Review Article

Response of Field Crops to Foliar Nutrition: A Review

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Abstract

Soil application of nutrients is not an effective method solely as it does not deliver nutrients effectively from soil to plant due to effect of various physicochemical properties of soil viz., soil pH, calcium carbonate content, organic matter content, ion imbalance, nutrients deficiency, soil texture, soil temperature, poor soil aeration, high humidity, soil compaction etc. Negative consequences of which are global food shortage as yield is not optimized, low fertilizer use efficiency, high input cost and poor quality produce. The alternative approach to overcome these problems is supplementary foliar nutrition. A lot of research work has been done to find out the response of field crops to foliar application of macro and micronutrients. Results of these studies well-lighted indicate the importance of foliar nutrition to improve productivity and quality of the field crops. The aim of this paper is to review the research work on response of field crops to foliar nutrition with respect to growth, yield and seed quality.

Keywords: Field crops, foliar nutrition, growth, quality, yield

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Introduction

In the backdrop of increasing world population, declining productivity and quality of field crops due to multi-nutrient deficiency especially that of secondary and micronutrients are the two major challenges leading to food and nutritional insecurity. According to FAO [1] agricultural production will have to be increased by 70 per cent to solve the food issues for increasing world population from the current 7 to 9.2 billion by 2050. Globally more than 840 million people do not get enough food and 3 billion people are undernourished suffering from multi-nutrient deficiency.The fifth major cause of diseases and death in human beings is due to multi-nutrient deficiency to food crops and food shortage in developing countries [2]. Approximately 80 per cent of future growth in crop production will come from limited arable land through yield advancement [1]. Research findings indicate that fertilizer is responsible for approximately half of all crop production; consequently, fertilizer will play a crucial role in meeting the challenge of food and nutrient security. The role of mineral nutrients applied through fertilizer is undeniable in field crop production as they have essential functions in plant metabolism [3]. Both macro as well as micronutrients are important for growth, development, physiology of plants and ultimately important for enhancing productivity and quality of field crops.

Soil application is most common method to supply essential nutrients to plant. However soil application does not deliver nutrient effectively from soil to plant. The current status of nutrient use efficiency is quite low in case of N (30-50%), P (15-20%), S (8- 12%) and micronutrients (<2%) due to deterioration in chemical, physical and biological health of the soil and the conditions which restrict root growth in soil for uptake of nutrients [4]. Apart from this, the problem of micronutrient deficiency is becoming more serious due to introduction of high yielding varieties, increasing cropping intensity, use of high analysis fertilizers and limited use of organic manures [5]. The consequences of nutrient deficit soil and less efficient nutrient application in soil are global food shortages as yield is not optimized, poor quality of field crop's produce and high input cost.

An alternative approach to overcome the problem of ineffective fertilizer nutrient supply is supplementary foliar nutrition [6]. It is defined as the application of foliar spray of one or more nutrients to plants to supplement traditional soil application of fertilizers. Though soil application of nutrients can not be replaced by foliar application completely, the latter could definitely boost the plant growth. Objectives of foliar nutrition are to stimulate the production process of crops for improving yield, to correct deficiency of nutrients quickly during critical requirement, to promote crop growth under abiotic stress conditions, to improve nutrient use efficiency and quality of field crops. During the last decades, foliar feeding of nutrients has become an established procedure to increase the efficacy of

fertilizer use, improve yield and the quality of crop products under the wide range of sites and climate [7, 8]. Foliar application is credited with the advantage of rapid absorption of nutrient by the leaf tissues and efficient movement to the developing parts of plant, eliminating losses through leaching, fixation and helps in regulating the uptake of nutrients by plants, efficient utilization of nutrients, increase plants mineral status, yields and quality of field crops [9-11]. Foliar application of nutrients would be more appropriate, efficient and economical than the soil application [12]. Foliar feeding was more efficient than soil application for N (6 times more efficient), B (4 times more efficient), Mn (30 times more efficient), Zn (20 times more efficient), P (20 times more efficient) and Mo (14 times more efficient [13]. Likewise, Liew [14] advocated that foliar application of micro-nutrients to be 6-20 time more efficient than soil application, depending on soil type. Similarly, in terms of yield it is more efficient than soil fertilization for both macro and micronutrients in different soil types [15, 16]. Foliar application of nutrients in field crops has significant positive effects on plant growth, yield, quality and correct nutrient deficiencies [17-19]. Foliar fertilizers can be used to enhance crop quality both in terms of grain protein and nutrient content [20-22]. According to the limitations of soil usage of micro-nutrients (such as consolidation and residual effects) foliar spraying or leaf feeding is one of the effective ways to resolve plants food requirement in terms of micronutrients [23].

However, benefits of foliar nutrition can be a highly debated topic. The full potential of this technology has not been fully realized due to an inadequate understanding of the principles involved. There is need to break knowledge gaps that hinder the development of improved and an effective foliar nutrition strategies. Growers must realize that foliar nutrition is not designed for every field and every situation. It is most effective and economical when nutrient uptake from the soil is restricted due to low nutrient availability, high degree of nutrient fixation, low soil moisture content or dry top soil, low soil temperature, decreased root activity during reproductive stage and when sink competition for carbohydrates among plant organs take place [24, 25]. Paying attention to foliar application's timing and utilizing an effective product under the right conditions can maximize the potential response of foliar nutrition.

Several researchers have been found the positive effects of foliar nutrition on growth, grain yield and seed quality of field crops for a wide range of sites and climates. The aim of this review article is to review the research work on response of different field crops to foliar nutrition.

Response of different field crops to foliar nutrition

Cereals

In rice crop, foliar spray of potassium nitrate at the rate of 0.5% at 50% flowering stage increased grain yield of high yielding and traditional cultivar significantly by 49.1 and 19.3% respectively over control of no foliar spray [26].The late-season urea spraying consistently increased wheat grain yield and better quality such as protein content at a low basal N rate [27, 28]. At Pantnagar, Roy [29] examined the effect of nitrogen level and foliar application of urea on yield and quality of seed in late sown wheat (11 December). Grain yield and quality parameters (protein content, starch, wet gluten and sedimentation value of seed) was significantly influenced by the foliar application of 3% urea at anthesis as compared to no spray and water spray at given nitrogen levels of 90, 120 and 150 kg/ha. Foliar application of urea+ KCl at double ridge, milky stage and double ridge+ milky stage resulted increased protein content and grain yield by 8 and 40 per cent respectively compared to control (no foliar spray) in wheat crop [30]. Nitrogen applied through urea ammonium nitrate at the rate of 35 kg/ha at pre flowering and post flowering stage increased grain N content by 2.7 and 2.4 g/kg, respectively in winter wheat. Grain protein was 16.5 and 16.3 per cent for foliar application at pre flowering and post flowering stage respectively compared to 14.9 per cent in control (no foliar spray) [31]. Optimum timing for N sprays on wheat showed that post-pollination foliar N gave the highest grain protein [32, 33]. In maize crop, application of P at 0.75% concentration at 25 and 45 days after sowing gave significantly higher growth parameters with thicker cobs and corns, increasing the individual cob weight, which in turn increased the green cob yield of as compared to control of no spray [34].

Foliar application of micronutrients lead to increase in yield components and quality parameters such as protein percentage, nutrients content in cereals; for instance wheat, maize, rice, barley and sorghum [35]. Foliar application of micro elements Fe, Mn and Zn at the rate of 1, 0.5 and 0.5% respectively at tillering & heading stage increased grain yield, protein, Fe, Mn and Zn contents in grains of wheat significantly over control (No spray) [36]. Foliar spraying with suspension, micronutrient induced stimulatory effects on growth parameters and nutrients uptake either before or after the salinization treatments in wheat and it has been suggested that foliar spray with micro-nutrient may have a potential role for increasing wheat tolerance to salinity stress too [37]. In cereal crops foliar spray of zinc, boron and copper micro-nutrients has been reported to be equally or even more effective as compared to soil application to overcome micronutrients deficiency in subsoil [38]. Maize crop responded significantly superior in term of grain yield and quality to foliar fertilization of 1.0-1.5 kg Zn/ha at the 5th leaf stage compared to control (No spray) [39]. Srivastava [40] in Pantnagar reported that as compared to soil application of 2.5 kg Zn/ha, foliar application of Zn at

the rate of 2.0 kg/ha in basmati rice (at 30 and 60 days after transplanting) and wheat (at 30 and 60 days after emergence) crop recorded higher grain yield, total uptake of Zn, P and their apparent utilization efficiency. There was 13.8, 6 per cent and 6.2, 2.8 per cent more grain yield in rice, wheat observed when applied Zn as foliar spray over control and soil application of Zn respectively. Soil application (5 mg Zn/kg soil) + foliar application of 0.5 % $ZnSO_4$ at 30, 60 and 90 days after transplanting of rice was most effective in increasing carbonic anhydrase activity and improving nutritional quality such as protein content of grains [41]. Integrated foliar spray of potassium and zinc at the rate of 1 and 0.1 per cent, respectively at 25 and 50 DAS resulted in higher photosynthetic rate, net assimilation rate, protein content, grain yield in maize over control of no foliar spray [42]. In rice crop too, foliar application of Zn significantly increased Zn accumulation in the grain [43]. Although foliar application of Zn is a promising method to increase seed Zn concentration, its effectiveness may also depend on several factors. One of these factors is the time of foliar Zn application. In the case of wheat it was shown that the highest Zn concentration in seed was achieved when foliar Zn was applied after the flowering stage compared to the applications realized before the flowering stage [44]. Zoz [45] evaluated the effect of foliar application of zinc in agronomic characteristics and yield of wheat. He found that foliar application of zinc increased the number of fertile tillers and wheat yield. Two times spray of 0.5% $ZnSO_4$ and 0.5% KNO_3 solution in wheat at tillering and booting stage were significantly affected number of tillers per square meter, plant height, number of spikes per square meter and grain yield compare to control (No spray) and water spray **[**46]. Dayanand [47] studied the effect of foliar application of thiourea and zinc on growth and yield of wheat. Treatments included water spray (control), 0.05% thiourea, 0.5% $ZnSO_4$ and 0.05% thiourea+0.2% $ZnSO_4$ at tillering and grain initiation stage of wheat. They recorded 10.4 and 12.7 per cent significantly higher grain yield by foliar spray of 0.5 per cent $ZnSO_4$ and 500 ppm thiourea + 0.2 per cent $ZnSO_4$ (mixed solution) respectively over control. Foliar spray of $ZnSO_4$ at the rate of 0.5 per cent at tillering and grain initiation stage resulted significantly higher ear length, number of grains per ear, test weight, grain yield and straw yield over control (No foliar spray) treatment [48].Wang [49] observed that in winter wheat three foliar application of 0.3% $ZnSO_4$ alone and along with 1.7% urea during early milking stage at 7 days interval significantly increased the grain protein along with P, K and Zn concentration in grain compare with control treatments (foliar application of deionized spray). Efficacy of Cu foliar application in wheat and found the separate spraying of 1 kg/ha of copper sulphate, copper oxychloride and copper chelated at the 6th leaf stage can enhance yield. The trials confirmed that the recommended rates of 1-2 kg/ha of copper sulphate spray are highly effective [50].

Pulses

In pulse crop, synchronized flowering altered the source-sink relationship due to rapid translocation of nutrients from leaves to the developing pods. Additional nutrition through foliar feeding is play a vital role in pulse production by stimulating root development, nodulation, energy transformation, various metabolic processes, increasing pod setting and thereby increasing the yield [51, 52]. Das [53] reported higher seed yield of pulses (green gram, black gram and lentil) with 2% urea and 3% NPK (19-19-19) spray at pre flowering stage, respectively over basal dose (N, P_2O_5, K_2O-20, 40, 40 kg/ha) and without basal dose of NPK application**.** As compared to without foliar spray, foliar application of 2% DAP or 1% KCl at flowering and 15 days thereafter reported the viable nutrient management package to the pulse crops viz., blackgram, greengram, cowpea and horse gram for getting higher productivity [54]. Foliar spray of KCl (1%) + KNO_3 (1%) at the initiation of flowering and 15 days after the first spray increased the grain yield of greengram by 21.8 per cent over control (no foliar spray) [55]. Foliar application of micronutrients such as Fe, Mn and Zn considerably boost the growth and yield parameters of mung bean plant [56]. Foliar application of nutrient and growth regulator at pre flowering and flowering stage was seen on reduction in flower drop percentage in green gram [57]. The foliar application of N, P and K with chelated micronutrients has increased the grain yield of blackgram [58]. Subramani [59] found the favourable influences of foliar application of 1 per cent DAP + 0.5% urea + 0.25% magnesium sulphate on seed yield of black gram compared to control of no foliar spray. The foliar spray of 1% Urea or 2% DAP at 35 and 55 days after sowing as compared to control (no spray) resulted significantly higher growth parameters viz., plant height, leaf area index, dry matter production, yield attributes viz., number of flowers per plant, number of pods per plant, number of filled grains per pod and grain yield of black gram [60]. Foliar spray of potassium sulfate at the rate of 0.5% at 30 and 45 days after sowing of black gram resulted significantly higher number of pods per plant, number of seeds per pod, 100 grain weight, grain yield and haulm yield as compared to control (no foliar spray) [61]. Kumaran and Subramanian [62] reported that seed treatment with 25 ppm ammonium molybdate + 100 ppm $ZnSO_4$ + 100 ppm $FeSO_4$ followed by foliar spray of 1% DAP + 0.5% urea + 0.5% $MgSO_4$ + 0.25% $ZnSO_4$ at 50% flowering stage of black gram recorded the highest grain yield during the kharif and summer season. In pigeon pea foliar spray of 2.0 per cent urea at green floral bud stage of inflorescence followed by another spray 2 days after the first spray resulted Higher leaf area, leaf area Index and crop growth rate at flowering and also

showed that the growth attributes are positively correlated with seed yield [63]. In red gram foliar application of 0.1 per cent $ZnSO_4$ at the initiation of flowering stage significantly increased reproductive efficiency, no. of pods per plant, no. of seed per plant, size of pods, boldness and vigor of seeds over no foliar spray in Zn deficient plants. However there is little difference in between foliar spray and no foliar spray in Zn sufficient plants. Therefore they suggested that foliar spray beyond optimum requirement does not improve reproductive efficiency of plant [64]. In transplanted pigeon pea pulse magic (contained 10 per cent nitrogen, 40 per cent phosphorous, 3 per cent micronutrient and 20 PPM plant growth regulator) at the rate of 10 g/l to at 50 per cent flowering stage and 15 days after first spray resulted higher number of pods per plant number of seeds per pod,100 seed weight and seed yield [65]. Combined spraying of 0.5% $FeSO_4$ and 0.5% $ZnSO_4$ at 45 days after sowing proved most effective and increased the seed yield of cowpea by 43.1 per cent when compared to control [66]. In chickpea, the foliar spray of 2% urea solution twice at flower initiation and 10 day thereafter was significantly superior as compared to water spray for crop growth and seed yield [67]. Foliar spray of 2.0 per cent of N:P:K (19:19:19) in chick pea at the time of flowering as well as pod development stage resulted significantly higher plant height, number of secondary branches, total dry matter accumulation, yield attributes such as number of pods per plant, pod weight per plant and seed yield as compare to control (no foliar spray) [68].

Oilseeds

In mustard, foliar spray of sulphur (80 WP) at the rate of 1.25 kg/ ha at 75 days after sowing along with basal application of sulphur at the rate of 25 kg/ha increased the seed and oil yields by 10 and 12%, respectively over sole basal application of recommended fertilizer [69]**.** Foliar application of zinc at the rate of 0.5% at flower initiation and 50 % flowering stage in Indian mustard has recorded significantly higher plant height, primary branches and seed yield as compared to control [70]. Combined foliar application of micronutrients (Zn, B and Mo) at different stages of Indian mustard recorded significantly higher plant height, primary branches, dry matter production, number of siliquae per plant, seed yield, stover yield and oil content (33.5 %) of Indian mustard as compared to control of no foliar spray [71]. White [72] evaluated the effects of foliar-applied N fertilizer on oilseed rape. Foliar application of N at 40 kg N/ha through urea at the end of flowering significantly increased the seed yield and protein concentration as compared to control of no foliar spray. Foliar spray of B in soybean altered seed composition of well-watered and water stressed plants, indicating a possible involvement of B in seed quality parameters. They observed that foliar spray of boron at the rate of 1.1 kg B/ha in both watered and water stressed plant significantly increased protein, oleic acid and sucrose content over no foliar spray of boron [73]. In soybean crop, Foliar spray of nitrogen, phosphorous, potassium and magnesium at the rate of 100 mg per liter of water corresponding to each nutrient at pod formation stage resulted significantly higher number of pods per plant, seeds per pod, 100 seed weight and seed yield as compared to control [74]. Foliar applications of 2% DAP and 1% KCl along with benzyladenine 25 ppm had significantly increased the growth parameter and yield in soybean [75]. Osman [76] reported that foliar application of Zinc at 0.4 per cent in soybean increased the seed yield as compared control (no foliar spray of zinc). Foliar spray of 2% DAP twice at flower initiation and pod formation stages of crop growth resulted in significantly higher number of pods per plant, number of seeds per pods, seed index and grain yield as compared to control (no foliar spray of DAP) [77].

In sunflower, foliar application of zinc at the rate of 0.5% at 35 and 55 days after sowing of sunflower has recorded significantly higher plant height, number of leaves and stem girth, head weight, 100 seed weight and seed yield as compared to control [78]. Foliar spray of boron at the rate of 0.2% at ray floret stage in sunflower had recorded significantly higher seed set, total number of seeds per head, test weight, seed yield as compared to control [79]. Foliar application of boron at the rate of 0.2% at 45 and 55 days after sowing of sunflower has recorded significantly higher number of leaves and dry matter production as compared to control (no foliar spray of boron). This was mainly due to boron which helps in cell differentiation translocation of photosynthates that leads to increase number of leaves and dry matter production [80]. The effects of foliar application of zinc and manganese on oil content and fatty acid profiles in safflower cultivars under drought conditions and found that the zinc and manganese foliar applications significantly increased palmitic and oleic acids, whereas these foliar applications decreased linoleic acid per cent [81]. Combined foliar application of iron at the rate of 0.5% + zinc 0.5% at 30 and 65 days after sowing of safflower has recorded significantly higher growth parameters like plant height, no. of leaves, primary, secondary branches per plant and dry matter production as compared to control [82].

Foliar spray of boric acid at the rate of 0.2% at 60 days after sowing of niger has recorded significantly higher 100 seed weight, seed yield, oil content, and oil yield as compared treatment of no foliar spray [83]. Foliar spray of sulphur at the rate of 2% as aqueous solution of ammonium sulphate in canola, significantly improved number of pods per plant, productive pods per plant, grains per pod, pod length, 1000 grains weight and grains oil content as

compared to control (water spray only) [84]. Supplemental foliar application of nitrogen through 1% urea in both soil applied nitrogen levels control (0 kg/ha) and recommended dose (115 kg/ha) significantly increased the growth, yield and yield components of sunflower as compared to no foliar spray and water spray. The increase in yield with 1% urea spray was recorded up to 1.37 t/ha in comparison to water spray (1.07 t/ha) and no spray (1.00 t/ha). Therefore, they reported that reasonable yield can be achieved by applying foliar application of urea (1%) as a supplemental source to soil applied nitrogen [85]. In groundnut, application of Zn and B through foliar application recorded higher pod and haulm yield, seed weight and shelling percentage compared to soil application [86]. Zinc spray at 0.25% at button stage of sunflower had a significant influence on plant height, 100 seed weight and oil content [87].

Conclusion

It can conclude on the basis of research findings that foliar nutrition can be a potential mean to improve productivity and quality of field crops. It needs to be an integral part of the crop nutrient management package for successful and sustainable production of field crops.

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