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Integrated nutrient management for hybrid sunflower (*Helianthus annus* L.)

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Abstract : **Field experiments were conducted in red sandy loam soil (Alfisol) at the Agricultural Research Station, Bhavanisagar during summer 1996-97 in order to optimize the integrated nutrient management (INM) practices for a popular sunflower hybrid (MSFH-17). Treatments consisted of two sources of P (single superphosphate and Mussoorie rock phosphate), three levels of enriched FYM to supply varying doses of P (100%, 75%, 50%) and four biofertilizer treatments (Azospirillum, phosphobacteria, Azospirillum + phosphobacteria and control) replicated thrice in a split plot design. Growth, yield, quality and nutritional parameters were measured to evaluate the effectiveness of the treatments. Among the treatment combinations, application of 100% N plus 100% SSP as enriched FYM in conjunction with Azospirillum and phosphobacteria inoculation produced highest grain yield, stalk yield and oil content. This treatment combination registered the highest values for most of the growth and yield attributes. The data revealed that application of recommended levels of N (75 kg ha^{-1}) and P (90 kg ha^{-1}) in combination with biofertilizers (Azospirillum and phosphobacteria) produced the highest grain yield (2211 kg ha^{-1}) and benefit cost ratio (2:80) for recently introduced sunflower hybrid (MSFH-17).**

Key words : Sunflower, Biofertilizer, Nutrient uptake, Yield, Quality, INM.

Introduction

Indiscriminate use of chemical fertilizers and agro-chemicals rendered the arable soils unproductive as a consequence of unfavourable physical, chemical and biological characteristics of soils. To make the farming sustainable, the integrated nutrient management (INM) was introduced two decades ago. The INM concept is gaining popular recently as the Indians have begun to realize the significance of inclusion of biological in soil fertility management. Integrated nutrient management is defined as the judicious mix of organics, inorganics and biofertilizers at suitable proportion to promote soil fertility and farm productivity without causing much deterioration in biogeocyling of nutrients in soils.

Sunflower is the fourth major vegetable oil seed crop grown in India, however, the per hectare yield is extremely low (600 – 700 kg ha^{-1}). This necessitates growing of hybrids to promote the productivity of sunflower crop. Boutros *et al.* (1987) reported that rockphosphate with P solubilizing bacteria (phosphobacteria) significantly increased the canopy spread area and yield attributes of sunflower. In another study, Kathiresan and Kothandaraman (1985) have shown that the availability of P from rock phosphate can be enhanced by enriched FYM or greenmanure. The nutrient use efficiency of crops can be further improved by the incluson of biofertilizer in the production system. With this in view, field experiments were conducted to optimize the INM practice by including cheap source of P enrichment of organic manure and biofertilizers to enhance the production of sunflower hybrid.

Materials and Methods

Field experiments were carried out at the Agricultural Research Station, Bhavanisagar, using a popular sunflower hybrid (MSFH-17), during two consecutive summer seasons of 1996-97. The experimental soil was sandy loam in texture, pH 7.2, EC 0.1 dSm^{-1}, OC 0.3% and low N (210 kg ha^{-1}), medium P (11.8 kg ha^{-1}) and high K (346 kg ha^{-1}) in soil available nutrient status. Treatments consisted of two sources of P (S_1 – single superphospate; S_2 – Mussoorie rock phosphate), three levels of N & P (L_2 – 100% N + 100% P enriched

Table 1. Integrated nutrient management on growth attributes of sunflower hybrid (MSFH-17)

Treatment	Plant height (cm)	DMP (kg ha^{-1})	LAI	RGR (g^{-1} d^{-1})	NAR (g^{-1} d^{-1})	Days to 50% flowering
P Sources (S)						
S_1 - SSP	160.4	7449	2.418	0.0301	44.85	56.7
S_2 - MRP	152.4	7033	2.274	0.0296	44.60	57.1
CD (P=0.05)	0.97	46	0.042	0.0005	NS	NS
Fertilizer levels (L)						
L_1-100% N + 100% P EFYM	160.7	7501	2.680	0.0289	38.69	56.8
L_2-75% N + 75% P EFYM	157.1	7222	2.292	0.0294	45.12	56.8
L_3-50% N + 50% P EFYM	151.5	6999	2.066	0.0313	50.36	57.1
Biofertilizers (B)						
B_1-Azo	157.1	7255	2.371	0.0295	44.31	56.7
B_2-PB	155.2	7103	2.298	0.0298	45.17	57.1
B_3-Azo + PB	160.2	7589	2.603	0.0282	38.58	57.0
B_4-Control	153.2	7016	2.113	0.0319	50.84	56.7
CD (P=0.05)	0.97	45	0.043	NS	0.94	NS
S x L						
S_1L_1	164.1	7676	2.762	0.0290	38.69	56.5
S_1L_2	161.8	7452	2.394	0.0299	45.07	56.5
S_1L_3	155.4	7219	2.100	0.0315	50.78	57.0
S_2L_1	157.2	7326	2.599	0.0288	38.68	57.0
S_2L_2	152.4	6992	2.190	0.0288	45.18	57.0
S_2L_3	147.6	6780	2.033	0.0310	49.93	57.2
CD (P=0.05)	NS	NS	0.073	NS	NS	NS
S x B						
S_1B_1	161.0	7430	2.445	0.0301	44.87	57.7
S_1B_2	159.2	7238	2.385	0.0301	44.82	56.7
S_1B_3	164.3	7944	2.653	0.0283	39.68	56.8
S_1B_4	157.2	7183	2.190	0.0321	50.02	56.6
S_2B_1	153.2	7080	2.297	0.0288	43.75	56.7
S_2B_2	151.3	6969	2.211	0.0296	45.52	57.4
S_2B_3	156.0	7234	2.552	0.0280	37.47	57.2
S_2B_4	149.1	6849	2.036	0.0318	51.65	56.9
CD (P=0.05)	NS	63	NS	NS	NS	NS
L x B						
L_1B_1	160.9	7507	2.795	0.0289	37.76	56.7
L_1B_2	159.0	7323	2.707	0.0293	38.16	57.0
L_1B_3	165.3	7912	2.807	0.0262	34.25	56.7
L_1B_4	157.5	7262	2.413	0.0312	44.59	56.7
L_2B_1	157.2	7243	2.277	0.0288	44.83	56.5
L_2B_2	156.0	7097	2.191	0.0295	46.69	56.8
L_2B_3	160.4	7590	2.658	0.0272	37.57	57.0
L_2B_4	154.7	6959	2.042	0.0320	51.41	56.7
L_3B_1	153.3	7015	2.042	0.0307	50.34	56.8
L_3B_2	150.7	6890	1.995	0.0307	50.67	57.3
L_3B_3	154.8	7267	2.344	0.0310	43.91	57.3
L_3B_4	147.3	6827	1.885	0.0326	56.52	56.8
CD (P=0.05)	1.69	77.6	0.074	NS	1.62	NS

Table 2. Effect of integrated nutrient management on yield attributes and yield of sunflower

Treatment	Head diameter	% of filled	100 seed weight (g)	Grain yield (kg/h)	Stalk yield (kg ha^{-1})	Oil Yield (kg ha^{-1})
P Sources (S)						
S_1 - SSP	14.4	91.6	6.50	2164	3556	775
S_2 - MRP	14.3	90.7	6.42	2103	3363	753
CD (P=0.05)	NS	NS	0.02	35	58	NS
Fertilizer levels (L)						
L_1-100% N + 100% P EFYM	14.8	91.8	6.55	2227	3668	802
L_2-75% N + 75% P EFYM	14.4	92.1	6.46	2146	3400	771
L_3-50% N + 50% P EFYM	13.9	90.1	6.36	2028	3310	719
Biofertilizers (B)						
B_1-Azo	14.4	91.3	6.42	2106	3409	753
B_2-PB	14.3	91.1	6.39	2078	3373	743
B_3-Azo + PB	15.0	93.2	6.70	2343	3795	848
B_4-Control	13.8	89.1	6.32	2007	3262	711
CD (P=0.05)	0.31	2.67	0.02	81	80	39
S x L						
S_1L_1	14.8	92.2	6.62	2244	3779	809
S_1L_2	14.5	92.6	6.48	2157	3522	773
S_1L_3	13.9	90.1	6.40	2090	3367	742
S_2L_1	14.7	91.3	6.49	2209	3557	795
S_2L_2	14.4	91.5	6.44	2134	3278	766
S_2L_3	13.8	89.3	6.32	1966	3254	696
CD (P=0.05)	NS	NS	0.03	NS	NS	NS
S x B						
S_1B_1	14.4	91.5	6.46	2134	3506	763
S_1B_2	14.3	91.6	6.42	2094	3462	748
S_1B_3	15.0	93.5	6.78	2377	3946	860
S_1B_4	13.8	89.9	6.34	2050	3309	729
S_2B_1	14.3	91.1	6.38	2078	3311	744
S_2B_2	14.2	90.5	6.36	2061	3283	738
S_2B_3	14.9	92.8	6.62	2308	3643	836
S_2B_4	13.7	88.3	6.31	1964	3215	693
CD (P=0.05)	NS	NS	0.03	NS	NS	NS
L x B						
L_1B_1	14.7	91.0	6.51	2207	3643	794
L_1B_2	14.6	92.8	6.48	2162	3611	779
L_1B_3	15.7	94.0	6.82	2632	4009	886
L_1B_4	14.1	89.3	6.40	2106	3411	749
L_2B_1	14.6	92.4	6.40	2100	3317	757
L_2B_2	14.4	91.0	6.39	2125	3252	761
L_2B_3	15.0	94.2	6.71	2336	3779	846
L_2B_4	13.8	90.8	6.35	2014	3252	715
L_3B_1	14.0	90.6	6.35	2001	3267	709
L_3B_2	13.9	89.4	6.31	1946	3255	689
L_3B_3	14.2	91.3	6.57	2262	3596	812
L_3B_4	13.4	87.4	6.22	1902	3124	666
CD (P=0.05)	NS	NS	0.04	138	NS	NS

Table 3. Effect of integrated nutrient management on uptake, oil content and crude protein contents

Treatment	Nutrient uptake (kg ha^{-1}) N	P	K	Oil content (%)	Crude protein content (%)
P Sources (S)					
S_1 - SSP	78.4	27.0	80.8	35.8	19.63
S_2 - MRP	73.5	25.0	76.5	35.8	19.20
CD (P=0.05)	0.92	0.81	0.53	NS	0.36
Fertilizer levels (L)					
L_1-100% N + 100% P EFYM	81.4	28.0	85.6	36.0	19.87
L_2-75% N + 75% P EFYM	76.0	26.3	79.4	36.0	19.33
L_3-50% N + 50% P EFYM	70.5	23.8	71.1	35.5	19.05
Biofertilizers (B)					
B_1-Azo.	73.9	25.3	78.4	35.8	19.53
B_2-PB	73.0	26.1	79.0	35.8	19.33
B_3-Azo. + PB	89.4	30.4	85.5	36.2	19.99
B_4-Control	67.6	22.5	71.8	35.4	18.83
CD (P=0.05)	0.77	1.18	1.32	NS	0.60
S x L					
S_1L_1	82.6	28.3	88.1	36.0	19.92
S_1L_2	78.9	27.6	82.5	35.8	19.71
S_1L_3	73.8	25.5	72.0	35.5	19.27
S_2L_1	80.2	27.7	83.1	36.0	19.82
S_2L_2	73.1	25.1	76.3	35.9	18.95
S_2L_3	67.2	22.1	70.3	35.5	18.83
CD (P=0.05)	1.60	1.39	0.91	NS	NS
S x B					
S_1B_1	76.1	26.2	80.4	35.7	19.77
S_1B_2	75.3	27.0	81.5	35.7	19.60
S_1B_3	92.9	32.3	89.2	36.2	20.26
S_1B_4	69.4	23.0	72.3	35.5	18.89
S_2B_1	71.7	24.3	76.4	35.8	19.26
S_2B_2	70.7	25.2	76.6	35.8	19.05
S_2B_3	85.8	28.4	81.8	36.2	19.71
S_2B_4	65.8	21.9	71.4	35.3	18.76
CD (P=0.05)	1.09	NS	1.87	NS	NS
L x B					
L_1B_1	79.5	27.0	85.4	36.0	19.96
L_1B_2	78.3	27.8	85.1	36.1	19.93
L_1B_3	96.8	32.6	94.1	36.4	20.58
L_1B_4	71.1	24.7	77.7	35.6	19.02
L_2B_1	73.7	25.6	78.8	35.9	19.52
L_2B_2	72.4	26.6	81.1	35.8	19.19
L_2B_3	89.9	31.1	86.2	36.3	19.78
L_2B_4	68.0	22.1	71.5	35.5	18.83
L_3B_1	68.6	23.1	71.1	35.5	19.10
L_3B_2	68.3	24.0	71.0	35.4	18.86
L_3B_3	81.4	27.5	76.2	35.9	19.61
L_3B_4	63.8	20.6	66.3	35.1	18.63
CD (P=0.05)	1.33	NS	2.29	NS	NS

FYM; L_2 – 75% N + 75% P enriched FYM; L_3 – 50% N + 50% P enriched FYM) and four biofertilizer treatments (B_1– Azospirillum; B_2 – Phosphobacteria; B_3 – Azospirillum + Phosphobacteria; B_4 – Uninoculated control) replicated three times in a split plot design. Seeds were sown by ridges and furrows method by adopting a spacing of 45 x 15 cm. Two seeds were dibbled at 4 cm depth in each sowing hole. One plant/hill was maintained after the establishment. Fertilizers @ 75:90:60 kg NPK ha^{-1} and was applied according to the treatments. In all the treatments, source of P was applied as either single superphosphate (SSP) or Mussoorie rock phosphate (MRP) enriched in FYM. The required quantity of SSP or MRP as per the treatment was blended with sieved FYM 750 kg ha^{-1}, covered with moist mud and allowed it for incubation for a month under shade. The enriched FYM was applied basally as per the treatment.

Sunflower seeds were treated with the Azospirillum and phosphobacterium inoculum as per the standard procedure. Three pockets (600 g) each of bacterial culture (Azospirillum Az 204; Phosphobacterium. *Bacillus megaterium* var. Phosphoticum culture PB-1) were thoroughly mixed in cooled rice gruel and the required quantity of 7 kg sunflower hybrid seeds were blended with bacterial culture and kept under shade for drying 15-30 minutes. Further, for soil application, 10 pockets (2000 g) each of the bacterial culture was mixed with well decomposed FYM and applied in furrows as per the treatment. Irrigation was given once a week. Need based plant protection measures was taken up as per the standard recommendation.

During the course of experimentation, growth (plant height, relative growth rate, net assimilation rate, leaf area index) reproductive behaviour (days to 50% flowering), yield attributes (head diameter, seed number, seed weight, seed filling), quality parameters (oil content, crude protein content) were determined by adopting a series of standard protocols. After the harvest, the plants were dried in hot air oven at 65°C for 8 hours and powdered and analyzed for N, P, K contents by adopting the procedure of Subramanian and Charest (1997). The uptake of nutrient was calculated by multiplying the nutrient content by the dry matter production in the individual treatments. The data collected were subjected to statistical scrutiny.

Results and Discussion

Growth components

Data on plant height, drymatter production (DMP), leaf area index (LAI), relative growth rate (RGR) and net assimilation rate (NAR) are presented in Table 1. The data clearly indicated that plant height, DMP and LAI were influenced significantly by sources of P, varying levels of enriched FYM and biofertilizer treatments. However, biofertilizer application did not affect the RGR while the NAR was not altered by the sources of P *viz.* SSP or MRP. In general, SSP increased all the growth components significantly except NAR. It is quite obvious that SSP carries 16% of water soluble P which could have been made readily available for the utilization by the plants and thus favours growth and canopy spread. The MRP has citrate soluble P and the plants can hardly utilize the P from this source. The data suggest that MRP would be more beneficial for the long duration crops than short duration crops such as sunflower. Enrichment of FYM with SSP significantly increased the available status of soil P. Application of 100% recommended dose of enriched FYM enhanced all the growth. The treatment that receives 100% P in the form of enriched FYM registered significantly higher values than the lower levels. The experimental soil is sandy loam in texture and low to medium in available P status. Under these circumstances, P fixation may be very high and the availability of P from the enriched FYM increased. Kathiresan and Kothandaraman (1985) had shown that the P enriched organi manures or green manures enhanced the availability of P in soils where the fertility status is low. Accordingly, the available P status increased correspondingly with the increasing levels of enriched, FYM which would have assisted the plants to grow luxuriantly than other treatments.

Biofertilizer treated plants had recorded significantly higher plant height, larger canopy spread area, and higher NAR than control treatments. Both azospirillum and phosphobacteria either single or in combination enhanced the growth components significantly. However, response was more pronounced when both the bacterial cultures were applied together. Application of azospirillum + phosphobacterium treatment had produced DMP 7589 kg ha^{-1} which was significantly higher than the control (7016 kg ha^{-1}). The data clearly indicated that biofertilizer is beneficial regardless of any combination of treatments. Murali and Purushothaman (1987) stated that the Azospirillum inoculation assists in atmospheric N fixation and promotes production of growth promoting substances. These two factors would have helped the plants to produce larger leaf area and biomass. In addition, P solubilizing bacteria (phosphobacteria) enhanced the availability of P in the soil (Illimer and Schinner, 1995). When both inoculants applied together, plants have the added advantage of effectively utilizing N and P that would have favourably increased the DMP of the biofertilizer treated plants. The interaction effect between enriched FYM and biofertilizer is highly significant for plant height, DMP and leaf area index. The data suggest that application of 100% P enriched FYM in combination with Azospirillum + Phosphobacteria is beneficial to enhance most of the growth components in sunflower. Despite the fact that integrated management practices helped the plants to grow luxuriantly, the flowering behaviour of sunflower did not altered by any of the treatments.

Yield components

Yield contributory parameters such as head diameter, % seed filling and test seed weight were significantly increased by biofertilizer treatment (Table 2). Inoculation of Azospirillum and Phosphobacteria increased the biomass production which may have favourably contributed for the seed weight and % seed filling. As the biofertilizer treated plants are well-nourished, these plants are capable of transporting sufficient quantities of minerals and metabolites to the developing seeds. Hence, the seed weight registered was higher in the biofertilizer treatments. The response to biofertilizer treatment was more pronounced when both the inoculants were applied together. The addition of enriched FYM would further increase the seed weight of the sunflower hybrid. The interaction effect between fertilizer level and biofertilizer was significant. Benefits of biofertilizer on seed filling have been reported earlier. Balasubramanian and Palaniappan (1994) reported that the inoculation of phosphobacteria increased the 100 seed weight of groundnut grown in red sandy loam soil where the P status was extremely poor. In this present study, it is found that conjunctive use of Azospirillum and phosphobacteria had a favourable effect in promoting the seed filling in sunflower.

Grain yield

Grain yield of sunflower hybrid (MSFH-17) was significantly influenced by the source of P, fertilizer levels and biofertilizers independently. Among the sources of P, single superphosphate treated plants yielded significantly higher grain yield than MRP treatment. The higher yield obtained in SSP treatment is mainly as a consequence of increase in yield attributing characters. Increased fertilizer levels enhanced the grain yield linearly. The highest grain yield of 2227 kg ha^{-1} was registered in treatment receiving 100% N + 100% P as enriched FYM. This may be attributed to the favourable growth and yield attributes. The treatment that received 100% N + 100% P had increased the canopy spread in sunflower which would have assisted in higher grain production. Rawson and Turner (1982) reported that there is a close relationship between leaf area and grain yield of sunflower. Besides the beneficial effect of N and P on growth contributing characters, this treatment maintained improved nutritional status that would have resulted in higher seed yield. Increase in grain yield due to the added nutrients had been well documented (Megur *et al.* 1993; Chakor and Chakor, 1993; and Nandhagopal *et al.* 1993).

Application of Azospirillum and phosphobacteria individually or in combination enhanced the grain yield of sunflower hybrid. The grain yield obtained in the biofertilizer applied treatment (2343 kg ha^{-1}) was 15% higher than the control (2007 kg ha^{-1}). The yield increase was more pronounced when the biofertilizers were applied in conjunction with

100% N + 100% P (2632 kg ha^{-1}). The interaction between biofertilizer and fertilizer levels is significant. Biofertilizers application increased the availability of soil nutrients which would have assisted in the greater utilization of nutrient by the plants. Murali and Purusothaman (1987) have shown that inoculation of Azospirillum assisted in N fixation and promotes production of growth promoting substances that contributes for the improved nutrient uptake and ultimately the grain yield. Similar trend of response was observed for stalk yield.

Oil yield

Fertilizer levels and biofertilizers had increased the oil yield of sunflower hybrid significantly. Application of recommended level of N and P (75:90 kg ha^{-1}) enhanced the oil yield by 10% over the 50% recommended level of fertilizer. The yield could be further increased by the inoculation of Azospirillum and phosphobacteria. The oil yield of sunflower hybrid was 848 kg ha^{-1} in biofertilizer treated plots as against the control (771 kg ha^{-1}). Similar results were reported by Sakthivel (1995).

Quality characters

Oil content of sunflower seeds remained unaffected due to P source, fertilizer levels and biofertilizers (Table 3). Oil synthesis of any oil seed crop is a genetic character and agronomic manipulation had no impact on the oil content. In contrast, the crude protein content was significantly influenced by the treatments. Highest crude protein content was registered in treatment receiving 100% of recommended dose of fertilizer in conjunction with biofertilizer. The supply of sufficient quantities of N and P from the soil may have assisted the plants to maintain higher crude protein content. The data are in agreement with the findings of Sidhu *et al.* (1991).

Nutrient uptake

Nutrient uptake pattern of sunflower hybrid was significantly affected by the P source, fertilizer levels and biofertilizers (Table 3). Application of 100% N + 100% P as enriched FYM supplemented with biofertilizers increased the N and K uptake of sunflower hybrid significantly and the uptake of N and K in this treatmer commensurate with the DMP of the treatment Response to biofertilizer application is mor pronounced when both inoculants are applie together.

From the results, it could be concluded that the sunflower hybrid responded to fertilize levels and biofertilizers significantly. Application of inorganic and organic sources of nutrients are essential to realize the fullest benefit from the sunflower hybrid. From this study, it is found that the 100% recommended level of N:P:K (75:90:60 kg ha^{-1}) in conjunction with biofertilizer (Azospirillum + phosphobacteria) produced the highest level of grain yield (2632 kg ha^{-1}) and oil yield (882 kg ha^{-1}) with added advantages of better plant nutritional status and improved soil fertility.

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