Phosphorus Management of Indian Soils— Problems and Prospects

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Abstract

Phosphorus is an essential input and often a major constraint for successful crop production in India, as about 98 per cent of the soils have inadequate supply of available phosphorus. However, phosphorus management in the soil is a difficult problem and it encompasses an array of factors the soil, crop, fertiliser and cropping system, each with a multitude of problems of its own.

In this paper various aspects of phosphate management problems in the light of crop removal of the nutrient and its balance sheet, direct, residual and cumulative effects on crop growth as well as cropping systems have been discussed. Areas of deficiency in relation to research on phosphate use efficiency have been outlined with suggestions for intensified research for the solution of the several complexities of the problem.

Phosphorus, one of the 'big three' plant nutrients, has long been considered as an essential constituent of all living organisms. It is now considered as a major constraint for successful crop production in Indian agriculture, because, on one hand, the finite reserve of this non-renewable resource is getting exhausted fast and, on the other, its deficiency has since become widespread.

Soil fertility map compiled by Ghosh & Hasan (17) based on more than 8 million tests for available phosphorus indicates that about 46.3 per cent of the districts are in the low category, 51.5 per cent represent the medium fertility class and only 2.2 per cent of the 363 districts showed a high phosphorus level. Thus, there is a need for the application of phosphate for achieving higher yields of crops in nearly 98 per cent of the soils in the country.

A critical appraisal of the available phosphorus status in relation to major soil groups or associations indicated that generally deep and medium black soils, grey brown, desert and red loamy soils of semi-arid regions, soils of the foot hills, alluvial strips of the northern region, and coastal alluvium which are not sandy in nature largely depict medium fertility class.

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Phosphorus consumption at the present stage is around 3 kg P_2O_5/ha of cultivated land in India as a whole (69). Yardsticks of additional production due to application of phosphate vary widely but 10 kg grain/kg P_2O_5 is normally used for planning purposes. Phosphorus management, therefore, encompasses an array of factors, the crop and cropping systems, fertiliser and water with a view to increase crop yields. Phosphate utilization is not only intimately linked with crop requirement and soil properties, but also with crop-soil-fertiliser complex taken as a whole. Judicious management of phosphorus should therefore take into account the soil factors, the fertilisers, and their time and method of application and cropping system. Goswami and Singh (20) have outlined the various approaches followed for studying the phosphorus requirements in cropping systems.

Crop recovery of added phosphates seldom exceeds 20 per cent and this calls for ways and means to increase the efficiency of P utilization by crops. In view of these facts, in this article the problem of phosphate management has been discussed in the light of crop removal of phosphorus and its balance sheet, direct, residual and cumulative effects of phosphate on crop growth, varietal differences, soil and fertiliser management, cropping sequences or systems and methods of fertiliser application.

Crop Removal of Phosphorus and its Balance Sheet

Phosphorus is removed in much lower amounts than N and K by crops; and for grain crops the phosphorus removal amounts to approximately one-fifth of the nitrogen removal. Some estimates on the uptake of phosphorus by the wheat crop have shown that each quintal of wheat grain removes about 1.4 to 1.6 kg P_2O_5 (33). Other estimates show that some of the high yielding varieties of wheat require 0.73 to 0.87 kg P_2O_5 for production of one quintal of grain whereas the requirement for hybrid maize cultivar Ganga-5 has been roughly three times and a half of that, the actual figures being 2.82 kg P_2O_5 per quintal of grain production (59). Ramamoorthy *et al.* (48) have pointed out that the requirement of major nutrients has nearly doubled with the introduction of high yielding varieties of rice and wheat. They further observed that older tall varieties of rice and wheat removed phosphorus of the order of 23 kg P_2O_5 for a grain yield of 28 q/ha of rice and 29 kg P_2O_5 for a grain yield of 22 q/ha of wheat. On the contrary, the new varieties which give yield of the order of 60 q/ha require 40 kg P_2O_5 for rice (IR-8) and 49 kg P_2O_5 for wheat (Sonalika). Kanwar and Datta (29) estimated that different agricultural crops in India annually remove about 4.2 million tons N, 2.1 million tons P_2O_5 and 7.3 million tons of K_2O, which is about 4 to 5 times that is presently added through the fertilisers. Removals of N, P_2O_5 and K_2O and their ratios are given in Table 1.

The quantity of P removed by crops is an important parameter for evaluating the fertiliser phosphorus requirement, although recommendations based exclusively on this criterion may vary often by misleading as other soil, plant, environmental and management practices may play a significant role in the utilization of phosphorus.

It is always not necessary to replenish the amount of P removed by crops, because not all that is removed is lost as certain amounts are returned as crop residues. Besides some phosphorus originally unavailable or carried below root zone are converted into an available form or transferred to the active root zones as a result of crop rotation or soil management practices normally followed in any good farming operation. However, it has been observed that every year Indian soils are becoming poorer with respect to available P status. A balance sheet proposed by Roy and Kanwar (54) is presented in Table 2.

Crop Response to Phosphorus

Enormous literature is available on the response of different crop species and crop varieties and therefore only recent work has been briefly cited.

Datta and Datta (8) working with different types of Indian soils observed that in case of cereals, degree of response was affected by available soil phosphorus and response curves generally followed law of diminishing returns. They recommended application of 45 to 47 kg P_2O_5/ha for all the phosphorus responsive soils. Sinha (62) observed a linear positive response up to 75 kg P_2O_5/ha dose in case of wheat, whereas Kacchave

Table 1—Plant nutrients removed by some selected crops.

Crop	Yield (kg/ha)	Nutrients removed (kg/ha)			Ratio		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Wheat*	6,000	135	65	143	100	48	106
Rice*	6,000	141	60	193	100	43	137
Maize*	6,000	205	87	178	100	42	87
Groundnut seed	1,906	78	22	45	100	28	58
Sugarcane	121,896	130	105	410	100	81	315
Jute	1,681	280	123	224	100	44	80
Potato	17,575	85	30	140	100	35	165

Source: FAI Fertiliser Statistics 1977-78

Reference (29)

Table 2—P balance sheet of Indian agriculture.

Additions/Removals	P_2O_5 ('000 t)		Source of information for gross figures
	Gross	Net	
A) Additions:			
1. Chemical fertilisers	867	—	FAI, Fertiliser Statistics (1977-78)
1a. Efficiency (20%) (direct)	—	173	
2. Cattle dung & urine	460	—	Dewan & Dongale (1975)
2a. Efficiency (10%)	—	46	
3. Human waste (70% of total)	490	—	Dewan & Dongale (1975)
3a. Efficiency (10%)	—	49	
4. Rural compost, etc.	903	—	Barooah (1975)
4a. Efficiency (10%)	—	90	
Total	2720	358	
B) Removals:			
1. Through crops	2100	2100	Kanwar & Datta (1970)
2. Grazing	N.A.	N.A.	
C) Balance:			
1. Addition—Removal	+620	−1742	
2. Addition : Removal ratio	1.3	0.17	

Reference (54)

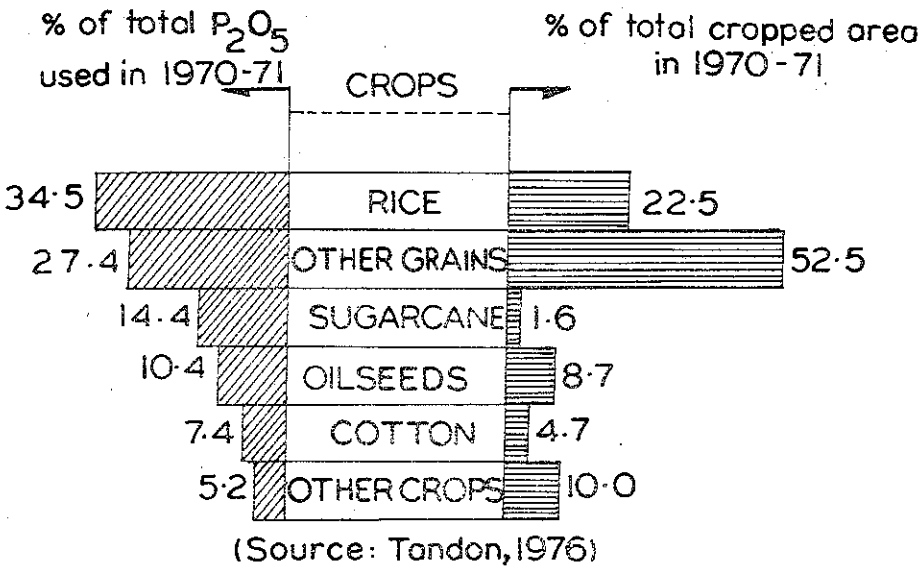


Figure 1—Share of Fertiliser P which went to various crops against their share of cropped area. All India=100.

et al. (26) observed response even up to 90 kg P_2O_5/ha. Direct effect of phosphorus was found to be significant on wheat in multiple cropping at most of the Model Agronomic Centres in the country. Generally residual responses were lower than direct responses of wheat (AICAES, 1970-71).

The removal of phosphate by crops in general far exceeds its addition through fertilisers and recycling. According to a survey carried out in 1970-71 by NCAER of the total fertilisers consumed, nearly 70 per cent is accounted for by food grain crops (cereals and pulses) and the remaining 30 per cent by cash crops. Negligible quantities of fertilisers are used on pulse crops as they are grown on soils in dryland areas. About 68 per cent of the P consumed went to cereal crops (primarily rice and wheat), 14 per cent to sugarcane, 10.4 per cent to oilseed, 7.4 per cent to cotton and the remaining 5 per cent to all other crops put together (NCAER)/FAI 1974). This is illustrated in Figure 1 as compiled by Tandon (69).

Phosphate Utilization by Crop Species

Greater utilization of P by wheat (cv. Sonora-64) has been observed at the higher level (60 kg P_2O_5/ha) of P application (41). On the contrary, gradual decrease in per cent utilization with increasing rates of phosphate application was evident from the findings of Sinha and Rai (64). According to Raychaudhuri (52), phosphate utilization ranged from 32 to 41 per cent for wheat (cv. Kalyansona) under different spacing treatments. Wheat cultivars Hira and Sharbati Sonora were more efficient utilisers of soil phosphorus than Kalyansona. A decrease in the per cent P derived from fertiliser (Pdff) with advancement of growth of maize was noticed by Chaudhury and Gupta (5) which they explained as due to the effect of dilution.

Tracer studies have revealed that during the first 30 days, groundnut, pigeon pea and soybean were relatively better feeders of native soil phosphorus than green gram, black gram and cowpea (25). Some varietal differences with respect to their capacity to feed on native soil phosphorus were also observed. Greenhouse studies have shown that 2 to 10 per cent of applied phosphate can be utilised by legumes such as cowpea, green gram and black gram in a mollisol (35). Tracer data on P utilisation by some cereals and legumes are given in Table 3.

Residual and Cumulative Effect of Phosphate Fertilisers

Residual effect of phosphatic fertilisers refers to the carry over benefit of an application to the succeeding crops. Removal of phosphorus by the first crop normally does not exceed 10 to 20 per cent of the added phosphorus and the rest stays on in the soil (69). The magnitude of the residual effect depends upon the rate and the kind of phosphatic fertilisers

Table 3—Response of some cereals and legumes to superphosphate at (80 kg P_2O_5/ha) under greenhouse conditions

Crop	Drymatter (g/pot)		Total P (mg/pot)		Per cent P utilization
	0	80	0	80	
Soybean (Bragg)	10.0	12.1	21.6	29.1	8.2
Cowpea (C-152)	23.4	27.6	37.5	59.9	18.8
Greengram (PS-K)	7.5	7.5	13.4	19.4	6.4
Pueraria	8.3	13.9	28.1	33.3	10.0
Rice (Pusa 2-21)	16.3	20.2	27.6	43.6	29.1
Maize (Ganga 5)	20.4	24.7	15.5	26.6	19.1
Wheat (Sonalika)	1.5	6.4	1.7	10.3	12.7
Barley (DL-36)	1.8	8.6	2.5	12.6	14.8

Reference (46)

used, the cropping and management system followed and to a great extent on the type of soil (50). A heavy rate of phosphatic fertiliser has more pronounced residual effect than a light dressing. Increasing the level of phosphate application results in an increase in the available P content of the soil. The yield of rice following *berseem* has been found to vary with the amount of phosphorus applied to *berseem* (60).

In view of the large residual response to fertiliser phosphorus and the observation that alternate application of phosphorus to Kharif and Rabi crops was nearly as good as its application to both, Sekhon (57) advocated the use of fertiliser phosphorus to be limited to only one crop in the rotation. He also stressed the need to determine adequately the discount rates for previous fertilisation for the individual crops in all dominant cropping sequences in a soil-climatic zone.

Residual effect of superphosphate, dicalcium phosphate and rockphosphate was observed even in the fourth succeeding crop in lateritic soils of Konkan region of Maharashtra (68). In neutral non-calcareous soils, application of rockphosphate and superphosphate mixture in the ratio of 1:2 or 1:3 was comparable with superphosphate at the same rate of application as evident by their effect on yield and P uptake by crop in a wheat-maize cropping sequence (70). Residual effect of phosphate applied to wheat on the succeeding green gram crop has been studied recently using radio tracers (44), and some of the salient results are given in Table 4.

Indigenous rockphosphates such as Jhamar Kotra, Kasipatnam, Mussoorie and Singhbhum have been found to be only about 40 per cent as efficient as superphosphate in terms of their direct effect on three succeeding crops on acid oils (55). On the contrary, Suhrawardy *et al.* (67) found Mussoorie rockphosphate to be superior to superphosphate in sandy soil in terms of direct, residual and cumulative effects. Some of the salient results are given in Table 5.

Similarly, in studies conducted by Chaudhari *et al.* (6), the residual effect of three sources of phosphorus applied to wheat on the succeeding rice crops, Suphala showed the maximum residual effect while rockphosphate the minimum (Table 6).

Phosphate Utilisation by Different Crop Species

Numerous field and greenhouse experiments have been reported relating to the evaluation of fertiliser phosphorus use efficiency by different crops. Uplands crops like wheat, maize, sorghum and pearl millet behave somewhat differently than rice which is grown under water-logged conditions (14, 19, 56, 71). Yield response per kg of P application is higher at lower levels than

Table 4—Residual effect of superphosphate applied to wheat on grain yield of green gram (field experiment)

(q/ha)

Treatment/level (kg P_2O_5/ha)	30	60	90	Mean
Single superphosphate (SSP)	6.28	6.68	7.08	6.68
Slurry coated SSP	5.13	5.18	5.43	5.25
Dung coated SSP	5.47	5.73	6.77	5.99
Pelleted SSP	7.41	8.11	8.34	7.86
$MgSO_4$+SSP	6.81	6.83	6.92	6.85
Silicate+SSP	7.96	7.76	8.11	7.94
No (P control)	5.21			
S.Em for treatment	0.38			
C.D. (5 per cent)	1.09			

Reference (44)

Table 5—Direct, residual and cumulative effect of phosphate on rice in acid soils

Mean grain yield of rice (q/ha)

Fertiliser P	Levels of P_2O_5 (kg/ha)	Summer TTB 4/7 direct effect	Kharif Pusa-33 (residual effect)	Cumulative effect	Net cumulative response over control
No phosphate	Control	13.4	26.1	39.5	—
Single superphosphate	80	21.9	27.0	58.9	19.4
	160	23.4	44.3	67.7	28.2
	240	28.9	49.1	76.0	36.5
Mussoorie rock phosphate	80	19.4	32.8	52.2	12.7
	160	22.0	35.9	57.9	18.4
	240	22.5	36.4	58.9	19.3
C.D. 5 per cent		5.0	7.1	9.4	

Reference (67)

Table 6—Direct and residual effect of different sources of P on rice crop in Hissar sandy loam soil (average of two years)

Treatment	P levels (kg P_2O_5/ha)			
	40	80	120	Mean
	Wheat yield q/ha			
Rock phosphate	28.6	30.3	31.7	30.2
Suphala	31.2	34.1	34.5	33.3
DAP	34.9	35.1	33.8	34.6
NK	—			27.2
Control	—			12.7
	Rice yield q/ha			
Rock phosphate	67.6	69.9	68.6	68.7
Suphala	74.0	73.1	70.1	72.4
DAP	70.1	71.1	69.8	70.3
NK	—			66.3
Control	—			

Reference (6)

that at higher levels for all the crops with exception to rice. The reason for such differences has been ascribed to higher availability of applied phosphorus under water-logged condition (71), which is well reflected in the higher uptake of soil phosphorus and corresponding lower uptake of fertiliser phosphorus and *vice versa* (8, 13). Certain crop species like cotton, linseed and gram respond poorly to applied phosphorus even under favourable growth conditions while peas and *berseem* show higher uptake of phosphorus. Using ^{32}P as a *tracer*, it has been shown that the feeding zone of cotton is deeper as compared to maize and therefore cotton responds poorly to applied phosphorus (63).

The capacity of legumes to utilise P from relatively insoluble sources has been reported in the literature, but little information is available as to the factors responsible for this. In recent years basic studies on the relative efficiency of two major indigenous rockphosphates (Udaipur and Mussoorie) and superphosphate on four legumes (Soybean, cowpea, green gram and tropical *Kudzu*) have shown that tropical *Kudzu* removed largest amount of P from rockphosphates followed by soybean, cowpea and green gram. This differential capacity is related to rate of dry matter production, root demand coefficient for phosphorus, root volume and root CEC (46). Crop association or mixed cropping has been found to influence the phosphate utilisation by crops. Under mixed cropping conditions wheat feeds more on fertiliser phosphorus while gram absorbs more of soil phosphorus. However, under monoculture conditions gram could utilise higher amount of fertiliser phosphorus (28). The data are presented in Table 7.

Hegde and Saraf (23) evaluated the economics of phosphate fertilisation of some legume crops such as green gram, black gram and cowpea as intercrops in pigeon pea under dryland conditions. Their results indicated that pigeon pea and cowpea combination had the maximum yield potential and gave the highest net profit and higher utilisation efficiency in terms of yield response per unit of fertiliser P. Salient findings reported by them are given in Table 8.

Crop Varieties and Use of Fertiliser Phosphorus

Varietal differences have been evaluated with respect to phosphorus uptake by several workers. Radioisotopic techniques offer a unique method of evaluation of these differences. Among the old varieties NP-870 was found to be better feeder of fertiliser phosphorus as compared to NP-880 (28). Under pot culture conditions varietal differences were observed in wheat with respect to per cent Pdff values (42), and in decending order they were Kalyansona, NP-860, Sonora-64, Sonalika, Sharbati Sonora and Lerma rojo. However, Subbiah *et al.* (66) found Hira to be the most efficient wheat variety which derived higher proportion of fertiliser phosphorus from applied source as compared to Kalyansona and Sonalika. Application of Krilium as soil conditioner enhanced the per cent Pdff values in all the varieties tested and also affected the soil phosphorus fractions.

The newly developed rice varieties are highly responsive to fertiliser application as a consequence of higher yields. Maximum phosphorus uptake was observed in case of TN-1 followed by Taiwan-3 (7). Using ^{32}P ratio tracer technique varietal differences to phosphorus response were recorded by Dev *et al.* (15). They concluded that IR-8 and Jaya were less efficient in utilising fertiliser phosphorus as compared to culture-95 and IR-6228. The verietal differences were also observed in barley crop. Barley cultivar Ratna utilised maximum and Jyoti the minimum proportion of phosphorus from the applied source (43).

Root activity and rooting systems of the crops have been found to influence nutrient uptake by the crops. A study of the root systems of maize cultivars tested under normal and adverse soil conditions showed a shift in the rooting system towards shallow and compactness. These findings suggest that a suitable method of fertiliser application depending upon the variety and soil conditions is likely to be more beneficial for nutrient uptake from native as well as applied source. Further, establishment of higher plant density with narrower row spacing should be the most important consideration under soil salinity and water-logged conditions for efficient nutrient utilisation (27). Leguminous crops affect the responsiveness to phosphorus in one more way as they fix atmospheric nitrogen which is significantly affected by the phosphorus dose applied

Table 7—Utilization of phosphate bycrops under mixed cropping conditions

Treatment	Drymatter yd (gm)	Total P uptake (mg)	% Pdff	Fert. P uptake (mg)
Wheat alone	2.95	8.67	45.25	4.19
Gram alone	1.13	3.45	25.25	0.90
Wheat in m.c.	3.36	10.39	50.25	5.18
Gram in m.c.	1.07	3.05	18.67	0.58

m.c.=mixed cropping

Reference (28)

Table 8—P utilization in intercropping systems

Inter crops with Pigeon pea	Optimum dose (kg P_2O_5/ha)	Yield at optimum dose (kg/ha)	Gross return/cost of input	Response per kg of fert. P
Alone	53.5	1,815	9.3	—
Green gram	68.6	2,235	9.0	9.4
Black gram	73.8	2,243	8.4	10.5
Cowpea	66.9	2,320	9.5	10.4

Reference (23)

and thus fertility status of the soil is indirectly affected (32).

Phosphorus Fertilisation in a Cropping Sequence

Recent research has brought to focus the need to determine fertiliser doses for a whole crop rotation rather than on individual crop basis. The FAI/FAO Seminar (1974) recommended that, "In general organic manures should be applied in the Kharif season (wet) and the phosphatic fertiliser in the Rabi (dry) season". Such generalised recommendations however not conclusive as they are based on insufficient research. Work therefore should be undertaken to establish the fertiliser requirements of various cropping sequences in different agroclimatic zones of the country.

The utilisation of applied phosphate in a wheat-rice cropping system is more when phosphate is applied to wheat than to rice (24) while results of multilocation trials showed that application of phosphorus only to Rabi crop is not conclusive for the two most important rotations, viz., rice-rice and rice-wheat (20). On the other hand, on purely theoretical considerations and analysing the results obtained under controlled experiments it has been suggested that application of phosphate to rice might be dispensed with in favour of wheat in view of the observations that rice has greater ability to exploit certain fractions of phosphorus which are relatively more abundant under rice soil conditions (61). Phosphate application only to wheat in maize-wheat, sorghum-wheat and pearl millet-wheat rotations has been found economical in most situations.

Root activity and feeding capacities of different crops with respect to soil and fertiliser phosphorus also need to be considered in formulating fertiliser P recommendations for cropping systems (54).

Nature of Fertiliser

The most important characteristic of phosphatic fertiliser that affects the response or uptake by crops is its water solubility. Phosphatic fertilisers vary in their solubility from practically nil to 100 per cent which has a bearing on their agronomic effectiveness. Chemical composition of the fertiliser, granule size and method of application do influence markedly the response to phosphatic fertilisers.

There is a need for continued research on evaluation of fertiliser because of the increasing number and complexity of fertilisers coming into the market. Using ^{32}P as tracer, different phosphatic fertilisers have been evaluated in greenhouse studies (12). The results indicated the superiority of mono- and diammonium phosphates in laterite soil, mono-calcium phosphate and monoammonium phosphate in black soil, ammonium phosphates and calcium metaphosphates in alluvial and di- and monocalcium phosphate in calcareous soils (Table 9).

In a sierozem soil, higher phosphorus utilisation by wheat observed with DAP, DCP and ammonium phosphate was attributed to increased yields and phosphorus content with these fertilisers when compared with rockphosphate or SSP (58).

Phosphatic fertilisers containing half as water soluble phosphate and the other half as citrate soluble phosphate were found efficient for wheat crop, while water soluble phosphates like SSP, DAP, etc., were so for maize (3). Nitrophosphates (70) per cent water soluble (P) DAP and tri- and tetra-pyrophosphates have been found superior to other phosphatic fertilisers in red soils of Andhra Pradesh for rice and sorghum (65).

Method of Phosphate Application

Placement of phosphatic fertilisers reduces fixation by minimising its contact with soil (5). Timely application of fertilisers in adequate amounts is very important for crop production. The time of application depends upon the requirement of the plant vis-a-vis the availability of P in the soil. It has been reported that rice favours basal application of P because of its poor ability to utilise soil P in the early stage (37).

Surface application or broadcast and mixing in by puddling of superphosphate has been found to be the best for rice crop as it resulted in greater phosphorus availability, higher dry matter production and more efficient utilisation of phosphate in comparison with placement of phosphate at depths of 5 to 20 cm (34). Highest per cent utilisation of phosphorus (20.8) under field conditions was reported on Delhi alluvium and calcareous soil of Pusa and broadcast was signifi-

Table 9—Per cent utilization of different phosphatic fertilisers by rice and wheat

(Per cent utilization)

Phosphate source	Laterite rice	Black cotton		IARI alluvium		Calcareous rice
		Rice	Wheat	Rice	Wheat	
Superphosphate	6.2	1.4	23.9	8.5	23.0	6.0
Mono calcium phosphate	6.5	3.9	17.4	4.2	19.5	18.5
Dicalcium phosphate	3.3	0.6	12.1	8.6	9.5	19.8
Calcium metaphosphate	11.4	2.4	19.7	13.3	11.5	12.5
Mono ammonium phosphate	21.5	3.4	28.4	3.4	30.9	12.9
Diammonium phosphate	19.9	2.2	17.1	2.6	26.5	6.3
Ammoniated superphosphate	3.7	2.3	1.9	9.8	5.8	9.0

Reference (12)

cantly better than placement at various depths up to 15 cm (17) (Table 10).

Split Application of Phosphatic Fertilisers

Split application of phosphorus may be useful in cases where initial supply of the nutrient is sufficient to meet the growth requirements of crops. For rice it has been suggested that 50 per cent should be applied at transplanting and the rest 50 per cent at tillering (21, 22). Almost similar observations have been made for wheat (50). Recently, pot cuture studies with DAP applied in split was found superior to full basal application of the fertiliser to wheat as judged by grain yield, total P uptake and per cent Pdff values (Table 11). Alternate tagging technique indicated that the utilisation of phosphate from top dressing was more in case of rice, wheat and barley, while maize absorbed more from basal dose (47). Split application of P at 60 kg P_2O_5/ha as DAP resulted in higher utilisation of P in case of rice under field conditions as compared to full basal application of the fertiliser, the respective figures being 12.4 and 10.0 per cent respectively. Similarly, in the case of wheat split application of P resulted in greater uptake of fertiliser phosphorus (47).

Seedling root dipping of paddy nursery in DAP slurry (20 kg P_2O_5/ha) resulted in higher utilisation of P as compared to soil application of the fertiliser at equivalent dose, the values being 45.5 and 31.1 per cent respectively under pot culture conditions (47), while many others (4, 45) did not find benefits of split application.

Seed Coating and Seedling Root Dipping

Seed coating is the extreme form of placing the fertiliser with the seed which aims at combining the economic usage of fertilisers with increased efficiency. Seed coating of maize seeds with DCP was found more efficient at 15 kg P_2O_5/ha than soil application of the fertiliser even at 30 kg P_2O_5/ha. However beneficial effects on wheat has not been observed with seed coating @15 kg P_2O_5/ha on alluvial soil of Delhi under pot culture conditions (40).

Table 10—Evaluation of best method of P application (rice)

Method of P application (80 kg P_2O_5/ha)	Dry matter yield per plot (g)	Total P_2O_5 uptake (g)	Per cent Pdff values	Per cent utilization of added P
Broadcast & mining	546	2.22	34.6	20.8
Placement at 7.5 cm depth	507	1.98	20.0	10.9
Placement at 15 cm	477	1.79	15.3	7.4
No phosphate	373	1.25	—	—
S.Em ±	24.9	0.10	1.12	2.0
C.D. (5 per cent)	79.7	0.32	3.88	6.4

Reference (17)

Table 11—Utilization of P by some cereal crops as affected by method of application

Fertiliser (40 kg P_2O_5/ha)	Per cent utilisation		Per cent utilisation	
	Basal	Split	Basal	Split
	Rice		*Maize*	
SSP	30.6	37.7	21.3	24.0
DAP	41.2	44.5	22.1	27.0
Mean	35.9	41.1	21.7	25.5
	Wheat		*Barley*	
SSP	13.3	18.0	15.2	16.9
DAP	7.6	11.5	7.8	9.4
Mean	10.4	14.8	11.5	13.2

Reference (47)

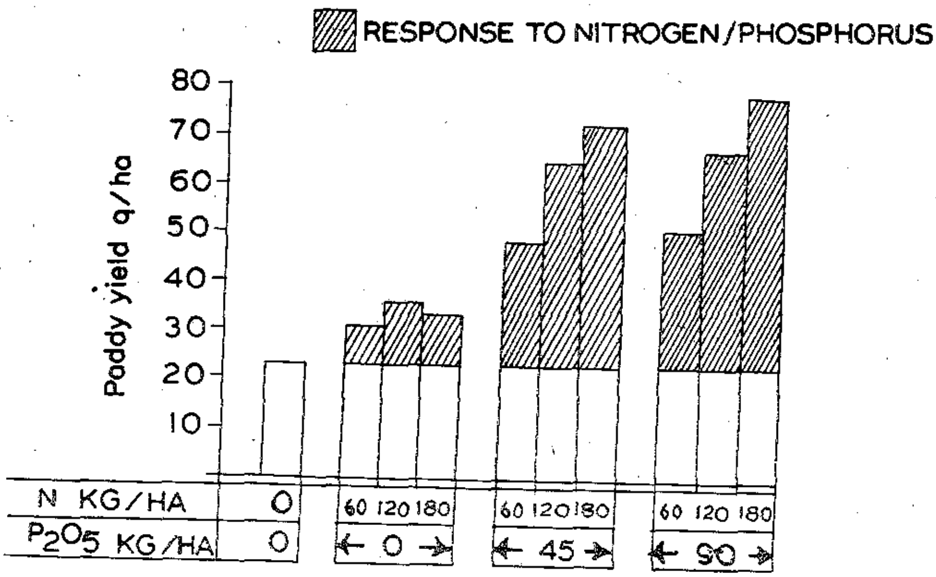
Soaking the seeds in phosphate solution has been suggested as an economical method for supplying the initial needs of plants, the remainder being supplied through fertiliser as application. This method enables the accumulation of nutrients inside the seed by absorption and is still more extreme form of fertiliser placement than the seed coating which obviously ensures the deposition of fertiliser materials on seed coat only. Soaking seeds with 10 to 20 per cent solution of KH_2PO_4 has been found to increase yields by 8 to 15 per cent over untreated controls by Abhichandani (1) while others have reported significant yield responses even at 15 to 20 per cent concentration of the solution (39).

Dipping of rice seedling roots in P solution/slurries before transplantation has been tried with advantages by some workers (47). However, short term dipping treatment of the rice seedling roots in slurry consisting of SSP, soil and water has been found to prevent the deterioration in crop condition which usually occurs during the first 30 days after transplanting (31).

Application of Phosphates with Other Salts

(a) *Nitrogen and phosphorus interaction*

Field experiments on the response of dwarf rice to N and P on a black clay soil at Hyderabad (Andhra Pradesh) clearly show the strong synergistic interaction of these two primary nutrients in a soil deficient both with respect to N and P. Data presented in Figure 2 show that nitrogen application was a paying proposition only when adequate phosphorus was applied.



(Source: AICARP, 1969)

Figure 2—Response of IR-8 rice to N and P_2O_5 on a clay soil highly deficient in both nutrients.

(b) *Magnesium and phosphorus interaction*

Application of magnesium is sometimes done to increase the efficiency of phosphate fertilisers. Research by Truog *et al.* (72) has also revealed an appreciable and consistent increase in P content with increasing supplies of available Mg. Addition of $MgSO_4.7\ H_2O$ to fertiliser increased rye grass production on a light soil not well supplied with magnesium. This increase in production appears to be due to the maintenance of a high level of phosphorus in the soil solution for the duration of the growth period by addition of magnesium sulphate (36).

(c) *Zinc and phosphorus interaction*

Studies on Zn-P interaction has gained importance with the introduction of high yielding varieties and consequent Zinc deficiency in intensive cropping areas. Its deficiency has been often associated with high phosphate soils. Application of Zn is now recommended as a prophylactic measures for high yielding varieties. The data presented in Table 12 indicate interaction between Zn and P (30).

A marked depression in yield resulted with application of P alone when zinc was deficient in soils and application of Zn alone resulted in two fold increase in grain yield of maize. The highest yield was recorded at high levels of both Zn and P. Therefore in fertilisation programme it is not only the major nutrients that should be applied in a balance but also micronutrients should be applied proportionately based on soil test crop response data.

Other Methods of Application to Increase Efficiency of Utilization of P

Several ingenious techniques such as coating SSP with biogas plant slurry or fresh cowdung, pelleting of SSP and application of SSP in conjunction with magnesium sulphate or sodium silicate have been tested for their efficiency to increase the utilisation of applied P by wheat-green gram cropping sequence in field trials. The results have shown that slurry coating treatment is the best in terms of utilisation of applied P by wheat in sandy loam soil resulting in an additional increase of about 5 per cent over SSP alone. In the clay loam soil, SSP + sodium silicate resulted in highest utilisation of P with an increase of about 9 per cent over SSP alone (44). Application of EDTA and sodium silicate has been found to increase the dry matter yield and uptake of phosphorus by wheat and rice in some soils but not in others. Further with addition of silicate, greater uptake of soil phosphorus appeared to be associated with soils of high P fixing capacity and that of fertiliser with low phosphorus fixing soils (9, 10).

Mycorrhiza and Phosphate Utilisation

Recent studies have shown that inoculation of mycorrhiza into different crops permit better use of the P available in the soil. Mycorrhiza responses were much larger in the second and third crop in soils to which rockphosphate was added than in those treated with soluble phosphate. Higher amount of rockphasphate application and allowing sufficient time for reaction in soil had better residual effect than superphosphate, especially for plants inoculated with mycorrhiza (18).

Conclusion

Phosphate management is a naughty (and knotty too) problem in most soils of the world, particularly in those with high clay, sesquioxides or calcium carbonate contents—the basic problem is one that of phosphorus fixation. A great majority of soils in India, the Vertisols, Alfisols and Oxisols are beset with this problem. Added to this more or less universal phenomenon which is dictated purely

Table 12—Effect of Zn and P treatments on yield of maize

$ZnSO_4$ (kg/ha)	Grain yield (q/ha) at levels of P_2O_5		
	0	50	100
0	11.69	5.92	2.10
10	22.26	28.75	28.05
20	20.31	27.56	32.53
40	22.08	24.26	26.96

Source: PAU, Ludhiana (1970)
Reference (30)

by the chemistry of soil phosphorus, practically no addition of fertiliser phosphorus over decades or even centuries, have depleted the available pool of soil P, as is clearly observed from the soil fertility map. Thus, the main problem of management of phosphorus in the soil is that of making good of the deficiencies of the soil in respect of its capacity to supply P to the crop for optimum crop production. This appears to be a simple problem but its solution is extremely complicated because of a variety of factors. For example, some of the Vertisols or Oxisols may require even 3 to 5 times as much fertiliser P as that for an alluvial soil for the same yield level. But more often than that it is an uneconomic proposition for the farmer who looks for his immediate gain from phosphate application. The residual effect could be encouraging only if the succeeding crop in the sequence is able to not only benefit from the past application but also meet its entire demand for P. This calls for a systematic study on the relative benefits of direct and residual effects on component crops in different sequences which have been found to be the best in a soil-climatic region. Prospects for a solution to the management of phosphate may also have to be searched in the choice of suitable crop varieties and fertiliser material and its time and method of application, which have shown promise for a more economic and efficient means of phosphate utilisation by the crop.

Enormous work has already been done to determine the optimum phosphorus requirement of different crop species. But what is more important in the present day context of high cost of phosphatic fertilisers and limited availability of the material is to work out the phosphate requirement for the most important cropping systems followed in various agro-climatic zones in the country. Keeping in view of the possible residual effects of P applied to one crop or the other in the cropping sequence, it is desirable to establish precisely which crop (or crops) in the cropping sequence should be fertilised and at what level.

Though many of the findings to increase the efficiency of utilisation of phosphates have been striking, their relative merits with respect to their adaptability and economic feasibility under field conditions have not been established. Unless information on such aspects are generated, it will not be possible to arrive at any viable recommendation which in reality would cater to the future needs of the country.

In conclusion, it could be stated that the problem of phosphate management in Indian soils is a serious one needing urgent solution not only for stepping up agricultural production but also to maintain the soil productivity at the present level. A great deal of research has been done but much more intensified research is necessary for solution of even a part of this very difficult problem.

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