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Foliar nutrition in cereals: A review

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Abstract
Cultivation of cereals done in large scale which leads to depletion of the nutrients from soil. Application of nutrients to the soil would not be always an efficient way solely as this method does not deliver the nutrients efficiently from soil to the plants due to impact of many physicochemical attributes of soil like organic matter levels, pH of the soil, soil compaction, soil temperature, texture, poor aeration and nutrient deficiencies etc. Lower nutrient use efficiency, higher input costs, poor quality produce and decline in the yields triggers global food shortages. The solution to surmount these issues would be the supplementary foliar nutrition. Though soil fertilization methods are very common, foliar nutrition methods are more effective as well as economical under certain circumstances. Foliar fertilization is more crucial as it enables quick and easy penetration and absorption of nutrients into the plants. Foliar nutrition mainly used for supplementing the nutrient doses. Supplementary foliar nutrition during the crop growth triggers mineral levels in plants and enhances the crop yields. Keeping all these facts in view, significance of foliar nutrition, impacts of foliar nutrition of macronutrients and micronutrients on cereal crops, appropriate source and timings as well as advantages and disadvantages of foliar nutrition were discussed in this paper.

Keywords: Foliar nutrition, cereals, nutrient use efficiency, yield

Introduction

With the increase in world population, there is decline in productivity and the crop's quality because of deficiency of multi nutrients especially secondary nutrients and micro nutrients are two significant challenges triggering nutritional and food insecurity (Reena *et al*., 2018) [49]. Agricultural production would have to be raised by 70% for solving food related problems for increasing population from 7 to 9.2 billion by 2050. Worldwide, above 840 million people have no enough food, 3 billion are suffering by multi nutrient deficiencies. About 80% of crop production's future growth would be from limited cultivable lands by advancements in yields (FAO, 2015) [20]. In developing countries, multi nutrient deficiency for food crops as well as shortage of food is the 5th significant reason for death and diseases in humans (World Health Report, 2002) [62]. Research investigations point out that fertilizer is accountable for about half of all the crop production. As a result, fertilizer would play significant role to meet challenges of nutrients and food security. Functions of nutrients applied by fertilizers are irrefutable in crop production because of their crucial roles in the plant metabolism (Marschner, 2012) [37]. Both macro nutrients and micro nutrients are crucial for the physiology, growth, development of plants and eventually crucial for improving quality, productivity of field crops (Reena *et al*., 2018) [49].

Plants utilizes various inorganic nutrients as well as O_2, CO_2, water for their growth and development. Many of these nutrients exists inherently in the soil and may depleted during various environmental conditions. Hence, soil fertilization which is the common practice is essential but this practice has various limitations regarding bioavailability of nutrients for crops. Soluble nutrients like nitrogen are prone to leaching losses whereas the availability of phosphorous, potassium and many micronutrients in soil solutions is low as they are fixed as insoluble forms on soil complex (EL-Ramady, 2014) [17]. Though soil application method is common, it does not effectively deliver nutrients to plants from soil. Present status of NUE is low in macronutrients like Nitrogen (NUE is 30 to 50%), Phosphorous (NUE is 15 to 20%), Sulphur (NUE is 8 to 12%), whereas in micronutrients NUE is less than 2% because of deterioration of physical, biological, chemical health of soil as well as the situations which limits growth of roots in the soil for nutrient uptake (Vision, 2013) [56]. Nutrient deficiency in soils and inefficient fertilizer application methods results in food shortage because of increased input cost and decreased yield and quality of crops (Reena *et al*., 2018) [49].

A solution to get over the issues of inefficient fertilizer supply is the supplementary foliar feeding (Kolota, 2001) [33]. Foliar nutrition or Foliar fertilization means supplying one or more essential nutrients through foliar spray to crops to supplement the traditional method of soil application. Although soil application method would not replace completely by the foliar nutrition, but it definitely lifts growth of the plants. Objectives of the foliar application of fertilizers are it triggers crop production to improve yields, it quickly ameliorates nutrient deficiencies at critical periods, it also encourages growth of the crops during abiotic stress situations further it also enhances nutrient use efficiency (NUE) as well as quality of the crops. Foliar nutrition within last decades, has turned into the most efficient method for increasing efficiency of the fertilizer usage, enhancing the yields and quality of crops during varying ranges of climate (Waisel *et al*., 2002) [57]. Foliar nutrition could be more efficient, profitable and appropriate method than the soil application of fertilizer (Balusamy and Meyyazhagan, 2000) [12]. Though foliar nutrition has several benefits, complete potential of foliar feeding has not realized because of inadequate knowledge about the processes involved. It is essential to break this knowledge gaps which impedes development of the effective and enhanced foliar feeding processes. Focusing on timing of foliar spray and using effective and right product at right situations could increase foliar nutrition response (Reena *et al*., 2018) [49]. This review focuses on foliar nutrition and its impacts on cereals.

Significance of Foliar Nutrition

Fertilizer acts as a significant source in agricultural practices for increasing the yields of crops. Among all nutrient application methods, foliar application of nutrients is the most significant method of nutrient application as it enables quick and easy consumption of the nutrients through penetrating into stomata or the cuticle then nutrients enter into cells (Latha and Nadanassababady., 2003) [35]. Foliar nutrition has some benefits like quick nutrient absorption by tissues, enhanced movement up to developing plant parts, removing leaching and fixation losses, controlling nutrient uptake by crops, triggering yield and quality of crops by enhancing nutrient utilization (Elayaraja and Angayarkanni, 2005) [18]. Soil application of micro nutrients has some disadvantages like residual impacts and consolidation which can be solved by foliar nutrition (Wang *et al*., 2004) [58]. Focus on foliar fertilization is increasing due to many compensations of this method such as efficient and quick responses to the requirements of crops, independent on soil conditions and less required products. Supplementary foliar nutrition during the crop growth triggers mineral contents of the plants and enhances yields of the crops (Kolota and Osinska, 2001) [33]. Foliar nutrition at proper and appropriate growth phases is crucial for their uptake and for improving the crop performances (Anadhakrishnaveni *et al*., 2004) [8].

Source of Foliar Application

Nature of the foliar fertilized materials describes ease of nutrient absorption into the foliage as well as the capable burning impacts on the foliage. compounds applied through foliar nutrition must be more soluble. Further to enhance the permeability as well as absorption of the nutrients via cuticle, surfactants such as Tween, Sodium stearate are essential (Gupta *et al*., 2016) [24]. For iron biofortification of the cereals, researchers investigated foliar fertilization with iron chelates and iron sulphate. Obviously, foliar fertilization of chiefly used iron sulphate significantly triggered iron contents in grains of wheat, maize and rice (Arabhanvi and Hulihalli, 2018). Zinc forms mainly used for spraying are zinc sulphate, zinc organic acid chelates, zinc nano particles and nano chelate. Other sources of zinc found to show same or lower impacts on the grain zinc contents in the cereals (Shivay *et al*., 2016) [51]. Among copper foliar feedings, mainly copper sulphate is in usage (Stepien and Wojtkowiak, 2016) [52, 53]. However, similar to zinc and iron chelated sources are also crucial (Hussain *et al*., 2020). Sodium selenate, sodium selenite are chief sources for Se foliar fertilization. For iodine foliar fertilization potassium iodide as well as potassium iodate were chiefly used. These 2 sources equally increase iodine levels in cereal grains but for high strength iodine sprayings, potassium iodide found to be a best source (Cakmak *et al*., 2017) [14].

Timing of Foliar Application

Growth Stage

Suitable growth stage is one of the crucial aspects of the foliar nutrition. Foliar feedings should be regulated to stipulate required nutrients at yield potential describing time period of the plant development which would in turn further influences favourably post reproductive developmental stages. Low rate and multiple applications would show suitable response within these time periods whether the plant is nutritionally good or not. Careful monitoring of the plant growth stages on weekly as well as sometimes on daily basis is required. Foliar fertilization of N (@34 or 67 kg nitrogen per hectare) at Growth Stage 30 or Growth Stage 32 (2nd node appeared on main stem) in the wheat crop by UAN or by UAN-S increased foliage burning with increasing rates of nitrogen. No impact seen on grain yield with either UAN or UAN-S when compared with the soil applications at either nitrogen rates. Further, no variation was seen in foliage burning between 2 foliar sources at Growth Stage 30 (Phillips and Mullins, 2004) [45]. Foliar mineral fertilizations during early growth stages of the cereals like tillering, stem elongation may increase the mineral densities of grains (Arabhanvi and Hulihalli, 2018).

Meteorological Conditions

Environmental conditions like temperature, windspeed, humidity and day time affects the biological and physical aspects of the foliar feedings. Plant tissues permeability would be the most crucial thing in plant nutrient absorption phenomena. Calm, moist and warm conditions favour more tissue permeability (Rajasekar *et al.*, 2017). Day timing of the foliar feeding is crucial aspect for the effective absorption of applied nutrients as well as for avoiding foliage injury. For improved foliar nutrient's absorption, stomata must be open as well as temperature during spraying should not be too more to trigger foliage burning. During afternoon hours when temperature is less after 2 to 3 PM would be the suitable time for foliar feeding. Windy day is another major factor affecting the foliar feeding which would drift the nutrient spray solutions. Therefore, for foliar applications windy days must be avoided. Minimum 3-4 hrs are required for applied nutrients to get absorbed into the plant leaves. Thus, there could not be any rains for minimum 3-4 hrs after foliar applications (Fageria *et al*., 2009) [22].

Crop Conditions

Generally, crops which are nutritionally good shows more responses to foliar nutrition. This may be because of improved tissue quality permitting maximum absorption of the nutrients into the leaves and stems and also because of better crop growth vigour permitting movement of translocatable nutrients to other parts of the plant. under moisture and heat stress conditions, crops show less responses for foliar feedings because of poor vigour and lower stem and leaf absorption rates. Foliar applications if done before moisture and heat stress conditions, enhances crop performance as well as yield. Recovery from herbicide stress and cold conditions would be hastened through suitable foliar feedings. However, because of economical and practical restrictions on amount of nutrients that could be foliar feeded for showing favourable growth responses foliar nutrition have restricted rescue potential (Rajasekar *et al*., 2017).

Effect of Foliar Nutrition of Macronutrients on Cereals Rice

Alam *et al*., 2010 after conducting an experiment in boro rice found that soil application of urea recorded more yields, B:C ratio, increased N levels in rice over foliar feeding of urea. Count of effective tillers per Mt square, grain number per the panicle, total filled grains were more by following INM along with urea phosphate (@2%) foliar application during panicle initiation stage and further after ten days. The reason behind this improvement would be due to partitioning of the assimilates effectively from vegetative parts into the grains. The grain yields as well as straw yield were also more in addition to gross returns (Jagathjothi *et al*., 2012) [30]. Improved impacts in rice crop were observed on B:C ratio through foliar nutrition (Kundu and Sarkar, 2009). Khan *et al*., 2012 [32] concluded that foliar feeding with KNO3 (@1.5 and 2%) found to trigger yields in rice crop over soil applied K2SO4, this improvement was because of positive impacts on the tiller count, length of the panicles, 1000 grains weight and also count of the grains per panicle. More profits and B:C ratios were found from KNO3 (@1.5% sprayings). Exogenous K feedings shown improved impacts on tillering (Arif *et al*., 2010) [9].

Wheat

Foliar and soil application of nitrogen improved wheat crop yields (Zafer and Muhammad, 2007) [63]. One would expect foliar phosphorous application to show enhanced use efficiencies than soil application, but the information available is limited. Experiment was conducted to observe impact of foliar P on grain yield, phosphorous (P) uptake, use efficiency on winter wheat. Foliar fertilization of Pat Feekes 7 (GS=2nd node of the stem formed) triggered grain yields as well as uptake of P over no foliar P application plots. While, use efficiency of P was observed to be high at Feekes 10.54 (GS= flowering completed). Therefore, lower foliar P rates would correct the mid-season phosphorous (P) deficiencies in winter wheat which leads to high phosphorous use efficiencies (Mosali *et al*., 2006) [39]. Increased length in spikes was observed from foliar N sprays at high dose. Increased availability as well as absorption of the N under foliar fertilization triggered more grains per the spike as well as 1000 grain wt. under nitrogen levels, higher grain yields were obtained from plots where higher foliar doses were used (Bakht *et al*., 2010) [11]. Foliar fertilization of wheat with nano fertilizer ‘super micro plus’ (@ 1 kg per ha) was found to be optimum quantity for the growth, nutrient uptake, productivity of fertilizer and yield. Positive impact of the combined nano (NPK) fertilizers as well as traditional NPK + TE supply on the growth and yield of wheat over control (Al-Juthery *et al*., 2018) [5].

Maize

Foliar fertilization with NPK in maize found to increase root length, fresh wt. and dry weight, leaf area and NPK, chlorophyll levels in leaves. However, effectiveness of the foliar feedings was restricted by holding capability of liquid spray solutions on leaf surface area. Leaves with more surface area hold and absorb more spray solutions. Foliar feedings only used as supplemental method for correcting the deficiencies but not recommended to depend entirely on foliar applications and it would not replace soil application of major nutrients (Ling and Silberbush, 2007) [36]. Soil fertilization with RDF in combination with foliar feeding of NPK WSF (19:19:19: @ 0.5%) at stages such as six leaf phase and at the tasselling phase found to activate or trigger the kernel yields when compared with other plots. Increased net benefits, B:C ratio were observed from plots where RDF with foliar feeding of WSF (@0.5) done at six leaf phase, tasselling phase (Nirere *et al*., 2019) [42]. Stigler *et al*., 2010 [54] reported that Foliar fertilization is the most efficient way to correct the nutrient deficiency issues and to overcome inability of soil for transferring nutrients to maize crop during situations like low moisture. Foliar feeding of NPK shown positive and beneficial effects on yield of maize crop over the soil application method (Abd EL-Fattah *et al*., 2012) [1].

Sorghum

In sorghum, foliar feeding of nitrogen (N@ 4.5 gm. L^{-1}) reported more grain yields in both spring as well as autumn seasons. Foliar fertilization with nitrogen at 3 different stages (vegetative stage, booting stage, 25% flowering stage) reported significant impacts only on leaf area and height of the plant in autumn but on biological yields during both seasons, when foliar fertilization at vegetative stage shown highest mean values for these characters (Abood *et al*., 2017) [2]. Foliar fertilization with P, K triggered P, K contents in both leaves and grains. Amount of increase in their contents was equal to both increments in the P, K levels. Further, N levels in grains and leaves raised with addition of foliar P as well as K. while, there was decrease in sodium in grains and leaves with P, K foliar application. Ca decreased in foliage and increased in grains with foliar P, K applications. Thus, foliar P, K surmount negative impacts of salinity as the evident from the increased leaves, shoot biomass, grain yield of sorghum (Hussein *et al*., 2010) [26]. Ishtar variety of sorghum found to be more superior for leaf area and plant height characters in spring as well as fall seasons for foliar potassium feedings over Lelo and Inkath cultivars. Grain yield and HI values increased in Ishtar with foliar potassium sprays (Abood and Salh, 2018) [3].

Oats

Foliar fertilization of Shafaa, Oat 11 varieties of oats with potassium and urea done at elongation stage, tillering stage and also at flowering phase. Shafaa cultivar shown more responses than Oat 11 for attributes such as tiller count, spike number, grain and biological yield and HI. Foliar feeding with urea and potash recorded maximum tiller count, spike number, grain yield and HI over control plots (Alrubaiee *et al*., 2019) [7]. Heyland and Werner, 2000 [25] reported that foliar applications are crucial to decrease consumption of energy needed for ion transfers within plants. Impacts of foliar feeding stages and the concentrations (levels) of leaf fertilizers were observed on growth and yield of oats. (Ram *et al*., 2017) [46]. Foliar feeding at starting stages of vegetative growth triggered height of the plant and tiller number. Foliar feeding at beginning of the flowering phase triggered wt. of 1000 grains, panicle count, grains, tiller and panicle number. Application of leaf fertilizers (@3000 mg L^{-1}) at beginning of the flowering period triggered profits in oats (Mahmood and Zeboon, 2017) [46]. Quantity of fertilizers and water volume for foliar fertilization of the macronutrients are given in table 1.

Table 1: Quantity of fertilizers (Nutrients) and water volume for foliar fertilization of the macronutrients

Fertilizer (Nutrient)	Salt or Formulation	Kg for 500 lts water
Nitrogen (N)	Urea (Carbamide) ($CO(NH_2)_2$)	3 to 5 Kg
Nitrogen (N)	A. Ammonium sulphate ($(NH_4)_2SO_4$), B. Diammonium hydrogen phosphate ($(NH_4)_2HPO_4$), C. Ammonium chloride (NH_4Cl), D. Ammonium dihydrogen phosphate ($NH_4H_2PO_4$), E. Ammonium nitrate (NH_4NO_3)	2 to 3 Kg
Phosphorous (P)	Phosphoric acid (H_3PO_4)	2 to 3 Kg
Potassium (K)	A. Potassium nitrate (KNO_3), B. Potassium sulphate (K_2SO_4), C. Potassium chloride KCl	1.5 to 2.5 Kg
Calcium (Ca)	A. Calcium nitrate ($Ca(NO_3)_2$), B. Calcium chloride ($CaCl_2$)	1.5 to 2.5 Kg
Magnesium (Mg)	A. Magnesium nitrate ($Mg(NO_3)_2$), B. Magnesium sulphate ($MgSO_4$)	3 to 10 Kg

Source: Fageria *et al*., 2009 [22].

Effect of foliar nutrition of micronutrients on cereals

Rice

Anand *et al*., 2017 reported two foliar feedings of ZnSO4, FeSO4 and Borax, sulphur along with RDF found to increase height of the crop, shoot number, LAI and protein levels over other treatments. Foliar fertilization of rice was done with silicon using sodium silicate as a source. Foliar applied silicon has no impacts on height of the plant, kernel count, opaque kernel % and HI. Maximum diameter of grains and proteins levels of grains were observed from 0.50% silicon spray. Whereas 1.0% silicon spray gave higher no. of the effective tillers, straw yield, starch content in grains and paddy yield (Ahmad *et al*., 2013) [4]. Micronutrients like Si are most crucial for the sustainable cultivation of the basmati rice crop (Joseph, 2009) [31]. Brunings *et al*., 2009 [13] observed that Si is the crucial micronutrient required for the healthy, competitive growth of cereals in Asia including rice. Ma and Takahashi, 2002 recorded that sufficient Si uptake would trigger tolerance of the crops specially rice crop for the biotic as well as abiotic stresses. Lower levels of Si uptake triggers sensitivity of rice crop to diseases like stem rot, leaf blight, blast, grain discolouration and brown spot (Massey and Hartley, 2006) [38]. Wang *et al*., 2010 [59] observed that Si not evolved directly in the quality improvement but controls stresses and various diseases which maximizes quality of crops. Foliar feeding of two varieties of rice with nano zinc oxides done, where Tarom variety shown increase in height and spikelets count per the panicle over the Shiroodi cultivar. More effective tillers per the hill, 1000 grains wt. were recorded by spraying nano zinc oxides (@ 40 ppm) at mid tillering period and at PI and also spraying it at PI and full heading stages. Increased height, straw yield, grain yield were recorded with zinc oxide sprays (20 and 40 ppm) at PI and full heading stages (Ghasemi *et al*., 2017) [23].

Wheat

Generally, soil application of the micronutrients is not recommended under calcareous soils (Watersa and Renuka, 2011) [60] because of finite availability of micronutrients to crops but which is exception case for molybdenum (Rashid and Ryan, 2004) [47]. During these conditions foliar nutrition would be the more profitable and effective (Pandey and Gupta, 2012) [43]. Micronutrients plays crucial role in many physiological processes of the plants. Application of N in combination with the micronutrients triggers grain yields advantageous consumer and technological attributes. Cu, Zn and Mn are major micronutrients needed for the cereals. NPK application supplemented by copper triggered copper levels, gliadins in the grains. Foliar application of Zn in combination with NPK raised copper levels up to 14% and high molecular weight glutenin (HMW) 38.8% and low molecular weight glutenin (LMW) 6.7%. mineral nutrients in addition with manganese triggered iron levels in the wheat grains. It also increased gluten, grain hardness and protein contents (Stepien and Wojtkowiak, 2016) [52, 53]. Foliar application of the micronutrients is most significant method of the fertilizer application in the agricultural practices for increasing iron concentration in the grains as the foliar nutrients enables quick and easy nutrient consumption through penetrating stomata or the cuticle. Foliar fertilization of iron alone or with other micronutrients would help to trigger beneficial results related to growth and yield attributes of wheat (Rawashdeh and Florin, 2015) [48]. Foliar feeding with micronutrients such as Fe, Zn and Cu raised up plant height, no. of leaves and branches, dry weight of roots and shoots, leaf area, chlorophyll, nitrogen, phosphorous, potassium, copper, iron and zinc levels, protein, starch levels finally grain yields (Farhan and Al-Dulaemi, 2011) [21].

Maize

Maize is the major cereal crop in agricultural economy in world and also in India after rice and wheat crops. Maize is the versatile crop grown during varied environmental conditions. It has many uses and has yield capability much more than other cereals thus called as 'Queen of Cereals' (Naveenaa *et al*., 2018) [41]. Application of nutrients to crops at critical stages triggers yields and profits. Maize yield depends on kernel number per ear as well as on the weight of the kernel. Those factors determined in advance at particular foliage stage and affected by environmental conditions and nutrient availability. Suitable timing period for nutrient demand as well as acquisition by the maize crop is nutrient specific and it is accompanied with crucial vegetative and reproductive crop growth stages. Thus, the knowledge related to fate of the foliar feeded nutrients and nutrient accumulation at specific crop growth stages will stipulate beneficial information to supply the nutrients efficiently for meeting the crop requirements hence, enhancing the nutrient management, yields and sustainable intensification. Foliar ZnSO4 application (@0.5%) in addition with recommended fertilizer doses during V5 and V6 stages which are early growth stages triggered biochemical and physiological attributes which would further increase yield and yield related properties in maize (Naveenaa *et al*., 2018) [41].

Barley

Foliar fertilization with NiSO4 (@0.2%) improved nutrient levels in the grains, growth and yield when compared with soil application. As nickel is costly product, foliar fertilization with it has importance in correcting the nickel deficiency problems in crop cultivation. Foliar application of 0.2% NiSO4 is economical over the soil application for correcting Ni deficiency thus, it is recommended for barley cultivation (Kumar *et al*., 2021) [34]. ZnO foliar application and G. mosseae inoculation in barley cultivar, Julgeh increased chlorophyll levels, Zn content, phytase activity of grains, soluble sugars (Moshfeghi *et al*., 2019) [40]. Copper involves in various enzymatic reactions. Manganese show impact such as reduction of the nitrates and hydrolysis of amides and peptides (Tobiasz-Salach and Augustynska-Prejsnar, 2020) Prejsnar. Iron and Soldo cultivars of barley shown raise in grain yields to foliar feeding of manganese over copper. While, Suweren variety shown better responses to foliar applied copper over manganese. Manganese foliar applications increased LAI relative to control recorded in crops fed by manganese (Mn) rather than copper (Cu). Barley fed with foliar micronutrients found to show increased crude ash and protein levels in the grains over control plots and great raise was seen after Cu application than Mn (Tobiasz-Salach and Augustynska-Prejsnar, 2020) [55].

RYE

Application of mineral fertilizers along with foliar feeding of micronutrients like Copper, Zinc, Manganese (@2.0%) triggered the protein levels in the grains of rye crop except for Copper (Stepien *et al*., 2016) [52, 53]. To improve the quality of cereal crops, protein as well as starch have crucial roles (Wojtkowiak *et al*., 2015) [61]. Mineral fertilizer application in combination with the micronutrients triggered phosphorous levels and potassium levels. Combined feeding of basic fertilizers with manganese and zinc reported to increase the manganese levels in grains when compared with treatments where no fertilizers were used and where only the mineral fertilizers were used (Stepien *et al*., 2016) [52, 53]. Quantity of fertilizers and water volume for foliar fertilization of the micronutrients are given in table 2.

Table 2: Quantity of fertilizers (Nutrients) and water volume for foliar fertilization of the micronutrients

Fertilizer (Nutrient)	Salt or Formulation	Kg for 500 lts water
Zinc (Zn)	Zinc sulphate ($ZnSO_4$)	1.5 to 2.5 Kg
Iron (Fe)	Ferrous sulphate ($FeSO_4$)	3 to 6 Kg
Manganese (Mn)	Manganese sulphate ($MnSO_4$)	1 to 2 Kg
Boron (B)	Sodium borate ($Na_2(B_4O_5(OH)_4).8H_2O$	0.25 to 0.5 Kg
Copper (Cu)	Copper sulphate ($CuSO_4$)	0.5 to 1
Molybdenum (Mo)	Sodium Molybdate (Na_2MoO_4)	0.1 to 0.15

Source: Fageria *et al*., 2009 [22]

Advantages Of Foliar Nutrition

Foliar nutrition stipulates quick utilization of elements and allows correction of the observed deficiencies in very little time than which would be needed by the soil application method. Authors observed that under favourable environmental conditions responses of crop to the soil applied nutrients seen in 5 to 6 days. While, responses of crops to foliar applied nutrients could be seen in three to four days. For few immobilized nutrients in soil like iron, foliar nutrition is more economical and efficient than soil application. During early growth stages when root is not completely developed, foliar nutrition has more advantage in absorption when compared with soil application. Nevertheless, for foliar nutrition proper Leaf Area Index is main requirement to maximize the spray interception. Micronutrients needed in smaller amounts, foliar application of these micronutrients is uniform than soil application (Fageria *et al*., 2009) [22]. The significance of foliar nutrition would lie in regulation and localization of enzyme systems which involved in the nitrogen assimilation. Mo ions are crucial parts of the co factor of various key enzymes of nitrogen fixation and nitrate reduction and uptake (Hristozkova *et al*., 2007) [29].

Disadvantages Of Foliar Nutrition

Soil applied fertilizers shows long influence on growth of plants. Whereas, responses of plants to foliar applied fertilizers are only temporary. Which means many foliar applications are required under excess nutrient deficiencies. Foliar nutrition is more successful in case of micronutrients but soil application method is successful in both cases macronutrients and micronutrients. The problem of foliage burning is seen if concentration of salt solution is more. Such problems are removed through soil fertilization. Wind is main cause of the differences in deposition of spray under foliar fertilization. Therefore, care must be taken on windy days to prevent irregular distribution of spray solution. This type of difficulties has not seen in soil fertilization method (Fageria *et al*., 2009) [22].

Conclusion

Foliar nutrition is increasing and the foliar nutrients would fill the gap, which then complements the soil applied fertilizers. Proper usages of foliar nutrients would be treated as the sustainable method for managing the mineral nutrition. Still farmers require more knowledge about quality, need, effectiveness of the foliar nutrition. Foliar feedings increase concentrations of the nutrients like iron, zinc, copper etc in the grains of cereals. This increase of the mineral densities in the grains would not be possible with other approaches because, compared to nutrient uptake from soil, foliar fed nutrients are available readily for the plant metabolism as well as grain accumulations. Good sources of foliar nutrients were suggested for foliar fertilization. Generally, 2 to 3 foliar feedings during the pre-flowering stage to milking phase were recommended. Additionally, it is mentioned that soil application along with foliar feedings of nitrogen and potassium triggers mineral accumulation in the grains but phosphorous might decrease zinc. Foliar feeding of macronutrients, micronutrients have crucial role in improving the grain yields. It helps in supplementing the soil application methods. In foliar feedings, nutrients penetrate the cuticle and then enters leaf cells. Thus, responses of the crops observed in very short time over soil application. Macronutrient requirements of cereals are high and rarely met through foliar feedings. Thus, so far crucial usages of the foliar sprays have been in micronutrient application. Generally, Macronutrient's concentrations less than two percent used for avoiding foliage burning issues. Yield responses of cereals for foliar nutrition is highly variable.

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