Indian Journal of Agronomy **56** (3): 242–246 (September 2011)

Effect of sources and levels of sulphur and spacing on the growth, yield and quality of spring sunflower (*Helianthus annuus*)

SATISH KUMAR*, S.K. TEWARI AND S.S. SINGH

Allahabad Agricultural Institute, Allahabad, Uttar Pradesh 211 007

Received: May 2010

ABSTRACT

A field experiment was conducted during the spring seasons of 2004 and 2005 at Allahabad to study the effect of 3 spacings (30 cm × 30 cm, 45 cm × 30 cm and 60 cm × 30 cm), 4 sulphur levels (control, 15, 30 and 45 kg S/ha) and 2 sulphur sources (gypsum and elemental sulphur) on the performance of sunflower (*Helianthus annuus* L.). The results indicated that growth, yield attributes, yield, oil content and oil yield were found to be significantly higher at a spacing of 45 cm × 30 cm. At 45 cm × 30 cm spacing, seed yield increased by 11.1 and 12.9%; oil content by 6.2 and 6.0%; oil yield by 18.2 and 18.1% over 30 cm × 30 cm spacing during 2004 and 2005, respectively. Significant increase was recorded in growth, yield component, oil content and oil yield with increase in sulphur levels from 0 to 45 kg/ha through gypsum. Application of 45 kg S/ha through gypsum recorded higher growth and yield attributes, oil content and oil yield over control. Higher seed yield (1.31t/ha), oil yield (0.53 t/ha) and net returns (₹7,468/ha) were obtained when the crop was sown at 45 cm × 30 cm spacing; with application of 45 kg S / ha through gypsum for spring sunflower in sandy loam soil of Allahabad.

Key words : Economics, Gypsum, Oil content, Oil yield, Spacing, Spring sunflower, Sulphur,

Sunflower holds promising position among edible oilseed crops due to its premium oil quality and fits well in cropping systems due to its short duration. The most important yield limiting factors are heavy weed infestation and improper production technology, particularly plant population which play an important role in determining yield and yield components of sunflower (Nawaz *et al.*, 2001). Proper row and plant spacing, which are responsible to maintain the plant population per unit area, are very important for obtaining the higher seed yield and good quality oil of sunflower. Application of sulphur in sunflower shows a great promise in promoting seed yield and oil content, which can be obtained by the proper adjustment of sulphur application. Plant nutrient sulphur is required by the plants in amounts similar to phosphorus and is important to the plants for protein formation and other functions. Functionally, sulphur significantly influences yield and quality of crops, improves odor and flavors, and imparts resistance to cold, and hence it is generally considered a 'quality nutrient'. Sulphur-deficient soils are widely distributed around the world. Sulphur-deficiency symptoms are more often observed in crops at early stages of growth, because sulphur can be easily leached from the surface soil (Hitsuda *et al.,* 2005). In acute deficiency of sulphur flowering and seed formation is greatly reduced, resulting in poor yield and oil content. Sulphur also plays an important role in the chemical composition of seeds. Sulphur is the component of the amino acids, cystine, cysteine and methionine, needed for chlorophyll. It increases the percentage of oil (Hassan *et al.,* 2007). Sunflower is a newly introduced oilseed crop in India in general and in SAT regions under rainfed conditions in particular, but it has gained good popularity among the growers because of its attractive price and demand for its oil. It is an energy-rich oilseed crop, so phosphorus and sulphur nutrition assumes greater importance in comparison to other nutrients. In the absence of sulphur, carbohydrates are not fully utilized for the formation of oil (Usha Rani *et al.,* 2009). Keeping those aspects in view, a field experiment was planned to study the effect of plant population and sulphur application, on spring sunflower.

***Corresponding author Email:** satish_agron@yahoo.co.in

MATERIALS AND METHODS

A field experiment was conducted during the spring seasons of 2004 and 2005 at Allahabad Agricultural Institute, Allahabad under irrigated conditions. The sandy loam soil, was low in organic carbon (0.33%) and available nitrogen (112.8 kg/ha), high in available phosphorus (55.8 kg/ha) and potassium (343.85 kg/ha), low in available sul-

phur (9.5 ppm) and was slightly saline in reaction (pH 7.35). The experiment was laid out in split-split plot design with three replications. There were 24 treatment combinations comprised of 3 spacing (30 cm × 30 cm, 45 cm × 30 cm, 60 cm × 30 cm) in the main plots, 4 levels of sulphur (control, 15, 30 and 45 kg/ha) in the sub-plots and 2 sulphur sources (gypsum and elemental sulphur) in the sub-sub plots. The gross and net plot sizes were 5.65 m × 3.85 m and 5.40 m × 3.60 m respectively. The FYM @ 10 t/ha was applied and mixed well in soil 15 days prior to sowing. The NPK applied at the rate of 60-50-40 kg/ha. Half dose of nitrogen and full dose of phosphorus and potassium was given as basal through urea, diammonium phosphate and muriate of potash, respectively. The sulphur was also applied as per treatment at the time of sowing. Remaining half dose of nitrogen was top dressed at the flowering stage of sunflower. Sunflower 'Morden' seeds were treated with bavistin 2.0 g/kg seeds to ensure good crop stand. The crop was sown on 18 February during both years. The crop was thinned at 15 DAS to retain one seedling per hill at 30 cm spacing. The total rains received during cropping period were 2.14 mm and zero mm in 2004 and 2005 respectively. Spraying of endosulfan 35 EC (1.25 liters/ha) was done to control the infestation of leaf eating caterpillars and other insect in the field before bud formation stage. The crop was harvested on 27 May and 28 May during 2004 and 2005 respectively. At harvest, five plants were randomly selected in each treatment for recording growth and yield parameters. These samples were oven dried at 70^{O}C temperature, and analysed for dry weight of stalk. The percentage of oil content in seed was determined by solvent extraction method in soxhlet's apparatus with petroleum ether (BP 40-60^{0}C) as solvent (AOAC, 1980). For working out the economics, prevailing market prices for sunflower seeds (₹150/kg), urea (₹6.50/kg), DAP (₹11.50/kg), MOP (₹5.00/kg) and cost of labour (₹60/day) were considered.

RESULTS AND DISCUSSION

Growth attributes of sunflower

The outcome of the investigation revealed that the plant height, leaves/plant, stem girth, leaf area, dry weight of plant, crop growth rate and relative growth rate was higher at a medium spacing of 45 cm × 30 cm than closer spacing 30 cm × 30 cm and higher spacing 60 cm × 30 cm (Table 1). The magnitude of increase in plant height (8.75% and 8.90%), leaves/plant (2.03% and 17.20%), stem girth (3.90% and 5.75%), leaf area index (1.14% and 0.80%) and dry weight of plant (1.79% and 2.84%) was higher over 30 cm × 30 cm spacing in 2004 and 2005 respectively. Plant height, leaves/plant, stem girth, leaf area index and dry weight/plant were superior under medium spacing, due to better resource availability and reduced interplant competition in the community. The poor yield at 30 cm × 30 cm, corresponding to 1.1 lakh plant/ha might be ascribed to more congestion and severe competition for light, space and nutrients. Similarly, lower plant population of 0.55 lakh plants/ha at 60 cm × 30 cm utilized re-

Table 1. Growth of sunflower as influenced by spacing, sources and levels of sulphur

Treatment	Plant height (cm)		Leaves/ plant		Stem girth (cm)		Leaf area index		Dry weight at maturity (g/plant)		CGR at maturity (g/m^2/day)		RGR at maturity (g/g/day)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Spacing (cm)														
30 × 30	80.2	79.9	11.3	9.59	6.66	6.43	1.04	1.05	74.6	73.5	12.32	12.17	0.527	0.513
45 × 30	87.2	87.0	11.5	11.24	6.92	6.80	1.15	1.12	75.9	75.6	9.54	9.19	0.535	0.516
60 × 30	82.5	82.2	11.2	9.98	6.71	6.59	1.07	1.07	75.2	74.2	6.18	6.17	0.534	0.514
SEm±	0.25	0.23	0.01	0.11	0.06	0.07	0.135	0.065	0.31	0.31	0.20	0.15	0.020	0.01
CD (P=0.05)	0.71	0.64	NS	0.30	0.17	0.20	NS	NS	0.87	0.87	0.57	0.43	0.057	NS
Sulphur level (kg/ha)														
0	81.3	81.0	9.68	9.27	6.43	6.29	1.01	0.98	67.4	64.4	8.94	8.46	0.497	0.455
15	82.7	82.4	10.86	10.08	6.57	6.44	1.05	1.03	74.7	73.7	9.30	9.32	0.505	0.470
30	83.9	83.6	11.46	10.66	6.84	6.70	1.12	1.14	77.3	77.9	9.44	9.17	0.528	0.521
45	85.2	85.0	12.01	11.07	7.22	7.00	1.16	1.17	81.6	82.0	9.70	9.37	0.599	0.611
SEm±	0.20	0.18	0.34	0.11	0.06	0.05	0.11	0.053	0.21	0.18	0.011	0.12	0.011	0.010
CD (P=0.05)	0.41	0.38	0.71	0.24	0.13	0.10	NS	0.112	0.04	0.38	0.023	0.24	0.023	0.022
Sulphur source														
Gypsum	83.9	83.7	11.73	10.60	6.89	6.69	1.13	1.10	75.8	75.2	9.43	9.19	0.534	0.512
Elemental sulphur	82.6	82.3	10.27	9.94	6.63	6.53	1.04	1.06	74.8	73.7	9.26	9.16	0.530	0.469
SEm±	0.28	0.31	0.41	0.16	0.08	0.07	0.157	0.075	0.33	0.24	0.01	0.01	0.01	0.01
CD (P=0.05)	0.58	0.61	0.84	0.33	0.16	0.14	0.032	0.015	0.68	0.50	NS	NS	NS	NS

sources less efficiently. These results are in conformity with those obtained by Wani and Rathor (2001) and Intodia and Tomar (1997).

Leaf area index (LAI) increased up to 60 days and declined progressively later because of senescence and leaf fall. Plant spacing of 45 cm × 30 cm recorded the highest LAI, CGR and RGR throughout the growth period, compared with 30 cm × 30 cm and 60 cm × 30 cm spacing possibly due to better growth environment leading to increased number and size of leaves. There was linear and significant increase in plant height, number of leaves/plant, stem girth, leaf area, dry weight of plant, crop growth rate and relative growth with increase in sulphur fertilizer levels from 0 to 45 kg/ha. Application of 45 kg S/ha sulphur applied through gypsum recorded significantly higher plant growth and growth attributes of spring sunflower. It increased successively till the maturity of crop due to increase in cell multiplication, cell elongation and cell expansion throughout the entire period of crop. This might be ascribed to adequate supply of sulphur that resulted in higher production of photosynthates and their translocation to sink, which ultimately increased the plant growth and growth attributes. S application induced increase in plant height (4.83% and 4.93%), number of leaves/plant (24.07% and 19.41%), stem girth (12.28% and 11.28%), leaf area index (1.60% and 2.28%), dry weight of plant (14.18% and 7.41%), crop growth rate (8.50% and 10.75%) and relative growth rate (20.52% and 34.28%) over control, during 2004 and 2005 respectively. The results obtained were also confirmed by Vijaya Kumar and Selvarju (2001) and Dev and Sarawgi (2004).

Yield attributes, yield and quality of sunflower

Higher head diameter, seed weight/head, test weight, seed and stalk yields, harvest index, oil content and oil yield was noticed at a spacing of 45 cm × 30 cm, which was significantly higher than other spacings (Table 2). The maximum head diameter (5.34 and 5.06%), seed weight/head (2.74 and 3.28%), test weight (3.10 and 2.95%), seed yield (11.11 and 12.93%), stalk yield (7.69 and 7.71%), harvest index (16.18 and 3.91%), oil content (6.20 and 6.03%) and oil yield (18.35 and 18.18%) were found to be higher over 30 cm × 30 cm spacing, during 2004 and 2005 respectively. The optimum plant population (45 cm × 30 cm spacing) of 0.74 lakh plants/ha favoured the higher yield and yield attributes of sunflower. Better distribution of plants

Table 2. Yield, yield attributes, oil content, oil yield and economics of sunflower as influenced by spacing, sources and levels of sulphur

Treatment	Head diameter (cm)		Seed weight/ head (g)		Test weight (g)		Seed yield (t/ha)		Stalk (t/ha)		Harvest index (%)		Oil content (%)		Oil yield (kg/ha)		Cost of cultivation (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit cost ratio
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005			
Spacing (cm)																			
30 × 30	12.51	12.44	32.56	32.24	42.54	42.43	1.17	1.16	4.29	4.28	21.19	21.18	38.17	38.14	446.9	446.1	11.86	5.45	1.48
45 × 30	13.20	13.07	33.45	33.30	43.86	43.68	1.30	1.31	4.62	4.61	24.62	22.01	40.54	40.44	528.1	527.2	11.86	7.46	1.75
60 × 30	12.86	12.79	32.94	32.70	42.89	42.84	1.18	1.18	4.40	4.40	21.39	21.18	39.61	39.46	468.5	467.6	11.86	5.79	1.60
SEm±	0.11	0.08	0.09	0.27	0.23	0.21	0.020	0.01	0.05	0.01	0.13	0.12	0.14	0.36	3.32	5.70	-	-	-
CD (P=0.05)	0.30	0.21	0.26	0.75	0.65	0.59	0.060	0.03	0.15	0.04	0.36	0.34	0.38	1.01	9.21	17.40	-	-	-
Sulphur level (kg/ha)																			
0 (control)	11.69	11.57	27.64	27.54	41.68	41.62	1.15	1.14	3.99	3.99	21.20	21.17	38.18	38.13	437.2	437.1	12.42	5.91	1.43
15	12.54	12.47	32.42	32.31	42.65	42.56	1.18	1.18	4.33	4.31	21.24	21.26	38.94	38.82	460.5	459.0	12.93	6.13	1.44
30	13.44	13.37	34.46	34.08	43.67	43.52	1.24	1.23	4.61	4.59	21.41	21.47	39.83	39.81	495.7	495.4	13.51	6.31	1.45
45	13.75	13.65	37.42	37.05	44.38	44.24	1.30	1.30	4.83	4.83	21.49	22.28	40.80	40.63	531.3	529.9	14.06	6.59	1.46
SEm±	0.12	0.09	0.11	0.12	0.19	0.20	0.02	0.01	0.04	0.03	0.15	0.15	0.11	0.31	3.17	2.40	-	-	-
CD (P=0.05)	0.25	0.19	0.22	0.25	0.41	0.42	0.04	0.02	0.09	0.06	0.31	0.32	0.22	0.66	6.67	5.03	-	-	-
Sulphur source																			
Gypsum	13.02	12.93	33.26	33.06	43.40	43.20	1.23	1.23	4.51	4.48	22.49	21.58	39.78	39.71	491.7	490.7	12,661	7.06	1.55
Elemental sulphur	12.69	12.60	32.71	32.43	42.79	42.77	1.20	1.19	4.37	4.38	21.56	21.52	36.10	35.69	470.6	470.0	13,802	5.41	1.39
SEm±	0.16	0.13	0.15	0.20	0.27	0.29	0.003	0.004	0.07	0.04	0.01	0.01	0.15	0.43	4.26	4.69	-	-	-
CD (P=0.05)	0.34	0.28	0.32	0.40	0.56	0.59	0.006	0.008	0.14	0.08	NS	NS	0.32	0.90	8.79	9.69	-	-	-

over the cropped area, coupled with better interception of solar radiation encouraged the effective use of resources, leading to increased growth and biomass production, which in turn increased yield attributes and ultimately seed yield of spring sunflower.

Application of 45 kg S /ha applied through gypsum recorded significantly maximum seed yield and yield attributes of sunflower. The marked increase in head diameter (17.62 and 17.97%), seed weight/head (35.38 and 34.53%), test weight (6.47 and 6.29%), seed yield (13.04 and 14.03%), stalk yield (21.05 and 21.05%), harvest index (1.36 and 5.24%), oil content (6.86 and 6.55%) and oil yield (21.50 and 21.21%) was recorded over the control, during 2004 and 2005 respectively. Sulphur deficiency can affect yield and quality of crops, as it is involved in protein and enzyme synthesis as well as it is a constituent of the amino acids methionine, cystine and cysteine. Sulphur depletion in soil is mainly caused by leaching. It takes place when the water-moving vertical downward in soil profile is higher than that of the water uptake of the plants, evapo-transpiration and the amount of water necessary for the saturation of the soil. Total sulphur requirement mainly differs between crop species and the development stages of plant. In general, sulphur demand of oilseed crops are higher than those of cereal crops as they contain more sulphur containing compounds needed for oil biosynthesis as reported by Hassan *et al.,* (2007).

Interaction effect between spacing and sulphur levels; spacing and sulphur sources and sulphur levels and sulphur sources; on head diameter, seed weight/head, test weight, stalk, harvest index, oil content and oil yield were found to be non-significant during both the years of experimentation. Interaction effects between spacing and sulphur levels; spacing and sulphur sources; sulphur levels and sulphur sources were found significant on seed yield only in 2004.

Sulphur uptake and use effeciency

Sulphur uptake by the crop increased with the increasing levels of S, due to higher biomass and seed yield. Total S uptake by the crop at maturity was significantly higher when gypsum was used as a source of sulphur. The total fertilizer S uptake by the crop at flowering stage and at maturity stage increased significantly with each increment in S application and reached to the highest when 45 kg S/ha was applied (Table 3). Sulphur use efficiency of the crop was not influenced by the sources through which it was applied by the time the crop reached the flowering stage. But, by maturity stage, the applied S use efficiency was found to be highest when gypsum was used as a source compared to that of elemental sulphur. Application of increasing levels of S, on the other hand, significantly decreased S use efficiency. Sulphur use efficiency doubled at maturity stage (7.37%) when compared to (3.41%) at flowering stage (Table 3). This observation points out that S requirement of the crop is more after flowering stage. This point out further research on time of application of

Table 3. Sulphur uptake and sulphur use efficiency of sunflower as influenced by spacing, sources and levels of sulphur at flowering and maturity stages

Treatment	Sulphur uptake (kg/ha)					Sulphur use efficiency (%)	
	Flowering stage		Maturity stage			Flowering stage	Maturity stage
	Leaves	Stems	Leaves	Stems	Seed		
Spacing (cm)							
30 × 30	2.65	0.47	1.01	0.51	2.38	4.02	6.98
45 × 30	3.33	0.83	1.06	0.73	3.28	2.98	5.85
60 × 30	3.21	0.80	1.01	0.56	2.99	3.56	6.77
SEm±	0.078	0.040	0.066	0.016	0.118	0.13	0.186
CD (P=0.05)	0.16	0.08	0.13	0.04	0.25	0.27	0.39
Sulphur level (kg/ha)							
0 (control)	1.55	1.05	1.70	0.84	3.79	3.58	6.23
15	2.54	1.16	2.19	0.90	3.99	2.82	5.46
30	3.26	1.28	2.37	0.92	4.33	2.57	4.89
45	3.35	1.33	2.40	0.94	4.28	3.41	7.37
SEm±	0.077	0.043	0.067	0.018	0.119	0.14	0.18
CD (P=0.05)	0.15	0.09	0.14	0.04	0.25	0.29	0.39
Sulphur source							
Gypsum	2.66	1.01	2.06	0.82	3.66	3.30	7.68
Elemental sulphur	2.69	1.03	1.87	0.80	3.70	3.51	1.05
SEm±	0.124	0.016	0.032	0.006	0.115	0.14	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.05

Table 4. Interaction effect of spacing, sources and levels on seed yield of sunflower as influenced by spacing, sources and levels of sulphur

		Seed yield (t/ha)							
		Zypsum				Elemental sulphur			
	Year	0	15	30	45	0	15	30	45
30 × 30	2004	1.12	1.15	1.23	1.26	1.10	1.11	1.19	1.22
	2005	1.11	1.15	1.23	1.26	1.10	1.10	1.15	1.22
45 × 30	2004	1.22	1.29	1.31	1.42	1.21	1.25	1.31	1.41
	2005	1.22	1.29	1.31	1.42	1.21	1.26	1.30	1.40
60 × 30	2004	1.13	1.17	1.23	1.28	1.11	1.12	1.19	1.23
	2005	1.12	1.17	1.25	1.28	1.10	1.12	1.19	1.23
	Year	Spacing	Level	Sources	Spacing × level	Spacing × sources	Level × sources	Spacing × level × sources	
SEm±	2004	0.003	0.002	0.003	0.003	0.004	0.004	-	
	2005	0.019	0.010	4.014	-	-	-	-	
CD (P=0.05)	2004	0.006	0.004	0.006	0.007	0.008	0.008	NS	
	2005	0.038	0.021	8.29	NS	NS	NS	NS	

sulphur to this crop before flowering stage as is done in case of groundnut and soybean.

Economics

Sowing the crop at 45 × 30 cm spacing resulted in maximum gross return (₹20,700/ha), net return (₹7,468/ha) and benefit cost ratio (1.75). Among the sulphur levels, application of sulphur at 45 kg/ha through gypsum resulted in maximum gross return (₹20,655/ha), net return (₹6,596/ha) and benefit cost ratio (1.46) during the experimentation (Table 2).

Thus it can be concluded that the spacing of 45 cm × 30 cm with sulphur application at 45 kg/ha through gypsum in addition to recommended dose of other nutrients was found optimum for sunflower crop for getting higher growth, yield, oil content, oil yield and net returns in sandy loam soil of Allahabad.

REFERENCES

A.O.A.C. 1980. Official Methods of Analysis, 13th ed. Association of Official Analytical Chemists. Washington D.C. pp. 376–84.

Dev, C.M. and Sarawagi, S.K. 2004. Balance sheet of nitrogen, phosphorus and potassium as influenced by spacing and nutrient management in sunflower (*Helianthus annuus* L.). *Journal of Oilseeds Research* **21**(1): 187–88.

Hassan, F., Hakim, S., Qadir, G., and Ahmad, S. 2007. Response of sunflower (*Helianthus annuus* L.) to sulphur and seasonal variations. *International Journal of Agriculture and Biology* **9**(3): 499–503.

Hitsuda, K., Yamada, M. and *Dirceu, K. 2005. Soil* and *crop management and sulfur requirement* of *eight crops* at *early stages* of *growth. Agronomy Journal* **97**: *155–59.*

Intodia, S. and Tomar, K. 1997. Effect of sulphur application on growth and yield of sunflower (*Helianthus annuus* L.). *Indian Journal of Agricultural Sciences* **67**(1): 46–7.

Nawaz, R., Ahmed, R., Cheema, Z.A. and Mahmood, T. 2001. Effect of row spacing and Sorgaab on sunflower and its weeds. *International Journal of Agriculture and Biology* **3**(4): 360–62.

Vijaya Kumar, M. and Selvaraju, R. 2001. Effect of plant population and split application of nitrogen on growth and grain yield of sunflower under rainfed condition, *Mysore Journal of Agriculture Sciences* **35**(4): 307–12.

Wani, M.A., Aga, F.A., Malik, M.A. and Rathor, Z.A. 2001. Response of sunflower to sulphur application under Kashmir condition. *Applied Biological Research* **3**(1&2): 19–22.

Usha Rani, K., Sharma, K.L., Nagasri, K., Srinivas, K., Vishnu Murthy, T., Maruthi Shankar, G.R., Korwar, G.R., Sridevi Sankar, Madhavi, K.M., and Kusuma Grace, J. 2009. Response of sunflower to sources and levels of sulfur under rainfed semi-arid tropical conditions. *Communications in Soil Science and Plant Analysis* **40**: 2926–44.