined more precisely than was possible in this study. The distribution of assimilate is a further important aspect for study. Indeed, it is essential that studies such as the above be performed in the field and upto grain production. For example, genotype differences have been found in wheat in uptake of nitrogen following anthesis [7] and in nitrogen redistribution in maize hybrids [8].

Referring to the two genotypes in this study with significantly higher shoot growth, Lalka Motka and Pokkali, how did they achieve their success? They both had relatively low root/shoot ratios ensuring a high translocation of P to the shoot and a relatively good PUE. They both had greater P uptake than two of the poor performers (IR-9884 and KDM-105), in one case achieved by greater root growth and in the other by enhanced P uptake mg $^{-1}$ root, especially at higher P levels. The study shows there are genotypic differences in root growth, P uptake mg $^{-1}$ root (especially in the medium to high P applications), differences in R/S ratios which flows on to translocation of absorbed P and in physiological phosphate use efficiencies, all of which would be valuable selection criteria [9] in selecting/breeding for P efficient genotypes.

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SUMMARY AND CONCLUSIONS

Developing countries in Africa struggling to increase food production face a dilemma in the form of limited essential physical resources such as arable land, water, nutrients and energy, and the limited availability of proper technologies. The situation is exacerbated by high population growth rates which make it even more challenging for Governments to achieve the elusive goal of food security and alleviating poverty. Due to intensive cropping, shorter fallow periods and the removal of nutrients in the produce, yields are often reduced to one third within one to two years. For economic reasons, farmers in many developing countries cannot afford the luxury of expensive soil inputs. In this situation, a more rational approach would be to identify genotypes of species which are efficient in the uptake and use of soil resources for plant productivity and to integrate these with minimum inputs of fertilizers where necessary. In order to investigate this approach, a Co-ordinated Research Programme on the use of isotope studies on increasing and stabilizing plant productivity in low phosphate and semi-arid and sub-humid soils of the tropics and sub-tropics was initiated in October 1989 and completed in October 1994. The programme was reviewed annually by a team from the Swedish International Development Authority (SIDA) which funded this CRP. In addition, a mid-term review was conducted by Dr. V. Middelboe of the Department of Mathematics and Physics, Royal Veterinary and Agricultural University, Fredereiksberg, Denmark from 5-20 December 1991. The Soil Science Unit of the FAO/IAEA Agriculture and Biotechnology Laboratory at Seibersdorf, Austria carried out back-up research in support of this CRP with assistance from its staff members as well as from collaborators in this programme who visited the laboratory as IAEA Fellows.

1. Phosphorus use efficiency

In Sierra Leone, experiments conducted over the five year period showed large differences in phosphorus use efficiency and in nitrogen fixation among cowpea (*Vigna unguiculata*) cultivars. Two such cultivars IT86D-1010 and IT86D-719 have been identified as exceptionally superior to others in their performance. Root morphological characteristics such as root length, root fineness and vesicular-arbuscular mycorrhizae appear to be responsible for high phosphorus uptake and use efficiency. Multi-locational testing of the cultivars showed that they cannot do well in areas with low rainfall. These cultivars have now have been distributed to farmers through the extension services for large scale production in southern Sierra Leone. It will be possible to assess the economic benefits to farmers and the impact of implementation of this programme will have in the near future in Sierra Leone.

In Egypt, substantial differences in phosphorus use efficiency of wheat (*Triticum aestivum* L.) were observed under field conditions. Detailed studies related to the work in Egypt were conducted in Germany in order to examine the morphological and physiological parameters responsible for high phosphorus use efficiency of wheat. From these results it can be concluded that the main factors contributing to higher phosphorus use efficiency of wheat are: (i) efficient use of assimilates for root-growth which enhance phosphorus acquisition and root branching and thus smaller mean root diameter and longer root hairs, (ii) an efficient phosphorus uptake system, (iii) efficient remobilization of phosphorus from vegetative organs to the grains, and most importantly, (iv) lower phosphorus requirement for grain yield formation because of lower ear number per plant but higher grain number per ear. This information would be invaluable to plant breeders involved in programmes aimed at developing wheat cultivars efficient in phosphorus use and higher grain yields.

In Kenya, *Acacia tortilis, Prosopis juliflora* and *Casuarina equisetifolia* provenances were screened to determine their potential for adaptability under phosphorus limiting conditions as a strategy to exploit genotypic differences in terms of uptake and utilization efficiencies. The results show considerable differences in growth performance and phosphorus use efficiency. *Acacia* provenances show the highest phosphorus use efficiency compared with *Prosopis* and *Casuarina* spp although this was not reflected in the total dry matter yield. However, it was observed that phosphorus application caused an increase in shoot dry matter, height, root collar diameter and root dry matter in the case of *Casuarina*. Similarly, the highest total phosphorus uptake was observed in *Casuarina* and *Prosopis* spp. The results show that phosphorus application probably contributed to reduction in root dry matter and root:shoot ratios of *Acacia* and *Prosopis* but not *Casuarina* spp. Based on these data, *Prosopis* provenances from Zimbabwe (9 and 10), India (6) and Somalia (7) can be considered suitable for introduction into areas where the soils are poor in phosphorus.

In Sudan, studies were concentrated on identification of gum arabic tree (*Acacia senegal* L. Willd) provenances with high efficiency for phosphorus uptake and use. Thirteen provenances were collected from different habitats within the gum belt of the Sudan and a preliminary trial was conducted during the period 1989-1992 at the Gezira Agricultural Research Station at Wad Medani. This study revealed that provenances of *Acacias* differ widely in phosphorus use efficiency, nitrogen yield and dry matter production. All the provenances tested also exhibited a high ability for survival under the dry climatic conditions prevailing in the gum belt of Sudan. Based on differences in phosphorus use efficiency observed in the preliminary study, 4 provenances were selected for a detailed study. The detailed study revealed that provenance 11 (from Goz Asher Forest) is superior to all others in terms of biomass production as well as in phosphorus use efficiency. Although the ability to take up phosphorus was low, this was compensated by having a high root length density enabling the tree to take up a quantity of phosphorus similar to that taken up by other provenances. The ability to convert the absorbed phosphorus into a greater quantity of dry matter made this provenance the best in phosphorus use efficiency. The results suggest that provenance 11 may be a suitable candidate for introduction into the gum belt through its rehabilitation programme in Sudan

Studies conducted at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria have shown that exploiting genetic differences in phosphorus use efficiency and using hedgerow trees selected for high N_2 fixation ability can improve tree establishment and growth on nitrogen and phosphorus poor soils, restore soil fertility and preserve soil from degradation. Soils low in phosphorus and nitrogen are common in the moist savanna climatic zones and consequently growth of hedgerow trees in alley cropping systems might require addition of nitrogen and phosphorus fertilizers. This is difficult for small scale farmers who have limited access to fertilizers and therefore depend only on limited input cropping systems. Field experiments carried out at Fashola (moist savannah) showed large differences in growth and phosphorus use efficiency between N_2 fixing trees such as *Gliricidia sepium*, and non N_2 fixing trees such as *Senna siamea* and *Senna spectabilis*. Provenances or isoline differences in phosphorus use efficiency also occurred within species and were also influenced by level of phosphorus and period of growth. Differences between species and provenances in phosphorus uptake and growth were largely related to differences in physiological phosphorus use efficiency, root length and VAM infection rate, especially in low phosphorus soils. Based on the results generated from this study, *Gliricidia sepium* provenances GS1 and GS2 can be considered as ideal for inclusion into agroforestry systems in areas where the soils are poor in phosphorus.

At the FAO/IAEA Agriculture and Biotechnology Laboratory, three sweet potato cultivars (TIS 2, TIS 3053 and TIS 1487) were tested for phosphorus and nitrogen use efficiency in the presence of two sources of phosphorus, Gafza rock phosphate and triple super phosphate. The results of these preliminary studies indicate that there is considerable genotypic variation among cultivars in the efficiency with which phosphorus and nitrogen are taken up and used to produce biomass. Their response to different sources of phosphorus are also variable. TIS-2 and TIS-1487 have a greater ability to absorb phosphorus from Gafza rock phosphate and produce higher tuber yields indicating their greater potential for using natural sources of phosphate fertilizer more effectively. Gafza rock phosphate also increased accumulation of nitrogen in TIS-1487, a characteristic which will place this cultivar at an advantage when growing in soils low in nitrogen. On an overall basis taking into account tuber yield, phosphorus use efficiency, and nitrogen use efficiency, TIS-2 may be considered the best candidate for introduction into soils poor in nutrients, particularly phosphorus. This study was conducted with a limited number of cultivars due to limited availability of germplasm. In spite of this, the differences in their abilities for phosphorus and nitrogen uptake and use are clearly visible which justifies the need for further research using a broader germplasm base.

2. Water use efficiency

Water is one of the most important limiting factors for crop production in rainfed areas particularly in the arid and semi-arid regions. In Africa, semi-arid soils with an average rainfall of

400 to 600 mm rain and dry sub-humid soils with a rainfall of 600-1000 mm account for some 30 per cent of the land area. Many of these are in relatively highly populated areas which are always at risk of water shortages for crop production. In these areas, overgrazing and harvesting of trees for fuelwood have been a major factor responsible for reduced productivity, increased soil erosion and desertification. Desertification is known to occur at a rate of 6 million ha per annum. Large parts of the developing world also have acute shortages of fuelwood which is the primary source of energy in rural areas and largely irreplaceable by other sources. Recent World Bank figures suggest that by the year 2000, approximately 3 million people will be living in areas where fuelwood is acutely scarce or has to be obtained from elsewhere. In this situation, introduction of tree and crop species with a high efficiency of uptake and use of the limited resources of water would certainly be an asset to increasing plant productivity.

Plant water use efficiency is an important factor for determining crop yields. A recent development in this field is the observation that water use efficiency is correlated with the $^{13}C/^{12}C$ ratios of the plant carbon. The basis of this is physiological. Although factors such as nutrition affect water use efficiency, a more intensive study of $^{13}C/^{12}C$ ratios may be an extremely important way to screen genotypes of plant species for water use efficiency. The method is rapid, non-destructive and relatively inexpensive. In this programme we verified some aspects of this techniques in experiments conducted under field conditions.

In Morocco, during four consecutive years, 20 durum wheat (*Triticum durum* Desf) and bread wheat (*Triticum aestrivum* L.) cultivars were grown under rain-fed conditions and supplementary irrigation with the objective of assessing the possibility of using ^{13}C discrimination (Δ) as a criterion to screen for wheat cultivars that produce high yields and have a better water use efficiency under water deficit conditions. In all four growing seasons, both treatments were subjected to some water stress which was higher under rain-fed conditions and varied according to the intensity and time of rainfall. There was substantial genotypic variation in ^{13}C discrimination. The total aboveground dry matter yield and grain yield were positively correlated with ^{13}C discrimination. Moreover, the ^{13}C discrimination value was also correlated positively with water use efficiency. This is in contrast to greenhouse experiments with wheat where plant water use efficiency and ^{13}C discrimination were negatively correlated. The data suggest that high ^{13}C discrimination values can be used as a criterion for selecting cultivars of wheat that have a relatively higher grain yield potential and high water use efficiency under water deficit conditions. The results of these field experiments are, however, preliminary and may warrant further research, probably under more controlled conditions, before these elite cultivars can be recommended for use by the farmers.

In Tunisia, as in Morocco, the water balance model using a neutron moisture probe and the ^{13}C isotope discrimination methods were used in the field to rank durum wheat genotypes for water use efficiency. The results show differences between cultivars with respect to water use efficiency, ^{13}C discrimination and grain yield. There is again a positive correlation between grain water use efficiency and ^{13}C discrimination.

Studies on water use efficiency of trees were conducted in Kenya and in Sudan. In Kenya, 11 provenances of *Acacia tortilis*, 6 provenances of *Prosopis juliflora* and 4 provenances of *Casuarina equisetifolia* were screened for drought tolerance in a semi-arid site in Machakos. Tolerance to drought was assessed by determining the water use efficiency and ^{13}C isotope discrimination by leaves. The results showed significant differences in ^{13}C discrimination, water use efficiency and dry matter yield by the different provenances tested. There were significant negative linear relationships between ^{13}C discrimination and water use efficiency as well as between ^{13}C discrimination and dry matter yield. The results also show a significant positive relationship between dry matter yield and water use efficiency. *Acacia tortilis* provenances from the Middle East and the neighbouring North Eastern Africa region appear to possess the greatest abilities for drought resistance in comparison with those from sub-Saharan Africa, as indicated by their ^{13}C isotope discrimination levels, dry matter yield and water use efficiency. *Prosopis* provenance from Costa Rica and *Casuarina* from the Dakar region of Senegal also emerged as the best provenances in terms of drought tolerance as shown by the ^{13}C isotope discrimination and dry matter traits.

The study in Sudan concentrated on the gum arabic tree *Acacia senegal* (L) Willd. An experiment was conducted in 1989 to screen *Acacia senegal* provenances collected from within the natural gum belt for high water use efficiency. Thirteen provenances were tested and later 6 of them were selected for further screening. Both the preliminary and the detailed study revealed that provenances 7, 3 and 11 have the combined characteristics of high dry matter production and high water use efficiency. Based on these studies, provenance 11 (which is also efficient in phosphorus use) can be recommended as a suitable candidate for introduction into the gum-belt of Sudan through its rehabilitation programme.

Studies conducted at the Soil Science Unit of the FAO/IAEA Agriculture and Biotechnology Laboratory confirmed the earlier reports of a strong correlation of Δ with grain yield and water use efficiency of wheat. High soil gypsum content and soil salinity, a widespread problem in soils of arid and semi-arid climatic zones, do not interfere with the association of Δ with crop yields, provided plants are grown with a similar soil water status and soil fertility level. Results of a greenhouse experiment using selected cowpea genotypes showed that Δ values measured at the flowering stage positively correlated with total dry matter production and per cent N_2 derived from atmosphere (%Ndfa), contributing to an earlier report from the laboratory that it may be possible to use Δ values for screening of leguminous crops for high N_2 fixation potential. ^{13}C isotope discrimination in the leaves of *Gliricidia sepium* was measured to examine if the technique could be extended to studies with trees. Results of a greenhouse experiment with 18 provenances of *Gliricidia sepium* showed highly significant correlations of Δ with total dry matter production, water use efficiency and total N accumulated through biological nitrogen fixation. While the correlations of Δ with water use efficiency and dry matter yield are reatively clear and better understood, the correlation with nitrogen fixation still needs a closer examination under different environmental conditions and with different species. In some ways, ^{13}C isotope discrimination as a tool for identifying plants with a high water use efficiency and high yield potential would be more attractive for tree species than for annuals considering the often long periods of time taken for trees to grow and produce economic yields either for food, fodder or fuelwood.

The data from experiments conducted in this programme in Morocco, Tunisia, Kenya and at the Soil Science Unit of the FAO/IAEA Agriculture and Biotechnology Laboratory suggest that while ^{13}C discrimination may be used as a criterion for selection of cultivars with high water use efficiency and potential for high yield, caution must be exercised in the selection process as the size of the canopy and the changes in environmental factors, mainly soil water content, can result in changes in the extent of ^{13}C discrimination and the yield of a cultivar. Nevertheless, ^{13}C discrimination of a genotype can provide valuable information with respect to plant parameters responsible for the control of ^{13}C discrimination and this information can be usefully employed in breeding programmes aimed at developing cultivars high in water use efficiency, high in yield, and suitable for cultivation in arid and semi-arid regions of the tropics and sub-tropics.

In conclusion, this five year programme has shown that there is a wealth of genetic diversity among the genotypes of crop and tree species in their capacity for uptake and use of phosphorus and water from soils limited in resources. Morphological as well as physiological parameters of the root system appear to play a significant role in making some genotypes superior to others in their ability to acquire phosphorus and water but the final conversion into dry matter probably depends on other inherent genetic characteristics as well. In Sierra Leone, cowpea cultivars were identified which are high in phosphorus use efficiency. Action has already been taken to multiply the seeds and distribute them to farmers through the agricultural extension services for large scale production in southern Sierra Leone. It will be possible to assess the economic benefits to farmers and the impact of implementation of this programme in Sierra Leone in the near future. In Sudan, an *Acacia senegal* provenance (provenance 11) has been identified which possess the combined characteristics of high water use efficiency and high dry matter yield. This provenance which is also efficient in phosphorus use can be recommended as a suitable candidate for introduction into the gum-belt of Sudan as a contribution to its rehabilitation programme. In other countries, the genotypes of crop and tree species identified should prove to be valuable starting material for plant breeding programmes aimed at developing varieties capable of growing and producing well in soils poor in phosphorus and water, particularly in Africa.

APPENDIX

APPENDIX - EGYPT
TABLE I. SOIL ANALYSIS DATA

Property	Estimate
$CaCO_3$ %	02.2
pH	07.9
EC.dS m^{-1}	02.2
Ca^{+2} meq l^{-1}	04.4
Mg^{+2} meq l^{-1}	02.8
Na^{+} meq l^{-1}	13.4
K^{+} meq l^{-1}	00.8
HCO_3^{-} meq l^{-1}	03.5
Cl^{-} meq l^{-1}	08.6
SO_4^{-2} meq l^{-1}	07.3
$NaHCO_3$ extractable - mg P $100g^{-1}$	00.5
Sand %	86.0
Silt %	07.8
Clay %	06.2
Textural class	Loamy sand

APPENDIX - EGYPT
TABLE II. SEEDING RATE, PLANT HIGHT, AND WEIGHT OF 100 GRAINS

No	Cultivar	Seeding rate g $20m^{-2}$	Plant height cm	Weight of 100 grains g
1	Giza 155	138.2	104	5.03
2	Giza 156	137.6	112	4.69
3	Giza 157	126.0	088	4.44
4	Giza 158	147.4	100	5.14
5	Giza 160	142.4	106	5.07
6	Giza 162	119.2	110	4.07
7	Giza 163	132.4	110	4.86
8	Giza 164	142.8	120	5.09
9	Giza 165	145.0	115	4.78
10	Sakha 8	140.6	100	4.69
11	Sakha 61	151.4	099	5.45
12	Sakha 69	150.0	088	5.57
13	Sakha 92	098.8	095	3.67
14	Sohag 1	172.2	088	6.33
15	Sohag 2	163.8	095	5.22
16	Baniswef 1	158.4	095	5.76
17	Gemaza 1	173.8	099	5.41
18	Sohag 3	137.6	100	4.80

APPENDIX - EGYPT

TABLE III. EFFECT OF P SUPPLY (KG P HA^{-1}) ON THE TOTAL DRY BIOMASS (KG M^{-2}) AND THE NUMBER OF SPIKES PER SQUARE METER, AT DIFFERENT DEVELOPMENT STAGES OF 18 WHEAT GENOTYPES UNDER FIELD CONDITION

		Development stages					
Gen.		Shooting	FLE	Anthesis		Maturity	
	P	A	A	B	A	B	A
	P1	0.114	0.358	227	0.71	163	0.798
1	P2	0.144	0.358	273	0.81	175	0.960
	P3	0.162	0.360	285	0.65	180	0.967
	P1	0.101	0.383	256	0.51	114	0.567
2	P2	0.117	0.650	288	0.68	177	0.760
	P3	0.138	0.721	293	0.64	187	0.847
	P1	0.130	0.211	174	0.58	142	0.614
3	P2	0.131	0.228	199	0.75	160	0.840
	P3	0.159	0.287	211	0.77	223	0.869
	P1	0.135	0.251	232	0.50	134	0.452
4	P2	0.138	0.294	333	0.66	182	0.675
	P3	0.151	0.306	289	0.65	184	0.734
	P1	0.117	0.333	171	0.50	168	0.690
5	P2	0.127	0.340	202	0.73	220	0.907
	P3	0.151	0.343	226	0.77	236	0.961
	P1	0.119	0.356	172	0.70	134	0.719
6	P2	0.124	0.364	201	0.91	148	0.797
	P3	0.127	0.367	214	0.96	159	0.819
	P1	0.124	0.321	180	0.67	170	0.610
7	P2	0.135	0.322	237	0.90	229	0.790
	P3	0.141	0.333	240	0.93	262	0.953
	P1	0.127	0.271	188	0.70	171	0.798
8	P2	0.129	0.292	205	0.92	227	0.908
	P3	0.129	0.320	217	0.95	230	0.948
	P1	0.145	0.295	214	0.76	184	0.793
9	P2	0.162	0.299	218	0.77	202	0.832
	P3	0.167	0.321	219	0.83	241	0.878
	P1	0.126	0.202	192	0.91	196	0.848
10	P2	0.184	0.272	219	0.94	222	0.899
	P3	0.164	0.282	249	1.05	231	1.031
	P1	0.127	0.242	214	0.75	205	0.898
11	P2	0.126	0.258	219	0.84	269	0.949
	P3	0.147	0.283	220	0.86	272	0.981
	P1	0.112	0.280	177	0.72	196	0.701
12	P2	0.126	0.287	200	0.91	222	0.872
	P3	0.138	0.291	202	0.99	230	0.899
	P1	0.132	0.236	181	0.59	167	0.751
13	P2	0.139	0.252	184	0.69	200	0.825
	P3	0.140	0.258	203	0.70	261	0.851
	P1	0.121	0.161	176	0.43	142	0.663
14	P2	0.122	0.229	179	0.65	164	0.745
	P3	0.125	0.238	178	0.67	205	0.783

APPENDIX - EGYPT
TABLE III. Continued

15	P1	0.094	0.201	185	0.65	179	0.771
	P2	0.114	0.201	186	0.67	198	0.816
	P3	0.117	0.209	208	0.70	200	0.959
16	P1	0.079	0.247	200	0.49	127	0.546
	P2	0.114	0.340	206	0.53	166	0.573
	P3	0.115	0.368	195	0.61	175	0.597
17	P1	0.112	0.236	151	0.63	163	0.677
	P2	0.121	0.238	174	0.71	204	0.736
	P3	0.125	0.250	175	0.73	235	0.858
18	P1	0.111	0.259	130	0.41	156	0.753
	P2	0.115	0.264	137	0.43	165	0.757
	P3	0.119	0.270	136	0.44	176	1.053
LSDo	05	0.0289	0.0573	23.1	0.021	46.3	0.076
		0.0139	0.0275	14.2	0.009	21.9	0.019

A = Dry weight, and B = number of spikes.
FLE = Flag leaf emergence

APPENDIX - EGYPT
TABLE IV. SHOOT BIOMASS AT 4 DEVELOPMENTAL STAGES OF WHEAT GROWN IN THE FIELD AS AFFECTED BY P SUPPLY

P supply kg ha^{-1}	Shoot biomass production kg dry matter ha^{-1}			
	Tillering	Flag leaf appearance	Anthesis	Maturity
8.3	1181	2691	6228	7027
25.0	1299	3049	7500	8134
75.0	1398	3226	7922	8882

Values are means of 18 cultivars

APPENDIX - EGYPT

TABLE V. EFFECT OF P-SUPPLY ON THE ROOT DENSITY (CM-CM^{-3}) VESICULAR-ARBUSCULAR MYCORRHIZA INFECTION (%) OF WHEAT CULTIVARS UNDER FIELD CONDITIONS, AT DIFFERENT PLANT DEVELOPMENT STAGES

Gen.		Shooting		Flag leaf appearance		Anthesis	
	P	A	B	A	B	A	B
	1	0.12	00	0.61	5	0.73	28
1	2	0.22	00	0.82	3	1.35	27
	3	0.64	00	0.84	<2	1.26	27
	1	0.44	00	0.87	<2	1.62	26
2	2	0.19	00	1.00	6	1.40	16
	3	0.24	00	0.68	<2	1.02	10
	1	0.99	00	1.62	7	2.37	26
3	2	0.44	00	1.01	<2	1.38	23
	3	0.56	00	1.09	<2	2.38	14
	1	0.36	00	1.00	9	1.48	19
4	2	0.99	00	1.56	3	2.11	13
	3	0.22	00	0.51	3	0.70	10
	1	0.43	00	1.00	6	1.27	65
5	2	0.11	00	0.24	3	0.56	27
	3	0.66	00	0.92	3	1.15	26
	1	0.89	00	2.00	1	3.42	51
6	2	0.21	00	0.62	6	1.01	26
	3	0.61	00	0.90	5	1.15	16
	1	0.11	00	0.15	17	0.37	34
7	2	0.33	00	0.45	7	0.87	18
	3	0.79	00	1.36	<2	1.70	13
	1	0.15	00	0.28	4	0.59	65
8	2	0.87	00	1.11	4	1.93	44
	3	0.81	00	0.58	<2	0.79	08
	1	0.42	00	0.88	1	1.28	58
9	2	0.36	00	0.99	4	1.71	36
	3	0.53	00	0.75	4	1.24	33
	1	0.44	00	0.55	4	1.06	51
10	2	0.71	00	0.79	5	0.92	16
	3	0.19	00	0.61	3	1.57	14
	1	0.19	00	0.25	16	0.65	52
11	2	0.43	00	0.66	4	0.92	26
	3	0.24	00	0.51	<2	0.82	26
	1	0.28	00	0.66	11	0.97	70
12	2	0.31	00	0.41	4	0.52	56
	3	0.26	00	0.80	<2	1.34	33
	1	0.15	00	0.61	2	1.00	33
13	2	0.71	00	0.93	3	1.75	21
	3	0.66	00	0.98	2	1.24	18
	1	0.97	00	1.42	<2	2.41	33
14	2	0.55	00	1.09	<2	2.84	29
	3	0.60	00	1.00	<2	1.19	08
	1	0.34	00	0.69	<2	1.03	43
15	2	0.52	00	0.87	<2	1.42	21
	3	0.87	00	0.97	<2	1.67	27
	1	0.40	00	0.57	<2	1.01	30
16	2	0.25	00	0.44	<2	1.11	26
	3	0.36	00	0.55	<2	0.99	13
	1	0.25	00	0.39	<2	1.06	55
17	2	0.39	00	0.63	<2	0.78	26
	3	0.36	00	0.67	<2	1.41	18

A = Root density, and B = VAM infection rate (%).

APPENDIX - EGYPT

TABLE VI. EFFECT OF P SUPPLY ON TOTAL ROOT VOLUME, ROOT DRY MATTER, ROOT DENSITY, AND VAM INFECTION RATE OF WHEAT UNDER FIELD CONDITIONS, AND ROOT VOLUME, ROOT DRY MATTER, AND ROOT LENGTH OF WHEAT GROWN IN NUTRIENT SOLUTION

		Field experiment				Nutrient solution		
Geno type	P level	Volume (cm^3 l^{-1})	Dry matter (mg pl.$^{-1}$)	Density (cm cm^3)	VAM (%)	Volume (cm^3 l^{-1})	Dry matter (mg pl.$^{-1}$)	Length (m pl.$^{-1}$)
1	1	3.00	356	0.73	28	-	-	-
	2	3.41	491	1.35	27	-	-	-
	3	4.79	584	1.26	27	-	-	-
2	1	1.71	228	1.82	26	-	-	-
	2	2.62	289	1.40	16	-	-	-
	3	1.90	283	1.02	10	-	-	-
3	1	2.92	400	2.37	28	0.487	27.34	09.38*
	2	4.93	338	1.38	23	-	-	-
	3	3.22	434	2.38	14	0.971	43.38	12.73**
4	1	2.32	402	1.48	19	0.492	30.85	10.96*
	2	3.43	520	2.11	13	-	-	-
	3	2.50	409	0.70	10	1.290	47.47	10.66**
5	1	2.01	400	1.27	65	0.603	38.71	13.25*
	2	2.60	326	0.56	27	-	-	-
	3	3.17	588	1.15	25	1.237	46.32	13.68**
6	1	2.91	480	3.42	51	-	-	-
	2	2.08	279	1.01	28	-	-	-
	3	2.33	346	1.15	16	-	-	-
7	1	2.76	055	0.37	34	0.485	31.	10.19*
	2	1.94	214	0.87	18	-	-	-
	3	2.07	292	1.70	13	0.933	37.40	08.23**
8	1	2.13	240	0.59	65	0.494	29.55	07.21*
	2	2.47	362	1.93	44	-	-	-
	3	1.62	166	0.79	08	1.058	43.10	12.74**
9	1	3.19	537	1.28	58	0.449	25.00	8.10*
	2	3.46	335	1.71	36	-	-	-
	3	2.62	219	1.24	33	0.965	38.61	08.25**
10	1	3.37	155	1.06	51	0.507	28.68	8.80*
	2	1.87	233	0.92	16	-	-	-
	3	3.09	413	1.57	14	1.131	44.343	11.57**
11	1	3.41	295	0.65	52	0.590	35.00	10.49*
	2	3.27	178	0.92	28	-	-	-
	3	3.41	141	0.82	28	1.129	47.37	09.73**
12	1	1.86	233	0.97	70	-	-	-
	2	1.86	162	0.52	56	-	-	-
	3	1.76	261	0.34	33	-	-	-
13	1	2.90	301	1.00	33	0.467	2852	10.31*
	2	2.70	234	1.75	21	-	-	-
	3	2.28	316	1.24	18	0.827	35.30	10.12**
14	1	2.67	287	2.41	33	0.466	29.68	05.77*
	2	2.88	329	2.84	29	-	-	-
	3	2.14	196	1.19	08	0.860	36.93	07.76**
15	1	3.19	331	1.03	43	-	-	-
	2	2.17	381	1.42	21	-	-	-
	3	2.95	413	1.67	27	-	-	-
16	1	2.20	353	1.01	30	-	-	-
	2	2.73	422	1.11	26	-	-	-
	3	2.55	453	0.99	13	-	-	-
17	1	1.75	161	1.06	55	-	-	-
	2	2.05	236	0.78	26	-	-	-
	3	2.16	321	1.41	18	-	-	-
18	1	2.85	269	2.19	22	-	-	-
	2	2.65	342	2.32	17	-	-	-
	3	1.78	273	3.02	12	-	-	-

APPENDIX - EGYPT
TABLE VII. ORIGIN OF WHEAT GENOTYPES

No.	Genotype	Origin	Year	Species	Yield t/ha
1	Giza 155	Regent/2*Giza 139//Mida-Cadet/2* Hindi 62	. 1968	W	4.0
2	Giza 156	Rio Negro/2*Mentane// Kenya/3/*2 Giza 135/l ino 950	1972	W	4.2
3	Giza 157	Giza 155/pit 62/LR 64/3/Tzpp/Knott	1977	W	5.1
4	Giza 158	Giza 156/7C	1977	W	4.4
5	Giza 160	Chemab 70/ G. 155	1982	W	5.3
6	Giza 162	Vcm/Cno 67"5" 7C/3/Kal/ Bb Pavon "S" CM 8290D-4M 3M-3m-14-1 m	1987	W	6.0
7	Giza 163	*T. aestivum*/Bon/Con/7C	1987	W	6.3
8	Giza 164	Kvz/Buha "S"//Kal/Bb-Veery "S"	1987	W	5.3
9	Giza 165	Cno/Mfd/Man "S"	1991	W	6.3
10	Sakha 8	Indus/Noreno "S" 34/8-65-1-sw-O5	1977	W	4.7
11	Sakha 61	Inia / 4220//7C/Yr "S"	1980	W	5.6
12	Sakha 69	--	1980	W	6.0
13	Sakha 92	Napo 63/Inia 66/ Wern "S" 1551-15-15	1987	W	5.7
14	Gemmeizal	Maya 74 "S" //Kal/Bb=Veery "S"	1987	W	6.5
15	Sohag 1	Gdo vz 469/JO "S"//61.130-Lds	1977	D	6.7
16	Sohag 2	Cr "S"/ Pelicano //Cr"S"/G "S" sh19-1sh-osh.	1987	D	6.6
17	Sohag 3	Mexi "S" Mgha/51792//Durum 6	1991	D	6.0
18	Beni Swief 1	Jo "S"/AA "S" // Fg "S"	1987	D	5.9

W = *Triticum aestivum*; D = *Triticum durum*

APPENDIX - EGYPT

TABLE VIII. MONTHLY METEOROLOGICAL DATA OF ISMAILIA LOCATION DURING 1992-93 AND 1993-94 SEASONS

Season	Month	Temperature (°C)			Relative humidity (%)	Rain fall (mm)
		Max.	Min.	Mean		
1992-93	November	23.6	11.9	17.8	65.3	0.0
	December	19.4	8.7	14.1	69.0	1.6
	January	17.8	6.9	12.4	69.0	2.1
	February	15.3	6.8	11.1	71.0	6.4
	March	22.0	10.1	16.1	58.7	1.1
	April	24.8	11.6	18.2	58.0	0.0
1993-94	November	25.9	14.6	20.3	65.3	0.0
	December	22.2	11.4	16.8	75.7	2.2
	January	20.6	10.2	15.4	70.0	2.7
	February	21.1	9.1	15.1	63.1	5.5
	March	22.7	10.6	16.7	63.0	0.9
	April	26.9	11.2	19.1	62.0	0.0

Data - Courtesy: Water Requirement Section, Agricultural Research Center, Suez Canal.

APPENDIX - EGYPT
TABLE IX. PERFORMANCE FOR WHEAT CULTIVARS BASED ON RESULTS OF TWO SEASONS

Cultivars	Grain yield kg/ha	Straw yield g/ha	1000 grains weight g	No. of grains per spike	No. of spikes per m^2	Total biomass kg/ha	Protein %	Phytin	WUE kg/mm
Giza 155	3600	5225	48.1	38.1	171.5	8825	11.74	3.34	10.75
Giza 156	2870	3230	40.4	36.0	119.0	6100	11.29	2.0	8.35
Giza 157	2900	4515	44.5	35.3	182.5	7415	11.47	3.21	08.50
Giza 158	2700	3230	52.2	36.1	159.0	5930	13.64	2.67	7.75
Giza 160	4240	4015	52.0	44.4	202.0	8255	10.48	2.59	12.30
Giza 162	3600	4090	41.4	29.4	146.5	7690	10.05	3.11	10.10
Giza 163	3580	4235	48.0	36.4	216.0	7815	11.42	3.15	9.90
Giza 164	4010	4720	50.5	38.9	200.5	8730	10.75	3.34	12.30
Giza 165	3950	4405	47.9	19.6	212.5	8355	10.69	2.99	12.35
Sakha 8	4850	4545	44.7	45.3	213.5	9395	10.00	2.99	14.00
Sakha 61	4140	5255	54.5	37.5	238.5	9395	8.34	3.47	12.28
Sakha 69	3980	4020	55.7	37.0	213.0	8000	9.56	3.31	11.80
Sakha 92	4050	3955	37.8	25.9	214.0	8010	11.13	2.72	11.45
Gemmeiza 1	3970	4005	53.3	19.0	199.0	7675	11.23	4.02	10.75
Sohag 1	3610	3620	64.1	35.3	173.5	7230	10.27	2.72	10.00
Sohag 2	3490	5160	52.1	44.8	189.5	8650	10.78	3.72	08.62
Sohag 3	2650	5610	46.9	18.3	166.0	8260	12.65	2.82	11.95
Beniswef 1	340	2725	47.1	43.4	151.0	5715	13.11	3.22	08.30
L.S.D. 5%	1000	1310	02.8	05.1	046.3	0716	01.43	0.42	00.11

APPENDIX - EGYPT

TABLE X. EFFECT OF IRRIGATION LEVEL ON GROWTH AND YIELD PARAMETERS, AND WATER USE EFFICIENCY (WUE)

Treatment	Grain yield kg/ha	Straw yield kg/ha	1000 grains weight g	No. of grains per spike	No. of spikes per m^2	Total biomass kg/ha	Protein %	Phytin %	WUE kg/mm
W1	3468	3818	48.8	33.75	161.7	7462	11.80	3.34	12.21
W2	4000	4689	50.2	34.63	212.4	8689	10.27	2.80	09.07
L.S.D. 5%	0430	0230	01.40	02.40	021.9	0195	00.46	0.19	00.04

W1 = 271 mm irrigation water supply; W2 = 441 mm irrigation water supply

APPENDIX - SIERRA LEONE

TABLE XI. COWPEA CULTIVARS USED IN EXPERIMENTS CONDUCTED FROM 1990 TO 1994

1990	1991	1992*	1993*	1994*
1 IT82E-32	IT82E-32	IT86D-1010(E)	IT86D-1010	IT86D-1010
2 IT86D-1010	IT86D-1010	IT86D-719(E)	IT86D-719	IT81D-832
3 IT86D-719	IT86D-719	IT81D-832(IE)	TEMNE(local)	TEMNE(local)
4 IT82D-699	IT82D-699	IT87S-1462(I)		
5 IT87S-1462	IT87S-1462	TEMNE(local)(I)		
6 IT85D-3577	IT85D-3577			
7 IT87S-1451	IT87S-1451			
8 IT83S-872	IT83S-872			
9 IT85E-2687	IT85E-2687			
10 IT81D-832	IT81D-832			
11 TEMNE(local)	TEMNE(local)			

*Cultivars with contrasting P use efficiencies were used: E = Efficicient; IE = Intermediate efficient; I = Inefficient

APPENDIX - SIERRA LEONE
TABLE XII. CLIMATIC DATA OF THE TRIAL SITES

Location	September		October		November		December	
Rainfall (mm) 1993								
South Njala Hendobu	681.0		481.6		130.0		13.0	
North Makeni	559.6		443.3		93.0		0.0	
Temp. (°C)1993	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
South Njala Hendobu	21.5	31.6	21.4	30.2	21.9	32.8	20.5	33.2
North Makeni	20.7	29.7	21.3	31.7	21.0	32.5	16.0	32.8

APPENDIX - SIERRA LEONE
TABLE XIII. SIOL ANALYSIS DATA

Trial site	pH	Available P (ppm)	%N	%OM
Njala	4.9	7.05	0.33	6.76
Hendobu	5.1	7.98	O.17	2.69
Makeni	6.7	5.71	0.27	3.73

APPENDIX - SIERRA LEONE

TABLE XIV. EFFECT OF P SUPPLY ON TOTAL PUE (KG DM/KGP) OF 5 COWPEA CULTIVARS AT DIFFERENT STAGES OF GROWTH

Cultivars	P rate (kg/ha)				Mean
	0	15	30	60	
14 DAE					
IT86D-1010(E)*	214.75	199.00	186.75	179.25	194.94
IT86D-719(E)	190.00	198.00	190.50	192.50	192.75
IT81D-832(IE)*	230.75	202.00	203.50	183.50	198.19
IT87S-1462(I)*	212.50	190.50	187.75	174.25	191.25
TEMNE(local check/I)	212.50	177.50	185.50	172.00	186.88
Mean	206.70	193.40	190.80	180.30	
50% flowering					
IT86D-1010	481.75	421.50	410.00	392.25	426.38
IT86D-719	496.00	459.00	451.00	390.50	449.13
IT81D-832	481.25	455.75	441.75	378.75	439.38
IT87S-1462	433.00	369.00	348.75	348.50	374.81
TEMNE(local check)	463.25	425.50	417.75	410.00	429.13
Mean	471.05	426.15	413.85	384.00	
Maturity					
IT86D-1010	632.75	559.25	478.75	486.75	539.38
IT86D-719	498.50	535.25	552.25	500.00	521.50
IT81D-832	711.25	644.75	557.00	558.75	617.94
IT87S-1462	690.50	548.00	488.25	499.00	556.44
TEMNE(local check)	573.50	592.00	532.00	476.75	543.63
Mean	621.30	575.85	521.70	504.25	

* E = Efficient , IE = Intermediate Efficient, I = Inefficient

APPENDIX - SIERRA LEONE

TABLE XV. EFFECT OF P SUPPLY ON GRAIN P YIELD AND PUE OF 4 COWPEA CULTIVARS

Cultivars	P rate(kg/ha)					
	0	15	Mean	0	15	Mean
	Grain P yield(kg/ha)			Grain PUE(kg grain/kgP)		
IT86D-1010(E)*	1.2	2.6	1.9	292.3	227.5	259.9
IT86D-719(E)	1.2	2.8	2.0	267.5	210.8	239.2
IT87S-1462(I)*	0.8	1.7	1.3	294.8	238.0	266.4
TEMNE(local check/I)	0.6	1.3	1.0	252.8	222.5	237.7
Mean	0.9	2.1		276.9	224.7	

Lsd(0.05)	Grain P yield	Grain PUE
Cultivar	0.5	11.4
P rate	0.7	30.9
C x P	NS	16.2

* E= Efficient I= Inefficient

APPENDIX - SIERRA LEONE

TABLE XVI. CORRELATION BETWEEN TOTAL AND GRAIN P USE EFFICIENCY AND SOME YIELD PARAMETERS OF COWPEA CULTIVARS AT DIFFERENT STAGES OF GROWTH

Cultivars	Total PUE	Grain PUE
14 DAE		
Dry matter yield(kg/ha)	-0.47ns	
P yield(kg/ha)	-0.57ns	
50% Flowering		
Dry matter yield(kg/ha)	-0.04ns	
P yield(kg/ha)	-0.19ns	
Maturity		
Grain yield(kg/ha)	-0.33ns	-0.60ns
Dry matter(Kg/ha)	-0.46ns	-0.60ns
P yield(kg/ha)	-0.53ns	-0.35ns

ns means not significant at $P > 0.05$

APPENDIX - SIERRA LEONE

TABLE XVII. EFFECT OF P SUPPLY ON NODULATION OF 5 COWPEA CULTIVARS AT FLOWERING

Cultivars	P rate (kg/ha)									
	0	15	30	60	MEAN	0	15	30	60	MEAN
	Nodule number/plant					Nodule dry wt.(mg/plant)				
IT86D-1010(E)*	15	18	33	38	26	22.5	22.5	52.5	62.5	40.0
IT86D-719(E)	22	23	26	36	26	28.8	53.8	88.8	140.0	77.9
IT81D-832(IE)*	17	20	26	26	22	16.3	26.3	38.8	43.8	31.3
IT87S-1462(I)*	11	12	18	20	15	13.8	16.3	28.8	36.3	23.8
TEMNE(local check/I)	14	15	20	24	18	15.0	20.0	36.3	43.3	
MEAN	16	18	25	28		19.3	27.8	49.0	62.3	

* E= Efficient, IE= Intermediate Efficient, I= Infficient

APPENDIX - SIERRA LEONE
TABLE XVIII. CORRELATION BETWEEN TOTAL AND GRAIN P USE EFFICIENCY AND NITROGEN FIXATION OF COWPEA CULTIVARS AT DIFFERENT STAGES OF GROWTH

Parameter	Total PUE	Grain PUE
14 DAE		
N fixed(kg/ha)	-0.40ns	
50% flowering		
N fixed(kg/ha)	-0.16ns	
Maturity		
N fixed(kg/ha)	-0.49ns	-0.48ns

ns means not significant at $P > 0.05$

APPENDIX - SIERRA LEONE
TABLE IXX. SHOOT AND ROOT DRY MATTER YIELDS AND ROOT:SHOOT RATIO OF 3 COWPEA CULTIVARS UNDER LOW AND HIGH P

	P rate(mg P/kg soil)					
Cultivars	0	30	0	30	0	30
	Shoot DW(g/pot)		Root DW(g/pot)		Root:shoot ratio	
IT86D-1010(E)	1.05	1.16	0.24	0.29	0.22	0.26
IT81D-832(IE)	0.81	0.97	0.25	0.28	0.29	0.29
TEMNE(I)	0.34	0.42	0.14	0.16	0.42	0.40
Mean	0.73	0.85	0.21	0.24	0.31	0.31
Lsd(0.05)						
Cultivar	0.17		0.03		0.07	
P-rate	NS		0.03		NS	
C x P	NS		NS		NS	

E = Efficient , IE = Intermediate Efficient, I = Inefficient

APPENDIX - SIERRA LEONE
TABLE XX. ROOT LENGTH(CM/POT), ROOT FINENESS(CM/G/POT) AND MYCORRHIZAL INFECTION(%) OF 3 COWPEA CULTIVARS UNDER LOW AND HIGH P

	P rate (mg P/kg soil)					
Cultivars	0	30	0	30	0	30
	Root length		Root fineness		VAM infection	
IT86D-1010(E)	421.2	648.9	1745.1	2225.9	40.3	59.3
IT81D-832(IE)						
TEMNE(I)	468.1	598.2	1876.8	2155.8	42.3	61.3
Mean	182.2	248.8	1356.6	1669.2	29.8	33.5
	357.2	498.6	1659.4	2016.9	37.5	51.4
Lsd(0.05)						
Cultivar		71.49		348.9		6.6
P-rate		58.37		314.3		5.4
C x P		NS		NS		NS

E = Efficient, IE = Intermediate Efficient, I = Inefficient

APPENDIX - NIGERIA

TABLE XXI. COMPARISON OF DIFFERENT PLANT CHARACTERS OF 20 COWPEA VARIETIES AT ILORA, NIGERIA, 1990-1992 WITH RESPECT TO ADAPTATION IN DRY AREA AND LOW SOIL PHOSPHORUS

	Code cultivar	Grain yield g/plant		Number of pods/plant		100 Seed Wt. (g)	
		+P	-P	+P	-P	+P	-P
V_1	Ife Brown	9.0	11.3	26.0	27.0	14.0	14.0
V_2	K - 28	14.5	25.6	24.0	38.6	15.1	14.2
V_3	IT86D-715	15.4	10.3	20.5	18.9	15.0	14.1
V_4	K - 39	17.0	11.2	30.2	26.7	14.0	13.5
V_5	IT86D-957	16.8	15.9	35.6	20.2	13.2	12.4
V_6	IAR 48	12.4	14.5	25.2	21.5	15.1	14.0
V_7	K - 59	14.7	19.4	30.8	35.8	11.0	11.0
V_8	TVX 3236	20.0	35.4	40.1	50.7	12.1	11.4
V_9	IFE BPC	15.6	7.9	22.8	19.4	13.5	14.0
V_{10}	AFB 1757	14.4	28.4	25.6	39.4	22.0	21.3
V_{11}	A_9	10.8	10.7	17.5	16.3	20.0	20.0
V_{12}	OGUNFOWOKAN	15.4	25.7	25.3	36.1	15.1	15.2
V_{13}	L - 72	12.0	9.6	23.6	20.1	14.0	14.0
V_{14}	IAR IAR 11/48-2	20.0	11.1	32.1	24.8	14.1	15.0
V_{15}	H 113 - 4	12.3	9.6	27.0	17.0	13.3	14.0
V_{16}	IT 86D-721	16.5	17.9	32.0	30.6	14.0	15.0
V_{17}	IT845 - 2246-4	11.2	17.9	27.0	26.1	14.4	14.2
V_{18}	H 64 - 3	14.2	16.7	28.0	25.0	14.0	14.0
V_{19}	L - 80	9.1	11.9	14.8	16.7	14.1	13.1
V_{20}	IT 86D - 719	7.2	13.5	23.7	20.8	14.0	14.0
	Mean	13.9	16.2	26.4	24.3	14.53	14.30
	Standard Error	1.6	3.6	2.5	5.1	1.19	1.17

APPENDIX - NIGERIA

TABLE XXII. DRY MATTER PRODUCTION OF 20 COWPEA VARIETIES PLANTED AT ILORA, NIGERIA IN 1990-1992

Code	cultivar	Root		Shoot		Leaf		Pod		Total	
		Dry weight (g)*									
		+P	-P	+P	-P	+P	-P	+P	-P	+P	-P
1	Ife Brown	2.4	5.8	26.6	51.5	14.8	25.7	14.4	19.2	55.8	71.7
2	K - 28	4.1	7.3	26.1	52.5	18.9	26.2	24.0	39.5	691	81.8
3	IT86 - 715	4.6	3.9	24.9	35.0	16.8	17.5	18.9	20.5	59.6	47.1
4	K - 39	2.4	4.0	27.2	35.9	16.4	17.9	32.0	20.2	75.6	46.3
5	IT86D-957	3.6	3.4	35.7	35.2	36.2	35.2	33.0	25.2	105.2	44.5
6	IAR 48	4.8	4.0	34.3	40.2	22.0	20.1	21.5	24.0	77.8	50.1
7	K - 59	3.5	3.6	30.5	37.0	25.8	18.5	29.2	33.8	85.6	53.9
8	TVX 3236	4.6	4.0	28.8	64.3	28.8	32.1	33.3	56.1	90.0	87.1
9	IFE BPC	2.3	3.2	15.0	30.8	22.8	15.4	23.7	18.1	61.6	43.6
10	AFB 1757	4.9	8.2	27.4	53.4	17.2	26.7	22.6	37.7	65.0	83.2
11	A_9	4.5	4.5	25.2	31.3	20.9	15.6	15.9	15.8	62.1	41.3
12	OGUNFOWOKAN	2.6	4.6	20.1	44.3	18.0	22.1	22.6	39.1	58.5	65.8
13	L - 72	2.8	3.9	7.1	35.5	17.7	17.7	21.6	18.1	64.2	41.8
14	IAR 11/48-2	3.3	4.6	18.7	39.1	17.7	19.5	30.2	17.1	66.4	46.1
15	H 113 - 4	2.6	3.7	29.1	46.0	15.6	23.0	20.7	17.0	65.5	53.9
16	IT86D-721	4.5	3.4	15.8	47.6	16.4	23.8	26.8	30.0	59.0	57.0
17	IT 845-2246-4	4.4	3.9	15.3	35.6	17.0	17.8	17.6	27.1	50.1	51.6
18	H 64 - 3	3.0	3.4	36.3	48.9	17.0	24.4	25.0	28.0	78.3	63.5
19	L - 80	4.4	4.0	31.0	43.1	16.3	21.5	14.8	17.5	62.4	55.6
20	IT 86D -719	2.6	3.0	18.1	31.9	16.8	15.9	24.5	22.8	46.2	40.2
	Mean	3.6	4.3	25.7	42.0	16.6	21.0	23.6	26.1	67.4	56.3
	S E	0.2	0.2	1.2	2.2	1.0	2.1	1.4	1.3	2.0	4.4

*Mean of 5 plants.

APPENDIX - SUDAN

TABLE XXIII. HABITAT DISCRIPTION OF *ACACIA SENEGAL* PROVENANCES

code	Origin	Soil type	Topography	Rainfall (mm)
1	Rawashda Forest Kassala Province	clayey	plain	450
2	Wad Dafta Gadarif Province	clayey	plain	473
3	Wad Bashier Forest Kassala	clayey	plain	485
4	Om Garra forest Hawata Circle	clayey	plain	490
5	Okalma Forest Blue Nile	clayey	plain	450
6	Dali Forest Blue Nile Province	clayey	plain	400
7	Khor Donia Blue Nile Province	clayey	plain	500
8	Bout Forest Blue Nile Province	clayey	plain	500
9	Om Naam Tendalti White Nile	sandy	undulated	300
10	Om Rawaba Forest Kordofan	sandy	undulated	300
11	Goz Ashger Forest Kordofan	sandy	undulated	280
12	Bara Forest Kordofan	sandy	undulated	295
13	El Nuhoud Kordofan	sandy	undulated	320

APPENDIX - NIGERIA -IITA

TABLE XXIV. EFFECTS OF DIFFERENT P RATES ON NODULE NUMBER AND NODULE DRY WEIGHT OF THREE *GLIRICIDIA SEPIUM* PROVENANCES AT 12 AND 24 WEEKS AFTER PLANTING IN THE GREENHOUSE AND IN THE FIELD

Provenance	Rate of P application									
	Greenhouse (mg P Kg^{-1} soil)					Field (kg ha^{-1})				
	0	20	40	80	Mean	0	20	40	80	Mean
					Nodule number plant^{-1}					
G_1	102	176	88	121	122	10	27	19	69	31
G_2	145	170	111	101	132	9	73	66	12	40
G_3	92	126	385	188	197	10	18	63	98	47
Mean	113	157	194	137		15	34	49	60	
LSD 5%	105					58				
					Nodule dry weight (mg plant^{-1})					
G_1	426	456	611	544	509	70	175	145	640	257
G_2	575	582	595	269	505	25	312	458	103	225
G_3	345	815	1826	723	930	150	110	582	642	371
Mean	452	618	1011	512		117	164	395	462	
LSD 5%	384					404				

APPENDIX - NIGERIA - IITA

TABLE XXV. EFFECT OF CUTTING MANAGEMENT ON PHYSIOLOGICAL P USE EFFICIENCY (PPUE) OF *GLIRICIDIA SEPIUM, SENNA SIAMEA* AND *SENNA SPECTABILIS* GROWN IN THE FIELD AT FASHOLA, ONE YEAR AFTER PLANTING

	Management practices	
Tree species	Cut	Uncut
G. sepium	0.71	0.32
S. siamea	0.86	0.52
S. spectabilis	0.7	0.46
Mean	0.78	0.43
LSD 5% (1)	0.19	
(2)	0.18	

Physiological P use efficiency (PPUE) in g shoot mg^{-1} P

APPENDIX - VIET NAM

TABLE XXVI. SOIL PROPERTIES OF THE EXPERIMENTAL SITE

	Depth	
Parameter	0 - 20 cm	20 - 50 cm
pH (H_20)	4.9	5.2
pH (KCl)	5.1	5.3
Ca^{++} (meq/100 g of soil	1.6	1.3
Mg^{++} "	0.4	0.2
K^+ "	1.22	1.02
Na^+ "	0.65	0.71
Bray II soluble P (ppm)	7.0	6.0
C (total, %	1.6	1.3
Total N (%)	0.12	0.1
Sand (%)	69.3	-
Clay (%)	11.6	-
Silt (%)	19.1	-

APPENDIX - VIET NAM

TABLE XXVII. RICE GENOTYPES USED IN THE EXPERIMENTS

Number	Genotype	Origin
Group 1 (Growth period: 90 days)		
1	OM 43-26	Stick rice IR 19794
2	OM 90-9	IR 35546-17
3	OM 74-14	IR 23843/OM 26/9R 25587-133
4	-	-
5	-	-
6	-	-
7	-	-
8	-	
9	MTL 103	-
10	IR 26	-
Group 2 (Group period: 105 days)		
11	OM 16 B	-
12	OM 269-65	IR 32843/NN 6A
13	OM 723-11 E	NN 6 A/A 69-1
14	OM 90-2	Trangchum/A 69/1
15	IR 72	IR 19661/IR 15795-199/IR 9124-209
16	IR 53915-29	-
17	IR 44592.62	IR 64/IR 1905-81/IR 28/28/45
18	IR 50401-77	IR 33021-39/IR 31802-48
19	WC 2	-
20	IR 56382-123	IR 28239-94/IR 24632-34
21	IR 64	IR 5657-33/IR 2061-455
22	IR 13240-108	-
23	KSB 212-85-2	-
24	KSB 212-46-1-2-3	-

APPENDIX - VIET NAM

TABLE XXVIII. GENOTYPIC DIFFERENCES IN STRAW YIELD (SY), GRAIN YIELD (GY), AND PLANT HEIGHT AT CONTROL AND 90 KG P_2O_5 HA^{-1}. EXPERIMENT 1.

Genotype	SY (kg/plot)		GY (kg/plot)		Plant height (cm)	
	P - 0	P - 90	P - 0	P - 90	P - 0	P-90
1	0.504	0.569	0.489	0.488	78.5	82.7
2	0.744	0.642	0.309	0.380	86.5	88.0
3	0.788	0.551	0.435	0.415	84.0	84.7
4	0.557	0.495	0.366	0.385	81.5	81.2
5	0.675	0.592	0.452	0.478	81.3	80.7
6	0.495	0.423	0.511	0.534	84.5	84.0
7	0.618	0.608	0.435	0.459	92.2	90.0
8	0.738	0.638	0.442	0.445	87.7	93.5
9	0.446	0.561	0.475	0.450	86.0	86.2
10	0.575	0.632	0.311	0.314	68.7	75.7
11	0.708	0.713	0.245	0.271	96.7	97.5
12	0.489	0.485	0.392	0.430	88.5	86.2
13	0.642	0.642	0.329	0.329	82.2	79.7
14	0.670	0.661	0.401	0.421	84.5	85.5
15	0.751	0.675	0.355	0.366	86.2	85.2
16	0.646	0.614	0.414	0.396	83.7	85.0
17	0.647	0.575	0.267	0.303	91.2	88.2
18	0.561	0.632	0.413	0.486	84.2	79.5
19	0.737	0.736	0.253	0.320	86.2	89.2
20	0.590	0.608	0.373	0.337	83.0	80.5
21	0.476	0.461	0.402	0.443	92.0	89.0
22	0.452	0.433	0.481	0.534	84.2	83.0
23	0.461	0.437	0.394	0.414	84.5	82.0
24	0.451	0.433	0.463	0.427	91.7	91.5
Mean	0.600	0.576	0.392	0.409	85.4	85.8
LSD 5%	0.100	0.090	0.079	0.089	5.7	5.0

APPENDIX - VIET NAM

TABLE XXIX. GENOTYPIC DIFFERENCES OF RICE IN P UPTAKE OF SHOOT (PSH) AND ROOT (PR), (GP/POT), AND IN PHOSPHORUS USE EFFICIENCY (PUE) (G SY/G PSH)

Genotype	0 ppmP			30 ppmP			90 ppmP		
	PSH	PR	PUE	PSH	PR	PUE	PSH	PR	PUE
G6	12.0	1.46	290	12.7	1.35	275	13.3	2.26	260
G22	11.3	1.24	282	14.4	1.82	261	16.1	2.65	218
G11	12.9	1.40	263	15.1	1.28	242	17.1	2.32	214
G19	12.7	1.11	261	13.9	1.15	234	14.7	2.54	243
LSD 5%	NS	0.19	15	2.3	0.22	15	2.1	0.35	16

APPENDIX - VIET NAM
TABLE XXX. GENOTYPIC DIFFERENCES OR RICE IN SHOOT DRY MATTER YIELD (SY), ROOT DRY MATTER YIELD (RY) (G/POT), AND ROOT/SHOOT RATIO (R/S) AT INCREASING P RATES

Genotype	0 ppmP			30 ppmP			90 ppmP		
	SY	RY	R/S	SHY	RY	R/S	SHY	RY	R/S
G6	3.59	1.71	0.47	3.44	1.52	0.44	3.47	1.91	0.57
G22	3.22	1.56	0.48	3.40	1.58	0.46	3.46	2.09	0.56
G11	3.33	1.36	0.41	3.75	1.42	0.36	0.36	1.66	0.48
G19	3.31	1.30	0.38	3.26	1.35	0.40	0.40	1.59	0.41
LSD 5%	NS	0.26	0.08	0.30	0.20	0.06	0.06	0.35	0.11

APPENDIX - VIET NAM
TABLE XXXI. GENOTYPIC DIFFERENCES OF RICE IN DRY WEIGHT OF SHOOT (G/M^{-2}) AT FLOWERING, AND OF STRAW AND GRAIN AT MATURITY

Genotype	Yield component	P rate kg P_2O_5/ha				
		0	30	60	90	120
G6	Flowering	559	581	548	551	531
	Straw	629	665	669	598	623
	Grain	420	481	397	396	393
G22	Flowering	480	528	608	576	550
	Straw	466	435	410	397	405
	Grain	416	410	388	374	376
G18	Flowering	508	533	559	526	552
	Straw	535	483	580	511	506
	Grain	249	293	342	337	297
G11	Flowering	468	494	530	516	560
	Straw	766	816	744	715	765
	Grain	178	159	211	193	159
G19	Flowering	519	533	543	546	548
	Straw	726	650	643	666	733
	Grain	149	166	169	181	144
Mean	Floweing	506	533	557	508	548
	Straw	624	609	609	577	606
	Grain	282	301	302	296	273
LSD 5%	Flowering	60	58	59	NS	NS
	Straw	42	40	43	40	42
	Grain	19	18	18	18	16

APPENDIX - VIET NAM

TABLE XXXII. DRY MATTER YIELD (DM), N CONCENTRATION AND N UPTAKE IN STRAW AND GRAIN OF RICE AT INCREASING P RATE

P rate, (kg P_2O_5/ha)	DM (g/m^{-2})		N (%)		N uptake (g/m^{-2})	
	Straw	Grain	Straw	Grain	Straw	Grain
0	529	397	0.91	1.55	5.59	6.15
30	665	418	0.99	1.66	6.63	6.97
60	669	433	0.99	1.64	6.66	6.51
90	629	396	0.93	1.55	6.77	6.77
120	623	393	1.09	1.59	6.79	6.27
LSD 5%	105	48	0.09	0.10	0.12	0.97

APPENDIX - FAO/IAEA AGRICULTURE AND BIOTECHNOLOY LABORATORY, SEIBERSDORF

TABLE XXXIII. EFFECT OF PHOSPHORUS SOURCE ON PHOSPHORUS USE EFFICIENCY OF SHOOT, ROOT AND TUBERS OF THREE SWEET POTATO CULTIVARS

		Harvest 1		Harvest 2			Harvest 3		
P sources	Cultivars	Phosphorus use efficiency (g DW^2/mg P)							
		Shoot	Root	Shoot	Root	Tubers	Shoot	Root	Tubers
0P	TIS 1487	0.75	0.21	2.40	0.60	7.03	3.99	0.91	6.99
	TIS 2	0.63	0.19	6.05	3.36		8.05	1.74	14.44
	TIS 3053	0.70	0.23	5.83	2.44		8.64	9.98	2.22
TSP	TIS 1487	0.78	0.18	3.59	1.08	6.80	5.90	1.73	11.13
	TIS 2	0.57	0.12	4.66	2.05		5.85	1.64	8.85
	TIS 3053	0.68	0.14	5.56	2.54		9.03	13.26	3.52
GPR	TIS 1487	0.53	0.13	2.08	0.60	6.02	3.10	0.75	8.95
	TIS 2	0.63	0.17	3.99	2.32		4.75	1.49	9.16
	TIS 3053	0.80	0.21	5.20	2.69		8.42	4.30	3.55

* LSD at the 0.05 level of probability to compare P-sources(P), cultivars (C), harvest (H) and any two means, respectively.

LSD ($p<0.05$) shoot; C: 0.8; H: 0.5; CxH: 0.8.

LSD ($p<0.05$) root; C: 1.1; H: 1.1; CxH: 1.8.

LSD($p<0.05$) tuber; C: 2.9.

APPENDIX - FAO/IAEA AGRICULTURE AND BIOTECHNOLOY LABORATORY, SEIBERSDORF

TABLE XXXIV. EFFECT OF PHOSPHORUS SOURCE ON NITROGEN UPTAKE BY SHOOT, ROOT AND TUBERS OF THREE SWEET POTATO CULTIVARS

		Harvest 1	Harvest 2		Harvest 3	
P	Cultivars	Nitrogen uptake (mg N/plant)				
sources		Shoot	Shoot	Tubers	Shoot	Tubers
OP	TIS 1487	84.92	87.37	159.10	79.50	43.65
	TIS 2	49.02	84.72	_	81.81	42.68
	TIS 3053	41.26	104.35	_	88.74	10.52
TSP	TIS 1487	98.53	97.52	117.13	99.72	51.04
	TIS 2	54.84	89.81	_	87.11	39.38
	TIS 3053	41.13	114.59	_	103.85	16.20
GPR	TIS 1487	57.19	84.64	139.05	73.54	60.96
	TIS 2	61.44	97.57	_	79.04	38.10
	TIS 3053	59.24	93.17	_	90.62	17.57

* LSD at the 0.05 level of probability to compare P sources (P), cultivars (C),

LSD ($p<0.05$) shoot; P: 13.4; C:6.1; H: 5.2; PxC: 10.5; CxH; 9.1.

LSD ($p<0.05$) tubers: C: 11.3.

APPENDIX - FAO/IAEA AGRICULTURE AND BIOTECHNOLOY LABORATORY, SEIBERSDORF

TABLE XXXV. EFFECT OF PHOSPHORUS SOURCE ON NITROGEN USE EFFICIENCY OF SHOOT, ROOT AND TUBERS OF THREE SWEET POTATO CULTIVARS

		Harvest 1	Harvest 2		Harvest 3	
P	Cultivars	Nitrogen use efficiency (g dw^2/mg N)				
sources		Shoot	Shoot	Tubers	Shoot	Tubers
OP	TIS 1487	0.06	0.27	0.48	0.82	4.65
	TIS 2	0.05	0.63	_	1.12	6.93
	TIS 3053	0.05	0.78	_	2.07	1.07
TSP	TIS 1487	0.09	0.56	0.66	1.42	10.07
	TIS 2	0.06	1.17	_	2.01	9.75
	TIS 3053	0.07	1.23	_	3.59	3.71
GPR	TIS 1487	0.06	0.33	0.56	0.85	8.62
	TIS 2	0.06	0.84	_	1.48	11.14
	TIS 3053	0.07	1.01	_	2.72	2.62

* LSD at the 0.05 level of probability to compare P sources (P), cultivars (C),

LSD ($p<0.05$) shoot; P: 0.3; C:0.2; H: 0.2; PxH: 0.3; CxH; 0.3.

LSD ($p<0.05$) tubers: P: 4;.0; C: 3.8.

APPENDIX - FAO/IAEA AGRICULTURE AND BIOTECHNOLOGY LABORATORY, SEIBERSDORF

TABLE XXXVI. GENOTYPIC DIFFERENCES IN P UPTAKE EFFICIENCY (mg P/ g ROOT DRY MATTER) OF RICE AT DIFFERENT LEVELS OF APPLED P

Genotype	P Level					LSD at 5%
	Control	20 ppm	40 ppm	80 ppm	120 ppm	
Lalka Mokta	3.78	5.59	7.01	8.33	9.70	0.62
Pokkali	3.24	5.13	6.75	6.95	7.83	1.15
IR-9884	3.31	4.41	5.92	6.72	6.87	0.93
IR-42	4.41	5.88	5.87	6.72	6.81	0.48
KDM-105	3.57	5.96	7.91	7.98	9.90	1.30
LSD at 5%	0.62	0.78	1.13	1.16	0.96	-

APPENDIX - FAO/IAEA AGRICULTURE AND BIOTECHNOLOGY LABORATORY, SEIBERSDORF

TABLE XXXVII. GENOTYPIC DIFFERENCES IN P TRANSLOCATION (%) TO SHOOT FROM ROOT AT DIFFERENT LEVELS OF APPLIED P

Genotype	P Level					LSD at 5%
	Control	20 ppm	40 ppm	80 ppm	120 ppm	
Lalka Mokta	78.4	82.4	84.1	83.9	84.4	3.1
Pokkali	74.4	81.1	83.2	82.0	81.3	4.0
IR-9884	69.2	75.5	79.8	79.2	78.1	3.1
IR-42	76.0	82.2	81.1	81.0	80.4	4.1
KDM-105	71.8	78.5	83.1	83.7	84.1	4.0
LSD at 5%	4.2	4.7	2.6	3.4	3.7	

APPENDIX - FAO/IAEA AGRICULTURE AND BIOTECHNOLOGY LABORATORY, SEIBERSDORF

TABLE XXXVIII. THE INFLUENCE OF P LEVELS ON NET PHOTOSYNTHETIC RATES OF RICE

Genotype	P Level					LSD at 5%
	Control	20 ppm	40 ppm	80 ppm	120 ppm	
	mg CO_2 dm^{-2} h^{-1}					
Lalka Mokta	21.69	22.49	22.89	25.31	23.75	3.64
Pokkali	16.60	20.89	21.15	23.00	23.31	3.53
IR-9884	19.60	22.49	22.90	20.08	21.29	1.55
IR-42	24.64	22.85	24.99	22.83	24.27	3.72
KDM-105	14.86	19.68	24.91	28.92	26.91	3.14
LSD 5%	3.82	4.69	3.90	5.75	4.45	

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