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Effect of Sulphur Levels on Growth, Yield Parameters, Yield, Nutrient Uptake, Quality and Economics of Sunflower: A Review

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ABSTRACT

Sunflower is an important crop cultivated all over world owing to its versatile nature of adaptation to different agro-climatic and soil conditions. In India sunflower gains momentum as an edible oil and ranks fourth substantially by reducing the shortage of vegetable oil. Nutritionally sunflower oil benefits human due to presence of high linoleic acid content and absence of linolenic acid content. The productivity is lower due to different factors among which nutrient management especially sulphur that plays pivot role in governing the growth, yield and quality of sunflower. Sulphur contains aminoacids *viz.,* cystein, methionine, cystine, vitamins B, biotin and thiamine. The protolytic enzymes aids in improving the oil content, protein content and quality of seeds by sulphur supplement. Extensive investigations of research scientist on sulphur levels were critically reviewed. Application of sulphur at 40 to 60 kg ha^{-1} was found to increase the growth and yield attributes, yield, quality as well as higher benefit cost ratio sustaining the livelihood of sunflower growers.

Key words: Growth, Oil content, Sulphur, Sunflower, Yield.

Sunflower being an oilseed is cultivated all over the world owing to its wide adaptability to different soil and climatic conditions, photo-thermo-insensitiveness, tolerance to drought and early maturity Kalaiyarasan *et al.* (2016). Sunflower ranks fourth among oilseed crops in India contributing major role in edible oil and consumption purpose. The contribution of sunflower oil for achieving self-sufficiency in edible oil production and yellow revolution was remarkable in India although it is an recent origin dating back to three decades only. The sunflower oil gains priority due to its higher poly unsaturated fatty acid in addition with high linoleic acid content and lack of linolenic acid content. Sunflower seed has 48-53% edible oil and contains 64% of linoleic acid which is considered good to heart patients. Sunflower oilcake serves as an high quality cattle as well poultry feed because of its high protein content and also organic manure for crop production (Taha, 2015). Among the different reasons nutrient management especially sulphur deficiency is remarkable. Sulphur is recognized as the fourth major nutrient next to nitrogen, phosphorus and potassium. Sulphur aids in the synthesis of sulphur containing aminoacids such as cystein, methionine and chlorophyll, vitamins B, biotin and thiamine. It is also involved in the metabolism of carbohydrates, oil content, protein content and in addition on growth and metabolism, especially by its profound effect on protolytic enzymes (Najar *et al.,* 2011). Lack of organic source of nutrient supplement, intensive cultivation, high nutrient exhausting nature of hybrids and repeated use of high analysis straight fertilizers without sulphur led to sulphur deficiency in the present hour. The sulphur plays a predominant role in determining the quality of grain, sunflower oil and also improves the nutrient use efficiency of nitrogen, phosphorus and potassium. The positive trend with regard to sulphur application on growth parameters, yield attributes, yield, nutrient uptake, quality and economics in sunflower from investigations of eminent research scientist have been cited in the review paper.

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Effect of sulphur application on growth and growth parameters of sunflower

Reddy and Singh (1996) reported that sulphur application

at 40 kg ha^{-1} significantly increased the plant height, leaf area and dry matter production of sunflower compared to control. Plant height and leaf area index was maximum with application of 45 kg ha^{-1} of sulphur in sunflower (Singh *et al.,* 2000). Ali *et al*. (2000) divulged that sulphur application at 30 kg ha^{-1} maximum leaf area in sunflower from his study. Poonia (2000) reported that sulphur application at 25 kg ha^{-1} gave significant increase in plant height and dry matter yield compared to control in sunflower. Awasthi *et al*. (2001) concluded that increasing levels of application of nitrogen, sulphur and boron gave a significant increase in height of plant, stem girth and dry matter production of sunflower. Budhar *et al.* (2003) concluded that sulphur application increased dry matter production compared to no application in sunflower. Application of sulphur at 40 kg ha^{-1} gave maximum plant height, leaf area index and dry matter production in sunflower Bhagat *et al.* (2003). Poonkodi and Poomurugesan (2005) found that sulphur application at 60 kg ha^{-1} gave maximum plant height (137.87 cm) and dry matter production (4490.52 kg ha^{-1}) of sunflower. Application of 45 kg ha^{-1} of sulphur gave a significant increase in the dry matter yield of sunflower Poonkodi and Kalpana (2005). Khan *et al*. (2007) revealed that sulphur application through sulphide materials (SM) at 75 kg ha^{-1} enhanced leaf area index of sunflower. Leaf area index, 50% flowering and crop growth rate were significantly increased with sulphur application at 60 kg ha^{-1} in sunflower Sarkar and Mallick (2009). Kale and Adsule (2009) obtained a significant increase in dry matter yield of sunflower with application of sulphur at 30 kg ha^{-1}. Kumar *et al.* (2011) found that sulphur application increased plant height (4.83% and 4.93%), leaf number $plant^{-1}$ (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%), CGR (8.50% and 10.75%) and RGR (20.52% and 34.28%) than control, during 2004 and 2005, respectively. Plant height was maximum with sulphur application at 40 kg ha^{-1} in sunflower crop compared to no application Patra *et al.* (2013). Plant height (112.7 cm) and dry matter production (7.40 t ha^{-1}) were higher with 60 kg ha^{-1} of sulphur application over 30 kg ha^{-1} in sunflower Faisul-ur-Rasool *et al*. (2013). Rana *et al.* (2015) registered a significant increase in plant height (198.2 cm) with sulphur application at 75 kg ha^{-1} compared to control (192.3 cm) in sunflower. Kalaiyarasan *et al*. (2016) concluded that sulphur application at 40 kg ha^{-1} gave significant increase in plant height (152 and 157 cm), LAI at flowering (4.49 and 4.57), dry matter production (5293 kg ha^{-1} and 5468 kg ha^{-1}) at harvest, total chlorophyll content at flowering stage (2.27 and 2.35) and brings earliness to fifty percent flowering (51.2 and 50.8 days) in both crops than other levels and control. Venkadesan (2016) observed that application of sulphur at 40 kg ha^{-1} registered higher leaf area index and dry matter production over control and other levels of in sunflower. Ravi kumar *et al.* (2016) found that application of sulphur at 45 kg ha^{-1} through elemental sulphur along with recommended dose of fertilizers (40:20:20) gave maximum plant height (144.80 cm and 146.73 cm), leaf area index (4.26 and 4.29) and dry matter production (4027 kg ha^{-1} and 4134 kg ha^{-1}) compared to control (123.2 cm and 124.1 cm), (3.12 and 3.16) and (2967 kg ha^{-1} and 2972 kg ha^{-1}) in both seasons. The CGR at flowering stage (16.02 and 16.09) and RGR (0.0762 and 0.0765) was also higher compared to control (12.36 and 12.39) and (0.0472 and 0.0471) in both seasons. Indu and Singh (2020) reported that sulphur application at 50 kg ha^{-1} along with 0.2% foliar spray of boron gave maximum plant height (137.32 cm), stem girth (3.06 cm) and number of leaves per plant (23.13) compared to control. Kalaiyarasan *et al.,* (2020) found that application of sulphur at 60 kg ha^{-1} increased the growth attributes *viz.,* plant height (153.18 cm and 156.58 cm), leaf area index (4.35 and 4.42), dry matter production (4996.11 kg ha and 5093.34 kg ha), crop growth rate (14.92 and 15.97), relative growth rate (0.0899 and 0.844), chlorophyll content (0.84 mg per g and 0.83 mg per g) and days to 50% flowering (51.14 and 52.31) compared to control in both crops.

Effect of sulphur application on yield parameters and of sunflower

Najeeb (1987) found that yield attributes of sunflower were significantly increased with sulphur application at 40 kg ha^{-1} compared to 20 kg ha^{-1} and control. Venkatesh *et al.* (2002) documented that increases doses of sulphur gave significant increase in yield attributes of sunflower. Kumar and Singh (2005) concluded that increasing levels of sulphur application up to 30 kg ha^{-1} significantly increased the head diameter and test weight of sunflower. Poonkodi and Kalpana (2006) found that combined application of sulphur and boron recorded highest head diameter (25.12 cm) and hundred seed weight (4.198 g) in sunflower. Patra *et al.* (2013) stated that sulphur and biofertilizers application significantly increased the yield attributes *viz.,* filled seeds $capitulum^{-1}$ and hundred seed weight (g) of sunflower. Faisul-ur-Rasool *et al.* (2013) found that yield attributes *viz*., achenes $capitulum^{-1}$, sterility percent, test weight were significantly increased with 60 kg ha^{-1} of sulphur application over 30 kg ha^{-1}. Rana *et al*. (2015) found that sulphur application at 75 kg ha^{-1} significantly increased the head diameter (21.9 cm), number of achene head (1276.0) and 1000 achene weight (50.6) compared to control in sunflower. Ravikumar *et al.,* (2016) revealed a significant increase in yield attributes such as capitulum diameter (16.92 and 17.22 cm), number of filled seeds $capitulum^{-1}$ (695 and 705), 100 seed weight (4.506 and 4.511) than control with 45 kg ha^{-1} of sulphurapplication. Kalaiyarasan *et al.,* (2016) found that application of sulphur at 40 kg ha^{-1} gave highest head diameter (18.6 cm and 20.4 cm), total number of seeds $head^{-1}$ (866.3 and 902.3) and hundred seed weight (6.16 and 6.42 g) over other levels and control in sunflower. Application of 50 kg sulphur ha^{-1} in addition to 0.2% foliar spray gave significant increase in capitulum diameter (15.57 cm) over no application (12.45 cm) Indu and Singh (2020). Kalaiyarasan *et al.* (2020) found that sulphur application at 60 kg ha^{-1} gave significant increase of yield attributes *viz*., head diameter (17.48 cm and 18.63 cm), number of seed

head^{-1} (818.22 and 847.21), number of filled seed head^{-1} (688.14 and 715.43), seed filling per cent (84.05 and 84.42) and 100 seed weight (6.03 and 6.54) than control in sunflower.

Effect of sulphur application on seed yield and stalk yield of sunflower

Krishnamurthy and Mathan (1996) observed that sulphur application resulted in increasing yield of sunflower over no application. Sreemannarayana *et al.* (1998) documented significant increase in stover yield of sunflower by sulphur application owing to its profound role in amino acid formation and protein synthesis. Seed yield was increased with sulphur application at 60 kg ha^{-1} in sunflower Agarwaland Verma (1998). Legha and Giri (1999) reported that sulphur fertilization increased the seed yield of sunflower by enhancing the photosynthesis rate and high carbohydrate metabolism. Poonia (2000) reported that application of sulphur at 25 kg ha^{-1} significantly increased the seed yield than no application in sunflower. Ghosh (2000) revealed that sulphur application at 60 to 80 kg ha^{-1} gave higher yield in sunflower. Agarwal *et al.* (2000) found that application of sulphur and phosphorus at 60 and 40 kg ha^{-1} gave a significant increase in seed yield and stalk yield of sunflower. Walia *et al.* (2001) obtained a significant increase in seed yield with application of more than 50kg ha^{-1} of sulphur in sunflower. Badr-Uz-Seed yield was significantly increased with application of sulphur at 80 kg ha^{-1} in sunflower Nasreen and Haq (2002). Zaman *et al.* (2002) revealed that sulphur application at 75 kg ha^{-1} recorded an significant increase in seed yield of sunflower. Kumar *et al.* (2002) registered that application of 50 kg ha^{-1} of sulphur increased the seed yield of sunflower. Seed and stalk yield of sunflower was increased with higher levels of sulphur application (Usharani *et al.*, 2002). Productivity of sunflower was increased with sulphur application at 30 kg ha^{-1} (Maity and Giri, 2003). Kawalenko (2004) found that sulphur application at 40 to 60 kg ha^{-1} significantly recorded higher yield and an improved quality in sunflower crop. Seed yield was significantly higher with sulphur application in sunflower with increasing levels of sulphur (Ramu and Reddy, 2004). Yield was significantly higher with increasing levels of sulphur application in sunflower (Ramu and Reddy, 2004). Seed yield was higher with sulphur application at increasing level of 30 kg ha^{-1} in sunflower (Kumar and Singh 2005). Ganapathy *et al.* (2006) revealed that application of sulphur gave significant increase the seed yield compared to no application in sunflower. Shubhangi *et al.* (2008) obtained a significant increase in seed yield and stalk yield with application of sulphur at 60 kg ha^{-1} in sunflower. Shakhawat and Shivay (2008) revealed that sulphur application at 25 kg ha^{-1} gave significant increase in seed yield of sunflower. Mishra *et al.* (2010) reported that sulphur application at 5 kg ha^{-1} gave significant increase in seed yield of sunflower over control. Hussain and Thomas (2010) revealed that sulphur application at 60 kg ha^{-1} recorded significant increased the seed yield and biomass of sunflower. Gandhi (2011) found that seed yield was higher with application of sulphur at 40 kg ha^{-1} in sunflower. Hussain *et al.* (2011) concluded that 60 kg ha^{-1} of sulphur application significantly increased the seed yield of sunflower. Patra *et al.* (2013) stated that stimulated photosynthetic activity and synthesis of protein due to sulphur application gave significant improvement in seed yield and biological yield of sunflower crop.Seed yield was 8.85% higher with 60 kg ha^{-1} of sulphur application than 30 kg ha^{-1} in sunflower Faisul-ur-Rasool *et al.* (2013). Tahirl *et al.* (2014) found that sulphur application at optimum levels had positive impact on seed yield and maximum seed yield of 814.7 kg ha^{-1} was obtained in sunflower. Vala *et al.* (2014) documented higher seed yield (1077 kg ha^{-1}) with application of sulphur at 40 kg ha^{-1} through gypsum over control (647 kg ha^{-1}) in sunflower. Sheoran *et al.* (2014) concluded application of sulphur at the range of 32.99 to 38.95 kg ha^{-1} is enough to attain economic optimum yield of sunflower. Application of 75 kg ha^{-1} of sulphur gave maximum seed yield (2335.6 kg ha^{-1}) compared to control (1932.8 kg ha^{-1}) in sunflower (Rana *et al.,* 2015). Seed yield was maximum (1060 kg ha^{-1}) with sulphur application at 45 kg ha^{-1} compared to no application (1072 kg ha^{-1}) in sunflower (Ravikumar *et al.,* 2016). Sulphur application at 40 kg ha^{-1} recorded maximum seed yield (2178 and 2278 kg ha^{-1}) and stalk yield (4422 and 4483 kg ha^{-1}) than other levels and control in both crops (Kalaiyarasan *et al.,* 2016). Kalaiyarasan *et al.* (2020) reported that sulphur application at 60 kg ha^{-1} gave higher seed yield (2115.59 and 2215.95 kg ha^{-1}) and stalk yield (4180.03 and 4273.20 kg ha^{-1}) in both crops respectively compared to no application. Seed yield was higher with sulphur application at 50 kg ha^{-1} (1476. 71 kg ha^{-1}) compared to control (1035.01 kg ha^{-1}) (Indu and Singh, 2020).

Effect of sulphur application on nutrient uptake of sunflower

Raju (1994) noticed that uptake of sulphur was higher with application of sulphur at 40 kg ha^{-1} than control in sunflower. Agarwal and Verma (1998) found that N, P and S uptake were significantly higher up to 60 kg ha^{-1} of sulphur application in sunflower. Thorat *et al.* (2003) stated that sulphur application increases the uptake of other macronutrients compared to control treatment in sunflower. Application of sulphur at 60 kg ha^{-1} significantly increased the uptake of nutrients in seeds *viz.,* nitrogen (40.56 kg ha^{-1}), phosphorus (3.36 kg ha^{-1}), potassium (56.90 kg ha^{-1}) and sulphur (4.70 kg ha^{-1}) over control (23.79, 1.93, 31.92 and 2.35 kg ha^{-1}) respectively. Similar increased uptake of nutrients were recorded in stalk *viz.,* nitrogen (14.97 kg ha^{-1}) phosphorus (6.01kg ha^{-1}), potassium (45.50 kg ha^{-1}) and sulphur (6.51 kg ha^{-1}) against no application (10.80, 3.93, 30.18 and 4.20 kg ha^{-1}) respectively in sunflower (Shubhangi *et al.,* 2008). Ravikumar *et al.* (2016) registered a significant increase in nutrient uptake of nitrogen (82.16, 85.80 kg ha^{-1}), phosphorous (14.94, 14.97 kg ha^{-1}), potassium (113.63, 113.80 kg ha^{-1}) and sulphur (11.68, 12.00 kg ha^{-1}) with elemental sulphur at 45 kg ha^{-1} along with recommended

dose of fertilizers (40:20:20) than lower levels and control in both seasons. Gandhi (2011) found that nitrogen phosphorus, potassium, sulphur uptake was significantly higher with sulphur application at 40 than other levels and no application in sunflower. Venkadesan (2016) reported that nitrogen phosphorus, potassium and sulphur uptake was higher with sulphur application at 40 compared to other levels and control in sunflower. Abilash (2017) found an significantly increase in uptake of N, P, K and S by leaves, stalks, seeds and total uptake at various growth stages with sulphur application at 45 kg ha^{-1} compared to lower levels in sunflower. Kalaiyarasan *et al.* (2020) documented that nitrogen, phosphorus, potassium and sulphur uptake was higher with sulphur application at 60 kg ha^{-1} of sulphur over other levels and control in sunflower.

Effect of sulphur application on quality of sunflower

Gangadhara *et al.* (1990) reported that sulphur application increased the oil content to 4 per cent over control in sunflower. Ghosh (2000) stated 60 to 80 kg ha^{-1} as optimum dose of sulphur for attaining higher oil yield in sunflower. Protein content of sunflower was significantly higher with sulphur application at increasing levels more than 50 kg ha^{-1} (Walia *et al.,* 2001). Kadar *et al*. (2001) revealed that increasing levels of sulphur gave a decrease in oil contents of seeds from 50% to 45% in sunflower crop. Oil yield was significantly increased with sulphur application up to 50 kg ha^{-1} in sunflower (Kumar *et al*., 2002). Singh *et al.* (2002) noticed that sulphur application at 45 kg ha^{-1} significantly increased the protein content, oil content and oil yield of sunflower. Dubey and Khan (2003) stated that application of sulphurupto 40 kg ha^{-1} gave a significant increase in oil content as well as oil yield of sunflower. Naik and Rao (2004) documented higher oil content of 40.8% in sunflower with sulphur application at 40 kg ha^{-1}. Sulphur application at 20 kg ha^{-1} registered significant increase in the oil content (44.6%) and protein content (18.4%) in sunflower over control (Mohapatra and Chandrajee, 2005). Kumar and Singh (2005) found an significant increase in oil content of sunflower with increasing dose of sulphur application of 30 kg ha^{-1}. Bakht *et al*. (2006) reported that higher oil production due to its high oil contents in seed by application of sulphur. Ganapathy *et al*. (2006) reported a significant increase in oil content in sunflower with sulphurapplication. Karthikeyan and Shukla (2008) obtained a significant increase in oil content and protein content of sunflower with sulphur application at 60 kg ha^{-1}. Rani *et al.* (2009) found that oil yield increased to the tune of about 23 per cent with sulphur application at 60 kg ha^{-1} over control in sunflower. Tamak *et al.* (2010) noticed that oil content and protein content was significantly increased with sulphur application at 50 kg ha^{-1} than 25 kg ha^{-1} and control in sunflower. Oil yield was found to be statistically higher with sulphur application at 60 kg ha^{-1} in sunflower (Hussain *et al*., 2011). Patra *et al.* (2013) stated that sulphur application enhances the oil content of sunflower. Lal *et al.* (2013) observed that sulphur application resulted in maximum oil content (40.26%) over no application. Oil yield was higher (1.00 t ha) with 60 kg ha^{-1} compared to 30 kg ha^{-1} (0.88 t ha) of sulphur application Faisul-ur-Rasool *et al.* (2013). Oil yield was higher (373.72 kg ha^{-1}) with 40 kg ha^{-1} of sulphur application compared to control (197.34 kg ha^{-1}) in sunflower (Vala *et al.,* 2014). Significant increase in oil yield (980.2 kg ha^{-1}) was documented with sulphur application at 75 kg ha^{-1} compared to no application (730.1 kg ha^{-1}) in sunflower (Rana *et al.,* 2015). Ravikumar *et al.* (2016) reported that application of sulphur at 45 kg ha^{-1} through elemental sulphur gave significant increase in oil content (38.54%, 38.51%) and crude protein content (16.39%, 16.35%) compared to control (37.04%, 37.11%) and (15.02%, 15.09%) respectively, than lower levels and control in two season. Venkadesan (2016) found that application of sulphur at 40 kg ha^{-1} registered higher oil yield over control and other levels in sunflower. Sulphur application at 45 kg ha^{-1} registered significant increase in oil content (38.23%), oil yield (657.75 kg ha^{-1}), protein content (17.08%) and protein yield (294.23 kg ha^{-1}) over lower levels in sunflower (Abilash, 2017). Indu and Singh (2020) concluded that application of sulphur at 50 kg ha^{-1} along with 0.2% foliar spray boron gave significant increase in oil content (45.7%) compared to control (35.17%) in sunflower crop. Kalaiyarasan *et al.* (2020) registered highest oil content (40.68% and 41.65%) with application of sulphur at 60 kg ha^{-1} over control treatment (37.67% and 38.19%) in first and second crop respectively. Similarly crude protein content was significantly higher (27.31% and 29.36%) than no application (23.76% and 24.51%) in sunflower.

Effect of sulphur application on economics of sunflower

Kumar *et al.* (2011) reported that application of sulphur at 45 kg ha^{-1} through gypsum gave higher gross returns (Rs. 20,655 ha^{-1}), net returns (6,596 ha^{-1}) and benefit cost ratio (1.46) over other levels and control in sunflower. Gandhi (2011) found that sulphur application at 40 kg ha^{-1} higher gross returns and benefit cost ratio in sunflower. Vala *et al.* (2014) found that application of sulphur at 40 kg ha^{-1} through gypsum gave maximum net returns (Rs.18060) and benefit cost ratio (Rs.1.82) compared to control in sunflower. Rana *et al.* (2015) documented higher net returns with application of 75 kg ha^{-1} of sulphur compared to control treatment in sunflower. Venkadesan (2016) registered maximum net returns (Rs. 35364) and benefit cost ratio (2.93) with application of sulphur at 40 kg ha^{-1} compared to control in sunflower. Maximum gross returns (Rs. 68793.33 ha^{-1}), net returns (Rs. 47,617.58 ha^{-1}) and benefit cost ratio (3.06) was recorded with sulphur application at 45 kg ha^{-1} which is significantly higher than application of 30 and 15 kg ha^{-1} in sunflower (Abilash, 2017).

Conflict of interest

All authors declare that they have no conflicts of interest.

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