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Role of foliar application of boron for improving agriculture crop production: A review

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Abstract

Water shortage or scarcity is most fundamental environmental issues that disturb plant growth and development. Foliar use of nutrients on plant can improve plant development process and plant growth rapidly with which advanced nutrient that are required by the plants are delivered for superior growth and yield. Boron (B) is very vital micronutrient for farming crops and desirable during the life cycle due to its various purpose as a plant cell wall basic element. Its absence is becoming a wide-spread issue in agriculture rising areas and the managing of boron is confronted by the unexpected rates of boron shortage or unpredictable influences of foliar use of boron. Inadequate source of B on dissimilar arrangements which are applicable for the plant water status have been seriously explored, but the resultant assumptions are clashing and have no clear image so far that completely clarifies the discrepancies. Lack of B can affect water application by root and shoot development inhibition and by water canals up regulation. The present review describes the role of foliar application of boron in improving agriculture crop production.

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Introduction

Water stress is the greatest significant issue that condensed stomatal conductance, transpiration ability, water impending, photosynthesis competence of plants. Many scientists stated the adverse effects of water stress on propagation of seed, development and expansion of many crops like sugar beet. sunflower, kochia, sorghum and maize (Moussa and Abdel, 2008). It significantly altered plant growth and yield (Toor *et al*., 2020; Adnan, 2020a). Agriculture is providing fuel, fiber and food to humans (Adnan, 2020b). Agriculture is an important sector of economy of Pakistan. The country's population is directly supported by agricultural sector. The Agricultural share in gross domestic product (GDP) is about 26% (Kalsoom *et al*., 2020). In moist circumstances, nutrients best practice stable use is sponsoring agriculture crop development, return and efficiency is the main factor. Crop fertilization improved water use efficacy, controls the loss of soil, stimulates fast and effective crop development to observe excess and improves the soil's capability to hold water (Pradeep *et al.,* 2014). Uses foliar spray of plant nutrients can also rise progression of agronomic crops and efficiency rapidly with which advanced nutrient that are required by the florae are providing for improved growing and production (Habib, 2012). Importance of foliar application of nutrients (bio fortification) is reported by many scientists (Bilal *et al*., 2020; Toor *et al*., 2020; Wasaya *et al*., 2019; Asif *et al*., 2020; Adnan *et al*., 2020a). The solution of nutrients has been useful foliar having quickly engaged, with fewer nutrients used, and can improve signs of plant nutrient shortage, improve the efficiency and upsurge plant utilities (Rehman *et al.,* 2014). In modern agriculture fertilizers are important element (Adnan *et al*., 2020b). Boron is a very important element for reproduction and growth (Adnan and Bilal, 2020). Boron is an energetic micro-nutrient that openly and incidentally impacts the development of plant and also biochemical and natural processes. It is also significant for healthier growth; efficiency and superiority of crop as well and up taken by roots (Mengel and Kirkby, 2001; Ali *et al*., 2020). The boron absence is extensive globally, with huge areas in numerous portions of the biosphere and a smaller amount in others, demanding operational examination and managing practices (Niaz *et al*., 2002). Boron was originating to be carefully connected to the production and process of the main cell wall. It is also well-known that 90% of cellular boron is found in cell walls. Boron shows a significant part in the configuration of cell wall. Sideways with the necessary of other elements of cell wall, the boron regulates the cell tissue utility and metabolic activities (Bolanos *et al*., 2004). It is essential for translocation, carbohydrates and metabolism (Adnan and Bilal, 2020). It has been prominent that lack of boron may damage tissue enactment, by distressing other biological adjustments (Shelp, 1993). Boron accessibility effects the ease of use and uptake of other plant nutrients from the soil. Upturn the uptake and translocation of other nutrients like P, N, K, Zn, Fe, and Cu in leaves, buds, and seeds was observed subsequently B use in cotton (Ahmed *et al*., 2011). The present review describes the role of foliar application of boron in improving agriculture crop production.

Role of Boron in Plant Growth

Boron is a micro-nutrient that openly and ultimately disturbs the natural and chemical processes and also plant progression (Mengel and Kirkby 2001). Boron is a very important element for reproduction and growth (Adnan and Bilal, 2020). Boron is an energetic micro-nutrient that openly and incidentally impacts the development of plant and also biochemical and natural processes. It is also significant for healthier growth; efficiency and superiority of crop as well and up taken by roots (Mengel and Kirkby, 2001; Ali *et al*., 2020). It is essential for translocation, carbohydrates and metabolism (Adnan and Bilal, 2020). The boron shortage is extensive globally, with huge parts in more than a few portions of the sphere and less in others, severe actual examination and managing applies (Niaz *et al*., 2002). The accessibility of boron for development of plant has been formerly recognized (Ahmed *et al.,* 2009). The boron main purposes show in plants are linked to establishment and growth of cell wall, sugar transference improves, upsurge the cell division, hormonal metabolism and also seed and fruit development (Herrera-Rodriguez *et al.*, 2010). Although the key determination of boron in plant is structural working of cell wall and alteration in elementary metabolic channels (Ahmed *et al.*, 2009). Boron is famous nearly 90% of cellular boron is reputable in cell walls. Purposes of boron in plants are in the cell wall arrangement. Laterally with the necessary of pectic materials to the cell wall, the boron regulates the cell membrane role and metabolic movements (Bolanos *et al.*, 2004). It has been labelled that boron shortage may damage membrane act, by disturbing other biological improvements (Shelp, 1993).

Use of boron enhancements the ATPase action and effect the skin hyperpolarization by thrilling the K^+ concentration. Intensification the expanding action of the extremely separated plasma membrane mains to an excessive energetic force of K+ fluidity (Ahmed *et al.,* 2009). Similarly, Cakmak *et al.* (1995) also noted that damage of boron disrupts the penetrability of membrane as determined by improved outflow of potassium in sunflower from cells of leaf. The boron is vigorously achieved in the separation of cell and it is complicated in the plant development. Boron is playing a vital part in essential basic of cytoskeleton which is energetically completed in the ruling of cell separation (Bassil *et al.*, 2004).

Role of Foliar Application of Boron on Agriculture Crop Production

The foliar use of plant nutrients is very easy to provide nutrients and its importance is reported by many researchers (Bilal *et al.*, 2020; Toor *et al.*, 2020; Wasaya *et al.*, 2019; Asif *et al.*, 2020; Adnan *et al.*, 2020). Boron is a micro-nutrient that makes a main part in crop growth and recovers the crop superiority (Dordas *et al.*, 2007; (Adnan and Bilal, 2020; Ali *et al.*, 2020). Foliar use of boron has been exposed to expand the seed set, produce and excellence of seed in various agriculture crops (Dordas *et al.,* 2007). Abdel-Motagally and El-Zohri (2018) showed a trial to assess the result of foliar use of boron and water draining on wheat crop throughout 2013-2014 and 2014-2015 seasons. In main plot, number of irrigation stages are three (I_1 = 50%, I_2 = 75% and I_3 = 100% and in subplot, boron was smeared at two development phases that are (booting or at anthesis phase) although purified water was used as switch. They informed that plant tallness detected (99.3 and 98.2cm), spike span renowned (11.6 and 11.5cm) and wheat return deliberate (1.84 and 1.82-ton fed.$^{-1}$) with exogenous use of boron at striking phase under usual irrigation level (100%) in both seasons. Furthermore, application of foliar boron upgraded all planned limitation under water strain level (50%) than boron raw plants. Sinha and Chatterjee (1994) accompanied trial to discover the outcome of seven level of boron on pearl millet. The boron was send out on crop at 0.0033, 0.011, 0.165, 0.33, 0.66, 1.32 and 3.3mg/litre as H_3BO_3. By the sprig of 0.33mg/L of boron demonstrations the supreme flowering weight (68.7g/plant), grain yield (50.8g/plant) and biomass of crop (116.2g/plant). On the other hand, small or great application of boron harmfully disturbs these parameters. The decline in grain income was more noticeable with short application of boron as associate to extra source of boron and the influence was more conspicuous in grain harvest as parallel to biomass. Application of boron at 0.66mg/L presented in a lowermost N-nitrate (0.11%) and phenol (0.009%) in crop grains. By boron absorption rises also increases its stuffing grain of millet.

Moeinian *et al.* (2011) exposed that the boron special effects on vegetation of numerous qualitative characters of wheat grain crop throughout emergent season of 2009-10 by by means of three irrigation levels (S_0: normal irrigation, S_1: irrigation termination at 50% stem elongation and S_2: irrigation termination at 50% flowering stage) and foliar stem of boron consuming three level (B_0: foliar spraying with distilled water, B_1: 0.5% boron foliar spraying and B_2: 1% boron foliar spraying) in subplots. The maximum crop was gained in S_0B_2 (5632.5kg ha^{-1}), which showed intensification of 53.9% of yield in relation to S_2B_0 (2591.4kg^{-1}). The gluten and proline content of wheat grains was meaningfully inclined by irrigation levels and use of foliar boron. The supreme gluten (9.87%) and slightest gluten (7.11%) fillings were noted under irrigation surface at 50% flowering phase + 1% foliar use and usual irrigation + foliar use of purified water correspondingly. The maximum and lowermost proline were distinguished by the action of S_2B_2 having (1.01mg/g.fw) and S_0B_0 having (0.803mg/g/fw), correspondingly. Leaf part and attentiveness of boron in grains were expressively pretentious by irrigation and foliar use of boron. Extreme (76.9 ppm) absorption of boron in grains was slow with management S_0B_2. General outcomes displayed that by the foliar spray application of boron has major influence to decrease the opposite influence of water pressure on excellence and manufacture of grains of wheat. Research was absorbed by Shanker *et al.* (2017) to displayed that the effect of exogenous boron on portion millet for three developing phases. According to this research showed that by the application of boron a countless increase has been prominent.

In this trial, regular revenue of millet presented that advanced worth of millet grain (3399kg/ha) and straw return (4504kg/ha) was originate by the boron practical application on vegetation @ 0.5kg/ha done the regulator action that formed 2999kg/ha, 3953kg/ha grain and straw harvest correspondingly in three-year average. Use of boron @ 0.5kg/ha formed 12.9% additional revenue of millet as associated to switch. Consequences also showed that relation of advantage to price (1.38) and nutrient approval such as Zn, Fe and B in millet plants was reached uppermost under the boron use on soil @ 1kg/ha. Raza *et al.* (2014) showed an investigation experiment in field circumstance to discover out the reaction of wheat crop to exogenous boron. The arrangement was applied for trial RCBD intended and the dissimilar actions having 0, 10.0, 20.0 and 30.0mg/L of foliar use of boron. The consequences of this investigation were displayed that effect of boron was significant on grain crop, amount of grains and 1000 grain weight. Amongst all the stages of boron, the use of boron at 10mg L^{-1} was more effectual highest (6.4-ton ha^{-1}) yield of wheat grains. Though, it was detected that a considerable droplet in the grain crop (4.6 ton/hectare) of wheat was eminent with complex level of boron use (20mg L^{-1}). Harmfully influences of top use of boron on crop mechanisms were also apparent. Due to contaminated special effects of boron revenue amount and superiority by increase is declined.

Ali *et al.* (2011) perform an experiment in 2007 and 2008 to explore the impact of boron and zinc on cotton seed yield by using 7 treatments of both (B & Zn) tested nutrients. H_3BO_3 were used as a source of boron and zinc apply in the form of $ZnSO_4$. The result is showed that all treatments boosted the cotton attributes. By the application of foliar spray of boron and zinc used in combination at 1.00 + 0.75kg/ha noted the most effective dose of fertilizer and produced the optimum yield of seed cotton (2176.46kg/ha) beside with NPK suggested doses. Rashidi *et al.* (2011) also perform an experiment to study the influence of B & N on cotton crop by using 3 level of boron and 4 level of nitrogen. The result of this study indicated that boron and nitrogen used in combination effect the characteristics of yield of cotton. The considerable interactive effect of B & N was perceived. The foliar spray of B with N produced the higher values of cotton attributes such as boll no, weight of boll and lint yield. Overall conclusion of this experiment that the foliar application of boron and nitrogen was produced more prominent impacts of cotton crop. Another experiment has also been directed by Tahir *et al.* (2009) to examine the impact of exogenous boron application at different growth phases of wheat in 2006 to 2007. The boron was scattered at 607.1mL in 237 L water and was sprayed at 4 different growth phase like tillering, joining, booting and anthesis of wheat. The foliar application of boron influenced significantly the all studied characters of wheat like grain weight, no. of grains as well as yield of wheat grain. They also showed that among all the treatments of boron at booting phase was most effective and produced best results than others phases of wheat crop. Mondal *et al.* (2012) also studied the impact of foliar application of boron and irrigation on growth of mung bean cultivar 'Samrat' during 2009 and 2010. A split-plot design was used in this experiment with 4 level of B in the sub-plot and 4 level of irrigation in main plot. Result of this experiment showed that when B is used in combination with irrigation treatments affect the characteristics of growth and yield components of mung bean. The irrigations applied at pre-flowering, branching and pod filling phases produced 879kg ha^{-1} seed yield of mung bean that was approximately 38% more than rain-fed treatment. Different level of boron, the foliar spray of borax at 0.2% on flowering stage constantly affects all parameters of growth and yield. On the other hand, permutation of all the irrigations at pre-flowering, branching and pod filling stage with exogenous borax application at of 0.2% on flowering phase produced highest seed yield of mung bean that was relatively more than when compare to other treatments. A research study was initiated by Tahir *et al.* (2012) to estimate the response of corn to various boron foliar applications on growth, yield and other related attributes by using different concentrations of boron have been used to test the impact of these nominated boron levels. They showed that all boron concentrations level substantially increase the studied traits of corn crop as compared to control having no boron spray was used.

The biological yield and no. of grains of corn was also found to be highest at 0.30kg/ha boron foliar application which produced 7.09 and 519.3t/ha yield respectively. Boron is the crucial mineral nutrient compulsory for the growth and natural development of plants. A field experiment was conducted by Hussain *et al.* (2012) to find the function of B at different stages of rice crop in growing season of 2009. In this research, a boron solution having 1.5kg/hm^2 was sprayed at 4 different stages of rice like (transplanting, tillering, flowering as well as grain development) and immersed roots of rice seedlings in 1.5% solution of boron before transplanting, whereas control treatment in which boron was not applied. The boron application enhanced the rice yield. In general, it is recommended that to improve the rice yield and growth, increase net financial return, boron can be applied as a soil submission during flowering.

Role of Boron for Improve Crop Production under water stress Conditions

Bellaloui *et al.* (2013) performed an experiment to inspect the impact of exogenous use of boron on yield and seed composition of soybean under water stress condition. In this experiment half plants of soybean were exposed to water stress (WS) under greenhouse condition, while the other half was well-watered. The boron was applied two times 1st at flowering stage and 2nd at seed-fill stage of soybean in boric acid form @ 1.1kg/ha. The treatments were comprised of water stressed plants with having no application of boron; water stressed plants having boron; watered plants having zero boron and watered plants with boron. The treatment watered plants without boron considered as control. Among all the other treatments, plants watered with boron produced highest boron concentration in seed and leaves of soybean plants (73% enhancement in seed and 84% in leaves). The growth of soybean enhanced significantly with boron application in well-watered plants. Results showed that seed oleic acid, protein and sucrose increased by 27, 11 and 40% respectively with application of boron under well-watered conditions.

Upadhyaya *et al.* (2012) directed a research to evaluate the impact of nutrients on post-dry recovery of *Camellia sinensis* L. clones (TV-20, TV-1, TV-30 and TV-29). The results of this experiment exhibited that due to the water stress the leaf dry mass, relative water contents and antioxidants in all clones were reduce significantly. After emergence, 10-15 days' drought was executed by stopping the water about twenty days. After twenty days the plants were desiccated. After the occurrence of the new foliage, 50 μM and 100 μM of KCl, $CaCl_2$, $MnCl_2$ and boric acid were applied once a week and samples were taken. Distilled water was used on control plants. The results showed that leaf dry mass and antioxidants activity reduced significantly in all studied clones of *Camellia sinensis* L. due to water stress. By increasing in phenol content with a decrease in H_2O_2 and lipid peroxidation was an indicator of reclamation of the oxidative injury caused by post-stress. Moreover, the exogenous spray of K, B, Ca and Mn improved the post drought recovery of plants. The various enzymes activities such as CAT, SOD, GR and POX enhanced by application of nutrients in dehydrated plants and there nutrient also helpful to overcome the post drought recovery. Results indicated that application of B, K, Ca and Mn shoes positive impact to overcome the drought stress and improved the growth and anti-oxidative activity of *Camellia sinensis* L. To examine the effect of boron and water strain on growth, oil, fatty acids, seed protein and yield a repeated greenhouse trial was led by Bellaloui (2011) where on one group of soybean plants water stress (WS) was applied and the other group was irrigated water. Application of B was imparted at a rate of 0.45kg ha^{-1}. They revealed that as compared to all other treatments, watered-plants with FB produced significantly higher values of growth, yield, protein and oil contents. However, when compared watered-plants with no FB, the higher values of RNA in roots & leaves were obtained with watered-plants with FB.

In seeds and leaves B contents were recorded maximum in irrigated plant having zero FB as compared to drought stress crop having no FB. Overall results are concluded that foliar application of boron and water stress significantly affects the composition of seed, growth and yield. Another experiment performed by Naeem *et al.* (2018) to examine the function of exogenous boron application on corn. The main purpose of this experiment was that can foliar boron application adjusts the physiological-disorders in two opposing genotypes of corn in which one is drought tolerance and second one is drought sensitive. Primarily, foliar boron level at 0, 2, 4 and 6mg per L was showed to be optimized which increase the corn plants growth under drought stress condition.

After that optimized B level @ 4mg per L was imparted to scrutinize the biochemical and physiological base of boron to improve growth of corn under limited water quantity. Under water stress condition, photosynthetic ability and permeability of membrane were observed. Conclusively, B application increase the yield of corn due to significant expansion of harvesting and productivity characteristics and thus improving net return of corn cultivar Dekalb-6525 over Yousafwala-hybrid under water stress condition. Hussein *et al.* (2011) perform a pot trial to determine the impact of exogenous boron spray and accessible water reduction before irrigation (AWRBI) on development & photosynthesis dyes of sugar beet plants. This trail having 2 boric acid (75 & 150 ppm) concentration and 3 AWRBI levels along a control treatment. A similar response showed for total fresh weight of plant, whereas the whole plant dry weight with two water treatments exhibited nearly the same values. Results showed that, significant increase the values of root, top and whole fresh and dry weight of plant were noted where 75 ppm of boric acid was applied with 150 ppm of boric acid. While, the shoot/root ratio and leaf area also increase significantly by increasing the level of boric acid up to 150 ppm. However, by the use of B, pant height and the no. of leaves per plant cannot affect significantly.

In view of chlorophyll contents, chlorophyll contents were recorded maximum with foliar spray of boric acid applied @ 75 ppm over 150 ppm or control treatment. Shehzad *et al.* (2018) stated that under atmospheric conditions, marginal moisture deficiency pressure (dry at maturity growth phase) has been identified a serious ecological risk which inevitably reduces Helianthus annus L. production. This experiment was performed to investigate the key role of foliar applied B (0, 15, 30, 45mg L^{-1}) at later sunflower growth periods in mitigating terminal drought pressure difficulties (75, 64, 53mm DI) through fruiting bodies to reproductive stage.

The relationships among crop moisture like plant comparative moisture content (RWC), moisture capacity (w), aqueous ability (widths), and turgor pressure (p) are substantially increased by B use while being subjected to marginal moisture deficiency. Implementation of foliar Boron significantly enhanced concentrations of N & B in leaves and plant cells and photosynthetic pigments a and b under circumstances of marginal moisture deficiency. Wasaya *et al.* (2011) also examine the function of B and Zn application alone and in combination by applying through seed, soil and exogenous spray to check the growth, yield and net returns of corn grown under rain-fed condition. They concluded that combination of B and Zn application on foliage notably increase the chlorophyll contents, relative water content, leaf area index, grain yield and growth rate of crop. Grain yield increase about 12% and 45% as considerably by using collective spray of Zn and B as compared to seed priming and control treatment respectively. Foliar Zn and B spray used in combination showed the impact of reduced precipitation by producing greater relative water content that helped to improve leaf area index, growth and chlorophyll contents. Conclusively, B and Zn enhanced maize yield due to significant expansion of harvesting and productivity characteristics when they used in combination and thus improving net return of maize cultivated under rainfed area. Putra *et al.* (2015) directed a study to estimate the response of B & Si application on oil palm to reduce the drought stress. The 1st factor was 6 level of (B): 0, 0.17, 0.44, 0.87 and 1.31g/plant.

The 2nd factor was 5 level of (Si): 0, 1.15, 2.31, 3.46 and 4.69g/plant. Results of this study indicated that application of B and Si at seedling stage of palm can stimulate the resistance against water stress. The B application to induce the resistance in palm sprouts to water pressure. While the Si application is able to enhance the green leaves and reduce the density of lower leaf stomatal surface. However, the optimum dose for B was 0.33-0.57 and for Si was 2.22g per seedlings which may cause the physiological resistance in oil palm seedlings to water stress. Shaaban *et al.* (2004) examine the influence of Zn and B application on cotton growth and development under water stress condition. Fresh and dry weight of cotton increased by the application of exogenous spray of @ 25 ppm boron or 50 ppm zinc + 25 ppm boron under water pressure circumstances.

Conclusion

The current review determined that B is that micro-nutrient that impacts openly or circuitously plant development and improvement, organic and biochemical processes. Conversely, the lack or upturn the ratio of boron harmfully disturbs these factors. Consequently, it is suggested that optimal amount of boron is desired to increase crop production.

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