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Effect of nitrogen sources, sulphur and boron levels on productivity, nutrient uptake and quality of sunflower (*Helianthus annuus*)

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ABSTRACT

A field experiment was conducted during spring season of 2005 and 2006 on sunflower (*Helianthus annuus* L.) at New Delhi to study the effect of N sources (prilled urea and calcium ammonium nitrate), S levels (0, 25 and 50 kg/ha) and B levels (0, 0.75 and 1.50 kg/ha) on yield attributes, yield and the oil quality of spring sunflower. Application of N, S and B fertilizers increased significantly yield attributes, yield and the oil quality parameters of spring sunflower. Calcium ammonium nitrate proved superior to urea in terms of nutrient concentration and their uptake by sunflower. Application of 25 kg S/ha was more effective in increasing the growth, yield attributes and yields than of 50 kg S/ha. However, the highest seed yield (1.99 t/ha) was recorded with 50 kg S/ha, which was 13% higher than that of the control. Boron application @ 0.75 kg and 1.5 kg/ha was effective and the crop responded well up to the second dose, and the higher (1.5 kg/ha) level gave the highest seed yield (2.01 t/ha), which was 13.5 and 6.3% more than of the control and 0.75 kg B/ha respectively. It also increased the total nutrient concentration and their uptake by sunflower. Application of S and B markedly improved the content of unsaturated fatty acids (linoleic and oleic) and reduced that of the saturated fatty acids (palmitic and stearic). S and B application reduced the saponification but increased the iodine value significantly. The N sources and S and B levels did not show marked changes in the acid value of sunflower oil. Thus, application of 80 kg N/ha through calcium ammonium nitrate along with 25 kg S/ha and 1.50 kg B/ha would be sufficient to sustain the productivity and quality of spring sunflower under north Indian conditions.

Key words: Boron, Fatty acid composition, Nutrient uptake, Polyunsaturated fatty acid, Productivity, Sulphur, Sunflower

Sunflower (*Helianthus annuus* L.) holds great promise as an oilseed crop because of its short duration, photo-insensitivity, and wide adaptability to different agro-climatic regions and soils types. It can be grown at any time of the year and can serve as an ideal catch crop during the period when the land is otherwise fallow. Spring sunflower best suits such conditions, with chances of area expansion and horizontal intensification for improving oilseed production in India. The shortage of edible oils has become a chronic problem in India with increasing demographic pressure. Sunflower can play an important role in meeting out the shortage of edible oils in the country. It covers 2.34 M ha and provides 1.44 M t total production with 615 kg/ha average productivity (Anonymous, 2007). The existing yield is very low, mainly because of the suboptimal soil fertility. After N, P and K, S is the fourth nutrient, whose deficiency is widespread in India (Yadav *et al.,* 2000; Sakal *et al.,* 2001). Results from 12 Indian states Co-operative study from TSI, FAI and IFA in association with agronomists at national centres showed that an average 30 to 35% of cropped soils were deficient in S and another 35% potentially deficient in it, indicating widespread soil S hunger (Morris, 2006). Sulphur deficiency is observed primarily due to high crop yield and therefore higher rate of S removal by crops, and lesser use of S-containing fertilizers (Messick, 2003). A suitable combination of major, secondary and micronutrients is by and large the most important single factor that affects the yield and quality of sunflower oil. Sulphur application has many advantages for sunflower regarding growth parameters, yield and quality. Boron is an essential element for sunflower, playing many important roles like flowering, pollen germination, fruiting processes and seed setting. Seed yield of sunflower significantly increases with 25 kg S/ha and foliar application of B. Hence both S and B have positive effect on seed yield and oil quality of sunflower. Sulphur application significantly improved the quality of sunflower oil in terms of free fatty acid, iodine value and lesser-saturated fatty acids like stearic and palmitic acids and higher polyunsatu-

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rated fatty acids (PUFA) like linoleic and oleic acid. The effect of S application on the uptake of other nutrients is also found to be synergistic, like between S and N, S and P and S and Zn; hence overall soil-nutrient balance has to be maintained for increased productivity. In new of these a field experiment was conducted to study the effect of N sources, and S and B levels on productivity, nutrient uptake and quality of spring sunflower oil.

MATERIALS AND METHODS

A field experiment was conducted during spring seasons of 2005 and 2006 at Division of Agronomy, Indian Agricultural Research Institute, New Delhi. The climatic condition of Delhi is semi-arid to subtropical with extreme cold and hot situations. The experimental soil was sandy loam (61.35% sand, 13.06% silt and 25.61% clay) with adequate internal drainage, and was low in organic matter (0.42% organic C) and available N (177.2 kg/ha), medium in available P (15.8 kg/ha) and high in available K (248.3 kg/ha), and neutral in soil reaction (pH 7.3), and was also medium in available S (23.5 kg/ha) and B (0.97 mg/kg soil). The experiment consisted of 19 treatment combinations including two sources of N, viz. prilled urea and calcium ammonium nitrate, three levels of S, viz. 0, 25 and 50 kg/ha; and three levels of B, viz. 0, 0.75 and 1.5 kg/ha; and an absolute control. These treatment combinations were laid out in randomized block design with factorial having three replications.

The basal dose of fertilizers, consisting of 26 kg P/ha through diammonium phosphate, 33 kg K/ha through muriate of potash, half the dose of N and full doses of S and B, as per the treatment was applied before sowing in the rows precisely with the help of *pora* below the seeds at 5 cm depth. The rest half of N was supplied at 35 days after sowing (DAS). Nitrogen was supplied through two different sources, i.e. urea and calcium ammonium nitrate. Sulphur was supplied as Cosavet, which contained 80% S and B through borax having 11% B content. The sunflower cv 'JK Chitra' was sown on 25 and 15 February in 2005 and 2006, respectively. The gross plot size was 6 m x 2.25 m and the net plot size was 5 m x 1.8 m. Row- to row- spacing was maintained at 45 cm, whereas plant-to-plant spacing was 20 cm. Other agronomic management practices were followed as per the standard recommendations. The mature heads were plucked in 2-3 installments and their seeds were separated with stick beatings a week after sun drying. The concentrations of various nutrients like N, P, K, S and B in seeds and stover of the plant were estimated by methods as given by Prasad *et al.* (2006). The nutrient uptake was determined by multiplying the concentrations with their respective dry-matter accumulation. The cold-extraction method of Folch *et al.* (1957) was used for extraction of total lipids from sunflower seeds. The fatty acids were analysed in AIMIL-NUCON 5500 Model Gas Liquid Chromatograph (GLC) equipment. Iodine number, saponification value and acid value of sunflower oil were estimated following the standard methods given by Association of Official Analytical Chemists (AOAC).

RESULTS AND DISCUSSION

Seed yield

Mean data of two crop seasons revealed that N application increased the size of capitula, although both the sources remained statistically on par with each other (Table 1). Both the doses of S produced statistically higher capitulum diameter, although the increase was more at lower dose (25 kg S/ha). Capitulum size under B application remained statistically superior at both the doses. However, B application @ 0.75 kg/ha increased its size up to 19%. All the fertilizer treatments proved statistically better than the control. Increased size of the head by N application was attributed to better partitioning of photosynthates from source to sink. Since head development occurs late in the growth stage of sunflower, the difference due to urea or calcium ammonium nitrate was almost diluted and both the sources performed equally well (Sadiq *et al.*, 2000).

Sulphur application was also highly beneficial in improving the capitulum diameter. Since it is an element inevitable for oilseeds, its greater diversion is required towards the head. Sulphur @ 25 kg/ha increased the capitulum diameter more than S @ 50 kg/ha. Boron requirement of sunflower during the reproductive growth was much higher than during vegetative growth. It increased the vegetative and reproductive dry-matter accumulation of plants by more than three folds, including that of the capitulum size. It prevents excessive conversion of sugars into starch. Hence it helps in the growth of the head, which ultimately resulted in bigger capitulum size. Boron regulates photosynthesis and respiration by maintaining carbohydrate and protein metabolism. Thus B deficiency leads to callus formation in sieve tubes, which reduces the formation of sugar-borate complex, ultimately lowering the sink capacity and reducing the capitulum diameter (Shen *et al.*, 1995).

The fertilizer treatments registered higher number of seeds/capitulum in sunflower. Increase in total number of seeds due to N application was the result of better assimilation of carbohydrates (Reddy, 2003). The number of seeds/capitulum was more with calcium ammonium nitrate as a source of N due to slower rate of its mineralization under higher temperature, which led to greater recovery. The total amount of N accumulation and its distribution among various plant parts indicated that 82% of the total amount of N was retained in the head (Oyverman *et al.*, 1995). Timely application of S increases the plant growth by increasing the assimilating surface area. The higher photosynthate assimilation helped in net export of carbon to sink and thus increased the number of seeds/capitulum. A significant increase in the number of seeds/capitulum was observed due to influence of B on flowering, pollen germination, fertilization, cell division and water relationship. The number of seeds/capitulum increased with B application, as it increased the pollen-producing capacity of anthesis and pollen grain viability.

Nitrogen and S doses were able to improve the seed weight to nearly 2-4 g/capitulum. The response of B application was also significantly higher than of the control. A minimum increase up to 10% was recorded due to application of different treatments, which is quite higher. Sulphur and B application proved effective at both the doses, although the increment was higher at the first dose of both the elements. The 1000–seed weight improved by 6-7%. All the fertilizer treatments were better than the control. A significantly higher test weight was recorded with N application due to overall increased productive growth of the crop. Application of S and B was also beneficial.

Sulphur application influenced the seed yield (Table 1). Sulphur @ 25 kg/ha also improved the yield by 0.16 t/ha compared with the control. At higher dose of S application (50 kg/ha), the response was positive but the differences in yield were not significant over 25 kg S/ha. The maximum total seed yield (2.01 t/ha) was recorded with B @ 1.5 kg/ha. The yield of any crop is the final product of various yield-attributing characters. The higher availability of nutrients, especially N and S, in the initial stage helped to acquire a definite advantage over the control in respect of growth and development. Better partitioning of photosynthates from source to sink might have led to higher yield attributes, which finally resulted in higher seed yield of sunflower. The B application improved the seed yield because it maintains good balance between photosynthesis and respiration. Boron removal alters the cell wall structure, with a transitory decrease in elasticity modulus, followed by a secondary hardening and reduction in the incidence of plasma membrane-bound reductase activity for better translocation to sink. This reduces the total seed yield (Yu *et al.*, 2002).

Calcium ammonium nitrate proved a better source of N than prilled urea with regard to stover yield. Sulphur application @ 25 kg/ha increased the stover yield over the control, but further increment of S application to 50 kg S/ha remained statistically on a par with that of 25 kg S/ha application. Boron 0.75 kg/ha recorded significantly higher stover yield of sunflower over the control and remained statistically on a par with that of 1.5 kg/ha. Absolute control produced minimum stover yield (1.88 t/ha), and a quantum jump in stover yield of 0.65-0.90 t/ha was experienced in various fertilizer treatments. Harvest index

Table 1. Effect of N sources, S and B levels on yield attributes and yield of sunflower (mean data of 2 years)

Treatment	Capitulum diameter (cm)	Number of seeds/ capitulum	Seed weight/ capitulum (g)	1,000-seed weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
N source							
Prilled urea	16.5	859.8	35.3	40.3	1.85	2.03	47.8
Calcium ammonium nitrate	17.1	845.8	35.6	40.5	1.93	2.17	46.7
SEm±	0.2	8.9	0.4	0.7	0.03	0.02	0.6
CD (P=0.05)	0.6	NS	NS	NS	NS	0.06	NS
S level (kg/ha)							
0	15.3	807.0	33.2	37.6	1.76	2.01	46.5
25	17.1	849.3	35.9	40.9	1.92	2.11	46.5
50	18.0	902.2	37.2	42.8	1.99	2.18	46.7
SEm±	0.2	10.9	0.5	1.2	0.03	0.03	0.7
CD (P=0.05)	0.7	30.4	1.5	3.3	0.09	0.08	NS
B level (kg/ha)							
0	14.9	824.0	34.2	37.7	1.77	1.98	47.1
0.75	17.3	855.1	35.5	40.2	1.89	2.14	46.9
1.50	18.3	879.4	36.9	43.9	2.01	2.18	47.7
SEm±	0.2	10.9	0.5	1.2	0.03	0.03	0.7
CD (P=0.05)	0.7	30.4	1.5	3.3	0.09	0.08	NS
Absolute control	12.3	752.7	29.0	29.0	1.11	1.88	39.8
Rest	16.9	852.8	35.5	35.5	1.89	2.10	47.2
SEd±	0.5	25.8	1.9	2.1	0.09	0.04	1.4
CD (P=0.05)	1.0	52.1	3.9	3.9	0.17	0.08	2.8

was not influenced significantly due to application of N sources, S and B levels, however significantly higher values of harvest index were recorded over absolute control.

Nutrient uptake

All the fertilizer treatments improved the total uptake of various nutrients by sunflower (Table 2). The total uptake of N, P and S was higher in seeds and that of K and B was higher in stover. Nitrogen application had a significant influence on nutrient uptake (P, K and S) over absolute control, but both the sources remained statistically on par with each other. Different levels of S and B improved the uptake of N, S and B significantly in the seed, stover and as well as total, however P uptake remained unaffected at both the doses of S and B. The rate of increase in uptake was higher at the first doses of S and B than at the higher application rates. Uptake of K by various plant parts also increased at higher levels of S, leading to increased total uptake. This was evident with B also. If a plant nutrient is involved in improving the vegetative growth, it would certainly improve the uptake of all nutrients, which are required to maintain the growth. The total uptake of B was higher due to various treatments of N, S and B. Since the application of different nutrients helped to improve the overall growth of the crop, it increased the total uptake as well, although the magnitude of increase depends upon the concentration and total dry- matter accumulation.

Quality parameters

Although N is an important element in deciding the fatty acid composition of oil, its sources were not effective in causing a significant difference in the composition of any of the major fatty acid of sunflower oil (Table 3). Application of S proved non-significant in increasing the linoleic acid content. A desirable and significantly negative effect of both doses of S application was recorded on saturated fatty acids (palmitic and stearic). Its application reduced the content of saturated fatty acid significantly in sunflower oil. Boron application proved to useful in improving the quality of sunflower oil, increasing the content of unsaturated fatty acids (linoleic and oleic) significantly and reducing that of undesirable saturated fatty acids (palmitic and stearic) significantly. All the fertilizer treatments were significantly superior to the control in increasing the unsaturated fatty acids (linoleic and oleic) content and reducing the undesirable saturated fatty acids (palmitic and stearic) content. N sources had no significant effect on saponification, iodine and acid values of sunflower oil. Sulphur and B application significantly reduced the saponification value, whereas absolute control plot produced oil with maximum saponification value. However, S and B levels increased significantly the iodine value, and absolute control produced the lowest iodine value compared with the rest of the fertilizer treatments.

Acid value decreased on N application but the difference due to N sources was not significant. Sulphur and B

Table 2. Effect of N sources, S and B levels on total nutrient uptake by sunflower (mean data of 2 years)

Treatment	Total nutrient uptake				
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	B (g/ha)
N source					
Prilled urea	78.3	20.8	92.4	8.6	140.8
Calcium ammonium nitrate	89.1	22.3	100.4	9.6	150.6
SEm±	1.2	2.9	4.3	0.4	1.8
CD (P=0.05)	3.3	NS	NS	NS	7.1
S level (kg/ha)					
0	75.3	18.9	87.0	7.5	148.5
25	84.7	21.9	96.8	8.8	149.3
50	91.1	23.8	105.4	11.1	152.6
SEm±	2.6	3.1	3.2	0.6	2.4
CD (P=0.05)	7.3	NS	9.0	1.6	1.8
B level (kg/ha)					
0	75.0	18.8	84.1	7.1	137.0
0.75	84.4	21.7	98.3	9.2	150.1
1.50	91.8	23.2	106.9	11.1	151.6
SEm±	2.6	3.1	3.2	0.57	2.4
CD (P=0.05)	7.3	NS	9.0	1.6	1.8
Absolute control	48.6	10.9	60.5	4.8	137.0
Rest	83.7	21.6	96.4	9.1	150.1
SEd±	4.8	2.4	3.0	1.1	6.9
CD (P=0.05)	11.3	4.8	6.1	2.2	13.9

Table 3. Effect of N sources, S and B levels on fatty acid composition of sunflower oil (mean data of 2 years)

Treatment	Linoleic acid (%)	Oleic acid (%)	Palmitic acid (%)	Stearic acid (%)	Saponification value	Iodine value	Acid value
N source							
Prilled urea	65.8	20.5	7.7	5.1	191.6	150.1	203.3
Calcium ammonium nitrate	65.7	20.2	7.7	4.6	193.0	150.2	204.5
SEm±	0.6	0.2	0.1	0.1	0.2	0.6	0.7
CD (P=0.05)	NS	NS	NS	0.22	NS	NS	NS
S level (kg/ha)							
0	64.9	21.0	8.6	5.1	193.2	148.5	205.4
25	65.7	21.4	7.8	5.0	192.4	149.3	203.8
50	66.9	21.7	6.5	4.4	189.7	152.6	202.5
SEm±	1.2	0.3	0.1	0.1	0.3	0.6	1.7
CD (P=0.05)	NS	0.6	0.3	0.3	0.8	1.8	NS
B level (kg/ha)							
0	63.5	20.9	8.1	5.4	193.3	148.2	205.2
0.75	66.1	21.3	7.7	4.8	192.4	150.1	203.7
1.50	67.8	21.8	7.3	4.4	191.0	151.6	202.8
SEm±	1.2	0.3	0.1	0.1	0.3	0.6	1.7
CD (P=0.05)	3.5	0.6	0.3	0.3	0.8	1.8	NS
Absolute control	58.5	19.2	10.2	7.1	195.0	137.0	216.5
Rest	65.8	21.3	7.7	4.8	192.1	150.1	203.9
SEd±	1.7	0.3	0.1	0.1	0.5	1.2	2.7
CD (P=0.05)	3.5	0.6	0.3	0.3	1.0	2.4	5.5

applications did not influence the acid value significantly but increasing levels of S and B gave its lower value. When linoleic acid increases, oleic acid reduces and *vice-versa.* Rani *et al.* (2006) also showed negative correlation of oleic acid with linoleic acid. Nitrogen application increased the desirable linoleic acid content, as it increased the dry-matter accumulation and oil-accumulation phases, with all the enzyme activities involved, including 12 desaturase, which is responsible for the desaturation from oleic to linoleic. An increase in linoleic acid was recorded in our experiment. The oleic acid content was also higher, as N application changes the oil constituents of the seed altering the oleic and linoleic acid ratio. Boron application increases the unsaturated fatty acids (UFA) and reduces saturated fatty acids (SFA), as B inhibits the incorporation of acetate into lipids, which increases the UFA : SFA ratio. Nitrogen application decreases the saponification value, increases refractive of seed oil index, unsaponifiable matter and total UFA, but it reduces the acid value. They reduce the oil stability and deteriorate its quality (Zakaria *et al.*, 2006). Sulphur application increased the iodine value but reduced the saponification value and acid value by improving the oil quality. Sulphur dressing to sunflower provides sufficient period for poly-unsaturating system, which is reflected in higher iodine value and less synthesis of free acid. Similarly B increased the iodine value and reduced the saponification value and acid value of the oil, indicating the formation of high-molecular fatty acid with less saturated fatty acids to improve the quality of the oil.

It was concluded that application of 80 kg N/ha through calcium ammonium nitrate along with 25 kg S and 1.50 kg B/ha would be sufficient to sustain the productivity and quality of spring sunflower under north Indian conditions.

REFERENCES

Anonymous. 2007. Agricultural Research Data Book. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi

Folch, J., Lees, M. and Sloane, C.H. 1957. A simple method for isolation and proliferation of total lipids from animal tissues. *Journal of Biochemistry* **226**: 497–506.

Messick, D.L. 2003. Sulphur fertilizers: a global perspective, pp 1-7. In: *Proceedings of TSI-FAI-IFA workshop on Sulphur Balanced Fertilization.* Sarkar M.C, Biswas B.C, Soumitradas, Kalwe, S.P. and Maity, S.K. (Eds).

Morris, R.J. 2006. Sulphur in agriculture: international perspective, pp 1-8. In: *Proceedings of TSI-FAI-IFA Symposium-cum-Workshop on Sulphur in Balanced Fertilization,* held at New Delhi, India.

Oyverman, A.R., Vidak, W., Allhands, M.N. and Perry, T.C. 1995. Models for partitioning of dry matter and nutrients in corn. *Journal of Plant Nutrition* **18**(5): 959–968.

Prasad, R., Shivay, Y.S., Kumar, D. and Sharma, S.N. 2006. Learning by Doing Exercises in Soil Fertility - *A Practical Manual of Soil Fertility.* Division of Agronomy, Indian Agricultural Research Institute New Delhi.

Rani, A., Kumar, V. and Chauhan, G.S. 2006. Fatty acid composition in germinating soybean. *Journal of Oilseeds Research* **23**(1): 139–141.

Reddy, B.M. 2003. Growth and yield of sunflower as influenced by N and S. *Indian Journal of Agricultural Research and Development* **18**(2): 192–195.

Sadiq, S.A., Shahid, M. and Jan, A. 2000. Effect of various levels of N, P, K on growth, yield and yield components of sunflower. *Pakistan Journal of Biological Science* **3**(2): 338–339.

Sakal, R, Singh, A.P. Choudhary B.C. and Shahi, B. 2001. Sulphur status of Usifluvents and response of crops to sulphur application *Fertilizer News* **46**(10): 61–65.

Shen, Z., Zhang, X., Wang, Z. and Shen, K. 1995. The relationship between B nutrition and development of anther in rapeseed plant. *Zhongguo Nougyl Kexue* (Beijing) **27**: 51–56.

Yadav, R.L., Dwivedi, B.S., Shukla, A.K. and Kumar, V. 2000. Sulphur in balanced fertilization in alluvial soils of western Uttar Pradesh, pp. 27-41. In: *Proceedings of TSI-FAI-IFA Workshop on Sulphur in Balanced Fertilization,* held at New Delhi.

Yu, Q., Hlavacka, A., Matoh, T., Volkmanm, D., Menzel, D. and Baluska, F. 2002. Short term B deprivation inhibits endocytosis of cell wall pectins in meristematic cells of maize and wheat root apices. *Plant Physiology* **130**(1): 415–421.

Zakaria, M.S., Hafez, S.A., Bosyony, A.E. and Alkassas, A.E. 2006. Cottonseed, protein, oil yields and oil properties as affected by N fertilization and foliar application of K and a plant growth retardant. *World Journal of Agricultural Science* **2**(1): 56–65.