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Productivity of Field Crops as Influenced by Foliar Spray of Nutrients: A Review

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ABSTRACT

Foliar application of nutrients plays an important role in changing growth and physiological characteristics of field crops. In optimizing fertilization strategies, inclusion of foliar application improves fertilizer use efficiency and reduces environmental pollution. Foliar application of nutrients during flower and grain formation stages has been shown to be effective in efficient utilization of nutrients by crops and thereby reduce flower shedding and increase the yield. Keeping this in view, the literatures on foliar application of Di-ammonium phosphate and boron on the growth, yield and quality of field crops are reviewed in this paper.

Key words: Boron, Crops, Di-ammonium phosphate, Foliar application, Nutrients, Yield.

Foliar application is a technique of feeding nutrients to plants in the form of liquid directly to their leaves. Nutrients are important and crucial elements, which are required for the plant for its growth and development. The translocation of photosynthates from source to sink is very important for the development of economic part. Foliar application was several times more efficient than the soil treatment (Sastry and Rao, 1958). The plant nutrients which are absorbed through roots can also be absorbed with equal efficiency through foliage (De, 1971). Among the methods of fertilizer application, foliar nutrition is recognized as an important method of fertilization. Since foliar nutrients usually penetrate the leaf cuticle or stomata and enter the cells, it facilitates easy and rapid utilization of nutrients (Latha and Nandanasababady, 2003). Foliar nutrition is designed to eliminate the problems of fixation and immobilization of soil applied nutrients. Nutrients applied through foliage would be easily absorbed and translocated in the plant without any loss (Manivannan and Thanunathan, 2003). Foliar application of fertilizers as a possible means of applying the needed nutrients for successful crop production is gaining considerable interest in recent years (Malarmathi and Thomas Abraham, 2003; Prakash *et al*., 2003).

It has been well established that most of the plant nutrients are absorbed through the leaves and absorption would be remarkably rapid and nearly complete. Moreover, foliar feeding practice would be more useful in early maturing crops, when it is combined with regular plant protection programmes. If foliar nutrition is applied, it reduces the amount of fertilizer which in turn reduces the cost of cultivation thereby economizing the crop production. Prabhakaran and Lourthuraj (2003) suggested that foliar application of fertilizers offers considerable scope not only for better utilization of nutrients but also for the economy of fertilizer application.

Application of nutrients through foliar spray at appropriate stages of growth is becoming important for their efficient utilization and better performance of the crop (Anandhakrishnaveni *et al.,* 2004). The interest of foliar fertilizers arose due to the multiple advantages of foliar application methods such as rapid and efficient response to the plant needs, less product needed and independence of soil conditions. It is also recognized that supplementary foliar fertilization during crop growth can improve the mineral status of plants and increase the crop yield (Elayaraja and Angayarkanni, 2005). Foliar application is credited with the advantage of quick and efficient utilization of nutrients, elimination of losses through leaching and fixation and regulation on the uptake of nutrient by plants (Manonmani and Srimathi, 2009). Foliar application of N at particular stage may solve the slow growth, nodule senescence and low seed yield of pulse crops without involving root absorption at critical stage. Foliar application of nitrogen in the form of urea significantly expressed the higher values in growth attributes *viz.,* Leaf area index, Crop growth rate, Net assimilation rate and Specific leaf weight by showing higher accumulation of total dry matter production with increased yield (Surendar *et al.,* 2013). Foliar application of N is more appropriate than soil application because it allows for a rapid and efficient transportation of N to the grain (Wagan *et al*., 2017).

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Importance of Di-Ammonium Phosphate (DAP)

DAP fertilizer is an excellent source of phosphorus (P) and nitrogen (N) for plant nutrition. Nitrogen is an essential and basic macronutrient for plants. It is a component of protoplasm as well as protein. Nitrogen is crucial in the production of vegetative biomass. Phosphorus and potassium also influence the beneficial effects of nitrogen fertilization. Deficiency of nitrogen in the plant slows down the processes of photosynthesis and physiological functions. Nitrogen is a component of proteins and nucleic acids. It stimulates the growth of underground and aboveground parts of plants, giving them intense green colour. Phosphorus is one of the universal nutrients. It is a component of organic compounds and therefore it is used for energy storage and plants metabolism. Transport of phosphorus in the plant is very poor what can cause deficiency of this element. High concentration of this element in plants stimulates intensive root system growth and in effect improves yield. In most cases plants absorb the most of the nutrients supplied to the soil by their root system which leads to the desired growth, plant rooting and to obtainment of high yield. However, sometimes nutrient uptake from soil is difficult due to physiological stresses such as drought, excessive moisture, inadequate soil pH and too low temperature. Insufficient moisture as well as drought in the period of spring and summer cause that plant root systems are not able to absorb from the soil nutrients which are required to achieve satisfactory healthy crop, both in a quantitative and qualitative sense. Foliar fertilizers are completely soluble in water and needed nutrients are fast delivered to plants in the form of foliar fertilization during the growing season. This is especially important in case of high deficiencies in the soil and the difficulty in uptake due to inappropriate weather or mechanical conditions. Both macro and micronutrients can be delivered to plants by foliar fertilization. In foliar application of nutrients the losses of macro and micronutrients are much lower than in case of application of soil fertilization. Foliar application of DAP at critical stages of the crop enhanced better photosynthetic activity as reported by Ganapathy *et al.* (2008).

Effect of Di-Ammonium Phosphate on growth parameters

Foliar spray of DAP twice with recommended dose of fertilizer recorded the maximum plant height in chickpea (Srivastava and Srivastava, 1994). Foliar application of nutrients with 1% DAP + 0.5% urea + 0.25% magnesium sulphate + 0.25% zinc sulphate recorded higher leaf area index, crop growth rate, net assimilation rate and relative growth rate along with seed treatment with nutrients in blackgram (Subramani and Solaimalai, 2000). In cowpea, application of recommended dose of inorganic fertilizer combined with 2% DAP spray twice recorded the maximum dry matter production of 2818 kg ha^{-1} (Parasuraman, 2001).

Application of basal dose of fertilizer along with 2% DAP spray twice registered higher plant height (73.5 cm) in greengram (Pandiyan *et al.*, 2001). Foliar application of 2% DAP and 1% potassium chloride (KCl) along with benzyladenine 25 ppm significantly increased the plant height, relative growth rate and net assimilation rate in soybean (Ramesh and Thirumurugan, 2001). Foliar spray of 2% DAP significantly increased the plant height of redgram (Solaiappan *et al.*, 2002).

Chandrasekhar and Bangarusamy (2003) observed that foliar application of 2% DAP and 1% KCl along with plant growth regulators significantly increased the total dry matter production (24.7 g $plant^{-1}$) of mungbean. Foliar application of 2% DAP along with micro nutrients significantly increased the plant height of chickpea (Pathak *et al.*, 2003). Foliar application of 2% DAP + 1% KCl spray increased the plant height, leaf area index and dry matter production of blackgram (Geetha, 2003). Foliar application of 2% DAP on 65 DAS through foliar spray recorded higher plant height (55.72 cm), number of branches $plant^{-1}$ (29.15) and dry matter $plant^{-1}$ (33.15 g) of cowpea (Shinde and Bhilare, 2003).

Ramanathan *et al.* (2004) found in rice fallow blackgram, foliar application of 2%DAP and 1% muriate of potash (MOP) four times (25, 32, 40 and 47 DAS) significantly increased the plant height. Foliar application of 2% DAP and 2% urea along with micronutrients twice significantly increased the leaf area index, crop growth rate and dry matter production of blackgram (Sritharan *et al.*, 2005).

Foliar application of DAP, micronutrient and naphthalene acetic acid (NAA) on mungbean had significant influence in plant height and dry matter production (Dixit *et al.*, 2008). Senthilkumar *et al.* (2008) observed a significant increase in growth characters like plant height (47.5 cm), dry matter production (2576 kg ha^{-1}) and leaf area index (3.74) of blackgram by foliar application of 2% DAP at flowering and pod development stage as compared to no spray (37.1 cm, 1712 kg ha^{-1} and 2.76, respectively).

Foliar application of 2% DAP increased the plant height, number of branches $plant^{-1}$ and dry matter accumulation in per metre row length (114.9 g) of cowpea (Choudhary and Yadav, 2011). Foliar application of 2% DAP + 1% KCl + nutrient mixture significantly increased the periodic plant height, dry weight $plant^{-1}$ and number of tillers $plant^{-1}$ in wheat (Latief *et al.,* 2012).

Foliar application of 2% DAP and 2% urea on chickpea increased the number of branches $plant^{-1}$ (Parimala *et al.*, 2013) Recommended dose of fertilizer + foliar application of 40 ppm NAA + 0.5% chelated micronutrient + 2% DAP significantly increased the plant height (37.11 cm), number of branches $plant^{-1}$ (8.27), leaf area index (4.18) and total dry matter production $plant^{-1}$ (15.98 g) in blackgram (Shashikumar *et al.*, 2013).

Effect of Di-Ammonium Phosphate on yield and yield parameters

Foliar spray of 2% DAP significantly increased the grain yield (955 kg ha^{-1}) and 100 grain weight (7.3 g) of blackgram over control (Muthuvel *et al.*, 1986). Solaiappan and Ramiah (1990) studied the effect of basal application of 12.5 kg of P_2O_5 ha^{-1} combined with foliar application of 1% DAP on

70th day after sowing to increase the seed yield of redgram. Foliar spray of 1% DAP twice at flowering and 20 days after the first spray has shown increased grain yield and seed weight plant^{-1} of gram (Setty *et al.,* 1992).

Annadurai and Palaniappan (1994) observed that 2% DAP spray at boot leaf stage, 50 per cent flowering and at post milk stage recorded higher grain and straw yield in rice along with recommended dose of 38 kg P_2O_5 ha^{-1}. Foliar application of 2% DAP with 1% humic acid increased the seed cotton yield (Chellaiah and Gopalasamy, 2000). Subramani and Solaimalai (2000) found that foliar application of nutrients with 1% DAP + 0.5% urea + 0.25% magnesium sulphate + 0.25 % zinc sulphate increased the grain yield of blackgram.

Basal application of N and P at 12.5 and 25 kg ha^{-1}, respectively and 2% DAP spray twice at flower initiation stage and 15 days after the first spray increased the 100 seed weight and grain yield to a tune of 165% over conventional method of raising rice fallow greengram (Pandian *et al.*, 2001). Foliar application of benzyl adenine 25 ppm twice with 2% DAP and potassium chloride 1% at flowering and 15 days after flowering increased the yield of soybean (Ramesh and Thirumurugan, 2001).

Basal application of 25 kg and 2% DAP spray at flowering and pod initiation stage increased the number of pods plant^{-1} and yield of blackgram compared to contro (Yakadri and Thatikunta, 2002)l. Yield attributes in blackgram was favourably influenced by foliar application of 1% DAP + 0.5% urea spray at flowering stage (Subramani *et al.,* 2002). Application of 2% DAP along with biofertilizers significantly increased the growth and yield attributes in chickpea (Pathak *et al*., 2003). Foliar application of 2% DAP + 1% KCl improved the harvest index of blackgram (Geetha, 2003).

Foliar application of 2% DAP recorded higher harvest index over control in greengram (Ghosh and Joseph, 2008). Manonmani and Srimathi (2009) studied that foliar spray of DAP 2% followed by urea 1% recorded higher 100 seed weight (5.6, 5.5 g) and seed yield (1240, 1040 kg ha^{-1}, respectively) in blackgram. Foliar nutrition of 2% DAP increased the number of seeds pod^{-1} and seed yield in cowpea (Choudhary and Yadav, 2011).

Foliar appliction of 2% DAP + 1% KCl + 100 ppm nutrient mixture on wheat increased the grain and straw yield and different yield contributing characters *viz.,* spikes plant^{-1}, spike weight, grains spike^{-1} and test weight (Latief *et al.,* 2012). Recommended dose of fertilizer + foliar application of 40 ppm NAA + 0.5% chelated micronutrient + 2% DAP increased the grain yield (1298 kg ha^{-1}), number of pods plant^{-1} (38.73), pod length (6.03 cm) and number seeds pod^{-1} (6.47) of blackgram (Shashikumar *et al.,* 2013). Foliar application of 2% DAP increased the number of pods plant^{-1} (62.75), 100 seed weight (14.62 g), grain yield (1460 kg ha^{-1}) and haulm yield (4027 kg ha^{-1}) of soybean (Vinoth Kumar *et al.*, 2013).

Effect of Di-Ammonium Phosphate on nutrient uptake

Foliar application of 2% DAP on blackgram at flowering stage significantly increased the total nutrient uptake (NPK) compared to control (Krishnasamy *et al.*, 1985).) Foliar application of 2% DAP and microsol spray recorded the higher nutrient uptake (75, 18 and 70 kg NPK ha^{-1}) of rice fallow blackgram (Manivannan and Thanunathan, 2003). Combined inoculation of biofertilizers and DAP on greengram increased the growth and yield attributes due to increased availability of N and P in the root zone by fixing more atmospheric nitrogen by rhizobium and solubilization of unavailable phosphates in the soil (Ghosh and Joseph, 2008).

Effect of Di-Ammonium Phosphate on economics

Application of basal dose of fertilizer along with 2% DAP spray twice registered higher net return per rupee invested in rice fallow greengram (Pandian *et al.,* 2001). Foliar application of 2% DAP has improved the grain yield and net income with high B:C ratio (2.44) in redgram (Solaiappan *et al.*, 2002). Yakadri and Thatikunta (2002) reported that foliar application of 2% DAP on blackgram recorded the higher B:C ratio of 3.78 compared to control.

Higher cost benefit ratio (3.47) was registered with foliar spray of DAP at 2%, which signifies that, foliar spray with DAP is the cheapest cultural practice in achieving good grain yield with minimum production cost in greengram (Chandrashekar and Bangarusamy, 2003). Shinde and Bhilare (2003) observed that foliar spray of DAP at 2% on cowpea at two different growth stages recorded higher gross monetary return (Rs. 49726 ha^{-1}), net monetary return (Rs. 32466 ha^{-1}) and benefit cost ratio (2.87) in chickpea.

Foliar application of 2% DAP + 100 ppm salicylic acid + 0.05% sodium molybdate twice proved to be the most promising nutrient management practice for summer greengram in terms of economic returns *viz.*, gross return and net return (Kuttimani and Velayutham, 2011).

Recommended dose of fertilizer + foliar application of 40 ppm NAA + 0.5% chelated micronutrient + 2% DAP on blackgram increased the net return (Rs. 35,431 ha^{-1}) and B:C ratio (3.03) (Shashikumar *et al.*, 2013). The higher net return and B:C ratio obtained under these treatments were due to higher productivity in terms of yield. Foliar application of 2% DAP increased the gross return (Rs. 36,500 ha^{-1}), net return (Rs. 20,090 ha^{-1}) and B:C ratio (2.22) of soybean (Vinoth Kumar *et al.*, 2013).

Importance of boron

Among the micro nutrients, boron is stated to influence many growth parameters and filling up of seeds in sunflower (Blamey, 1976). Garg *et al*. (1979) found that germination capability, size and fertility of pollen grains of rice were considerably improved as a result of boron application at 2.5 ppm concentration. They also reported that inclusion of boron in the nutrient solution with optimum level has stimulatory effect on the pollen vitality and there by improved the grain yield of rice.

Sugar transport, pollen formation, seed germination and development of nodules are also affected in its absence. Seed and grain production are also reduced with low boron supply (Sillanpae, 1982). Moreover a high proportion of cells in boron deficient seeds tend to become empty or collapse

(Welch, 1986). Fernandez (1990) observed that the requirement of boron was maximum during flowering, the plant was therefore most susceptible to limitations and so the content of the 5th and 6th leaves under the flowering head should be maintained at 20 and 40 ppm respectively.

Foliar application of 0.2% boron in combination with Fe and Zn to cotton proved its superiority in the production of chlorophyll 'a' and 'b'. Boron is required for reproductive plant parts, cell wall formation and stabilization, membrane integrity, carbohydrate utilization, stomatal regulation and pollen tube formation (Patil and Malewar, 1994). During seed development, the need for boron is higher than the vegetative growth period (Marschner, 1995).

Boron is thought to increase nectar production in flower and this attracts pollinating insects. Additionally, boron has a role in the cell structure. Tissue of boron deficient plants often breaks down permanently causing brown flecks, necrotic spots, cracking and corky areas in fruits and tubers (Dear and Weir, 2004).

Boron is one of the sixteen essential nutrient elements required for proper growth and yield of crop plants (Tariq and Mott, 2006). Foliar spray of boric acid has been reported to be more effective than soil application for fulfilling boron requirements and curing its deficiency in maize. Although correction of boron deficiency can be achieved through soil or foliar application, foliar treatments are more effective under dry conditions due to the low root absorption rates from dry soils (Rufat and Arbones, 2006).

Deficiency of boron can cause reduction in crop yield, impair crop quality or have both of these effects. Protein and soluble nitrogenous compounds are also found decreased in boron-deficient plants (Gupta, 2007). It plays an important role in water relations, cell wall formation, cations and anions absorption, pollen viability and metabolism of N, P, carbohydrates and fats in the plant (Oyinlola, 2007).

Effect of boron on growth parameters

Foliar application of boron increased the plant height, stem girth and dry matter accumulation of sunflower (Rao and Vidyasagar, 1981a). Foliar application of boron and molybdenum brought significant improvement in plant height of chickpea (Masood Ali and Mishra, 2001). Foliar application of boron (0.2%) on greengram increased the plant height (32.26 cm) and dry weight plant^{-1} (12.9 g) (Dixit and Elamathi, 2007).

Dixit *et al.* (2008) found that combined foliar application of 2% DAP with 0.2% boron and 0.05% Mo significantly registered higher plant height and branches in greengram. Application of Zn (15 kg) and B (1.5 kg) ha^{-1} significantly increased the dry matter production, leaf area index, crop growth rate and net assimilation rate of sunflower (Muzzammil *et al.,* 2009). Foliar application of boron (0.5%) at early, mid and late whorl growth stages increased the plant height (195.05 cm) and stem girth (5.21 cm) of fodder maize compared to soil-applied boron (Soomro *et al.,* 2011). Application of boron at 2 kg ha^{-1} on wheat produced higher crop growth rate, net assimilation rate and number of tillers (234.5 m^{-2}) (Nadim *et al.*, 2012).

Combined application of 2.0 kg boron and 5 kg zinc ha^{-1} on wheat significantly increased the number of tillers m^{-2} (Ali *et al.*, 2013). Foliar application of boron at 500 g ha^{-1} increased the plant height (172.86 cm) of sunflower (Muhammad *et al.*, 2013).

Effect of boron on yield and yield parameters

Foliar application of boron increased the total seed number head^{-1}, weight of filled seed head^{-1}, test weight and seed yield of sunflower (Rao and Vidyasagar, 1981a). Sarkar and Sasmal (1989) found that applying 0.5 kg ha^{-1} boron to sunflower grown in *rabi* season increased the capitulum diameter, number of filled seeds head^{-1}, 1000 seed weight and seed yield.

Khan *et al.* (1990) found that dusting of borax at 2 kg ha^{-1} on sunflower heads during seed filling stage significantly increased the seed yield by 87%, test weight by 60%, seed filling by 25% and head diameter by 21% compared to control. They also found dusting borax on ear heads gave the higher germination of 96% and vigour index of 2162 compared to control (84% germination and 1263 vigour index, respectively). Foliar application of boron at different growth stages increased the seed cotton yield and lint yield significantly (McConnel *et al.,* 1992). Foliar spray of 0.1% borax at peak square and peak flowering stages recorded significantly more seed cotton yield over control (Wankhade *et al.,* 1994).

Spraying boron as borax or boric acid with 0.2% at the seedling stage, early flowering and boll formation stage increased the yield of cotton 16.1% over control (Dong Jinfeng, 1995). Foliar spray of borax at 0.2% increased the percentage of filled seeds in sunflower. This might be due to better pollen germination, increased pollen viability and fertilizing capacity of pollen (Susheela, 1996). Boron fertilization on sunflower increased the seed yield (Brown and Hu, 1997).

Application of boron at 2 kg ha^{-1} and 4 kg ha^{-1} increased the yield of sunflower by 38 and 59%, respectively over control (Satyanarayana *et al.*, 1997). The seed yield of soybean was improved by the combined application of 2% DAP, 1% KCl, 0.2% boron along with 40 ppm NAA sprayed at 50% flowering and a fortnight later (Kalpana and Krishnarajan, 2003).

Dixit and Elamathi (2007) observed that foliar application of boron (0.2%) on greengram increased the number of pods plant^{-1} (18.1), 100 seed weight (28.7 g), grain yield (7.53 quintal ha^{-1}) and haulm yield (30.0 quintal ha^{-1}). Foliar application of boron at booting stage increased the number of grains spike^{-1} (54.75) and seed yield (4592 kg ha^{-1}) of wheat. They also reported that foliar application of boron at jointing stage increased the 1000 grain weight (43.83 g) and anthesis stage increased the harvest index (40.11%) of wheat (Muhammad *et al.*, 2009).

Foliar application of zinc and boron on wheat significantly increased the number of spikes m^{-2}, number of

grains spike^{-1} thousand grain weight, biological yield and grain yield (Sajid Ali *et al.*, 2009). Mohammed *et al.* (2011) stated that normal irrigation with foliar spray of boron (1%) recorded the higher grain yield (5632 kg ha^{-1}) of wheat.

Boron application at 3 mg L^{-1} increased the head diameter, number of seeds head^{-1}, 1000 seed weight and seed yield of sunflower (Ayad and Saad, 2011). Application of nitrogen 200 kg ha^{-1} and foliar spray of boron 1 kg ha^{-1} on cotton significantly increased the boll number plant^{-1}, boll weight, seed cotton weight of boll and seed cotton yield and lint yield (Majid Rashidi *et al.*, 2011). Foliar application of boron (0.5%) at early, mid and late whorl growth stages increased the green and dry fodder yield (58.04 t ha^{-1} and 17.59 t ha^{-1}, respectively) in fodder maize compared to soil-applied boron (Soomro *et al.* 2011).

Application of boron at 2 kg ha^{-1} on wheat increased the number of grains spike^{-1} (52.92) and grain yield (3.14 t ha^{-1}) as reported by Nadim *et al.* (2012). Foliar application of boron at 0.5 mg L^{-1} on barley significantly increased the weight of straw and grains by 5.5% as compared to control (Soad Soliman El-Feky *et al.,* 2012). Combined application of 2.0 kg boron and 5 kg zinc ha^{-1} produced significant increase on the grain yield and its components *i.e.,* spike length, number of grains spike^{-1} and 1000 grain weight of wheat (Ali *et al.*, 2013).

Effect of boron on nutrient uptake and economics

Boron when applied to soil resulted in increased N content of leaf, K content of stem and P content of petiole during early vegetative stage, N and P contents of leaves during flowering stage and P contents of leaves and stems and N and K contents of petioles at harvest. Boron when sprayed on foliage helped to increase the mineral composition of leaves, stems and petioles during different growth stages of sunflower. They also noticed that foliar sprayed boron influenced the absorption and preferential translocation of mineral elements into different parts of the plant (Rao and Vidyasagar, 1981b). Uptake of N, P and boron was the highest when fertilized with boronated super phosphate as compared to single super phosphate (SSP) and DAP (Ateeque and Malewar, 1992). Beegle (2002) stated that when boron was given as a foliar application it increased the grain yield and nitrogen uptake in crop. Rhizobium inoculation along with zinc and boron in greengram gave better response in terms of N uptake as compared to rhizobium alone (Jain *et al*., 2007).

The net return and B:C ratio was higher with 60 kg P_2O_5 ha^{-1} combined with of 2% DAP and 0.2% borax spray on sunflower (Susheela, 1996). Foliar application of boron (0.2%) in greengram increased the B: C ratio (1.54) as revealed by Dixit and Elamathi (2007). Foliar application of boron at booting stage recorded the maximum net return (Rs. 34132 ha^{-1}) and B:C ratio (2.07) of wheat (Muhammad *et al.*, 2009).

CONCLUSION

From the above review it can be concluded that, foliar application of DAP and boron twice at pre and post flowering stage of crop growth along with recommended dose of fertilizer would be an ideal practice for getting higher yield and economic returns in field crops.

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