International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(6): 512-516

Received: 16-08-2020
Accepted: 02-10-2020

R Ariraman
Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India

R Arockia Infant Paul
Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India

Sugali Nanu Abhilash Naik
Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India

P Anandan
Assistant Professor, Department of Agronomy, Annamalai University, Chidambaram, Tamil Nadu, India

A Arun
Assistant Professor, (Nematology), JSA College of Agriculture and Technology, Tholudhur, Tamil Nadu, India

Corresponding Author:
R Ariraman
Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India

Effect of boron application on growth, yield parameters, yield, quality, nutrient uptake and economics of sunflower

R Ariraman, R Arockia Infant Paul, Sugali Nanu Abhilash Naik, P Anandan and A Arun

DOI: https://doi.org/10.22271/chemi.2020.v8.i6h.10825

Abstract
Sunflower (*Helianthus annum* L.) being the third most important oilseed crop is grown extensively in India owing to its wider adaptability. Oil is considered premium for human consumption due to higher nutritional properties such as polyunsaturated acids, linoleic and oleic acid controlling blood cholesterol and good for heart patients. Sunflower is sensitive to boron deficiency which is a concern in present agricultural soils as a result of improper management and practices. Boron has various functions *viz.*, translocation of sugar, pollen fertility, stigma receptivity and nectar production resulting in higher number of filled seeds. Deficiency symptoms are noticed in leaves, stem, reproductive parts and heads. Boron application was found to play a significant role in achieving potential yield by improving the growth attributes, yield attributes, nutrient uptake leading to increase productivity of sunflower. Research evidences from investigations of different eminent research scientist on application of boron by soil or foliar spray in sunflower has been reviewed panoramically.

Keywords: Boron, economics, growth, sunflower, quality and yield

Introduction
Sunflower (*Helianthus annum* L.) is the third important oilseed crop grown in different agro-climatic conditions owing to its short duration, photo-insensitiveness and adaptability to various soils. It plays a significant role in vegetable oil production and satisfying the demand for human consumption. Sunflower seeds contain 20-27% protein and eaten as roasted form with salt. (Oil has tremendous nutritional properties with higher polyunsaturated fatty acid (60%) in addition linoleic acid (72.5%) and oleic acid (16.0%) containing higher oil content 35% to 48%, that controls blood cholesterol in humans Patra *et al.*, (2013) [25]. The agricultural lands are found to be deficient in micronutrient status in recent years due to lack of organic matter addition, crop residues and high exhaustive nature of high yielding cultivars. Boron, an micronutrient also found to be deficient in soils and immobile nature is a major problem leading to unavailability to plant system. Boron has numerous function *viz.*, cell wall formation, transportation of sugars, nucleic acid, phenol and membrane stability. It is also involves with metabolism of carbohydrates and indole acetic acid. Sunflower is one among the crops that are more sensitive to boron deficiency. Deficiency symptoms of boron deficiency had been made B deficiency symptoms in sunflower were found on leaf, stem, dry matter, reproductive part, yield components and also on seed yield Blamey *et al.*, (1997). Asad *et al.*, (2002) [10, 4] stated that boron is highly required during reproductive stage while compared to vegetative stage in sunflower. Deficiency of boron causes pollen tube deformation and fertilization during flowering stage is inhibited resulting in increased empty seed in sunflower. It also causes deformation of heads prior, at flowering and weakens the stem behind head leading to fractures in sunflower. Pollen fertility, pollen tube growth, flower retention, stigma receptivity and number of filled grains head^{-1}, seed yield and oil yield were also increased with boron application in sunflower Brighenti and Castro (2008) [11]. Higher photosynthetic activity aided in increased biomass accumulation, yield attributes, yield and quality as a result of more photosynthate translocation to sink with boron application. Positive effect of boron application through foliar or soil application on growth parameters, yield parameters, yield, nutrient

uptake and quality were evident from research finding of research scientists in sunflower have been critically reviewed and cited in this present paper.

Effect of boron application on growth and growth parameters of sunflower

Boron application at increasing levels positively increases the dry matter production of sunflower Prasad *et al.,* (1978). Sarkar and Sasmal, (1989) [26, 33] stated that boron supplement enhanced the growth parameters due to increased photosynthetic process in sunflower. El-Shintinway, (1999) reported positive trend in increasing number of leaves plant^{-1} of sunflower with boron application in sunflower. Reddy *et al.,* (2002) [28] stated that boron application at 2 kg ha^{-1} results in higher dry matter production plant^{-1} than lower levels of application in sunflower. Asad *et al.,* (2003) [3] stated that external application of boron to sunflower significantly increased the vegetative and reproductive parts due to positive role of boron on cell division and cell elongation. Gitte *et al.,* (2005) [16] noticed significant increase in plant height of sunflower with application of boron against control in sunflower. Oyinlola, (2007) [23] reported positive trend in plant height and dry matter production of sunflower when boron supplied exogenously. Zahoor *et al.,* (2011) [42] found that head diameter (21.2 cm) was higher with 2 kg ha^{-1} boron application than no application in sunflower. Shaker and Mohammed (2011) [31] found that foliar spray of boron 3 mg. L^{-1} resulted in maximum leaf area (3500 and 3580.3 cm^2) over no application (3385.1 and 3496.9 cm^2) respectively in spring and autumn sunflower. Increased plant height (160.6cm) and stem girth (3.6 cm) was recorded with application of NPK + 1.5 kg ha^{-1}Zn + B 1 kg ha^{-1} compared to no application of boron (144.1 and 3.0 cm) in sunflower Baloch *et al.,* (2015). Khan *et al.,* (2015) [5, 32] reported a significant increase in plant height (150.78 cm), number of leaves plant^{-1} (22.67) and stem diameter (1.62 cm) with soil application of boron at 2 kg·ha^{-1} during sowing against control (141 cm, 21.89 and 1.0cm) respectively in sunflower. Saeed *et al.,* (2015) [32] registered maximum plant height (176.01 cm) and stem diameter (1.86 cm) with 1% boric acid spray at vegetative and anthesis stage compared to control (155.20 cm and 1.62 cm) respectively in sunflower. Bhattacharyya *et al.,* (2015) [6] noted maximum plant height (218.0 cm), and dry matter accumulation (11.1 t ha^{-1}) with boron application at 2 kg ha^{-1} compared to control (175.0 cm and 7.5 t ha^{-1}) in sunflower. Indu and Singh (2020) [17] reported that boron application at 1 kg ha^{-1} gave maximum plant height (145.69 cm), leaves plant^{-1} (23.20), higher stem girth (3.06 cm) at 60 days after sowing compared to control treatment in sunflower. Kalaiyarasan *et al.,* (2020) [20] disclosed that boron application at 1 kg ha^{-1} significantly influences the growth attributes *viz.,* plant height (148.25 cm and 155.56 cm), leaf area index (4.22 and 4.30), dry matter production (4857.16 kg ha and 4987.83 kg ha), crop growth rate (14.34 and 15.47), relative growth rate (0.0897 and 0.0826), chlorophyll content (0.80 mg g and 0.80 mg g) and days to 50% flowering (55.10 and 55.96) compared to control in both crops of sunflower.

Effect of boron application on yield parameters of sunflower

Sarkar and Sasmal, (1989) [33] stated that boron application increases the sunflower yield parameters as a result of higher translocation of photosynthetates. Ahmadkhan *et al.,* (1990) [1] revealed that yield attributes of sunflower increases with boron application. Ghani *et al.,* (2000) [15] reported that number of achenes head^{-1} were higher with boron application as a result of boron effect in increasing the pollen tube germination in sunflower. Khan *et al.,* (2000) [21] found significant increase in number of achenes head^{-1} as compared to no application in sunflower. Reddy *et al.,* (2003) [27] documented boron application increased the test weight of sunflower seeds. Renukadevi and Savithr (2003) [30] noted significant increase in head diameter with boron application against control in sunflower. Achene number head^{-1} was significantly higher when sunflower supplied with boron compared to control in sunflower Parkash and Mehra (2006). Oyinlola (2007) [23] reported that boron application increases the test weight of achenes as compared to no application in sunflower. Shekhawat and Shivay (2008) [35] reported significant increase in head diameter over control with boron application in sunflower. Bilen *et al.,* (2011) [7] stated that test weight of achenes were significantly higher with application of boron in sunflower. Shaker and Mohammed (2011) [31] recorded maximum head diameter (21.5 and 22.2 cm), number of seeds head^{-1} (1084.3 and 1103.1) and test weight (75.5 and 77 g) with application of 3mg L^{-1} foliar spray of boron than control (20.5 and 21.1 cm, 991.2 and 1015.1, 65.0 and 66.0**)**respectively in spring and autumn sunflower. Application of NPK + 1.5 kg ha^{-1}Zn + B 1 kg ha^{-1} gave maximum head diameter (20.4 cm), seeds head^{-1} (1255.3), seed weight (60.9 g head^{-1}), test weight (64.8 g) over control (16.2cm, 1013.0, 46.7 and 57.6 g) respectively in sunflower Baloch *et al.,* (2015). Mekki (2015) [5] found boron application at 600 ppm increased the oil content and oil yield of sunflower. Khan *et al.,* (2015) [32] found that 200 mg L^{-1} boron application at ray floret stage resulted in significant increase in yield attributes such as head diameter (18.30 cm), test weight (43.17 g) and number of achenes head^{-1} (1266) than no application and remained statistically on par with 2 kg ha of soil application of boron at sowing in sunflower. Saeed *et al.,* (2015) [32] found significant increase in head diameter (16.79 cm), number of achenes head^{-1} (1270) and test weight (42.74g) with foliar spray of 1% boric acid at vegetative and anthesis stage against control (15.34 cm, 1221 and 38.63 g) respectively in sunflower. Mekki (2015) reported that boron application at 600 ppm registered highest values for head diameter, seed number head^{-1} weight and test weight of sunflower. Kalaiyarasan *et al.,* (2020) [20] found that sulphur application at 60 kg ha^{-1} gave significant increase of yield attributes viz., head diameter **(**16.82 cm and 18.07 cm), number of seed head^{-1} **(**804.40 and 829.11**),** number of filled seed head^{-1} **(**663.37 and 688.35**),** seed filling percent **(**82.33 and 82.88) and 100 seed weight **(**5.94 and 6.35) than control in sunflower. Boron application at 0.2% spray registered maximum capitulum diameter (15.5 cm) compared to control (12.45 cm) in sunflower Indu and Singh (2020) [17]. Yield parameters were significantly maximum head diameter (6.33cm) and dry weight of head (20.64g), number of filled seeds head^{-1} (183) and weight of seeds (6.15g) with soil application of boron at 2 kg ha^{-1} than control in sunflower Jagadala *et al.,* (2020) [18].

Effect of boron application on yield of sunflower

Sarkar and Sasmal, (1989) [33] reported that boron application significantly increases the seed yield of sunflower. Ahmadkhan *et al.,* (1990) [1] concluded that application of boron increases seed yield of sunflower cultivars. Blarney et al., (1997) [9] stated that seed yield of sunflower increases with boron application. Tamak *et al.,* (1997) [40] stated that boron application increases the seed yield of sunflower.

Renukadevi *et al.,* (2002) obtained significant increase in yield of sunflower with boron application. Reddy *et al.,* (2003) [27] stated that achene yield increases with boron application as a result from active translocation photosynthetic assimilates during ray floret stage. Sumathi *et al.,* (2005) [38] reported significant increase in seed yield with boron fertilization. Increase in biological yield could be due to boron role in triggering the cell division, cell elongation and active biomass accumulation in sunflower Gitte *et al.,* (2005). Brighenti and Castro (2008) [16, 11] disclosed that seed yield was significantly higher with boron application which might be due to increased pollen fertility resulting in more number of filled grains in sunflower. Martin *et al.,* (2010) [22] reported that application of boron increased the harvest index of sunflower. Al-Amery *et al.,* (2011) [2] obtained significant increase in sunflower yield crop with boron application at 200 and 250mg L^{-1} decreasing seed sterility percentage (5%) and small increment increase in seed size. Zahoor *et al.,* (2011) [42] stated that application of boron significantly increased the biological yield of sunflower than control. Silva *et al.,* (2011) [37] found that boron application significantly increases the harvest index of sunflower hybrids from his study. Shaker and Mohammed (2011) [31] found that 3 mg L^{-1} boron spray seed yield was higher (2.89 and 2.82 t ha^{-1}) over control (2.60 and 2.66 t ha^{-1}) in spring and autumn sunflower. Tahir *et al.,* (2014) [39] found an increase in yield of sunflower with boron application. Higher seed yield (2386.0 kg ha^{-1}) was obtained with supplement of NPK + 1.5 kg ha^{-1}Zn + B 1 kg ha^{-1} against no boron application (2030.7 kg ha^{-1}) in sunflower Baloch *et al.,* (2015) [5]. Seed yield (2.09 t ha^{-1}) and stalk yield (9.01 t ha^{-1}) were significantly higher with 2 kg ha^{-1} of boron fertilization against control (1.46 t ha^{-1} and 5.91 t ha^{-1}) respectively in sunflower Bhattacharyya *et al.,* (2015) [6]. Seed yield $plant^{-1}$ significantly higher with increasing levels of B concentration from 300 ppm (26.85%) and 600 ppm (34.81%) than control in sunflower Mekki (2015). Achene yield (2039 kg ha^{-1}), biological yield (9233 kg ha^{-1}) and harvest index (22.10%) were significantly higher with 2 kg ha^{-1} of boron application as compared to control treatment (1866 kg ha^{-1}, 9117 kg $ha^{-1}$and 20.49%) in sunflower Khan *et al.,* (2015). Saeed *et al.,* (2015) [32] concluded that foliar spray of 1% of boric acid at vegetative stage and anthesis stage significantly increased the achene yield (2408 kg ha^{-1}) and biological yield (10065 kg ha^{-1}) than no application (2308 kg ha^{-1} and 9770 kg ha^{-1}) respectively in sunflower. Boron application at 1.0 kg ha^{-1} gave maximum seed yield of 2.33 t ha^{-1} respectively in sunflower than control Jegadeeswari and Muthumanickam (2017) [19]. Harvest Index was maximum with 2 kg ha of boron application over control in sunflower Jagadala *et al.,* (2020). Kalaiyarasan *et al.,* (2020) [18, 20] reported that boron application at 1 kg ha^{-1} gave maximum seed yield (2001.00 and 2102.03 kg ha^{-1}) and stalk yield (3932.01 and 4038.80 kg ha^{-1}) in first and second crop of sunflower respectively. Seed yield (1476. 71 kg ha^{-1}) was maximum with boron application at 0.2% spray compared to control treatment (1035.01 kg ha^{-1}) in sunflower Indu and Singh (2020) [17].

Effect of boron application on quality of sunflower

[a]Renukadevi and Savithri (2003) [29] found that oil content of sunflower increased with boron application from his study. Oil yield increases with boron application in sunflower Sumathi *et al.,* (2005) [38]. Castro *et al.,* (2006) reported increasing levels of boron significantly increased the oil contents of sunflower. Oyinlola (2007) [23] found significant increase in oil content and oil yield of sunflower with boron application compared to control. Significant increase in oil content with boron application in sunflower seeds Ceyhan *et al.,* (2008). Brighenti and Castro (2008) [13, 11] reported that oil yield increases with boron application in sunflower. Oil content significantly increases with boron application in sunflower Martin *et al.,* (2010). Saeed *et al.,* (2015) [22, 32] found significant increase in oil content (39.07%) with 1% boric acid foliar spray over control (37.12%) in sunflower. Foliar spray of 300 ppm B recorded an increase of palmitic, stearic and oleic acids as compared to the treatment with 600 ppm B and control in sunflower. Similarly linoleic acid increased to the tune of 8.72% and 7.19% over control in sunflower Mekki (2015). Shehzad *et al.,* (2016) [34] found that quality parameters were increased with foliar spray of boron at 30 mg L^{-1} compared to no application in sunflower. Application of boron at 0.2% as foliar spray gave higher oil content (45.70 %) compared to no application (35.17 %) in sunflower Indu and Singh, (2020) [17]. Kalaiyarasan *et al.,* (2020) [20] reported that boron application at 1 kg ha gave significant increase in oil content (39.82% and 40.87%) and crude protein content (26.26% and 28.04%) over control of two crops. Jagadala *et al.,* (2020) [18] registered increased oil content (29.105 %) compared to no application of boron in sunflower.

Effect of boron application on nutrient uptake and economics of sunflower

Boron application at 1.5 kg ha^{-1} in addition with 15 kg ha^{-1} of zinc recorded maximum uptake of nitrogen (52.25 kg ha^{-1}), phosphorus uptake (16.72 kg ha^{-1}), potassium uptake (78.94 kg ha^{-1}), zinc uptake (294.60 g ha^{-1}) and boron uptake (157.53 g ha^{-1}) against no application in sunflower Siddqui *et al.,* (2009). Bhattacharyya *et al.,* (2015) [36, 6] found that foliar spray of 2% boron significantly increased the boron uptake in stalk (270.44 g ha^{-1}) and total uptake of boron (327.20 g ha^{-1}) over control (132.83 and 172.87 g ha^{-1}) respectively in sunflower. Pattanayak *et al.,* (2016) [24] reported that boron application at 1 kg ha^{-1} increased total nutrient uptake of nitrogen (79.05 kg ha^{-1}), phosphorus (21.34 kg ha^{-1}), potassium (91.62 kg ha^{-1}), sulphur (18.99 kg ha^{-1}) and boron (3634.74 mg ha^{-1}) than control (64.37, 15.64, 83.67,14.06 and 2301.02) respectively in sunflower. Kalaiyarasan *et al.,* (2020) [20] reported that application of boron at 1 kg ha^{-1} recorded maximum uptake of nitrogen (76.09 and 78.15), phosphorus (20.08 and 19.72 kg ha^{-1}), potassium (69.94 and 70.24 kg ha^{-1}) and sulphur (13.42 and 14.62 kg ha^{-1}) compared to control (71.26 and 73.25, 16.98 and 15.97, 65.08 and 66.26, 10.73and 11.88 kg ha^{-1}) respectively in both crops of sunflower. Jagadala *et al.,* (2020) [18] reported that application of boron at 2 kg ha^{-1} increased uptake of boron resulting in higher total boron concentration (120.2ppm) and higher concentration of boron in seeds (24.79ppm) in sunflower.

Bhattacharyya *et al.,* (2015) [6] found foliar spray of 0.2% boron with gross return (Rs. 63560 ha^{-1}), net return (Rs. 46250 ha^{-1}) and (2.67) than control (Rs. 47040 ha^{-1}, Rs. 30330 ha^{-1} and 1.82) respectively in sunflower. Shehzad *et al.,* (2016) [34] registered that boron application at 30 mg L^{-1} gave maximum gross income (Rs. 144379 and Rs. 136609 ha^{-1}), net income (Rs. 66379 and Rs. 60604 ha^{-1}) and benefit cost ratio (1.85 and 1.80) as against control (Rs. 131843 and Rs. 118358 ha^{-1}, Rs. 55402 ha^{-1} and Rs. 43812 ha^{-1}, 1.72 and 1.59) respectively in two years in sunflower. Pattanayak *et al.,* (2016) [24] recorded higher gross returns (Rs.79500 ha^{-1}), net

return (Rs. 50400 ha^{-1}) and benefit cost ratio (2.73) with 1 kg ha^{-1} of boron application against no application (Rs. 6785 ha^{-1}, Rs. 3987 ha^{-1} and 2.42) respectively in sunflower. Binh *et al.*, (2017) [8] reported maximum gross income (Rs.75600 ha^{-1}), net return(Rs.49194 ha^{-1}) and benefit cost ratio (1.86) compared to no application (57000 ha^{-1}, 30650 ha^{-1}and 1.16) respectively in sunflower. Kalaiyarasan *et al.*, (2020) [20] recorded higher gross income, net returns and benefit cost ratio over with 1 kg ha^{-1} of boron application control in sunflower.

References

1. Ahmadkhan T, Venugopal K, Devaiah C, Seenappa A. Effect of secondary nutrients and boron on some growth characters and yield in sunflower. Journal of OilSeed Research. 1990; 7(1):159-167.
2. Al-Amery MM, Hamza JH, Fuller MP. Effect of boron foliar application on reproductive growth of sunflower (*Helianthus annuus* L.) International Journal of Agronomy, 2011, 1-5.
3. Asad A, Blamey FPC, Edwards DG. Effects of boron foliar applications on vegetative and reproductive growth of sunflower. Annals of Bot. 2003; 92:565-570.
4. Asad A, Balmey FPC, Edwards DG. Dry matter production and boron concentrations of vegetative reproductive tissues of canola and sunflower plants grown in nutrient solution. Plant Soil. 2002; 243:243-252.
5. Baloch RA, Baloch SU, Baloch SK, Baloch AB, Baloch HN, Bashir W *et al*. Effect of zinc and boron in combination with NPK on sunflower (*Helianthus annuus* L.) growth and yield. Journal of Biology, Agriculture and Healthcare. 2015; 5(19):101-107.
6. Bhattacharyya K, Mandal J, Banerjee H, Alipatra A, Ray K, Phonglosa A. Boron fertilization in sunflower (*Helianthus annuus* L.) in an inceptisol of West Bengal, India. Communications in Soil Science and Plant Analysis. 2015; 00:1-17.
7. Bilen S, Bilen M, Bardhan S. The effect of boron management on soil microbial population and enzyme activities. African Journal of Biotechnology. 2011; 10:5311-5319.
8. Binh NT, Huong NTT, Quoc HT. Effect of boron foliar application on growth, yield and seed quality of sunflower (*Helianthus annuus* L.) grown in Hochiminh, Vietnam. Bull. Inst. Trop. Agr., Kyushu Univ. 2017; 40:1-10.
9. Blarney FPC. Boron nutrition of sunflowers (*Helianthus annus* L.) on an Avalon medium sandy loam. Agrochemopysica. 1976; 8:5-10.
10. Blamey FPC, Zollinger RK, Schneiter AAA. In sunflower technology and sunflower production and culture. American Society of Agronomy, Madison, WI, USA, 1997, 595-670.
11. Brighenti AM, Castro C. Boron foliar application on sunflower (*Helianthus annuus* L.). Helia. 2008; 48:127-136.
12. Castro C, Moreira A, Oliveira RF, Dechen AR. Boro e estresse hidrico na producao do girasol. Ciencia e Agrotecnologia. 2006; 30:214-220.
13. Ceyhan E, Önder M, Öztürk Ö, Harmankaya M, Hamurcu M, Gezgin S. Effects of application boron on yields, yield component and oil content of sunflower in boron-deficient calcareous soils. Afr. J. Biotechnol. 2008; 7(16):2854-2861.
14. El-Shintinawy F. Structural and functional damage caused by boron deficiency in sunflower leaves. Photosynthetica. 2000; 36:565-573.
15. Ghani A, Hussain M, Qureshi MS. Effect of different irrigation regimens on the growth and yield of sunflower. International Journal of Agriculture and Biology. 2000; 2:334-335.
16. Gitte AN, Patil SR, Tike MA. Influence of zinc and boron on biochemical and yield characteristics of sunflower. Indian Journal of Plant Physiology. 2005; 10:400-403.
17. Indu T, Singh R. Effect of sulphur and boron on growth and yield of sunflower (*Helianthus annuus* L.). Int. J. Curr. Microbiol. App. Sci. 2020; 9(8):3320-3323.
18. Jagadala K, Bhol R, Sahoo JP. Effect of boron on growth and yield parameters of sunflower in acid soil. Journal of Pharmacognosy and Phytochemistry. 2020; 9(4):215-218.
19. Jegadeeswari D, Muthumanickam D. Boron Fertilization and Its Fate: Maize – Sunflower cropping system. Madras Agric. J. 2017; 104(4-6):124-128.
20. Kalaiyarasan C, Tamizhselvan D, Jawahar S, Ezhilkumar S, Suseendran K, Madhavan S *et al*. Effect of sulphur and boron on hybrid sunflower. Plant Archives. 2020; 20(1):741-746.
21. Khan A, Iqbal M, Ahmad I, Iqbal N, Hussain M. Effect of different water stress levels on yield and oil content of sunflower (*Helianthus annuus* L.) Cultivators. Pakistan Journal of Biological Sciences. 2000; 3:1632-1633.
22. Martin TN, Pavinato PS, Glasenapp LF, Bertoncelli P, Ortiz S. Phytomass partition of sunflower silage, under boron and calcium fertilization. 19th World Congress of Soil Science, Soil solutions for a changing world, Brisbane, Australia, 2010, 191-194.
23. Oyinlola EY. Effect of boron fertilizer on yield and oil content of three sunflower cultivars in the Nigerian savanna. Journal of Agronomy. 2007; 6:421-426.
24. Pattanayak S, Behera A, Jena SN, Das P, Behera S. Growth and yield of sunflower (*Helianthus annuus* L.) hybrids under different nutrient management practices. International Journal of Bio-resource and Stress Management. 2016; 7(4):845-850.
25. Patra P, Pati BK, Ghosh GK, Mura SS, Saha A. Effect of biofertilizers and sulphur on growth, yield, and oil content of hybrid sunflower (*Helianthus annuus* L.) In a typical lateritic soil. Open Access Scientific Reports. 2013; 2:603.
26. Prasad TG, Sastry KSK. Effect of tri-iodbenzoic acid on diffusable growth substances from sunflower heads. Indian. Journal Expirimental Biology. 1978; 11:1209-1211.
27. Reddy NYA, Shaanker RU, Prasad TG, Kumar MU. Physiological approaches to improve harvest index and productivity in sunflower. Helia. 2003; 26:81-90.
28. Reddy SS, Yadahalli YH, Kumar VKK, Kumara O, Naik AHK. Effect of fertilizer, gypsum and boron application on yield and economics of sunflower hybrids. Crop Research. Hisar. 2002; 23:450-453.
29. [a]Renukadevi A, Savithri P. Sunflower (*Helianthus annuus* L.) oil yield and quality as influenced by boron application. Madras Agriculture Journal. 2003; 91:74-76.
30. Renukadevi A, Savithri P, Audi K. Sources, levels and methods of boron application on the dry matter production, yield attributes and yield of sunflower crop. Crop Research, Hisar. 2003; 25:436-440.

31. Saad ATS, Mohammed A. Effect of different levels and timing of boron foliar application on growth, yield and quality of sunflower genotypes *(Helianthus annuus* L.*)* Mesopotamia J. of Agric. 2011; 39(3):16-26.
32. Saeed U, Sher A, Hussain S, Khan A, Ameen A, Jincai L *et al*. Impact of foliar application of boron on growth and yield of sunflower (Helianthus annuus L.) under different irrigation conditions. Acad. J. Agric. Res. 2015; 3(9):219-225.
33. Sarkar RK, Sasmal TK. Response of sunflower to application of micronutrients on rice fallow gangetic alluvial soil. Indian Agriculturist. 1989; 33:39-44.
34. Shehzad MA, Maqsood M, Abbas T, Ahmad N. Foliar boron spray for improved yield, oil quality and water use efficiency in water stressed sunflower. Sains Malaysiana. 2016; 45(10):1497-1507.
35. Shekhawat K, Shivay YS. Effect of nitrogen source, sulphur and boron levels on productivity, nutrient uptake and quality of sunflower (*Helianthus annuus* L.). Indian Journal of Agronomy. 2008; 53:129-134.
36. Siddiqui MH, Oad FC, Abbasi MK, Gandahi AW. Zinc and Boron fertility to optimize physiological parameters, nutrient uptake and seed yield of Sunflower. Sarhad J. Agric. 2009; 25(1):53-57.
37. Silva CAT, Cagol A, Silva TRB, Nobrega LHP. Boron application before sowing of sunflower hybrids. Journal of Food, Agriculture and Environment. 2011; 9:580-583.
38. Sumathi V, Rao DSK. Effect of organic and inorganic sources of nitrogen with different irrigation schedules on growth and yield of sunflower *(Helianthus annum).*Indian Journal of Agronomy. 2007; 52(1):77-79.
39. Tahir M, Younas-Ishaq M, Sheikh AA, Naeem M, Rehman A. Effect of Boron on Yield and Quality of Sunflower under Agro-Ecological Conditions of Faisalabad (Pakistan). Sci. Agric. 2014; 7(1):19-24.
40. Tamak JC, Sharma HC, Sing KP. Effect of phosphorus, sulphur and boron on seed yield and quality of sunflower {*Helianthus annuus* L.). Indian Journal of Agronomy. 1997; 42:173-176.
41. Vyakaranahal BS, Shekharagouda M, Patil SA, Prabhakar AS, Giriraj K. "Effects of planting date and chemicals (TIBA and Boron) spray on seed yield, its attributes and quality of single and three-way cross sunflower hybrids during different seasons." Seed Res. 2001; 29(2):127-35.
42. Zahoor R, Basra SMA, Munir H, Nadeem MA, Yousaf S. Role of boron in improving assimilate partitioning and achene yield in sunflower. Journal of Agriculture and Social Sciences. 2011; **7**:49-55.