Plant and Soil **176**: 325–328, 1995.

Short communication

VA-mycorrhiza mediated P effect on growth and yield of sunflower (*Helianthus annuus* L.) at different P levels

C.P. Chandrashekara[1], V.C. Patil[1] and M.N. Sreenivasa[2]
[1]*Department of Agronomy and* [2]*Department of Agricultural Microbiology, University of Agricultural Sciences, Dharwad-580 005, Karnataka, India*

Received 7 December 1994. Accepted in revised form 18 April 1995

Key words: dry biomass, *Glomus fasciculatum*, P uptake, seed yield, sunflower

Abstract

A field trial was conducted to study the response of sunflower (*Helianthus annuus* L.) to different phosphorus levels (16, 24 or 32 kg P ha^{-1}) and inoculation with vesicular-arbuscular mycorrhizal fungus, *Glomus fasciculatum* on vertisol during summer 1993. At the vegetative stage of sunflower, percent mycorrhizal root colonization, spore count, dry biomass and P uptake did not differ significantly between inoculated and uninoculated control plants. However, at later stages (flowering and maturity) percent root colonization, spore count, total dry biomass and total P uptake were significantly higher in inoculated plants than in uninoculated control plants. The total dry biomass, P content and seed yield increased with increasing P level in uninoculated plants, whereas no significant difference was observed between 16 and 32 kg P ha^{-1} in inoculated plants. The positive effect of mycorrhizal inoculation decreased with increasing P level above 16 kg P ha^{-1}, due to decreased percent root colonization and spore count at higher P levels.

Introduction

Sunflower, one of the potential oilseed crops for India has a high P requirement (32 kg P ha^{-1}). Increased plant growth in the presence of mycorrhizal infection has been attributed mainly to the enhanced uptake of P (Bolan, 1991). The beneficial effects of VAM inoculation on P uptake, growth and yield responses of sunflower in pot culture have been reported (Cabello, 1987; Jones and Sreenivasa, 1993; Koide, 1985; Thomson, 1987). However, fewer field experiments have been carried out in the field on other crops such as onion (Nelson et al., 1981), wheat (Hayman, 1970) and barley (Hayman et al., 1975). These studies showed response of crops to VAM inoculation at lower levels of P fertilization. Such mycorrhizal studies have not been carried out on sunflower under field conditions. Hence, the effect of *Glomus fasciculatum* on P availability, growth and yield of sunflower was investigated at different P levels on a vertisol.

Materials and methods

Sunflower (*Helianthus annuus* L.) was cultivated at the Main Research Station, University of Agricultural Sciences, Dharwad on a vertisol with pH 7.6; organic carbon 0.63%; available N 126 kg ha^{-1} (Modified Kjeldahl method), P 13.76 kg ha^{-1} (Olsen's method) and K 242 kg ha^{-1} (Flame photometer), under irrigated conditions during summer 1993. The available N, P and K in soil were measured according to the procedures given by Jackson (1967). The P levels tried were 16, 24 and 32 kg P ha^{-1} applied as single superphosphate with and without inoculation of VA-mycorrhizal fungus *Glomus fasciculatum* (Thaxt.) Gerd and Trappe. The experiment was laid out in randomized complete block design with four replications, on plots 5.0 m × 3.6 m in size. Nitrogen (62.5 kg ha^{-1}) and potassium (51.25 kg ha^{-1}) were applied in the form of urea and muriate of potash, respectively. *Glomus fasciculatum* (Thaxt.) Gerd and Trappe inoculum was obtained from INVERMAY Agricultural Centre, New Zealand and

Table 1. Percent root colonization, spore count and P content at different growth stages of sunflower inoculated with *Glomus fasciculatum* at different P levels

Treatment (kg P ha^{-1})	VAM components		P content (kg ha^{-1})		
	Percent root colonization	Spore count per 50 cm^3 soil	Root	Shoot	Total
Vegetative stage					
16 I	42.00	170	0.11	1.04	1.15
16 UI	40.12	60	0.07	0.68	0.75
24 I	58.87	162	0.12	1.22	1.34
24 UI	37.62	56	0.08	0.98	1.06
32 I	57.25	156	0.13	1.19	1.33
32 UI	34.12	50	0.12	0.99	1.08
L.S.D.($p = 0.05$)	NS	NS	NS	NS	NS
Flowering stage					
16 I	88.12	320	1.44	12.29	13.73
16 UI	47.00	138	0.91	7.15	8.06
24 I	82.62	259	1.34	12.98	14.32
24 UI	43.75	135	1.10	8.12	10.03
32 I	74.62	237	1.58	12.43	14.02
32 UI	40.50	110	1.68	11.75	12.28
L.S.D.($p = 0.05$)	2.20	8.80	NS	1.93	1.51
Maturity stage					
16 I	90.87	179	0.96	17.59	18.56
16 UI	47.00	64	0.53	12.31	12.84
24 I	84.87	177	1.55	19.67	20.83
24 UI	42.37	61	0.77	13.80	14.54
32 I	79.87	155	1.03	19.30	20.33
32 UI	38.50	69	1.55	17.21	18.37
L.S.D.($p = 0.05$)	2.17	NS	NS	2.12	1.77

NS = Not significant.
I = *Glomus fasciculatum* inoculated.
UI = Uninoculated.

maintained in sterilized sand:soil mix (1:1 by volume) using Rhodes grass *Chloris gayana* Kunth. (Sreenivasa and Bagyaraj, 1988). The inoculum (@ 30 cm^3 per dibbling spot) was placed 2 cm below the sunflower seeds. The inoculum consisted of colonized root fragments, hyphae and chlamydospores (126 per 50 cm^3 inoculum). Sunflower seeds were dibbled at a spacing of 60 cm × 20 cm. In each treatment, five plants were uprooted at 30 days after sowing (DAS) (vegetative stage), 60 DAS (flowering stage) and 105 DAS (maturity). The shoot portion was cut at ground level, dried at 70°C to constant weight to record root and shoot dry biomass and P was analysed by vanadomolybdate-phosphoric yellow colour method (Jackson, 1967). Roots were washed free of soil and representative fresh samples were stained with trypan blue and percent root colonization was estimated (Phillips and Hayman, 1970). The chlamydospore count in soil was determined by wet sieving and decanting technique (Gerdemann and Nicolson, 1963). The seed yield (kg ha^{-1}) was computed by using net plot yield (7.2 m^2). Analysis of variance was done by MSTAT statistical programme and least significant difference was used for mean separation.

Results and discussion

VAM formation

Sunflower plants responded well to the inoculation of *Glomus fasciculatum*. The percent root colonization at flowering and at crop maturity stage and spore count at flowering stage were significantly higher in inoculated plants than in uninoculated plants (Table 1). Significantly higher colonization and spore count were recorded at 16 kg P ha^{-1} than at 24 and 32 kg P ha^{-1} in both inoculated and uninoculated control plants. As previously observed for sunflower (Jones and Sreenivasa, 1993), colonization and spore count were reduced, perhaps due to the inhibitory effect of P on the mycorrhizal colonization (Ratnayake et al., 1978; Kucey and Paul, 1983).

P content

P content in shoots and total P content of inoculated plants was higher than uninoculated plants at flowering and maturity stages (Table 1). Increased P content due to mycorrhizal inoculation has been reported for several subtropical field crops (Champavat, 1990; Jones and Sreenivasa, 1993; Krishna et al., 1982). Total P content of inoculated plants increased significantly only up to 24 kg P ha^{-1} at maturity, while shoot P and total P content increased up to 32 kg P ha^{-1} in uninoculated plants at flowering and maturity stages, which suggests a beneficial effect of uptake of P by mycorrhizal sunflower roots.

Dry biomass and seed yield production

Inoculation of *Glomus fasciculatum* significantly improved the total dry biomass and shoot dry biomass production at flowering and maturity stages as compared to uninoculated control plants (Table 2). In uninoculated plants, total biomass and shoot biomass increased with each increasing P level, while biomass did not differ significantly between 16 and 32 kg P ha^{-1} for inoculated plants. Thus, the principal way in which VAM fungi improved plant dry biomass, growth and yield in the field was P mediated (Nelsen et al., 1981).

In uninoculated plants, the seed yield increased with increase in P levels. But in inoculated plants, there was no increase in seed yield at higher P levels (Table 2). The seed yield of inoculated plants was 22, 15 and 7 percent higher than uninoculated plants at 16, 24 and 32 kg P ha^{-1}, respectively. VA-mycorrhizal fungi were more efficient in P uptake at lower levels of P and the efficiency was reduced with increasing P level. This is supported by the results of a number of workers who reported that added inoculum enhanced plant growth beyond the response to the indigenous fungal population in potted soils (Bagyaraj and Manjunath, 1980; Mosse and Hayman, 1971), and in the field (Black and Tinker, 1977; Nelsen et al., 1981).The increase in seed yield of sunflower at low P fertility in the vertisol may be ascribed to higher P uptake and growth response due to additional colonization by *G. fasciculatum* beyond

Table 2. Root, shoot and total dry biomass at different growth stages and seed yield of sunflower inoculated with *Glomus fasciculatum* at different P levels

Treatment (kg P ha^{-1})	Dry biomass (g $plant^{-1}$) Root	Shoot	Total	Seed yield (kg ha^{-1})
Vegetative stage				
16 I	1.05	8.20	9.25	
16 UI	0.93	7.57	8.80	
24 I	1.09	8.70	9.79	
24 UI	0.96	8.21	9.17	
32 I	1.24	8.92	10.16	
32 UI	1.16	7.74	8.90	
L.S.D. ($p = 0.05$)	NS	NS	NS	
Flowering stage				
16 I	11.05	71.35	82.40	
16 UI	8.63	55.14	63.77	
24 I	11.08	70.57	87.65	
24 UI	9.86	57.71	67.57	
32 I	11.31	68.55	79.86	
32 UI	11.27	63.37	74.64	
L.S.D. ($p = 0.05$)	NS	5.23	4.69	
Maturity stage				
16 I	8.89	98.56	106.65	1824
16 UI	6.39	79.14	86.09	1484
24 I	9.35	102.26	111.61	1885
24 UI	7.91	86.63	94.54	1644
32 I	9.74	101.94	111.68	1870
32 UI	8.82	94.64	103.46	1752
L.S.D. ($p = 0.05$)	NS	5.40	4.70	63

NS = Not significant.
I = *Glomus fasciculatum* inoculated.
UI = uninoculated.

the levels produced by the indigenous inoculum in the soil.

Our study established that inoculation with *Glomus fasciculatum* at 16 kg P ha^{-1} was the optimum for the most efficient utilization of P based on increased P uptake, root and shoot dry biomass and seed yield. This suggests that there is an opportunity to substitute mycorrhizal inoculation for P fertility to an extent of 16 kg P ha^{-1} under field conditions.

References

Bagyaraj D J and Manjunath A 1980 New Phytol. 85, 33–36.

Black R L B and Tinker P B 1977 Nature 267, 510–511.

Bolan N S 1991 Plant and Soil 134, 189–207.

Cabello M N 1987 Resista de la Facutad de Agronomia, Universidad Nacional de la Plata 63, 46–52.

Champavat R S 1990 Indian J. Agric. Sci. 60, 425–427.

Gerdemann J W and Nicolson T H 1983 Trans. Br. Mycol. Soc. 46, 235–244.

Hayman D S 1970 Trans. Br. Mycol. Soc. 54, 53–63.

Hayman D S et al. 1975 Plant and Soil 43, 489–495.

Jackson M L 1967 Soil Chemical Analysis. Prentice Hall of India Ltd., New Delhi, India.

Jones N P and Sreenivasa M N 1993 J. Oilseeds Res. 10, 86–92.

Koide R 1985 J. Exp. Bot. 36, 1087–1098.

Krishna K R et al. 1982 Indian J. Microbiol. 22, 206–208.

Kucey R M N and Paul E A 1983 Can. J. Soil Sci. 63, 82–95.

Mosse B and Hayman D S 1971 New Phytol. 70, 29–39.

Nelsen C E et al. 1981 J. Am. Soc. Hort. Sci. 106, 786–788.

Phillips J M and Hayman D S 1970 Trans. Br. Mycol. Soc. 55, 158–167.

Ratnayake M L T et al. 1978 New Phytol. 81, 543–552.

Sreenivasa M N and Bagyaraj D J 1988 Plant and Soil 106, 289–290.

Thomson J P 1987 Aust. J. Agric. Res. 38, 847–867.

Section editor: J H Graham