Phosphorus requirements and management of oilseeds

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The recent literature on the P requirements and management of annual edible oilseeds groundnut *Arachis hypogaea* sunflower *Helianthus annuus* safflower *Carthamus tinctorius* rapeseed *Brassica campestris* mustard *B juncea* and sesame *Sesamum indicum* is reviewed The internal P requirement to produce a given level of seed yield varies among the oilseeds but in general they use the soil and fertilizer P efficiently The external P requirement is also greatly modified by soil moisture season supply of nutrients other than P and P status of soil Effects of P management practices especially those relating to source method and time of application on the yield response and fertilizer P requirement of oilseeds are discussed Recommendations are made for future research

Oilseeds form an important component of the human diet in Asia and the Pacific Oilseeds are grown on diverse soils mostly under unirrigated and less than ideal conditions and plant nutrients are one of the most important constraints on their growth and yield (Directorate of Oilseeds Research 1984,1985 Reid 1981) The P requirement of oilseeds is higher than that of cereals because P is involved in the synthesis of energy rich oils and proteins However such requirement varies not only from crop to crop but also among cultivars of the same crop

This paper reviews the recent literature on the P requirements and management of selected annual edible oilseed crops in Asia and the Pacific region Where available preference is given to data from well planned field studies and to reports with wider scope and broader perspective The oilseeds covered in this review are groundnut *Arachis hypogaea* sunflower *Helianthus annuus*, safflower *Carthamus tinctorius* rapeseed *Brassica campestris*, mustard *B juncea*, and sesame *Sesamum indicum* Phosphorus requirements and management are discussed separately for each oilseed crop

Several soil fertility and agroclimatic factors that affect growth and yield also affect the P requirements of oilseeds

- *Soil fertility factors*
  - Available P status of soil
  - Supply of macro and micronutrients other than P
  - Available soil moisture
  - Importance of vesicular arbuscular mycorrhizal fungi

Agroclimatic factors

- Total rainfall and its distribution during the cropping season
- Availability of irrigation
- Temperature
- Solar radiation

In addition, the source and time of fertilizer P application, as well as soil type greatly affect the P response of oilseeds.

The term *internal P requirement* of an oilseed generally refers to the minimum P concentration in tissue or the P uptake by tops at maximum seed yield or at the yield corresponding to a critical limit, e.g., 90% of maximum yield. However, in this paper, internal P requirement has been used rather loosely to signify P concentrations and content, not necessarily at 90% of maximum yield.

Groundnut

Groundnut is a legume oilseed, and most of its N requirement is met by biological N fixation. Groundnut is monocropped or intercropped with various crops in different cropping sequences (Directorate of Oilseeds Research 1985).

Internal phosphorus requirement

Satyanarayana and Krishna Rao (1962) found that the leaves of healthy groundnut plants at the start of flowering contained 0.22% total P, which is similar to the values reported by Nelson (1980). Typical approximate P concentrations of groundnut at harvest have been reported as 0.07% in the haulms, 0.03% in the shells, and 0.36% in the kernels (Nelson 1980).

Tissue concentration in the uppermost fully expanded leaves during vegetative growth was 0.3% and declined linearly during reproductive growth from 0.27% at 60 d after emergence (DE) to 0.12% at 100 DE. Regression equations satisfactorily described the relationships between yield and tissue P concentration at all stages of plant growth except at day 42, which corresponded to the early reproductive development period when P accumulated in the developing pods. Variability could also have been caused by translocation of P from vegetative tissues to developing fruit parts (Bunting and Anderson 1960).

Tissue testing for the internal P requirement of groundnut during early reproductive development may not be valid.

Fertilizer phosphorus requirements and management

Aulakh et al. (1985) determined the P content of several oilseed crops including groundnut by analyzing seed and stover samples. The oilseeds were grown at four sites on the Punjab Agricultural University farm in Ludhiana, India, and in farmers' fields. Yield and P uptake data (Table 1) show that the total amount of P taken up to produce 1 t of seed varied from 8.3 to 20.0 kg among the oilseeds. Groundnut required about 10 kg to produce a 1-t kernel yield. The amounts of P taken up by different oilseeds to produce 1 t of seed were much higher than those for cereals such as rice and sorghum, as well as pulses such as chickpea and pigeonpea (Tandon 1987).

Table 1. Seed yield and P uptake of selected oilseeds[a] (from Aulakh et al 1985)

Crop	Cultivar	Seed yield (t/ha)	Total P uptake (kg/ha)	P taken up (kg) to produce 1 t of seed
Raya (*B juncea*)	RL 18	2.0	18	9.0
Groundnut (*A hypogaea*)	M 145	1.9	19	10.0
Sarson (*B campestris*)	BSH 1	1.5	17	11.3
Taramira (*E sativa*)	Selection 1	1.5	17	11.3
Sesame (*S indicum*)	Pb Till No 1	1.2	24	20.0
Sunflower (*H annuus*)	Ramson Record	0.6	5	8.3

[a]Sarson and taramira are also known as rapeseed, and raya as mustard

In a recent study, Sahrawat et al (1988) found that 15.1 kg of total P/ha was taken up by a groundnut crop (cultivar Robut 33-1) producing 3.1 t pods. After correcting for shelling percentage, the total P uptake for a crop producing 1 t groundnut kernels would be around 7.2 kg P/ha. At harvest, the P concentrations were 0.41% in the kernels, 0.14% in the haulms, and 0.09% in the husks (shells).

Bell (1985) made detailed investigations of the P requirement of Virginia Bunch groundnut grown on virgin cockatoo sand (pH 5.7, 2.0 mg 0.5 *M* $NaHCO_3$-extractable P/kg, CEC 2.0 meq/100 g) in a 3-yr study. A range of 0.5 *M* $NaHCO_3$ extractable P levels in soil was created by incorporating 0-80 kg P/ha as triple superphosphate (TSP) in band in the first year and as broadcast application in the second year. The soil P concentrations (0.5 *M* $NaHCO_3$-extractable) required for 90% of maximum pod and kernel yield were 7.3 and 7.9 mg/kg, respectively. These soil critical values for 0.5 *M* $NaHCO_3$-extractable P are similar to that of 8.3 mg/kg soil found by Singh and Rana (1979) for sandy soils in Punjab (India).

Bell (1985) further showed that the relation between pod or kernel yield and extractable soil P level before planting in the top 10 cm of soil followed a Mitscherlich-type equation and could be represented by the following equations

$$\text{Pod yield (t/ha)} = 4.764^{0.395\ \text{extractable P}}$$
$$R^2 = 0.85$$
$$\text{Kernel yield (t/ha)} = 3.14\ 1^{0.375\ \text{extractable P}}$$
$$R^2 = 0.83$$

Fertilizer P responses vary with the soil's available P status, its phosphate adsorption-desorption characteristics, and the supply of other nutrients (Nelson 1980, Landon 1987). Unfortunately, a large number of experiments gave only minimum data on the status of available soil nutrients, making their interpretation difficult.

Hall (1975) examined the effects of P, K, and Ca on Virginia Runner groundnut grown in Nuata clay loam (New Zealand). P and Ca together gave large yield increases, but P or Ca applied separately was relatively ineffective. Potassium depressed yield when applied together with P and Ca. This shows the interdependence of P response on Ca supply.

Nelson (1980) analyzed fertilization data from 722 location-years in the United States and reported that 1 kg of applied P increased groundnut yield by 20 0 ± 4 3 kg/ha The experiments had P rates ranging from 10 to 41 kg/ha (average, 21 5 kg/ha)

Laurence (1982) made a detailed 2-yr evaluation of P response of groundnut under irrigated conditions on Cockatoo Sands in the Ord River Valley of Western Australia The soils (2 sites) had pH 6 5 and 6 1, extractable P 3 and 10 mg/kg, and CEC 3 3 and 1 4 meq/100 g Pod yield increased from 3 35 to 4 56 t/ha with 20 kg P/ha, the highest mean pod yield reported was 4 68 t/ha at 60 kg P/ha Shelling percentage was improved from 66 8 to 68 9% at 20 kg P/ha

Tandon (1987) summarized the data from numerous experiments conducted during 1969-84 in India under rainfed and irrigated conditions (Table 2) Although indicating a response of groundnut to P application, the data are hard to interpret because the experiments were conducted under diverse soil and climatic conditions details about soil P status, other soil characteristics, source of P, and supply of other nutrients are not available

A guide to fertilizer P recommendations for oilseeds in India prepared by the Directorate of Oilseeds Research is summarized in Table 3 As expected, the rates recommended for irrigated conditions are higher than those for rainfed farming The rates of fertilizer P recommended for groundnut are similar to the typical recommendations for the United States and other parts of the world which range from 15 to 50 kg P/ha, depending on available soil P (Nelson 1980) In the Punjab (India), single superphosphate (SSP) gave superior yield responses in groundnut compared with TSP and diammonium phosphate (DAP) (Pasricha et al 1987) The response to SSP could be due to S rather than to P in view of the high S requirement of groundnut The N content of DAP may have depressed yields Evidently, P content in groundnut kernels was increased by all sources, while S content increased only where SSP was added The P content of groundnut kernels was poorly correlated with pod yield ($r = 0\ 23$), but S content was significantly correlated with pod yield ($r = 0\ 77^{**}$) These results confirm the superiority of SSP to DAP and TSP because of S supply (Pasricha et al 1987) SSP is a good source of secondary nutrients such as Ca, Mg, and S and of some micronutrients that could markedly affect the yield, oil content, and shelling percentage of groundnut (Puri 1972) Early

Table 2 Average yield responses of groundnut to applied P in farmers' fields under rainfed and irrigated conditions in India[a] (adapted from Tandon 1987)

Parameter	Rainfed		Irrigated	
Trials (no)	1307		266	
Season	Rainy (Jun-Sep)		Postrainy (Oct Jan)	
Average pod yield without applied P	0 86 t/ha		1 62 t/ha	
P applied	26	kg/ha	26	kg/ha
Average yield response to P	290	kg/ha	450	kg/ha
Average yield response	11	kg/kg P	17	kg/kg P

[a]Trials made during 1969-84 using different P fertilizers

Table 3 Fertilizer P recommendations for oilseeds in India[a] (adapted from Directorate of Oilseeds Research 1984, 1985)

Oilseed	Recommended fertilizer P (kg/ha)	
	Rainfed	Irrigated
Groundnut	16-60	26 75
Sunflower	13 17	17 26
Safflower	9-13	–[b]
Rapeseed and mustard	15-40	20 50
Sesame	10-40	10-40

[a]P recommendations are general and depend on soil P status and yield goal Other nutrients especially N K and micronutrients are essential their requirements and rates vary widely [b]Data not available

root growth in groundnut is primarily by the taproot Lateral root growth contributes little to P absorption until the crop is 10-11 wk old Therefore, fertilizer P placement below the seed row is most satisfactory for P management of groundnut (Directorate of Oilseeds Research 1984,1985, Nelson 1980, Pasricha et al 1987)

Sunflower

Sunflower is an important oilseed crop in Asia and the Pacific Its oil is assuming importance as a high-quality product for human consumption Sunflower can be cultivated year round, but being a nonlegume, it requires fertilizer N Sunflower is grown both as a monocrop and as an intercrop in different combinations, especially in India (Directorate of Oilseeds Research 1985) It is better adapted to water stress and salinity than other oilseeds After N, P is the most important nutrient limiting sunflower productivity (Blamey et al 1987, Robinson 1978)

Internal phosphorus requirement

In one greenhouse and three field experiments, Spencer and Chan (1981) found that the lamina of the youngest fully expanded leaf is a suitable plant part for diagnosis Critical P concentrations for this tissue decreased from about 0 35% in the 4th week from sowing to 0 20% in the 10th week The P content of the lamina of the youngest fully expanded leaf reflected shoot growth at 7 and 10 wk, and seed yield under both rainfed and irrigated conditions (Table 4)

Loubser and Human (1983) determined P concentrations in sunflower leaves in a 5-yr field study Low-oil cultivar Kortrus and high-oil hybrid cultivar SO 320 were grown in a P-deficient soil with treatment combinations of 0, 60, 120, or 180 kg N/ha and 0, 20, 40, or 60 kg P/ha The P content of the youngest fully expanded leaf tissue was highly correlated with seed yield The critical P concentration required to achieve 90% of maximum yield varied among cultivars and years in the range 0 21-0 31% P The critical P concentrations for the low- and high-oil cultivars were 0 27 and 0 24%, respectively These results agree with those of Spencer and Chan (1981) and reinforce the utility of tissue testing for P requirements for sunflower

Table 4. Effect of applied P on shoot growth, leaf P concentration seed weight, and oil content of sunflower cultivar Hysun 10 (from Spencer and Chan 1981)

P applied[a] (kg/ha)	Top weight (g/plant)[a] at		P content of lamina of youngest fully expanded leaf at 6 wk (%)	Seed weight (t/ha)	Seed oil content (%)
	7 wk	10 wk			
			Rainfed[b]		
0	2 3	11 5	–	0 31	38 9
2 5	3 2	15 2	–	0 34	39 5
5	3 6	17 2	–	0 38	40 2
8	4 4	20 6	–	0 41	40 2
14	5 8	22 0	–	0 43	41 6
30	7 0	25 8	–	0 48	41 3
LSD				0 06	
			Irrigated[c]		
0	–		0 24	2 74	48 9
20	–	–	0 31	3 52	46 5
40	–	–	0 35	4 02	45 4
LSD				1 21	

[a]Response curve showed that 90% of maximum shoot weight occurred at 21 kg P/ha at 7 wk and at 20 kg P/ha at 10 wk [b]P applied as TSP was drilled below the seed All other nutrients (N K S B and Mo) were added in adequate amounts [c]P applied as TSP was drilled below the seed A basal application of 2 t limestone/ha and 160 kg N/ha as NH_4NO_3 was given

Aulakh et al (1985) reported that the P concentrations in the seed and stover of sunflower cultivar Ramson Record at harvest were 0 57 and 0 05%, respectively

Ramam and Dhingra (1981) reported that maximum P uptake rates in cultivars FC68414 and Latur occurred between 60 and 120 d Field studies on the pattern of P uptake and its distribution in sunflower showed that 41-70% of the P was taken up during the grain filling and ripening stages Phosphorus accumulated in the leaves during vegetative growth, in the head during button formation and flowering, and in the grain during grain filling and ripening (Mitreva and Iliev 1984) Maximum P concentrations in the tissues of the 2 cultivars grown in an alluvial soil occurred at 40 or 60 d and were 0 12 and 0 08% in the stem, 0 16 and 0 12% in the leaves, 0 20 and 0 16% in the inflorescence, and 0 16 and 0 08% in the root, respectively

Blamey et al (1987) found that 5 1 kg P (3 9 kg by the seed and 1 2 kg by the stover) was taken up by a sunflower crop producing 1 t seed/ha Phosphorus concentration was 0 39% in the seed and 0 08% in stover The 5 1 kg total P uptake is lower than the 8 3 kg P reported by Aulakh et al (1985) (Table 1), perhaps because of differences in the harvest index of the cultivars used (Blamey et al [1987] assumed a harvest index of 40%.)

Fertilizer phosphorus requirements and management

In an early study, sunflower was similar to wheat in uptake and utilization of soil and fertilizer P but was less efficient than barley (Warder and Vijayalakshmi 1974)

In a series of experiments, Spencer and Chan (1981) reported that the P response of sunflower depended greatly on the availability of irrigation and the yield levels obtained (Table 4). In general, the P fertilizer requirement of sunflower, as of other oilseeds, is higher under irrigated conditions (Table 3). Spencer and Chan (1981) (Table 4) found that under rainfed conditions, seed yield increased from 0.31 (no P applied) to 0.48 t/ha with 30 kg P/ha applied as TSP; under irrigated conditions, seed yield increased from 2.74 (no P applied) to 4.02 t/ha with 40 kg P/ha applied as TSP when other nutrients were added in adequate amounts. While P application under rainfed conditions increased the seed oil content, it decreased the oil content under irrigated conditions. Generally, P fertilization was reported to have increased the oil content of sunflower seeds (Directorate of Oilseeds Research 1985).

Available Australian literature indicates that the fertilizer P requirement for sunflower resulting in 90% of the maximum yield is on the order of 20 kg/ha (Spencer and Chan 1981). Studies in India indicate a requirement ranging up to 30 kg/ha, depending on the soil available P status and yield goal (Ankineedu et al 1983, Tandon 1987). Yield responses to applied P have commonly occurred up to 20 kg P/ha if the fertilizer was banded below and to the side of the seed; about 4 times this rate was required when the fertilizer was broadcast and incorporated by plowing, especially in phosphate-fixing soils (e.g., Spencer and Chan 1981). Generally, deep band placement of P has been found most effective under rainfed conditions (Ankineedu et al 1983, Tandon 1987).

Safflower

Like sunflower, safflower requires fertilizer N and other macro- and micronutrients, which affect its P requirements and seed yield.

Internal phosphorus requirement

Data on the internal P requirement of safflower are lacking. A recent study at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (T. J. Rego, ICRISAT, unpubl. data) showed that 4.1-6.0 kg P was taken up by safflower (cultivar Manjira) grown on a Vertisol with application of 21 kg P/ha (as SSP) and 120 kg N/ha (as urea) to produce 1 t of seed (Table 5).

Table 5 Concentration of P in seed and stover and total P uptake at harvest in relation to seed yield of safflower (cultivar Manjira) grown under rainfed conditions on a Vertisol[a]

Year	P concentration (%)		Yield (t/ha)		Total P uptake (kg) to produce 1 t seed
	Seed	Stover	Seed	Stover	
1984	0.30	0.05	0.93	1.95	4.1
1985	0.47	0.05	0.26	0.64	5.9
1987	0.35	0.08	0.97	3.07	6.0
Mean	0.37	0.06	0.72	1.89	5.3

[a] Unpublished data from T. J. Rego, ICRISAT, Patancheru, Andhra Pradesh 502 324, India. The crop was grown in the postrainy season (Oct-Jan) and received 120 kg N/ha as urea and 21 kg P/ha as SSP.

Fertilizer phosphorus requirements and management

Gaur and Tomar (1980) studied the response of safflower N P 30 grown on a sandy loam (pH 8.0) to application of N and P fertilizers, at 60 kg N/ha and 12 kg K/ha P application at 9 kg/ha significantly increased seed yield from 0.78 to 0.87 t/ha. Further increase in the P rate to 17 or 26 kg/ha did not affect seed yield. In rainfed trials during 1974-76, safflower yield increased with up to 60 kg N/ha and 17 kg P/ha (Sharma and Verma 1982).

The limited data on P response of safflower indicate that up to 20 kg P/ha may be enough for meeting the fertilizer P requirement under rainfed conditions and about 30 kg P/ha may be needed for irrigated safflower cultivation. In a recent study, application of 13 and 26 kg P/ha to safflower at 12- or 24-cm soil depth increased the growth and P uptake of fertilizer P compared with broadcast P (Sinha et al 1985).

Rapeseed and mustard

Several oilseeds belonging to the Cruciferae are included under rapeseed and mustard. These can be divided into four groups:

- Brown mustard (raya or laha) *Brassica juncea* (L.) Czern. & Coss.
- Sarson = Yellow sarson *B. campestris* L. var. *sarson* Prain, and Brown sarson *B. campestris* L. var. *dichotoma* Watt
- Toria (lahi) *B. campestris* L. var. *toria* Duth
- Taramira *Eruca sativa* Mill

Commercially sarson, toria, and taramira are known as rapeseed, and raya as mustard.

Rapeseed and mustard are important oilseed crops in the Indian subcontinent (Directorate of Oilseeds Research 1984, Kaul and Das 1986). Their cultivation is confined mostly to the temperate and warm temperate regions of China, Pakistan, Bangladesh, and India where both summer and winter varieties are common (Kaul and Das 1986). These crops are grown on a small scale in Australia (Reid 1981).

Internal phosphorus requirement

Aulakh et al (1985) found that P concentrations in mustard (*B. campestris* cultivar BSH1) seed and stover at harvest were 0.77 and 0.08% P, respectively, while those for raya (*B. juncea* cultivar RL 18) were 0.65 and 0.06% P, respectively. The amounts of P taken up by mustard and raya crops producing 1 t seed were 11.3 and 9.0 kg P, respectively (Table 1). Calculations made from the data of Singh et al (1988), who studied P utilization by *B. juncea* for 2 yr in a sandy loam soil (pH 8.2, 13.2-14.4 kg available P/ha) show that about 9 kg P was taken up by the crop producing 1 t of seed. For taramira cultivar Selection 1, 11.3 kg P was taken up to produce 1 t of seed (Aulakh et al 1985, Table 1).

Fertilizer phosphorus requirements and management

Osborne and Batten (1978) investigated the effects of soil and fertilizer N and P on the yield and on oil and protein contents of rape (cultivar Zephyr) grown at two sites in Wagga Wagga, New South Wales, Australia, having a range of available P concentrations At both sites, drilled TSP caused significant increases in dry matter production and in seed, oil, and protein yields Phosphorus response was greatly affected by the soil N supply Oil yields were 237-1,273 kg/ha at the high-N site and 229-916 kg/ha at the low-N site

The results from 1,014 experiments in 1977-78 and 1981-82 on the P response of rapeseed mustard in farmers' fields throughout India showed a large response to P (Pillai et al 1984) The average yield from unfertilized plots was 0 56 t/ha (range 0 24-1 20), average responses to P application of 9 and 17 kg P/ha were 191 (range 51 267) and 329 (range 116-453) kg/ha, respectively (Unfertilized plots did not receive any N P, or K fertilizer, while fertilized plots received 60 kg N/ha uniformly) These results, conducted under diverse agroclimatic and soil conditions, indicate the role of P fertilization in increasing the yield of this group of oilseeds The data from these national demonstrations further indicate that it is possible to obtain seed yields of 1 5-2 0 t/ha with balanced fertilization and good cultural practices (Pillai et al 1984) A rate of 17 4 kg P/ha was found to be adequate when other nutrients such as N and K were supplied in optimum amounts

Singh et al (1988) showed from a 2-yr study of P response of mustard grown on a sandy loam (pH 8 2, 0 5 M $NaHCO_3$-extractable P 13 2-14 4 kg/ha) that seed yield was significantly increased by application of 13 kg P/ha as SSP Further increasing P rate to 26 and 39 kg/ha did not significantly increase seed yield Single superphosphate blended with biogas plant slurry was a superior source of P in both years for increased yield and P uptake

It thus seems that about 20 kg P/ha may be sufficient for moderate yields of the rapeseed-mustard cultivars, depending on the soil P level, availability of irrigation, and yield target Higher P rates are recommended for irrigated crops (Table 3)

Sesame

Sesame is an important oilseed crop in India, Pakistan, Burma, Indochina, Japan, and China (Kaul and Das 1986) It is grown as a rainfed crop in the rainy season and also as an irrigated crop after the rainy season in the Indian subcontinent Sesame is very responsive to N, and P response is greatly dependent on the N supply

Internal phosphorus requirement

Aulakh et al (1985) reported that sesame cultivar Pb Til No 1 at harvest had P concentrations of 0 80% in the seed and 0 30% in the stover By their data, about 20 kg P would be taken up by a sesame crop producing 1 t of seed (Table 1) This value is the highest for the oilseeds discussed in this paper However, Ankineedu et al (1983) reported that a sesame crop producing 2 2 t seed/ha removed about 32 kg P/ha, which works out to be 14 5 kg P uptake to produce 1 t of seed a considerably lower P requirement than that reported by Aulakh et al (1985)

Fertilizer phosphorus requirements and management

The fertilizer P requirement of sesame has been investigated much less than those of the other oilseeds discussed in this paper The limited data available indicate that, depending on the available P status of the soil, about 15-20 kg P/ha would be sufficient to meet a crop's need for P for moderate seed yields (Kaul and Das 1986 Singh and Kaushal 1975) In a 2-yr study in Peshawar, Pakistan, Zaidi and Khan (1981) found that cultivar S 17 gave a higher seed yield than Calida, P 37-4, or the local black seed varieties Application of nitrophos (20% N, 8 7% P) at 165 kg/ha to supply 33 kg N/ha and 14 3 kg P/ha gave a higher seed yield than those obtained with SSP applied at 14 3 kg P/ha or urea at 33 kg N/ha, clearly suggesting the need for applying N and P together for best results

Placement of P at 2 or 4 cm below the seed in a soil low in available P (pH 4 5) increased the height and P uptake of sesame Placement of P with or immediately below the seed increased dry matter production (Ramirez et al 1975) Phosphorus placement near the seed was found to promote initial development of the sesame plant

Suggestions for research

The foregoing discussion on the P requirements and management of selected edible oilseeds brings out the role of P nutrition in increasing oilseed yields under both rainfed and irrigated conditions The yields of oilseeds and their P requirements are clearly modified by the availability of other nutrients Available P status and the behavior of fertilizer P, especially phosphate adsorption-desorption, are good indices of the amount of P likely to be available to plants Unfortunately, a large body of data on the P response of oilseeds is difficult to interpret because of lack of minimum data sets on available P and other soil characteristics that control P availability It is also not clear from the literature whether the experiments were irrigated or not, and for a number of studies the data on rainfall during the growing season are not available There is little information available about the P requirements of oilseeds under rainfed conditions, future research should devote attention to that important area Different sources of P have been used, but there is no mention of balancing the secondary nutrients supplied by some P sources making comparison with other sources invalid Also, there is little mention of the availability of the other nutrients (in soil or through added fertilizers) that greatly affect P response and yield

For P response, very few rates have generally been employed, giving data that cannot be used for precise determination of a crop's P requirement Experiments with at least five or six P rates are needed to compute the P requirement from a range of yield levels Data are lacking on the internal P requirements of oilseeds, except perhaps for groundnut The data from experiments described by Laurence (1982) and Bell (1985) on groundnut and by Spencer and Chan (1981) on sunflower provide excellent examples of how plant analyses can be used to determine the internal and fertilizer P requirements of crops Data on P uptake at maximum yield or at yields corresponding to a critical limit, e g , 90% of maximum seed yield, would be true indicators of the internal P requirement of an oilseed In most cases, however, the data on P uptake are available without reference to maximum yield, which could be at best treated as a gross requirement Fewer but well-planned experiments would furnish highly desirable and useful information in developing suitable P management strategies for increasing the productivity of oilseeds

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