CROP SCIENCE RESEARCH IN DEVELOPING COUNTRIES

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ABSTRACT

Soil phoshorus(P) uptake mechanisms of chickpea (*Cicer arientinum* L.)(CP) and pigeonpea (*Cajanus cajan* (L.) Millsp) (PP) were studied at ICRISAT, India, from 1983 to 1999 with funds of Tropical Agricultural Research Center (present JIRCAS) and Government of Japan Special Project. Earlier in 1983, TARC arrived at the agreement with ICRISAT to staion younger scientists at ICRISAT hoping to expand their activities to the semi-arid tropics. ICRISAT, on the other hand, expected to increase of research grant from Japan. I was dispatched to ICRISAT to conduct small reseach project on legume physioligy for three years on October, 1983. However, the visitation of Diet Member of Japan, Mr. Tsutomu Hata and Mr. Taichi Ohkawara to ICRISAT changed the the situation. Government of Japan decided to support larger scaled research project at IRRI and ICRISAT. The renewaled project, called Government of Japan Special Project (GOJ Project), received Dr. Noriharu Ae, Chugoku Natl. Agric. Expt. Stn. in May, 1985, and Kensuke Okada in December, 1985.

ICRISAT prepared good reseach theme for us. That was to reveal reasons why CP and PP do not respond to phosphorus application even on soils of very poor phosphorus availability. As both Director General Dr. D L Windale and Deputy Director General Dr J S Kanwar, ICRISAT are soil scientists and familier with Japanese soil sciences, they might have expected us to answer the questions.

For the members of GOJ Project, everything on agriculture in the semi-arid tropics was new. We started field experiments to know how CP and PP grown on Alfisols and Vertisols. What we decided was to rely on what we saw and not to rely on literatures. At that time, there were lots of discussions on poor responses of CP and PP to P application, they were diffusion, root mass, micro nutrients, mychorizae etc. Those theories did not fit well with our observations on the several field trials we did.

We decided to start NPK experiments using CP, PP, maize (MZ) and sorghum (SG) on Alfisols and Vertisols of poor available P even though most people said it would be useless. NPK trials, however, gave us very valuable information. CP, MZ and SG grown on Vertisols showed no P deficiency symptoms. In the SAT area, soil available P is usually measured with Olsen's method using alkaline solution, 0.5 M $NaHCO_3$. Available P value with Truog method, standard method in Japan, contrary uses acidic solution or pH 3.0, gave much higher than Olsen method. As we already know higher Ca-P content of Vertisols, we estimated CP can lower rhizosphere soil pH close to pH3.0 with some mechanisms. We later could show CP can lower rhizoshere soil pH close to 3.0 with exuding organic acid especially citric acid from root surface.

It was a big finding for us, as we were confounding with the discrepancy between available P level and crop growth. Available P level measured with Olsen's method is higher for Alfisols than Vertisols. Crops growth, however, was usually higher on Vertisols than on Alfisols. With this finding, we thought we could well relate crop growth with available P level. We thought we could answer the question given by ICRISAT.

However, things were not so simple and easy. With NPK pot trials using Alfisols and Vertisols try to clear P response curves of several crops, among crops only PP was not responding at all to P applications in Alfisols, though it was responding very well in Vertisols. It was very big headache for us. We had to conclude PP could uptake iron-P with some mechanisms as we know that in most of P exists as iron-P in Alfisols. From that time, we started days of discussion for several months.

One morning when we were continuing long tea time discussion, I said PP flowers scented very fragrant. Then, Dr. Ae shouted "it must be flavonoids". He explained if PP could exude flabonoids from root surfaces, they could combine iron and release P from iron bound P. We rushed to the PP field and confirmed bitterness of the PP plant and brought back its roots. We prepared agar gel containing iron P reagent and placed PP roots on it. Then gel around roots became clear. After that we started long laborious works with Indian staffs to extract material which can solubilize iron P and finally could get pscidic acid as iron chelating substance. The conclusions at that time were revealed not complete one. Most important thing of our work, however, is not the identification of piscidic acid, but the findings of plant capability to actively uptake nutrients from soil.

Along with these studies, we conducted many experiment using PP and CP. From those experiments, we learned that the active P uptake mechanisms are playing very important role in crop production systems in the semi-arid tropics. We also realized the limiting factor of crop productivity in the SAT is not the drought but the low nutrients level of soils, especially P.

Maybe because of the frustration to settle down to international organization and India, we often made conflicts with ICRISAT. Our intension to keep Japanese style of research might had accelerated crash with ICRISAT. People around us, Dr. T. Takenaga, agricultural machinery, Dr. C.W. Hong, soil scientists, Korea, and Dr. K.K. Lee, soil microbiologist, kindly tried to take very good care of us. Management staffs of ICRISAT, Dr. C. Johansen, leader of Pulse Agronomy, Dr. Y.L. Nene, Director of Legume Department, Dr. Kanwar, DDG and Dr. Swindale, DG were also paying attention to us. All of them must be worrying about us. In spite of their kind efforts, we finally made the serious conflict with ICRISAT staffs. One day, DG finally called me to his office and told me to go back home. We didn't have option to go back home. Option we could take is to stay there. Then we had serious discussion among us and decided to change our attitude. We also established the manner to cool down heat of serious discussion among us. That is to take tea break during or after serious discussions or quarrels. Then we were gradually shaking down with ICRISAT. We also gradually could produce some good results. It was a kind of surprise for me to see the changes of attitude of ICRISAT staff toward us after we change our attitude toward ICRISAT. On our last days in ICRISAT, it was our greatest pleasure to receive wards of appraisal from ICRISAT staff toward our works.

After coming back from ICRISAT, all of us are keeping strong interest in role of root systems in crop productions. Dr. Ae extended his activities from phosphorus to other nutrients such as nitrogen, cadmium etc. and has been produced unique and exciting results. Dr. Okada revealed soil acidity itself is not limiting factor of crop production in highly weathered soils in Colombia. He also showed how to improve productivity of highly weathered soils with mixed cropping system using acid tolerant rice varieties and tropical grass and leguminous forages. I also studied crop rotation systems in Hokkaido in relation with mychorizae and soybean production systems on paddy soils. In both studies I utilized experiences in ICRISAT. Most interesting experience for me is to find similar types of soils to Vertisols and Alfisols exist in Japan and learned that there are little differences in temperate soils and tropical soils.

However, I, maybe Dr. Ae and Dr. Okada too, feel regretful when we think we could not contribute much to agriculture in the SAT after leaving ICRISAT. In the SAT area, especially in African SAT area, agricultural productivities continuously declining only because of lack of fertilizers, especially P. Ironically very high amount of high quality P deposit of African SAT area is exported to developed countries and not utilized locally. Dr. Bationo, ICRISAT, West and Central Africa, has been conducted many field experiments and showed the effectiveness of rock phosphate, combined with proper crop rotation systems, in increasing crop production for longer period than SSP. Dr. Hong, Korea, worked in Ghana in early 1990's as a member of Global 2000 could realized in boosting crop production there. I would like suggest Japanese organizations to start a realistic project based on these achievement to boost agricultural production in SAT.

KEYWORDS
Pigeonpea, chickpea, phosphorus uptake, Vertiosols, Alfisols, ICRISAT

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Noriharu Ae, Joji Arihara, Kensuke Okada, Teruhiko Yoshihara, and Chris Johansen. 1990.
Phosphorus Uptake by Pigeon Pea and Its Role in Cropping Systems of the Indian Subcontinent. *Science* 248:477 – 480.

Crop Science Research in Developing Countries -Our Experience at ICRISAT –

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Deccan Plateau

Alfisol: Typical soil of the semi-arid tropics

Pigeon pea (*Cajanus cajan*)

Grown in approximately 50 countries in Asia, Africa and the Americas, mostly as an intercrop with cereals

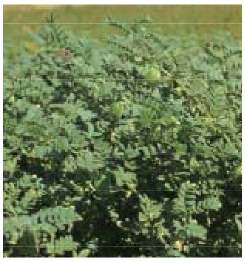
Pigeonpea can grow well on Alfisols of poor phosphorus avilability

Pigeonpea inter-cropped with Rabi Sorghum

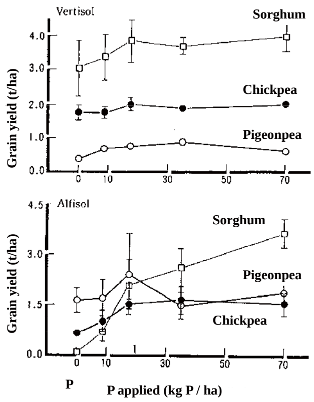
Vertisol : Another typical soils in the semi arid tropics

Chickpea (*Cicer arietinum*)
Commonly known as Bengal gram or garbanzo

The third most important food legume globally, grown in over 40 countries representing all the continents. Over 95% of the area, production and consumption is in developing countries.



Chikpea can grow well on Vertisols of poor phosphorus availability



P responses of chickpea, pigeonpea and sorghum on Vertisol and Alfisol fields of low phosphorus availability

Table 1. Electrical conductivity (EC), *p*H, and P contents (in milligrams per kilogram of soil) of low-available-P Alfisol and Vertisol at the ICRISAT Center at which pot and field experiments were conducted.

Soil	EC ($mS\ cm^{-1}$)	*p*H	Total P	Ca-P	Al-P	Fe-P	Olsen P ($NaHCO_3$ extraction) (*18*)
Alfisol	0.04	6.0	122	3.8	8.1	51.3	4.1
Vertisol	0.11	8.1	153	52.8	18.1	77.4	0.7

Table 3. Shoot phosphorus contents (mg pot^{-1}) of several crop species at the grain-filling stage after growth in potted Alfisol (RCW 8) and Vertisol (BR 4J) without phosphorus fertilizer in a greenhouse.

Soil	Chickpea	Pigeonpea	Sorghum	Soybean	Pearl millet	Maize
Alfisol	4.73	5.72	0.59[1]	1.40[1]	0.64[1]	0.51[1]
Vertisol	7.79	2.34	3.91	6.53	5.38	6.13
SE	±0.77	±0.82	±0.39	±0.20	±0.34	±0.25

1. Plants died 1 month after sowing.

Fig. 2 Phosphorus responses of rainy season sorghum and pigeonpea and post-rainy season chickpea in an Alfisol and a Vertisol field, 1987/88.

Table 3 Major organic acids of root exudates* from sorghum, soybean, chickpea and pigeonpea

Crop	Organic acid (mg/g dry root*)			
	Malonate	Succinate	Citrate	Malate
Sorghum	trace	trace	0.045	0.008
Soybean	0.324	0.046	0.481	0.078
Chickpea	trace	0.054	1.292	0.025
Pigeonpea	trace	0.025	0.101	0.047

* Roots of two months old plants were washed in water and soaked in 2mM $CaCl_2$ for collection of root exudates.
(from Ae *et al.*, 1991b)

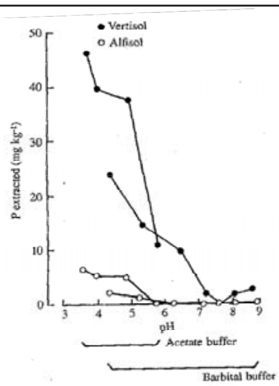


Figure 3. Extraction of P by buffer solutions at various pH levels from an Alfisol and a Vertisol used in a pot experiment at ICRISAT Center.

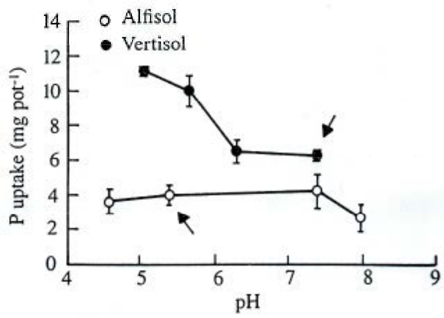


Figure 10. Effect of soil pH on P uptake by sorghum. Soil pH was modified by adding either dilute H_2SO_4 or $Ca(OH)_2$ (→ = Initial pH). Standard errors indicated.

Table 3. Shoot P contents (milligrams of P per pot) of crop plants at the grain-filling stage after growth in potted Alfisol or Vertisol in the greenhouse, without P addition.

Soil	Sorghum (cultivar CSH 5)	Pigeon pea (cultivar ICPL 87)	Soybean (cultivar JS 7244)	Pearl millet (cultivar WCC 75)	Maize (cultivar Deccan 103)
Alfisol	0.59*	5.72	1.40*	0.64*	0.51*
Vertisol	3.91	2.34	6.53	5.38	6.13
SE†	0.39	0.82	0.20	0.34	0.25

*Plants died 1 month after sowing. †Standard error of difference for comparing means (n = 3) within a crop across soil types.

Contents of major organic acids in the root exudates of sorghum, pigeonpea and soybean.

Crop	Malonate	Saccinate	Citrate	Malate
		(mg/g dry root)		
Sorghum	trace	trace	0.045	0.008
Pigeonpea	trace	0.025	0.101	0.047
Soybean	0.324	0.046	0.481	0.078

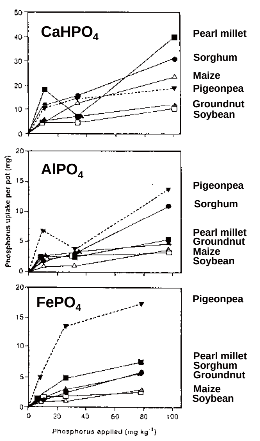
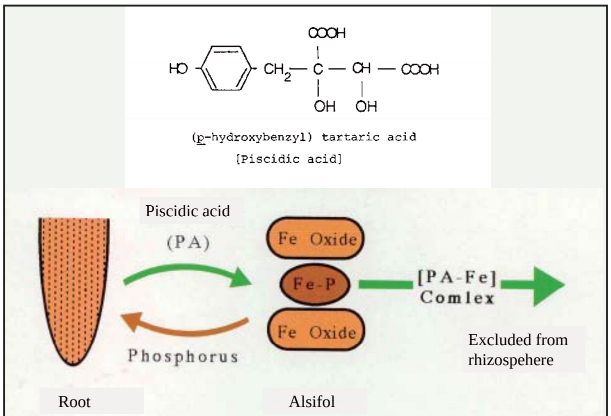
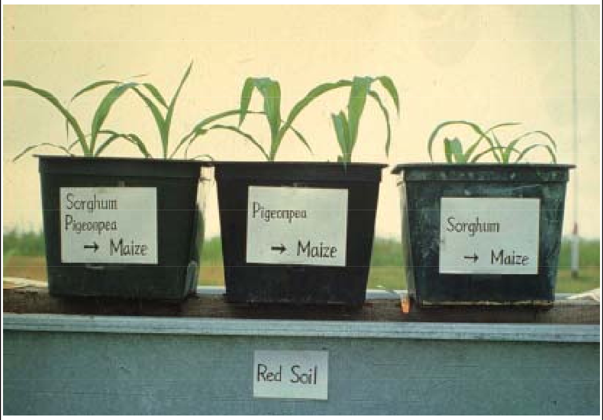
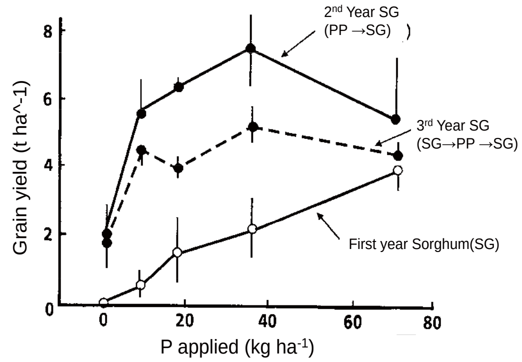


Fig. 1. Effect of P applied as different sources of phosphate ($CaHPO_4$, $AlPO_4$, and $FePOP_4$) on P uptake by various crops (▼, pigeon pea; ■, pearl millet; ▲, groundnut; ●, sorghum; Δ, maize; □, soybean) in a sand-culture experiment. Standard error of difference = 2.91, for comparing means (n = 3) for each crop at the same combination of source of P and P level.

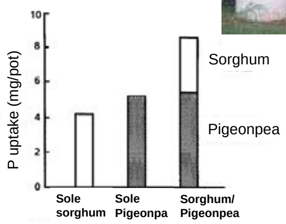


P uptake mechanism of pigeonpea (hypothesis)

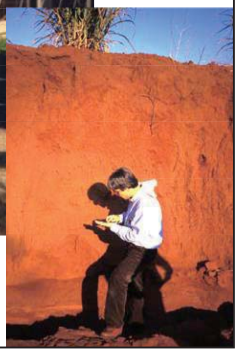


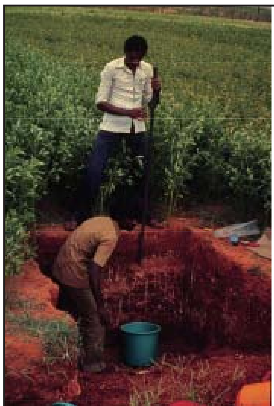


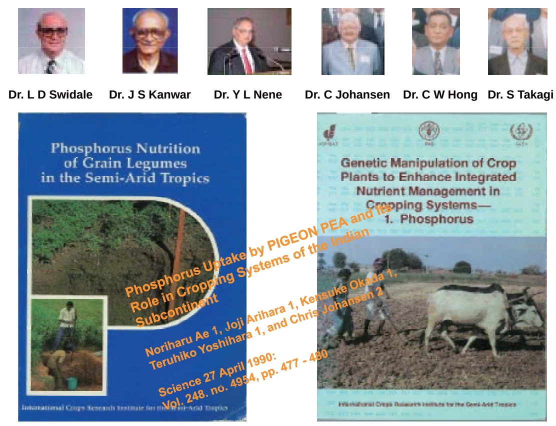
Effects of previously grown pigeonpea on grain yield of following sorghum on Alfisol field of poor P availability



Effect of mix cropping on P uptake of sorghum and pigeonpea from low P fertility soil







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