Phosphorus Response of Oilseeds and Pulses in India and Profitability of Phosphorus Fertilizer Application

By K. Majumdar and V. Govil

Oilseed and pulse crops are critical to the food security scenario in India, with both showing strong responses to fertilizer P application.

Developing appropriate P management strategies involves an understanding of both crop responses to nutrient supply and crop P removal.

Castor crop being inspected by Dr. Majumdar. The inset photo shows severe P deficiency symptoms in a chickpea plant.

The importance of oilseeds and pulses in the Indian diet and economy is well documented. India is the world's largest producer of pulses. Besides providing the cheapest source of vegetable protein for human and animal nutrition, pulses play a significant role in sustainability of agriculture. Oilseeds occupy an important position in the agricultural economy of India. The country is also the largest producer of oilseeds in the world and contributes 7% of the global vegetable oils production, with a 14% share in the global oilseeds area (Jha et al., 2012). Oilseeds are major sources of fats and oil supplements in our diet. Oilseed meal, obtained after oil extraction, is used as an animal feed. They are a rich source of good quality proteins and can be utilized for production of value-added products like protein concentrate, baby food and biscuits after some processing.

Abbreviations and notes: N = nitrogen; P = phosphorus.

India produced 18.3 million t (M t) of pulses and 30.9 M t of oilseeds with an annual productivity of 789 kg/ha and 1,168 kg/ha, respectively in the year 2012-13. The largest production of pulses and oilseeds in India has been recorded in Madhya Pradesh with production of 5.2 M t of pulses and 9.3 M t of oilseeds in 2012-13 (FAI, 2014).

Oilseeds area and output are concentrated in the central and southern parts of India, mainly in the states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra,

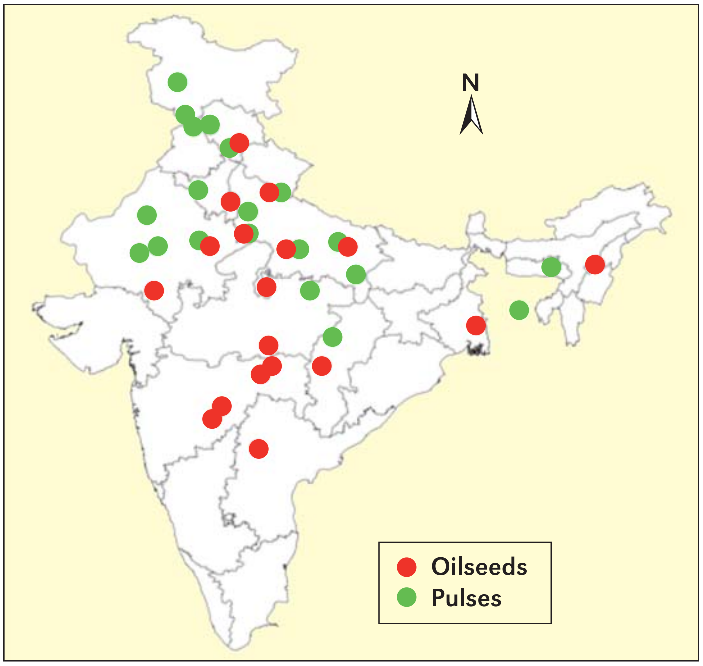

Figure 1. Location map of P response study sites in oilseeds and pulses.

and Rajasthan (FAI, 2014), while pulses are mainly grown in Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh (FAI, 2014).

India imports 2 to 3 M t of pulses every year to meet the growing demand. The projected pulse requirement for the year 2030 is 32 M t, which will require an annual production growth rate of 4.2% (Nadarajan et al., 2013). In case of edible oilseeds, the demand is projected to grow at 12.6% per year during 12th 5-year Plan (2012-2017), which is two and half times more than the growth rate experienced in the domestic production of oilseeds during the previous decade.

The major oilseeds produced in different areas of India are groundnut, mustard, rapeseed, soybean, sunflower, safflower, sesamum, niger, and castor whereas some major pulses are chickpea, pigeonpea, black gram, green gram, lentil, cowpea, horsegram, field pea, lathyrus and kidney bean. Phosphorus plays an important role in the growth and development, as well as maturity of all crops. An adequate supply of P in the early stages helps in initiating its reproductive parts. It hastens the maturity and improves the quality of seeds. In legumes, P plays a major role in the formation and effective fixation of N by plant nodulation. The P requirement of oilseeds and pulses is relatively high as it plays an important role in plant metabolism (Kubsad et al., 2008).

Pulses respond well to applied P in most of the Indian soil types. Since N is applied only to meet the initial vigour of the crop, and response to applied K in pulses is not encouraging, phosphorus application has become the base of fertilizing pulses in India. Pulses are energy rich crops and remove sizeable quantities of nutrients from the soil. Pulse crops require 9.2 kg (chickpea grain) to as high as 48.1 kg (greengram grain) P_2O_5 for producing one tonne of grain. In the case of oilseeds, uptake of P_2O_5 per tonne of economic produce ranges between 8.4 kg (safflower seed) to 30.9 kg for soybean (FAI, 2014). The share of major nutrients in the total uptake pattern of oilseeds is 48% N, 16% P_2O_5 and 37% K_2O. The higher requirement of phosphorus by oilseeds are well documented (Tandon, 2002).

It is estimated that 40.6 and 76.5% of the area under pulses and oilseeds are fertilized in India. The estimated application rate of P_2O_5 is 43.2 and 40.5 kg per hectare of area treated with fertilizer under pulses and oilseeds, respectively (FAI, 2014).

Considering the importance of P nutrition in oilseeds and pulses, the present review was conducted to assess the P responses in reported studies in four leading scientific journals of India namely, Journal of the Indian Society of Soil Science, Indian Journal of Agronomy, Indian Journal of Agricultural Sciences and Indian Journal of Fertilisers, over the period between 2003-2012. There were 87 reported studies on P responses in oilseeds, while 62 studies reported on P responses in pulses. The studies were well distributed across major pulse and oilseeds growing areas of the country, covering major soil types. The study locations are shown on the map of India (**Figure 1**), where each individual point represents multiple sites in the state. The reported studies for oilseeds were from Andhra Pradesh, Chhattisgarh, Delhi, Himachal Pradesh, Maharashtra, Nagaland, Rajasthan, Uttaranchal, Uttar Pradesh, and West Bengal. The studies on pulses were distributed over Chhattisgarh, Delhi, Haryana, Himachal Pradesh, J&K, Rajasthan, Uttaranchal, and Uttar Pradesh. The studies that reported the grain yield responses due to P were chosen for analysis, while the ones that reported the effect of P application on quality parameters like oil content were ignored.

The information on crop yield responses to applied P level was collated from the reviewed papers to estimate P yield response in oilseeds and pulses using the following equation:

P response = Yield of the crop at the applied P level (kg/ha) - Yield of the crop at no P application (kg/ha)

Current value of the crop commodities and cost of P fertilizer was used to estimate the return on investment (ROI) on P application to oilseeds and pulses (Jat et al., 2012):

ROI for P fertilizer = Yield increase due to P fertilizer (kg/ha) x minimum support price (MSP) of crop (Rs/kg) / Applied P_2O_5 (kg/ha) x cost of P_2O_5

Figure 2 shows the extent of P response in oilseeds and

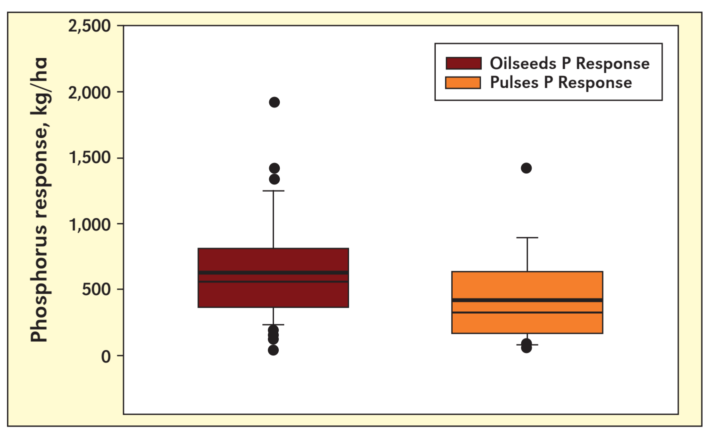

Figure 2. Range of grain yield response to P application in oilseeds and pulses. Boxes represent data within the first and third quartiles (interquartile range). The thin line denotes the second quartile or median and the thick line represents the mean. Lines extending beyond the interquartile range denote the 10th to 90th percentile of the data. Statistical outliers are plotted as individual points outside these lines.

Table 1. Distribution of reviewed data in yield response classes.

	------ Oilseeds ------		------ Pulses ------	
Yield response for P, kg/ha	Number of samples (total = 87)	% samples	Number of samples (total = 62)	% samples
<300	17	19.5	30	48.4
300-600	27	31.0	12	19.4
>600	43	49.4	20	32.3

pulses across the reviewed studies. Phosphorus response in oilseeds was higher than pulses. Average grain yield response of oilseeds averaged 700 kg/ha, while average P response in pulses was 400 kg/ha. The response range of the reviewed data was classified in three yield response classes (**Table 1**). In oilseeds, 19.5% of the studies showed P response of < 300 kg/ha, 31% showed a response of 300 to 600 kg/ha, while 49.4% of the studies showed greater than 600 kg/ha of grain response due to P application. In pulses, the majority of the studies (48.4%) showed P response of < 300 kg/ha, while 19.4% and 32.3% studies showed 300 to 600 kg/ha and > 600 kg/ha of yield response to P, respectively.

Subsequently, P response of individual crops (such as mustard or chickpea), within the broad groups of oilseeds and pulses, were grouped together and average yield response to P application for each crop was estimated. The average yield response in each crop and the average P application rates were used, along with MSP of crops and current cost of P fertilizer, to estimate the ROI on P fertilizer application. **Table 2** showed that P response in oilseeds range from 0.9 to 12 kg of grain per kg of applied P. The ROI on P in oilseeds was 0.8 to 10.4 Rs/Re on P. The results showed that ROI was reasonably high even at the perceived high cost of P fertilizer and generally low P response of oilseeds, showing that farmers can make significant profit from P application in oilseeds. Phosphorus response of pulses was lower than oilseeds, ranging from 1.9 to 11.5 kg per kg of P_2O_5 application (**Table 3**). The ROI on P application in pulses was between Rs.1.9 to 12.9 Rs/Re on P (**Table 3**).

Phosphorus application rates varied widely within and between crops in the surveyed literature. While calculating the ROIs (**Table 2 and 3**), the application rates in different experiments for an individual crop were averaged out to a common application rate. This has an inherent weakness of data redundancy, which might lead to inappropriate representation of ROI. Besides, such average application rates, combining different experimental data from varied locations, may not provide guidance to the user to achieve a particular yield response or ROI.

To avoid data redundancy, the P response data were classified in quartiles within the observed range of P responses in the reviewed literature. This is expected to help guide P application based on yield response and crop uptake. The first, median and third quartile of P responses in oilseeds and pulses were estimated and are given in **Table 4**. Return on investment was re-calculated based on the response levels in **Table 4** and at three chosen P application rates. The three P application rates were selected on the basis of current state recommended P application rates in pulses and oilseeds in different states of India (Tandon, 2002). In case of oilseeds, the range of application rates used were 30, 60 and 90 kg P_2O_5/ha, while 40, 60 and 80 kg P_2O_5 application rates were used for pulses for estimating ROI (**Table 5**). The application of 30 kg P_2O_5/ha in oilseeds gives an ROI of 10.7, 17.1 and 24.6 Rs/Re invested in P at the 370, 590 and 850 kg/ha P responses, respectively. Increasing application rates to 60 and 90 kg/ha in oilseeds decreases the ROI, and the lowest ROI of 3.6 was observed at 370 kg/ha response level and at 90 kg application rate. Similarly for pulses, ROI of 4.4, 9.1 and 17.7 Rs/Re were achieved at the 156, 325 and 633 kg/ha P response levels with application rate of 40 kg P_2O_5/ha. The economic return from P application in pulses is lower than oilseeds due to lower P responses evident in the reviewed literature.

Table 5 shows that applying P based on P response of oilseeds and pulses are economically viable at current cost of

Table 2. Yield response and net return on P fertilizer application in different oilseeds

Crop	P_2O_5 applied, kg/ha	Yield increase due to P_2O_5, kg/ha (±SE)	Net return due to P_2O_5, Rs./ha	Net return, Rs/Re invested on P_2O_5	Response per kg of P_2O_5 applied, kg/kg
Soybean (30)	101	633 (±60)	17,713	7.08	8.14
Pigeonpea (2)	79	605 (±15)	16,940	6.67	7.67
Groundnut (7)	64	401 (±55)	11,216	6.34	7.30
Mustard (32)	102	611 (±76)	17,098	5.69	6.54
Sunflower (2)	80	73 (±30)	2,044	0.79	0.91
Raya (4)	60	720 (±95)	20,160	10.43	12.00
Castor (4)	195	667 (±244)	18,676	2.96	3.40
Sesame (6)	158	1,180 (±18)	33,040	6.6	7.59

*Price of P: Rs.32/kg P_2O_5; Average minimum support price of oilseeds: Rs.28/kg of grain; numbers in parentheses represents the number of studies in a particular crop.

Table 3. Yield response and net return on P fertilizer application in different pulses

Crop	P_2O_5 applied, kg/ha	Yield increase due to P_2O_5, kg/ha (±SE)	Net return due to P_2O_5, Rs./ha	Net return, Rs/Re invested on P_2O_5	Response per kg of P_2O_5 applied, kg/kg
Blackgram (7)	90	106 (±20)	3,821	1.90	1.70
Gram (5)	147	445 (±91)	16,020	3.68	3.29
Greengram (6)	58	221 (±19)	7,956	4.91	4.39
Pigeonpea (9)	111	460 (±41)	16,572	5.09	4.55
Urdbean (5)	72	129 (±33)	4,658	2.09	1.87
Cowpea (1)	20	139	5,004	7.77	6.95
Chickpea (26)	68	640 (±60)	23,051	12.89	11.53
Mungbean (3)	59	127 (±3)	4,560	3.75	3.36

*Price of P: Rs.32/kg P_2O_5; Average minimum support price of pulses: Rs.36/kg of grain.

Table 4. Classes of P response in oilseeds and pulses.

	Yield Response for P, kg/ha	
	Oilseeds	Pulses
1st Quartile	370	156
Median	590	325
3rd Quartile	850	633

P. The generally low P response of oilseeds and pulses, because of achieved low yields in these crops and high cost of phosphate, makes it important that P fertilizer is applied based on a critical assessment of yield response. **Table 5** also poses the important question that at 850 kg/ha P response in oilseeds, how would a farmer decide the appropriate application rate? All the three P application rates, at 850 kg/ha P response, gives significant ROI in P. The highest return is always the most attractive for a farmer, but are there other considerations that need to be taken into account before choosing the appropriate rate? It seems that while deciding about the right P applicaton rate, one has to consider the uptake per tonne of economic produce. Phosphorus is usually accumulated in the grain of a crop, with very little amount of P stored in the aboveground biomass. In such a scenario, crops with comparatively higher uptake requirement to produce one tonne of grain (soybean, sesame, groundnut, etc.) should be treated with higher fertilizer rates than crops with lesser uptake requirement of P. In other words, P application rates should also be based on uptake requirement besides the expected response to P application to limit P mining from the soil. Soils showing higher P response suggests lower availability of P, such as red & lateritic soils, and a higher P application rate in a high P requiring crop in such a soil would ensure reasonably high return and maintainence of P fertility levels of the soil. Similar logic could be extended to other P response levels in **Table 5**, where more P should be applied to oilseeds or pulses that have high P uptake requirement even if the response levels are similar.

Summary

Improving oilseeds and pulses production in India is required to meet the growing demands. Area expansion is possible in these crops as the relative prices with competing crops are favorable and the relative profitability is higher. Crop intensification in underutilized farming situations like rice fallows can contribute to an increase in area under oilseeds and pulses. However, there are ample opportunities to improve productivity of these crops from the existing area through proper nutrient management. This will lead to sustainable intensification, without sacrificing the area under other crops, while meeting the national requirement. BC-SA

Table 5. Return on Investment (ROI) on P fertilizer in oilseeds and pulses at different crop response levels and application rates.

Yield response classes of Oilseeds, kg/ha	370	590	850
	Return on Investment (Rs/Re) in oilseeds#		
At 30 kg P_2O_5/ha application rate*	10.7	17.1	24.6
At 60 kg P_2O_5/ha application rate	5.4	8.6	12.3
At 90 kg P_2O_5/ha application rate	3.6	5.7	8.2
Yield response classes of Pulses, kg/ha	156	325	633
	Return on Investment (Rs/Re) in pulses@		
At 40 kg P_2O_5/ha application rate	4.4	9.1	17.7
At 60 kg P_2O_5/ha application rate	2.9	6.1	11.8
At 80 kg P_2O_5/ha application rate	2.2	4.5	8.8

*Price of P: Rs.32/kg P_2O_5; #Average minimum support price of oilseeds: Rs.28/kg grain; @Average MSP of pulses: Rs.36/kg of grain

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