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Zinc and boron nutrition in pulses: A review

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Abstract
Zn plays major role in many physiological processes *viz*., chlorophyll formation, pollen formation, fertilization, protein synthesis, cell elongation, nodule formation *etc*. Hence, Zn nutrition favourably influences the growth, yield, physiological parameters and nodule formation in pulses. Similar to that of Zn, B also plays a major role in the functioning of reproductive tissues, structural integrity of plasma membrane, sugar transport, nodule development *etc*. Boron nutrition reduces the flower drop, increases the pod setting in pulses and also increased nodulation in pulses. The review elaborates the effect of Zn and B nutrition on the physiological, growth and yield parameters and yield of pulses and their effect on nodule formation and uptake of nutrients in pulses.

Keywords: Boron, Growth, Nodule, Nutrient Uptake, Physiological, Yield, Zinc

INTRODUCTION

Zinc plays a major role in plant growth and development. Stevenson and Cole (1999) reported that a healthy plant contain 27 to150 mg Zn kg^{-1} plant biomass. Deficiency of Zn causes chlorosis, sterility, reduction in leaf size and reduction in spikelet number (Cakmak, 2000). Zinc also have a significant role in plant metabolism and synthesis of auxins, carbohydrate, phosphate and nucleic acid (Latef *et al*., 2017).
Zinc is an important constituent of enzymes and proteins. It is the only metal element present in all the six enzyme classes, oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases (Auld, 2001). It also acts as the co-factor of enzymes and stabilizes the structure of proteins (Evans and Halliwell, 2001). It also plays a vital role in stomatal regulation and maintaining an ionic balance in plant system (Baybordi, 2006). Zinc is also involved in chlorophyll production, pollen function, fertilization and germination (Pandey *et al*., 2006; Cakmak, 2008).
Zinc content in newly developed radicles and coleoptiles were much higher up to 200 mg kg^{-1} (Ozturk *et al*., 2006). The high concentration of Zn indicates the role of Zn in physiological processes *viz*., protein synthesis, cell elongation, membrane function and resistance to abiotic stresses in early seedling development. Marschner (1995) reported that higher seed Zn content during germination and seedling development stage expressed greater resistance to soil-borne pathogens, thus ensured good crop stand and better yield.
Boron is considered to be an essential micronutrient element for plant growth and development. Boron deficiency leads to several physiological damages in plant. It is considered to be essential for sugar transport, synthesis of cell wall, cell wall structure, metabolism of carbohydrate, RNA, phenol and indole acetic acid, respiration and membrane integrity (Parr and Loughman, 1983). It is essential for maintaining the structural integrity of plasma membrane. Boron enhanced the uptake of K^+ ion and membrane bound ATPase activity which caused the hyperpolarization of plasma membrane. Serrano (1989) observed that the driving force for K^+ influx was increased by the pumping activity of membrane and hyperpolarization. Schon *et al*. (1990) observed an enhancement in the opening and closing of stomata by increased K^+ ion influx due to boron in dayflower (*Commelina communis*). Cheng and Rerkasem (1993) opined that plasma membranes are highly leaky and lost their structure due to B deficiency.
Boron is involved in the functioning of plant reproductive tissues. Marschner (1995) reported that B is found to be essential for pollen tube germination, cell elongation, cell division, male flower sterility and fruit and seed formation in plants. Aslam *et al.* (2002) reported that B nutrition leads to better pollination, seed setting and lower spikelet sterility, which finally contributed to higher grain yield in rice cultivars. Tariq and Mott (2007) pointed out

that B deficiency during flowering prevents the pollen tube growth which causes pollen sterility, flower drop and poor pod setting. Boron deficiency was more under dry weather and low moisture conditions and its deficiency reduced the number of pollen grains, pollen germination and filling up of grains. It was also observed that foliar nutrition of B enhanced the flower development, pollen grain formation, pollen viability, pollen tube growth and seed development in green gram (Praveena *et al*., 2018).

Rerkasem (1996) reported that the growing points *viz*., root tips, new leaves and buds required higher amount of B than mature tissues. Dell and Huang (1997) pointed out that B deficiency in soil retards root elongation, cell division in the root tip, leaf expansion and reduction in photosynthesis. Boron is also involved in root growth (Moeinian *et al*., 2011) and impart stress tolerance in plant and enhances grain production (Hussain *et al*., 2012).

Effect of Zn and B nutrition on physiological parameters of pulses: Tripathy *et al*. (1999) reported that soil application of zinc 25 kg ha^{-1} + B 10 kg ha^{-1} recorded significantly higher leaf area index (LAI) in soybean. In mung bean foliar application of one per cent Zn recorded significantly higher LAI (Mondal *et al*., 2011). Thamke (2017) pointed out that Zn nutrition significantly influenced the LAI of pigeon pea and higher LAI was recorded at 15 kg $ZnSO_4$. Seed polymer coating with $ZnSO_4$ + B + $FeSO_4$+ ammonium molybdate each at 2 g kg^{-1} seed followed by foliar application of $ZnSO_4$ + B + $FeSO_4$+ ammonium molybdate (0.5 + 0.2 + 0.5 + 0.1 per cent) at 50 DAS and 60 DAS recorded significantly higher LAI in chick pea (Shinde *et al*., 2017).

Akay (2011) reported that application of Zn 1 kg ha^{-1} significantly enhanced the chlorophyll content in chickpea. Application of B 4 µg g^{-1} resulted in increase in chlorophyll and carotenoid content in mung bean (Seth and Aery, 2014). Rahdari *et al*. (2013) reported that in soybean, chlorophyll and carotenoid content increased with the application of Zn 200 µM. Seed polymer coating with $ZnSO_4$ + B + $FeSO_4$+ ammonium molybdate each at 2 g kg^{-1} seed along with two foliar sprays (0.5+ 0.2 + 0.5 + 0.1 per cent) recorded significantly higher chlorophyll content in chick pea (Shinde *et al*., 2017). Samreen *et al*. (2017) reported that in mung bean, the highest chlorophyll content was observed at 0.2 µ M concentration of Zn. Foliar nutrition of potassium nitrate 2 per cent + boric acid 50 ppm +$ZnSO_4$ 1 per cent at 30 days after sowing (DAS) and 60 DAS significantly enhanced the total chlorophyll content in soybean (Gowthami *et al*., 2018). In pigeon pea, foliar application of 0.5 per cent $ZnSO_4$ resulted in 3 to 8 per cent increase in chlorophyll content (Purushottam *et al*., 2018).

Mahilane and Singh (2018) observed higher crop growth rate (CGR) with the application of Zn 7.5 kg ha^{-1}. In black gram, foliar application of $ZnSO_4$ 0.3 per cent and H_3BO_3 0.2 per cent recorded significantly higher CGR and relative growth rate (RGR) than control (Akshata, 2013).

Effect of Zn and B nutrition on growth parameters of pulses: In sandy loam soils and alfisols, soil application of 12.5 kg $ZnSO_4$ significantly enhanced the plant height in cowpea (Nagaraju and Yadahalli, 1996). Masuthi (2005) revealed that cowpea seeds pelleted with $ZnSO_4$ increased the number of green leaves compared to control. Patel *et al*. (2011) revealed that application of $ZnSO_4$ 25 kg ha^{-1} significantly enhanced branches per plant in rainfed cowpea. Usman *et al*. (2014) reported that seed treatment with $ZnSO_4$ significantly increased the pod bearing branches in green gram. Application of 0.2 per cent $ZnSO_4$ along with 1 per cent each Ca, S and Mg significantly enhanced the growth parameters in black gram (Lakshmi *et al*., 2017). Kuldeep *et al*. (2018) observed that Zn nutrition had positive effect on growth attributes of chick pea and it was observed that application of Zn 5 kg ha^{-1} recorded higher number of branches per plant and DMP at harvest compared to Zn applied at 2.5 and 1.25 kg ha^{-1}. Praveena *et al*. (2018) reported that foliar application of 0.2 per cent B at 20 and 35 DAS along with basal soil application of $ZnSO_4$ 5 kg ha^{-1} recorded significantly higher plant height, branches per plant and DMP per plant. Seed priming with $ZnSO_4$ 0.05 per cent for 4 h recorded significantly higher number of branches and green leaves and DMP per plant at harvest in grain cowpea (Raj, 2019).

Similar to that of Zn, B nutrition also had significant effect on growth attributes of pulses. Foliar application of 02 per cent B in green gram significantly improved the plant height and dry weight in green gram (Dixit and Elamathi, 2007). Kaisher *et al*. (2010) reported that in boron deficient sandy loam soil, application of B 5 kg ha^{-1} significantly improved the plant height and number of branches per plant in mung bean. Foliar application of 0.2 per cent B as borax at 20 DAs and 35 DAS with the soil application of Zn recorded significantly higher plant height (64.16 cm) and dry weight per plant (8.48 g) at 60 DAS (Praveena *et al*., 2018). Mahadule *et al*. (2019) revealed that foliar application of boric acid either at 0.4 per cent or 0.6 per cent at 25 and 55 days after sowing recorded significantly higher number of branches in French bean.

Effect of Zn and B nutrition on nodulation in pulses: Zinc plays a major role in N fixation through nodule formation (Nandwall *et al*.,1990; Balusamy *et al*.,1996). Khorgamy and Farina (2009) reported that in chick pea, application of $ZnSO_4$ 20 kg ha^{-1} markedly increased the root nodulation. Das *et al*. (2012) observed that, Zn plays a major role in leg haemoglobin synthesis and also observed that nodule number, size, leghaemoglobin content and dry weight of nodules depend on the Zn availability. Application of Zn 5 kg ha^{-1} resulted in 91 per cent enhancement in nodulation in soybean (Chauhan *et al*., 2013). Soil application of 15 kg Zn ha^{-1} recorded higher number of nodules, effective nodules and nodule fresh weight per plant in cowpea (Upadhyay and Singh, 2016). However, Debnath *et al*. (2018) observed that, soil application of Zn 7.5 kg ha^{-1} along with recommended dose of fertilizers recorded greater number of nodules per plant in cowpea. In cluster bean, nodule number and nodule fresh weight were greatly influenced by soil application of Zn 5 kg ha^{-1} (Kuniya *et al*., 2018).

Boron had significant effect on symbiotic N fixation. Bolanos *et al.* (1994) reported that absence of B in the culture medium resulted in reduction in the number of nodules and variations in nodule development.

Boron is essential for the cell wall maintenance of nodule and symbiosome development (Bolanos *et al*., 2001). Subasinghe *et al*. (2003) observed that B had a positive effect on nodulation and observed that up to 4 ppm, B enhanced the dry matter content and nodulation, but beyond 4 ppm it had negative impact. Noor and Hossain (2007) also revealed that B is essential for nodulation and N fixation in legumes. Application of B 0.5 kg ha^{-1} significantly enhanced the N fixation in cowpea and ground nut by 89 per cent and 126 per cent, respectively over control, however higher dose (1 kg ha^{-1}) significantly reduced the N fixation in cowpea and groundnut (Yakubu *et al*., 2010). Nodule number, nodule weight and size of nodule improved with B 2.86 mg L^{-1}, however higher level of B 4.86 mg L^{-1} significantly reduced the nodule number, size and weight in pea (Mehmood *et al*., 2011). Parry *et al*. (2016) reported that application of 30 kg S + 2 kg B ha^{-1} recorded higher number of nodules per plant, nodule fresh and dry weight in garden pea. In black gram, the highest number of nodules per plant and nodule dry weight was observed in the treatment receiving 0.2 per cent borax along with 0.1 per cent Zn EDTA, 2 per cent urea and 2 per cent single super phosphate (Meena *et al*., 2017). Quddus *et al*. (2018) observed that nodulation increased with increase in rate of B application and the highest number of nodules was observed, when B was applied @ 2 kg ha^{-1}. Raj (2019) reported that cowpea seeds pelleted with borax recorded higher number of total nodules and effective nodules per plant compared to seed priming with $ZnSO_4$.

Effect of Zn and B nutrition on nutrient uptake in pulses: Hassanein *et al*. (1999) reported that B nutrition enhanced the B content in cowpea and they also found that with the increase in concentration an increase in B content was observed in different plant parts. Kumar and Sidhu (2013) reported that B uptake by soybean increased with increasing B level up to 0.44 mg kg^{-1} and decreased after that. Ganie *et al*. (2014) opined that B nutrition significantly improved the N, P, K, S and B uptake in French bean. Quddus *et al*. (2018) reported that the highest B uptake was recorded in filed pea when boron was applied @ 2kg ha^{-1} along with 3 kg Zn ha^{-1}. Debnath *et al*. (2018) who observed that application of B along with recommended dose of fertilizers increased the B uptake in grain cowpea. Raj (2019) observed that seed pelleting with borax significantly improved the B uptake in grain cowpea compared to control and it was also observed that compared to seed pelleting with 50 mg borax kg^{-1} seed, 100 mg borax kg^{-1} seed recorded higher uptake of B.

Seema *et al*. (2014) reported that N content in seeds significantly increased with the application of Zn in green gram. Umesh and Shankar (2013) revealed application of Zn 12.5 kg ha^{-1} significantly enhanced the Zn uptake in pigeon pea. Application of 5 kg Zn along with 60 kg P_2O_5 and 20 Kg S ha^{-1} recorded higher N and P uptake by seed and stover in pea (Singh *et al*., 2015). Application of $ZnSO_4$ 10 kg ha^{-1} recorded higher N, P, K and Zn uptake in green gram (Ranpariya *et al*., 2017). Foliar application of $ZnSO_4$ 0.05 per cent increased the Zn uptake from 18 to 37 per cent (Purushottam *et al*., 2018). Grain cowpea seeds primed in 0.05 per cent $ZnSO_4$ for 4 h recorded higher total uptake of N, P and K by crop (Raj, 2019).

Effect of Zn and B nutrition on yield of pulses: Zinc fertilization had positive effect on the yield of pulses. Application of Zn 5 kg ha^{-1} along with S 60 kg ha^{-1} recorded 67 per cent higher seed yield over control in mung bean (Mali *et al*., 2003). Khorgamy and Farina (2009) opined that soil application of $ZnSO_4$ 20 kg ha^{-1} markedly enhanced the seed yield in chickpea cultivars. Foliar application of 0.4 per cent Zn at pre flowering and post pod forming stage increased the seed yield by 16.2 per cent over control in lentil (Singh and Bhati, 2013). Umesh and Shankar (2013) revealed that soil application of $ZnSO_4$ 12.5 kg ha^{-1} along with the recommended dose of NPK recorded the highest seed yield (1759 kg ha^{-1}) in pigeon pea. Malik *et al*. (2015) revealed that significantly higher seed yield per plant (78.2 g) was recorded with foliar nutrition of 20 ppm Zn. In black gram, foliar nutrition of secondary nutrients *viz*., $CaNO_3$, $MgNO_3$ and S each at one per cent along with 0.2 per cent $ZnSO_4$ at 25 DAS and 45 DAS recorded the highest seed yield (Lakshmi *et al*., 2017). Kuniya *et al*. (2018) indicated that soil application of Zn 5 kg ha^{-1} greatly enhanced the seed and stover yield of cluster bean.

Boron is essential for pod and seed formation in pulses (Vitosh *et al*., 1997) Sakal *et al*. (1998) reported that in calcareous soil, soil application of

2.0 and 2.5 kg ha^{-1} increased the seed yield of black gram by 33 per cent and chickpea by 38 per cent, respectively. Soil application of B 1 kg ha^{-1} alone or in combination with S 30 kg ha^{-1} were found best for higher yield in soybean (Sarker *et al*., 2002). Foliar application of borax 0.2 per cent at vegetative and flowering stage significantly enhanced the seed yield in mung bean compared to control (Patra and Bhattacharya, 2009). Combined application of B 1.5 kg ha^{-1} + Zn 3 kg ha^{-1} enhanced the seed yield in lentil (Quddus *et al*., 2014). Chatterjee and Bandyopadhyay (2017) observed that foliar nutrition of B 1.5 g L^{-1} at four weeks after planting (WAP) recorded 39 per cent higher pod yield per plant over control in vegetable cowpea. Adhikary *et al*. (2018) reported that in lentil, foliar spray of 0.5 per cent B at 15 DAS, 40 DAS and flower initiation stage recorded 26.98 per cent higher seed yield in lentil. Soil application of Zn 5 kg ha^{-1} followed by foliar spray of B 0.5 per cent at 20 DAS and 35 DAS registered the highest seed yield (2.18 t ha^{-1}) in green gram (Praveena *et al*., 2018).

Effect of Zn and B nutrition on protein content of pulses: Taliee and Sayadian (2000) opined that due to the role of Zn in N metabolism, the seed quality was improved. Pigeon pea seeds treated with $ZnSO_4$ 4 g ha^{-1} seed had significant impact on grain protein content (Sharma *et al*., 2010). Chavan *et al.* (2012) opined that compared to soil application of Zn 20 kg ha^{-1} the higher dose of 40 kg ha^{-1} registered the highest protein content in cowpea. Application of 10 kg Zn ha^{-1} recorded the highest protein content in mung bean (Ram and Katiyar, 2013). Higher protein content was observed with soil application of Zn
5 kg ha^{-1} in cluster bean Kuniya *et al*. (2018). Raj (2019) observed that among the various seed invigouration methods, seed priming with $ZnSO_4$ 0.05 per cent for 4 h recorded higher crude protein content of grain.

Debnath and Ghosh (2011) reported that B plays a major role in metabolism of protein and nucleic acids. Foliar application of Zn 2 ppm and B 2 ppm significantly enhanced the protein content in cowpea seeds (Salih, 2013). In French bean, the highest crude protein content was observed with the application of B 1.5 kg ha^{-1} (Ganie *et al*., 2014).

Conclusion

Zinc and B nutrition significantly improves the physiological, growth and yield parameters and yield in pulses. The availability of these nutrients in soil depends on the texture of soil, nature and amount of clay present, soil organic matter, soil moisture and the relationship with the other nutrient elements present in the soil. All the three methods of application (soil, foliar and seed) show favourable results. However, the magnitude of B and Zn response varies with crop, variety and also with the soil type. It has been observed that soil application of B up to 2.5 kg ha^{-1} gave positive response in pulses and foliar application up to 0.5 percent. The critical limit for B deficiency is less (15 ppm), sufficiency is 15-100 ppm and toxicity is more than 200 ppm. The critical limit for Zn is 15 mg kg-1 of dry matter and the sufficiency range is more than 20 mg kg^{-1}. The positive response Zn has been observed up to soil application of 5.5 Zn kg ha^{-1}. The residual effect of Zn persists in the soil for four seasons in calcareous soils and six seasons in non-calcareous soil. Hence, based on soil test results, soil type and crop, Zn and B can be applied to enhance the production and productivity of pulses.

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