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INTERACTION AMONG NUTRIENTS AND NUTRIENTS WITH IRRIGATION FOR SUSTAINABLE OILSEED PRODUCTION - A REVIEW

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ABSTRACT

India is a paradise for oilseed crops. Oilseeds, the second largest agricultural commodity after cereals in India, play a significant role in India's agrarian economy, sharing 14% of the gross cropped area and accounting for nearly 5% of the gross national product and 10% of the value of all agricultural products. A range of oilseed crops viz., groundnut, rapeseed and mustard, soybean, sesame, sunflower, safflower, niger, linseed and castor are cultivated in the country. Though India occupies a premier position in terms of area, its contribution towards World's production of annual oilseeds is less than 10%. It is mainly due to extremely low productivity of oilseeds. Nutrients and water are the key inputs for higher yields. The interaction among the nutrients (NxP, NxK, PxK, NxPxK, NPK with S, NPK with organic manures, NPK with micro and secondary nutrients and NPK with biofertilizers), interactions of water and nutrients are the most important factors responsible for higher productivity and greater oilseed stock of the country. If the nature of interaction is properly understood, large increase in oilseeds is expected to come from such interactions. Several nutrient interactions and irrigation x nutrient interactive technologies are available, but their potential in increasing yield has not yet been exploited properly. There exists a tremendous scope for further increasing the oilseed productivity through exploiting these interactive technologies.

India is blessed with diverse agro-ecological conditions ideally suited for growing all nine annual oilseed crops. The oilseeds play a significant role in India's agrarian economy, as more than 85% of the country's vegetable oil supply depend upon seven edible (groundnut, rapeseed and mustard, soybean, sesame, sunflower, safflower and niger) and two non-edible oilseeds (linseed and castor) traditionally grown in different parts of the country (Table 1). It is the second largest agricultural commodity after cereals in India sharing 14% of the gross cropped area and accounting for nearly 5% of the gross national product and 10% of the value of all agricultural products. The production of oilseeds increased from a mere 10.83 million tonnes in 1985-86 to 25.68 million tonnes in 1998-99. Credit goes to the Technological Mission on Oilseeds (TMO) for bringing out the so called 'Yellow revolution' in India. Though India occupies better position with respect to area and production, the yield level is far behind the other countries (Table 2). The productivity of oilseeds in India is around 935 kg/ha as compared to the world level of 1632 kg/ha. A major reason for the low average yield is the cultivation of oilseeds mostly under conditions where soils are both thirsty and hungry. Less or no use of plant nutrient is one of the important factors for low productivity of oilseeds. Also, there is an inherent biological limitation for the yield of oilseeds. It has been estimated that one gram of glucose synthesised through photosynthesis produces 0.83 g starch, 0.40 g protein and only 0.32 g of lipid. The nutrient requirement of oilseeds is high, in general, for all the nutrients and for P and S in particular, and needs to be supplied in adequate quantities. Unless, oilseeds are provided with extra input to produce more biomass, it is not expected to generate high yields. Therefore, what really we need is the increased input-use efficiency through exploiting interactive effects of nutrients and water.

Table 1. Productivity of different oilseed crops in India

Crops	Productivity (kg/ha)		Major states ranked on the basis of area occupied#
	World $	India *	
Groundnut	1273	1078	Gujarat, Andhra Pradesh, Karnataka, Maharastra, Rajasthan.
Rapeseed-mustard	1451	667	Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, West Bengal, Assam, Bihar.
Soybean	2174	1126	Madhya Pradesh, Maharastra, Rajasthan, Karnataka.
Sunflower	1219	549	Karnataka, Maharastra, Andhra Pradesh, Tamil Nadu.
Sesame	366	345	Gujarat, Rajasthan, Madhya Pradesh, Uttar Pradesh, Tamil Nadu, Maharastra, Andhra Pradesh, West Bengal, Karnataka.
Linseed	720	294	Madhya Pradesh, Uttar Pradesh, Maharastra, Bihar, Orissa, Karnataka.
Safflower	898	242	Maharastra, Karnataka, Andhra Pradesh.
Castor	942	1292	Gujarat, Andhra Pradesh, Rajasthan, Tamil Nadu, Karnataka.
Niger	-	299	Madhya Pradesh, Orissa, Maharastra, Karnataka, Bihar.

*1997-98, $1997, #Figures in the parentheses indicate the state contribution (%) in area.

Source: Damodaram and Hegde (1999)

Table 2. India's rank in area, production and yield of different oilseeds grown in different countries during 1997-1998

Crops	Area	Production	Yield
Groundnut	1st	2nd	10th
Rapeseed-mustard	1st	1st	11th
Soybean	5th	5th	17th
Sesame	1st	1st	15th
Sunflower	2nd	3rd	16th
Safflower	1st	1st	7th
Castor	1st	1st	3rd
Linseed	1st	3rd	14th

Source: Damodaram and Hegde (1999)

Interaction

An interaction occurs when the response of one or a series of factors is modified by the effect of one or more other factors. The interaction is positive (synergistic) when response to factors used together is greater than the sum of their individual responses. There is an add-on effect. The nature of other possible interactions can be negative (antagonistic). Thus interactions and their recognition is the key for significant progress towards maximum yields and maximum profit to farmers. In this context, it will be worth mentioning the statement of George W. Cooke, former Chief Scientific Officer of Britain's Agricultural Research Council as: *"In a highly developed agriculture, large increases in yield potential will mostly come from interaction effects. Farmers must be ready to test all new advances that may raise yield potentials of their crops and be prepared to try combinations of two or more practices".* Many interactions are vital to high yields. Among the different interactions, nutrient x nutrient and nutrient x irrigation interactions are vital to boost the oilseed yield of the country, as these two are the key inputs.

Nutrient interaction: Interactions among plant nutrients are often overlooked though they have considerable positive effect on plant growth and development. Moreover, the physiological and biochemical processes within the plants are influenced both ways owing to nutrient interaction. Improved nutrition seems to alter rooting habits thus changing the

access to stored water. Fertilizer application permits deeper penetration of roots into the soil, thus, the amount of water available for utilization is increased. This, however, depends on the amount of water stored in the profile. The estimated nutrient removal by the oilseeds is given in the Table 3. The interplay of plant nutrients is best studied in multi factorial experiments which test each nutrient at three or more rates. The importance of nutrient interaction was highlighted by Biswas *et al.* (1991). There are many types of nutrient interactions, which include interaction between

- Two or more nutrients
- Nutrients and biofertilizers
- Major nutrients and micronutrients
- Nutrients and manures

Table 3. Nutrient uptake of oilseed crops raised in India

Crop	Yield(q/ha)	Nutrient uptake (kg/ha)						Uptake (g/ha)			
		N	P	K	S	Ca	Mg	Zn	Fe	Mn	Cu
Groundnut	19.0	170	30	110	15	39	20	08	4340	176	68
Mustard	15.0	83	17	71	26	63	13	150	1684	143	25
Soybean	25.0	125	43	101	22	35	19	192	886	208	74
Sunflower	6.0	38	5	63	7	41	16	28	645	109	23
Sesame	12.0	62	24	64	14	45	19	202	925	138	140
Safflower	19.1	74	7	35	24	-	-	-	-	-	-
Linseed	16.0	96	13	72	9	50	21	73	1062	283	48

Source: (Pasricha and Tandon, 1993)

Irrigation and nutrients interaction: The crop needs for irrigation water and fertilizer is interrelated. The irrigation can give maximum benefits to the crop only if supply of nutrients during plant growth is maintained in the soil and *vice-versa*. Adequate water supply enhances the mass and distribution of the root system. The roots which are actively growing are capable of taking up nutrients by exploiting a greater volume and depth of soil compared to other roots. Thus, with a given amount of non-atmospheric supplied plant nutrients, oilseeds are producing significantly less grain and require significantly more water (Prihar and Gajri, 1988). Thus, cropwise interactive technologies are herein discussed.

Groundnut

Groundnut is the most important oilseed crop of India with an acreage of about 8 million ha and production of about 8 million tonnes. Although India ranks first in area and second in production, around 6.8 million ha of the crop area is under rainfed where productivity fluctuates between 500 and 1500 kg/ha. Groundnut is grown in the winter/summer season in about 1.5 million ha with assured moisture. The four states viz., Andhra Pradesh, Gujarat, Maharastra and Tamil Nadu account for about 89% of the total groundnut area of our country and contribute nearly 88% of the total production. Groundnut requires all the essential macro and micro-nutrients for its growth and development. On an average to produce 2.0 to 2.5 t/ha of economic yield, it requires 160-180 kg of N, 20-25 kg of P, 80-100 kg of K, 60-80 kg of Ca, 15-20 kg S, 30-45 kg Mg, 3-4 kg Fe, 300-400 g Mn, 150-200 g Zn, 140-180 g B, 30-40 g Cu and 8-10 g Mo (Singh *et al.*, 1990a &b; Singh and Joshi, 1993; Singh and Chaudhari, 1995 and Pasricha and Tandon, 1993).

Interactions of nutrient x nutrient and nutrient x irrigation for groundnut

Location	Soil	Economic combination	Reference
		Nutrient x nutrient interaction	
Junagadh, Gujarat	Medium black soil	15 t FYM + 12.5 kg N + 11 kg P/ha	Malavia *et al.* (1998)
Bijapur, Mysore	Red sandy loam	40 kg N + 40 kg P_2O_5/ha	Kulkarni *et al.* (1977)
Kolar, Karnataka	Sandy clay loam	10 kg S + 10 kg Ca/ha + 5 ppm K	Badiger *et al.* (1982)
Dharwad, Karnataka	Sandy loam	30 kg N + 40 kg P_2O_5/ha 20 kg N + 40 kg P_2O_5/ha	Goudreddy *et al.* (1977) Vali *et al.* (1978)
Vidarbha region, Maharastra	Medium black soil	25 kg N + 50 kg P_2O_5 + 30 kg K_2O/ha	Bhalerao *et al.* (1993)
Akola, Maharastra	Clayey soil	25 kg N + 50 kg P_2O_5 + 10 kg B + 20 kg S/ha	Mahakulkar *et al.* (1994)
Southern Telangana zone of A.P.	Red sandy loam (chalka)	30 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha	Yakadri *et al.* (1992)
Vriddhachalam, T.N.	Sandy loam	12.5 t/ha FYM + Bacterial culture with seed (600 g/ha) and soil application (2000 g/ha)	Balasubramanian and Palaniapappan (1994)
Chattisgarh	Light textured inceptisols	60 kg P_2O_5/ha + Rhizobium inoculation	Patel and Thakur (1997)
Kalyani, W.B.	Loamy, alluvial medium fertile	40 kg N + 45 kg K_2O/ha 100 kg N + 50 kg K_2O/ha	Patra *et al.* (1995) Bandyopadhyay and Samui (1999)
Kanpur, U.P.	Sandy loam	15 kg N + 30 kg P_2O_5 + 45 kg K_2O + 150 kg gypsum + 4 kg borax/ha	Chauhan *et al.* (1993)
Ludhiana, Punjab	Alluvial soil	15 kg S + 10 kg Zn/ha	Pasricha *et al.* (1987a)
Western Rajasthan	Desert type soil	20 kg N + 30 kg P_2O_5/ha	Bhan and Misra (1971)
		Nutrient x irrigation interaction	
Hyderabad, A.P.	Sandy loam	Irrigation at 50% depletion of available soil moisture (ASM) regime and P @ 22 kg/ha	Narasimham *et al.* (1977)
Udaipur, Rajasthan	Sandy	Irrigation scheduling from 0.4 to 1.0 IW/CPE ratio x 40 kg N/ha x 80 kg P_2O_5/ha	Tiwari *et al.* (1997) and Tiwari and Dhakar (1997)
Sriganganagar, Rajasthan	Sandy loam	4 irrigations at vegetative, flowering, pegging and pod development stages along with 60 kg P_2O_5/ha	Singh *et al.* (1994a)

Rapeseed and mustard

Rapeseed-mustard is the most important *rabi* oilseed crop of the country. Among the oilseeds *Brassica* mustard is the most important member of the group accounting for more than 80% of the area under rapeseed-mustard followed by *toria*, yellow sarson, *gobhi* sarson, brown sarson and taramira. *Gobhi* sarson is predominantly grown in Punjab and gaining importance in other states where there is a longer winter. The major rapeseed-mustard growing states of the country are Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat representing 80% of the national acreage and contributing 82.9% of the total production. Very high amount of primary and secondary nutrients viz., 144 kg N, 87 kg S, 35 kg P_2O_5, 40 kg K_2O, 115 kg Ca and 7 kg Mg/ha are removed by rapeseed and mustard (Srivastava and Pathak, 1980). Further, cruciferae group of oilseeds have relatively high S requirement. Sulphur helps in the formation of S-containing amino acids and glucosinolates; the SH-sulphydryl linkages provide the source of pungency in oils, thus improves the quality and quantity of oilseeds. It improves the as-

similation of N in oilseeds. S application has increased seed yield in these crops when S was applied in combination with N in an appropriate balance.

Interactions of nutrient x nutrient and nutrient x irrigation for rapeseed and mustard

Location	Soil	Economic combination	Reference
		Nutrient x nutrient interaction	
Hoshiarpur, Punjab	Alluvial soil	125 kg N + 45 kg P_2O_5+ 30 kg K_2O/ha	Gill *et al.* (1993)
Ludhiana, Punjab	Sandy loam	150 kg N + 60 kg S/ha	Pasricha *et al.* (1987b)
		75 kg N + 60 kg S/ha	Aulakh *et al.* (1980)
Gurgaon, Haryana	Sandy loam	30 kg N/ha + Biofertilizer (*Azotobacter / Azospirillum*)	Chauhan *et al.* (1996), Sharma *et al.* (1997a & 1997b)
Udaipur, Rajasthan	Sandy loam	60 kg N + 100 kg S/ha	Khanpara *et al.* (1993)
Jobner, Rajasthan	Loamy sand	90 kg N + 160 kg S/ha	Rathore and Manohar (1990)
Palampur, H. P.	Sandy loam	60 kg P_2O_5 + 90 kg S/ha	Jaggi and Sharma (1997) Jaggi (1998)
Kangra, H.P.	Clay loam	120 kg N + 40 kg P_2O_5/ha	Thakur and Chand (1998)
N-Western, Himalyas, H.P.	Acidic silty clay loam	5 t FYM + 160 kg N/ha	Mankotia and Sharma (1997)
		5 t FYM + 35 kg P/ha	Mankotia and Sharma (1997)
Kanpur, U.P.	Sandy loam	17 kg P + 33 kg K/ha	Ganga Saran and Kinra (1979)
Pantnagar, U.P.	Silty clay loam	80 kg N + 20 kg S/ha	Kachroo and Kumar (1997)
Meerut, U.P.	Sandy clay loam	120 kg N + 60 kg P_2O_5+ 60 kg K_2O/ha(Pusa Bold) 80 kg N + 40 kg P_2O_5+ 40 kg K_2O/ha (Varuna)	Tomer *et al.* (1996)
Faizabad, U.P.	Silty loam	60 kg N + 40 kg S/ha	Singh and Kumar (1996)
Ghaziabad, Western U.P.	Light textured slightly alkaline	90 kg N + 90 kg P_2O_5+ 60 kg K_2O/ha	Singh *et al.* (1994a)
Sabour, Bihar	Clay loam soil	75 kg N + 50 kg S/ha	Mohan and Sharma (1992)
Powerkheda (Tawa Command Area), M.P.	Clayey alluvial (deep Vertisol)	90 kg N + 40 kg S/ha	Dubey *et al.* (1994)
		90 kg N + 30 kg S/ha	Dubey and Khan (1993)
Tikamgarh, M.P.	Clay loam	90 kg N + 45 kg S/ha	Tomar *et al.* (1996)
Gwalior, M.P.	Sandy clay loam	120 kg N + 60 kg P_2O_5 + 10 kg Zn + 90 kg S/ha	Singh *et al.* (1998)
Hyderabad, A.P.	Sandy loam	160 kg N + 40 kg S/ha	Bhanurekha and Ramasubba Reddy (1998)
Krishna-Gardavri zone, A.P.	Sandy loam slightly alkaline	150 kg N + 50 kg S/ha	Deekshitulu *et al* .(1998)
		Nutrient x irrigation interaction	
Faizabad, U.P.	Sandy loam	Irrigations at 0.6 IW/CPE ratio and 120 kg N/ha	Singh and Dixit (1989)

(Contd.

Location	Soil	Economic combination	Reference
Cuttack, Orissa	Sandy loam	3 irigations at 25, 50 and 70 days after sowing with 60 kg N/ha	Chandra (1997)
Udaipur, Rajasthan	Clay loam moderately alkaline	Irrigations at 0.4 IW/CPE ratio and 60 kg N/ha	Padmani *et al.* (1992)
Udaipur, Rajasthan	Clay loam	2 irrigations with N: P_2O_5 @ 60:30 kg/ha	Agarwal and Gupta (1991)
Kharagpur,W.B.	Sandy clay loam	3 irrigations at 0.6 ID/CPE ratio along with 60 kg N/ha	Parihar (1991)
Arnej, Gujarat	Clayey alkaline	1 supplemental irrigation under conserved soil moisture along with 60 kg N/ha	Sonani *et al.* (1999)
Uttar Pradesh	Gangetic alluvium soil	Irrigations at 60% ASM depletion along with 120 kg N/ha	Bhan (1979)
Gurukul Narsam,U.P.	Sandy loam	2 irrigations (1 at pre-flowering and + 1 at pod development stage) with N: P_2O_5:K_2O @ 120:60:60 kg/ha	Tomer *et al.* (1992)
Bhopal, M.P.	Deep clay(Vertisol)	2 post sowing irrigations (at rosette stage and at pod development stage) along with 100% recommended dose of N: P_2O_5:K_2O @ 60:30:20 kg/ha + FYM @ 10 t/ha applied to previous soybean crop	Hati *et al.* (2000)
Junagadh, Gujarat	Clayey	Irrigations at 0.8 IW/CPE ratio along with wheat straw mulch and N: P_2O_5 @ 50:50 kg N/ha + FYM @ 10 t/ha	Sadhu *et al.* (1997)
Pantnagar, U.P.	Clay loam	2 irrigations along with 80 kg N/ha	Sharma and Kumar (1989 & 1992)
New Delhi	Sandy loam	Irrigations at 0.6 IW/CPE ratio and 100 kg N/ha	Pramanik *et al.* (1996)
Hisar, Haryana	Sandy loam	2 post sowing irrigations at 0.4 IW/CPE ratio (1 at 50% flowering + 1 at 25% siliqua formation stage) at 100% recommended fertility levels (N @ 100 kg/ha and P @ 16.0 kg/ha)	Thakral *et al.* (1996)
Ludhiana, Punjab	Sandy loam	Irrigation at 28 days after sowing followed by irrigation at 80 mm CPE and 150 kg N/ha	Gill and Narang (1993)
Ludhiana, Punjab	Sandy loam nonsaline	2 irrigations (at about 3-4 weeks after sowing and at pod development stage i.e., 9-10 weeks stage) with 120 kg N/ha	Mahal *et al.* (1994)
New Delhi	Sandy loam	2 irigations based on 0.4 IW/CPE ratio and 80 kg N/ha	Sachdeva and Ganga Saran (1993)
Hisar, Haryana	Sandy loam	2 post sowing irrigation along with 80 kg N/ha	Singh *et al.* (1994)

Soybean

Soybean is the third major oilseed crop of the country next to groundnut and rapeseed and mustard. India ranks fifth in the World in area and production, but the productivity is very low (less than 1000 kg/ha) and far behind the other soybean producing countries. The predominant soybean growing states are Madhya Pradesh (74%), Maharastra (15%) and Rajasthan (9%). Soybean grown in rainy season in India is generally not irrigated. However, it could desirably require one pre-sowing irrigation in case of delayed onset of monsoon and one or two irrigations during pod filling stages in case of early withdrawal of monsoon.

Interactions of nutrient x nutrient and nutrient x irrigation for soybean

Location	Soil	Economic combination	Reference
		Nutrient x nutrient interaction	
Ludiana, Punjab	Sandy loam	35 kg P + 40 kg S/ha	Aulakh *et al.* (1990)
Pithoragarh, Kumaon hills and foot hills of U.P.	Sandy loam soil	40 kg N + 80 kg P_2O_5/ha	Singh *et al.* (1994a)
Raipur, Chattisgarh	Clayey soil (deep vetisol)	45 kg N + 90 kg P_2O_5/ha	Patel and Chandravanshi (1996)
		30 kg N + 60 kg P/ha + *Rhizobium*	Sarkar and Tripathi (1996)
Rewa, Chattisgarh	Sandy clay loam	30 kg N/ha + *Brady rhizobium*	Tiwari *et al.* (1993)
Sehore, M.P.	Medium black soil	Superphosphate @ 13.2 kg P/ha + *Pseudomonas striata*	Dubey (1996)
Bhopal, M.P.	Black clay soil	10 t FYM + 25 kg N + 60 kg P_2O_5 + 30 kg K_2O/ha	Mandal *et al.* (2000) and Hati *et al.* (2000a)
		Nutrient x irrigation interaction	
Navsari, Gujarat	Clay (Vertisol)	Irrigation at 0.8 IW/CPE ratio Irrigation (60 mm depth of water) or at 75 mm CPE i.e., 10-12 days interval and N: P_2O_5 @ 45:90 kg/ha at sowing	Patel *et al.* (1998)

Sunflower

Sunflower is a highly promising crop under different agroclimatic regions in India because of its thermoinsensitivity. It is grown in India in an area of about 1.7 m ha, of which 90% area is occupied under four states viz., Karnataka, Maharastra, Andhra Pradesh and Tamil Nadu. The total production in the country is about 0.94 million tonnes with a very low productivity of 550 kg/ha (1997-98). Like other oilseeds, sunflower requires a large quantity of both macro- and micronutrients for its growth and development as indicated in the Table 3.

Interactions of nutrient x nutrient and nutrient x irrigation for sunflower

Location	Soil	Economic combination	Reference
		Nutrient x nutrient interaction	
Parbhani, Maharashtra	Medium black soil	80 kg N + 90 kg P_2O_5/ha	Dhoble (1998)
Coimbatore, T.N.	Red loam soil	10 t FYM + 50 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha (rainy season)	Sathiyavelu *et al.* (1994a)
		50 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha (winter)	Sathiyavelu *et al.* (1994a)

(Contd.

Location	Soil	Economic combination	Reference
Bangalore, Karnataka	Sandy loam	112.5 kg P_2O_5 + 10 kg S + 5 kg Zn	Prabhuraj *et al.* (1993)
Dharwad, Karnataka	Black clay	75% of recommended P + VAM fungi (*Glomus fasciculatum*)	Srihari *et al.* (1993)
New Delhi	Sandy loam	80 kg N + 30 kg S/ha	Legha and Giri (1999)
Hisar, Haryana	Sandy loam	10 t FYM + 40 kg N + 20 kg P/ha or, 80 kg N + 40 kg P/ha	Singh and Singh (1997)
		10 t Vermicompost + 120 kg N + 60 kg P_2O_5/ha	Devidayal and Agarwal (1998)
		Nutrient x irrigation interaction	
Meerut, U.P.	Alluvial sandy loam	Irrigation at 0.6 IW/CPE ratio in conjunction with 80 kg N/ha	Tomar *et al.* (1997)
Junagadh,Gujarat	Clayey	Irrigation at 0.5 and 0.7 IW/CPE ratio along with 80 kg N/ha, or Irrigation at 0.9 IW/CPE ratio with 60 kg N/ha	Chandra *et al.* (1989)
Tirupati, A.P.	Sandy loam	Irrigation at 1.0 IW/CPE ratio in conjunction with 100 kg N/ha	Nagavani *et al.* (1997)
Pusa, Bihar	Sandy loam	Irrigation at 0.8, 0.6 and 0.4 IW/CPE ratio along with 40 kg N/ha	Prasad *et al.* (1999)
Palampur, H.P.	Sandy loam	Irrigation at 0.9 IW/CPE ratio with 80 kg N/ha	Vivek *et al.* (1994)
Jagtial, A.P.	Red chalka soil	Irrigation at 0.4 IW/CPE ratio along with 30 kg N/ha or, Irrigation at 0.6 IW/CPE ratio with 60 kg N/ha or, Irrigation at 0.8 and 1.0 IW/CPE ratio with 90 kg N/ha	Reddy and Kumar (1996)

Sesame

Gujarat, Rajasthan, Madhya Pradesh, Uttar Pradesh, Tamil Nadu, Maharastra, Andhra Pradesh, West Bengal and Karnataka are the major sesame growing states in the country. The first four states account for more than 50% of the area in the country. Sesame is grown in three seasons, *kharif* (70%), post-rainy (20%) and summer (10%). The production of sesame is 0.6 million tonnes from an hectarage of 1.8 million ha with a productivity of about 350 kg/ha (1997-98). The best economic combination of N and P is 120 kg N/ha + 50 kg P_2O_5/ha at Parbhani (Maharastra) on slightly alkaline black cotton soil (Jadav *et al.*, 1992) and sesame registered optimum yield with irrigation at 0.8 IW/CPE ratio in conjunction with N: P_2O_5 @ 50:30 kg /ha on sandy loam soil of Hyderabad (Ravinder *et al.*, 1996).

Linseed

Linseed is cultivated over 0.82 million ha in the country in which more than three fourth of the area lies in three states viz., Madhya Pradesh (50.3%), Uttar Pradesh (15.9%) and Maharastra (13.5%). The total production of linseed in the country is 0.24 million tonnes, but the productivity is very low (around 300 kg/ha during 1997-98). Interaction of irrigation with nitrogen was significant

for seed yield in different locations.

Interactions of nutrient x nutrient and nutrient x irrigation for linseed

Location	Soil	Economic combination	Reference
		Nutrient x nutrient interaction	
Eastern U.P.	Ganga Diara (flood prone)	40 kg N + 20 kg P_2O_5 + 20 kg K_2O/ha	Singh (1993)
Lakhaoti, U.P.	Sandy loam	120 kg N + 40 kg P_2O_5	Vashishtha (1993)
Raipur, Chattisgarh	Sandy loam	40 kg P_2O_5 + 20 kg K_2O/ha	Pali *et al.* (1995)
Rewa, Chattisgarh	Clayey soil	45 kg N + 20 kg P/ha	Awasthi *et al.* (1989)
Jabalpur, M.P.	Clay loam	60 kg N + 30 kg P_2O_5+ 20 kg K_2O/ha	Agrawal *et al.* (1997)
Tikamgarh, Powerkheda, M.P.	Heavy black soil	90 kg N + 30 kg S + 1.1 kg B/ha	Chaurasia *et al.* (1992)
		Nutrient x irrigation interaction	
Powerkheda, M.P.	Clay Deep Vertisol	Irrigation at 0.4 and 0.6 IW/CPE ratio with 60 kg N/ha, or Irrigation at 0.8 IW/CPE ratio with 90 kg N/ha	Tiwari *et al.* (1988)
Faizabad, U.P.	Silty loam	Irrigation at 0.8 IW/CPE ratio (4 irrigations of 60 mm each) along with 90 kg N/ha	Singh *et al.* (1997)
Jabalpur, M.P.	Sandy clay loam	2 irrigations with N: P_2O_5: K_2O @ 60:30:20 kg/ha	Agrawal *et al.* (1997 & 1999)

Future research needs

1. The behaviour of different nutrient elements and their interaction needs to be studied for oilseeds with a view to economise and optimise the use of these limited and costly inputs.
2. Plants uptake all the essential nutrients from soil which interact among each other both synergistically and antagonistically and regulate the crop yield accordingly. Location specific synergistic interaction among nutrients for oilseed has to be precisely recognised and utilized for improving the productivity of oilseed crops for different agroclimatic regions.
3. Sulphur is an essential element required by the oilseeds particularly the *Brassica* group in a large quantity, the best combination of S with other nutrients and water has to be developed for different locations and both the quantity and quality of the produce have to be studied.
4. Location specific irrigation water x nutrients management technologies has to be generated considering the stored soil moisture, rainfall pattern, evapotranspiration and availability of irrigation water.
5. Thus, both water and nutrients use efficiency has to be increased for higher productivity and sustainability of oilseeds.

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