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REVIEW ARTICLE **OPEN ACCESS**

Impacts of foliar nutrition on cereal crop growth and productivity: A Review

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ABSTRACT

Nature greatly influences cereal crop plants growth and yield. Proper timing of fertilizer, irrigation, insect, weed, disease control and harvest can improve yields significantly. Knowledge of the plant growth process provides the means to enhance the maize crop growth. The plant makes its determination as to what it can (has the potential to) produce at the early stages of growth. Hence, it's very important for the plant to have the ideal conditions and right nutrients at these critical stages of its life to perform the initiation to the fullest of its practical potential. Nutrient application timing is very important to maximize the potential response from foliar applied nutrients. Higher yield and profits can be obtained by supplying the nutrients to the plant at critical stages of development. The yield of cereal crop plants is based on the number of kernels per ear and kernel weight. These factors are predetermined at the particular leaf stage and are influenced by the availability of nutrients and environmental conditions. At present, the nutrients are applied only at the time of sowing and in addition nitrogen is top dressed at 45 days after sowing. Timing of nutrient demand and acquisition by cereal crop plants is nutrient specific and associated with key vegetative or reproductive growth stages. Thus, the knowledge of dynamics of nutrient accumulation to sink organs and the fate of foliar-applied nutrients at specific growth stages would provide useful information to deliver nutrients more efficiently to meet requirement, thus improving nutrient management and sustainable intensification and obtaining greater yield.
***Key words**: Cereals, growth, nutrients, foliar spray, and higher yield*

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INTRODUCTION

The nutrients are known to alter the various physiological and biochemical functions which finally influence on the yield of the crop. In recent years, the use of nutrient as foliar spray is gaining importance in improving the yield potential and also the quality produced in several crops as to meet out their nutrient requirement in spite of abrupt soil conditions. Foliar application of nutrients constitutes one of the important milestones in the progress of agriculture production. Foliar applications are done for quick and efficient utilization of nutrients, elimination of losses through leaching and fixation and helps in regulating the uptake of nutrients by plants. Foliar fertilization has been documented as early as 1844 [20], when an iron sulfate solution was sprayed as a possible remedy for "chlorosis sickness" to correct iron deficiency and was widely used to correct nutritional imbalances in plants. Thus foliar application of nutrients, conceptually over 100 years old, is gaining importance in many crops in recent years. 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. Other advantages are quick compensation of nutrient deficiency and application of lesser rates and thus, reducing toxicity which arises from excessive accumulation of elements and preventing nutrients fixation in the soil. It is also determined that during crop growth, supplementary foliar fertilization increase plants mineral status and improve crop yields [23]. It is also confirmed that, foliar nutrition gives better results if plant cultivation is conducted on soil with optimal pH value and level of mineral nutrients [38]. Foliar spray of 3 per cent potassium concentration was more efficient for increasing growth and yield of maize crop as compared to soil application and fertilization of potassium fertilizer [2].

Crop management practices can be adopted by applying fertilizers through soil as well as foliage. Foliar application is most effective when roots are incapable of absorbing required amount of nutrients from soil due to some reasons like high degree of fixation, lack of soil moisture, losses from leaching and low soil temperature [39].Under rice fallow situation, there is no possibility of basal application of fertilizer for pulses, since the pulses are sown prior to harvest of rice crop and fertilizer incorporation becomes impossible. Under these circumstances foliar application of nutrients would be more appropriate, efficient and economical than the soil application [12].Supplying a plant's major nutrient needs (N, P and K) is most effective and economical via soil application. However, for short and/or critical growth periods of a crop, foliar application has proved to be an excellent method as supplementing N-P-K needs [14].The efficacy of foliar fertilization is higher than that of soil fertilizer application under drought conditions [1] and in saline soils. In such conditions, the required nutrients are supplied directly to the location of demand in the leaves and are quickly absorbed. Another reason for high efficacy of foliar application is the independence of root activity and soil water availability [37]. Application of nutrients through foliar spray at appropriate stages of growth becomes important for their utilization and better performance of the crop [24].Foliar applications should be timed to provide needed nutrients during the yield potential determining time frame of plant development, which will in turn favorably influence the post reproductive and development stages [36]. The existing research findings impacts of foliar nutrition on crop growth and productivity are well marked in various crops which are reviewed in this article and some of them are discussed here under.

MORPHOLOGICAL PARAMETERS

The plant makes its determination as to what it can (has the potential to) produce at the early stages of growth. Hence, it's very important for the plant to have the ideal conditions and right nutrients at these critical stages of its life to perform the initiation to the fullest of its practical potential. Nutrient application timing is very important to maximize the potential response from foliar applied nutrients. Urea spray at the rate of 6 per cent during the V12 stage in maize improved the plant height (166 cm) and leaf area (299 cm2). Days to tasseling, silking and maturity were delayed significantly when urea was applied at the rate of 6 per cent at V12 stage of maize [10]. Similarly , [18] also reported that the foliar fertilization of zinc (0.5% $ZnSO_4$) and Boron (0.3% H_3BO_3) to maize in calcareous soil recorded significantly higher uptake of zinc (45.2 mg kg^{-1}) and leaf dry matter production of maize. The foliar application of 0.5 per cent boron as a boric acid at early, mid and late whorl stages resulted in taller plants (195.05 cm), thicker stem girth (5.21 cm), more number of green leaves (8.00) plant-1, less number of dry leaves (3.00) plant-1, more fresh (58.04 t ha-1) and dry fodder yield (17.59 t ha-1). Soil applied boron at 2 kg ha-1 did not show effective improvement in growth and yield of maize crop as compared to foliar applied boron[44]. . According to [19] data showed that foliar NPK fertilizer at 125 per cent in maize resulted in remarkable increase in fresh weight (284.68 g plant-1) and dry weight (129.35 g plant-1). The foliar application of boron was carried out after 20 days of emergence at 0, 0.15, 0.30 and 0.45 kg of boron per hectare. The results revealed that the foliar application of boron at 0.3 kg ha-1 at 20 DAE in maize increased plant height (163.1cm), leaf area (19 cm2) and stem diameter (3.138 cm) [47]. The response of maize to foliar application of nitrogen (2%) from different sources viz. urea, ammonium sulphate (AS) and calcium ammonium nitrate (CAN) at different application time (15, 30, 45, and 60 days after emergence) and found that plant height (203 cm), leaf area (451cm2) and biomass (9145 kg ha-1) was increased when foliar-N was applied late (45 and 60 DAE) than early (15 and 30 DAE) application[4]. [2] noted significant differences for days taken to 50 per cent pollen shedding and 50 per cent silking which were at the lowest (53.0 and 54.7 days, respectively) under 3 per cent K2O foliar spray at 40 and 65 DAS. More number of days were noted for 50 per cent pollen shedding and 50 per cent silking (60.0 and 61.3 days, respectively) in control (no potassium), followed by soil applied K fertigation. The highest plant height (187 cm) was recorded under 3 per cent K2O foliar spray. The foliar spray of 1 per cent ZnSO4) at V9 stage in maize recorded the maximum plant height (191.22 cm). El-Azab (2015) results revealed that combined foliar application of zinc (2%) with NPK (19:19:19) at 5th leaf stage significantly improved plant height (259.81 cm), leaf area (635.03 cm2) and dry weight (161.41 g) compared to foliar NPK[16]. The soil application of recommended dose of N, P2O5, K2O along with foliar application of ZnSO4 @ 1.0 per cent during grand growth stage in maize recorded significantly higher plant height (205.20 cm), stem diameter (29.70 mm), leaf area (93.28 dm2) and dry matter production per plant (409.95 g) [26]. The integrated use of foliar potassium and zinc spray at 25 and 50 days after sowing @ 1.0 and 0.1 per cent, in maize recorded less number of days (49.33) to reach 50 per cent pollen shed and minimum number of days (53.33) to 50 per cent silking with increased leaf area (3814.3 cm2) and plant height (225.33 cm) compared to control [10]. [45] they found that days to tasseling were delayed to 53 days, days to silking were delayed to 55 days and days to maturity were delayed to 97 days when foliar urea was applied @ 7 per cent at V7 + V10 stages over control in maize. Plant height was 177 cm tall and average leaf area was 353 cm2 wider when applied with foliar urea @ 7 per cent at V7 + V10 stages of maize. The integrated use of 75 per cent RDF, foliar application of 1.5 per cent 19:19:19 spray (at 20 and 40 DAS), 0.2 per cent ZnSO4 and 0.1 per cent FeSO¬4 (at 30 DAS) enhanced growth parameters viz., plant height (144.91 cm), leaf area (9229.37 cm2 plant-1), dry matter in leaves (67.11 g plant-1), dry matter in stem (85.17 g plant-1) and total dry matter (152.28 g plant-1) in baby corn[34]. The effect of zinc nutrition on morphological characters in chickpea and reported that soil application of ZnSO4 @ 10 kg ha-1 and foliar application of ZnSO4 @ 0.5 per cent increased plant height (40.85 cm), number of branches (10.27) and delayed days to 50 per cent flowering (37.93) [42].

PHYSIOLOGICAL PARAMETERS

The foliar application of potassium (K_2O) at 3 per cent at 40 and 65 DAS in maize increased photosynthesis rate than soil applied potassium. But the foliar treated plants showed less transpiration rate than soil applied potassium[2]. [29] they reported that zinc foliar treatment gradually increased photosynthetic rate at a steady level but declined with increasing zinc concentration in maize. [10] they showed that integrated use of foliar potassium and zinc spray at 25 and 50 days after sowing @ 1.0 and 0.1 per cent, respectively in maize showed maximum leaf area index (LAI) (37.80), higher photosynthetic rate (25.31 µ mol m-2 s-1), lowest transpiration rate (3.96 m mol m-2 s-1), maximum crop growth rate (28.14 g m-2 day-1) and net assimilation rate (8.16 g m-2 day-1) . The results revealed significantly that boron foliar application at 4 mg l^{-1} at V6 and tasseling stage of maize improved photosynthesis rate (34 %), stomatal conductance (26 %) and transpiration rate (21 %) as compared to control[30] . [35] they found that foliar application of combination of micronutrients (boron, zinc, molybdenum, iron, manganese, copper and cobalt) enhanced leaf area index (2.24), specific leaf weight (4.21 mg cm-2), specific leaf area (237.4 cm2 g-1), relative growth rate (101.3 mg g-1 day-1), crop growth rate (21.1 g m-2 day-1), net assimilation rate (1.20 mg cm-2 day-1) and leaf area duration (27.01). [50] they found that combined foliar application of zinc and boron significantly increased leaf area index (2.50) and crop growth rate (35 g m-2 day-1). [34] they found that integrated use of 75 per cent RDF, foliar application of 1.5 per cent 19:19:19 spray (at 20 and 40 DAS) 0.2 per cent ZnSO4 and 0.1 per cent FeSO¬4 (at 30 DAS) enhanced physiological parameters viz., absolute growth rate (1.79 g day-1), crop growth rate (1.77 g-2 day-1), net assimilation rate (5.56 g dm-2 day-1), leaf area index (6.84) and leaf area duration (78.53 days).

BIOCHEMICAL PARAMETERS

The plant performance is attributed to the genetic factors which are controlled by the differences in the biochemical parameters. It is well known that thousands of biochemical reactions are undergoing in plants simultaneously which ultimately decide the plant growth and development and the final yield. All the nutrients when given through foliar spray have been shown to influence these parameters in one way or the other. [9] They found that application of 0.5 per cent ZnSO4 spray at 30 and 45 DAS significantly improved chlorophyll content of leaves . [33] they reported that zinc exerts a great influence on basic plant life processes, such as (i) nitrogen metabolism – uptake of nitrogen and protein quality and (ii) photosynthesis – chlorophyll synthesis. The effect of foliar fertilization of iron, manganese and zinc on wheat. The nutrients were sprayed at tillering and heading stage. Among the three nutrients, foliar application of zinc at 0.5 per cent enhanced plant nitrogen absorption by increasing the nitrogen concentration in flag leaves of wheat plants. Whereas, all the micronutrient gave similar effect for phosphorus content[51]. [19] they reported that foliar NPK fertilizer at 125 per cent in maize resulted in remarkable increase in N (2.16 g plant-1), P (0.26 g plant-1) and K (1.53 g plant-1) nutrients absorbed by corn plant tissues over the soil application of NPK . The foliar application of zinc at flowering stage in blackgram and found that foliar application of zinc at pre flowering stage enhanced seed nutritional status by enhancing seed carbohydrate (sugar and starch content) [31]. [2] they found that potassium foliar sprays at 40 and 65 DAS in maize hybrid exhibited greater grain protein and starch contents than fertigation and soil application of potassium. Application of foliar K @ 3 per cent K2O showed higher grain protein (7.77 %) and starch contents (69.9 %). The results revealed that combined foliar application of zinc (2 %) with NPK (19:19:19) at 5th leaf stage increased N, P and K uptake in plants and grain compared to foliar application of NPK[17] . Boron spraying at booting stage enhanced plant pigments contents recording its highest mean values under normal water level. The highest mean values of chlorophyll a (31.08 and 31.42 mg g-1 FW) and chlorophyll b (12.50 and 11.90 mg g-1 FW), in the first and second seasons respectively were recorded in plants grown under normal irrigation level and sprayed with boron at booting stage [27]. [46] their study results revealed that foliar application of KNO3 (1.0 %) + MnSO4 (0.3 %) + ZnSO4 (0.5 %) at 30 and 50 DAS recorded increased chlorophyll a (1.42 mg g-

1 fresh weight), chlorophyll b (0.90 mg g-1 fresh weight) and total chlorophyll (2.32 mg g-1 fresh weight). [25] they stated that the effect of exogenous application of boron and zinc at different concentrations at three important growth stages (flushing, flowering and fruiting) on leaf area, chlorophyll content, carotenoids, stomatal count and yield of cashew var. Bhaskara. Irrespective of growth stages, foliar application of zinc sulphate (0.5 %) + borax (0.1 %) was found to be superior in all the parameters. The highest chlorophyll content (chl a, chl b and total chlorophyll), carotenoids and leaf area were recorded in trees sprayed with zinc sulphate (0.5 %) + borax (0.1 %). At flushing stage, spraying with zinc sulphate (0.5%) + borax (0.1%) resulted in highest stomatal number (31.05) whereas unsprayed (control) trees recorded least stomatal number (12.18). According to [15] the treatments were sprayed on plant leaves at the vegetative growth stage 30 and 40 DAS. The results revealed that foliar applications of iron and zinc significantly increased chlorophyll a, chlorophyll b content and sugar while, starch content shown significant enhancement effect by boron foliar spray as compared to control treatment

YIELD AND YIELD ATTRIBUTES

Nutrient management at the critical stage is an important factor which largely decides the yield of the crop produced. The economic yield is the manifestation of various biological events involving morphological, growth, biochemical and physiological changes which take place during development in accordance with the supply of light, water, temperature and nutrients. The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The production and translocation of synthesized photosynthates depend upon mineral nutrition supplied either through soil or foliar application and plant growth and development during early stages of crop growth. Foliar nutrition increases the utilization of plant nutrients more efficiently. Grain yield is an ultimate end product of many yield-contributing components, physiological and morphological processes taking place in plants during growth and development. Grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. This may be attributed to fulfillment of the demand of the crop by higher assimilation and translocation of photosynthates from source (leaves) to sink (grains) through supply of required nutrients by foliar spray. [48] they studied the effect of foliar application of boron at 617.5 ml in 247 liter of water applied at tillering, jointing, booting and anthesis stages in wheat and concluded that significantly higher number of fertile tillers (383.88 m-2), number of grains per spike (54.75), 1000-grains weight (43.04 g) and grain yield (4592 kg ha-1) were obtained at boron application at booting stage. [33] observed that the foliar application of zinc fertilizer at the range of 1 to 1.5 kg ha-1 sandy loam soil at the 5th leaf stage recorded the maximum length of cob (151.9 mm), number of rows per cob (15.04), number of kernels per cob (29.4), 1000-grains weight (275 g) and harvest index (43.2 %) compared to control. [8] they concluded that urea spray at the rate of 6 per cent during the V12 stage in maize improved the grains per cob (404), grains per line (29), 1000-grains weight (278 g), grain yield (2989 kg ha-1) and stover yield (8345 kg ha-1).[22]they reported that foliar spray of nitrogen @ 3 per cent at the beginning of seed filling gave higher grain rows ear^{-1} (15.3), grains per row (46.33), number of seeds ear^{-1} (714.1) and grain yield (2037 g m^{-2}). The foliar application of zinc @ 0.5 per cent (ZnSO4.H2O) at tillering and heading stage of wheat significantly increased grain yield (3416 kg fed-1), 1000-grains weight (34.7g), straw yield (4173.1 kg fed-1) and number of grains (42.4 spike-1) [51]. [49] they found that foliar application of 1 per cent zinc (ZnSO4) at 9th leaf stage of maize increased the grain yield (8.76 t ha-1) and maximum value of harvest index (78.37 %) compared to foliar application of zinc at anthesis stage and soil application of zinc. [16] they found that foliar spray of 1 per cent ZnSO4 at V9 stage in maize recorded the maximum numbers of rows per cob (15.47), number of grains per cob (506.22), 1000-grain weight (280.78 g), biological yield (21.48 t ha-1), grain yield (8.76 t ha-1) and harvest index (78.37 %). He also concluded that foliar application of ZnSO4 at V9 stage gave 12 per cent more grain yield than soil applied and 38 per cent higher than control. [21] they found out that foliar boron, solubor applied at V4–V6 at resulted in higher grain yield (2.24 kg ha^{-1}) than VT applications in maize. The grain yield (89.73 q ha-1 was significantly higher with soil application of recommended dose of N, P2O5, K2O along with foliar application of ZnSO4 @ 1.0 per cent during grand growth stage due to improvement in yield attributing characters like cob length (21.3 cm), cob girth (16.7), number of grains per row (44.33), total number of grains per cob (614.00), grain weight per cob (194.50 g) and 100-grain weight (38.73 g) [26]. The effects of foliar application of nitrogen, boron and zinc in maize and observed that foliar application of boric acid recorded highest number of kernels per cob (590) than foliar application of urea at the grain filling stage whereas foliar application of urea increased the grain yield (115 g plant-1) and harvest index (45 %) particularly when applied before flag leaf emergence and when N availability was limiting. Foliar application of zinc in tasseling stage had the highest 100-grain weight[43]. [28]they revealed that integrated use of foliar potassium and zinc spray at 25 and 50 days after sowing @ 1.0 and 0.1%, respectively enhanced number of grains per ear (684.22), 1000-grains weight (384.67g), grain protein content (8.65 %), grain yield (6327.5 kg ha-1) and harvest index (38.76 %) . The highest mean values were obtained due to boron application viz. spike length (11.86 and 11.72 cm), number of spikelets per m2 (332.65 and 324.35), grain yield per plant (21.56 and 20.26 g), 1000-grain weight (35.2 and 37.4 g) and grain yield (1.87 and 1.85 ton fed-1), which were recorded at normal irrigation level (100 % from the amount of water consumption for wheat) with boron spraying at booting stage (B1) in the first and second seasons, respectively. Furthermore, boron application significantly enhanced all studied growth traits under water stress levels (50 % from the amount of water consumption for wheat) compared to boron untreated plants[27]. [13] They concluded that there was a significant result observed in quality (crude protein) and yield with soil application of ZnSO4 @ 25 kg ha-1 + foliar spray of ZnSO4 @ 0.2 per cent at 25 and 40 DAS over control (no zinc) application. [11] they reported that combined foliar application of boron (0.5 %) and zinc (1 %) at 9th leaf stage in maize produced more cob length (22.60 cm), girth (5.56 cm), shelling percentage (71.13 %), number of grains per cob (627.33), number of grains per row (42.26), 1000-grain weight (313.33 g), harvest index (42.61), grain yield (9.03 t ha-1) and biological yield (21.23 t ha-1). Maximum marginal rate of return was obtained with foliar application of both Zn and B and using foliar Zn alone. Integrated B and Zn application produced more marginal rate of returns both in soil and foliar applications. Use of foliar Zn application also depicted promising results while foliar or soil B application without using Zn enhanced cost of production. [34] they found that yield attributes like number of cobs plant^{-1} (3.67), length of babies (10.90 cm), girth of babies (4.07 cm) and weight of babies (23.87 g cob^{-1}) was significantly higher when integrated application of 75% RDF, foliar application of 1.5% 19:19:19 spray (at 20 and 40 DAS), 0.2% $ZnSO_4$ and 0.1% $FeSO_4$ (at 30 DAS) was given to baby corn. Baby corn and green fodder yield (244.05 q ha^{-1} and 85.16 t ha^{-1}, respectively) also found to be enhanced.

CONCLUSION

Nutrient management at the critical stage is an important factor which largely decides the yield of the crop produced. The economic yield is the manifestation of various biological events involving morphological, growth, biochemical and physiological changes which take place during development in accordance with the supply of light, water, temperature and nutrients. The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts.The production and translocation of synthesized photosynthates depend upon mineral nutrition supplied either through soil or foliar application and plant growth and development during early stages of crop growth. Foliar nutrition increases the utilization of plant nutrients more efficiently**.** The growth and development of plant is a complex process and is under the control of three main factors viz., genetics, environment and endogenous growth substances. The present study reveals whether the role of foliar nutrition in manipulation of growth and development in crop plant and to know which nutrient maintains the photosynthetic apparatus for long time and and also it helps in identifying which nutrient improves yield, yield components and protein content of crop plants .

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