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Biram Singh Gurjar
Department of Agronomy, SKNAU, Jobner, Jaipur, Rajasthan, India

Kuldeep Singh
Department of Agronomy, SKNAU, Jobner, Jaipur, Rajasthan, India

Akshay Kumar Yogi
Division of Agronomy, ICAR-IARI, New Delhi, India

Anju Kanwar Khangarot
Department of Agronomy, SKRAU, Bikaner, Rajasthan, India

Corresponding Author:
Kuldeep Singh
Department of Agronomy, SKNAU, Jobner, Jaipur, Rajasthan, India

Effect of foliar nutrition on pearl millet performance: A review

Biram Singh Gurjar, Kuldeep Singh, Akshay Kumar Yogi and Anju Kanwar Khangarot

Abstract
Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is one of the most important staple food crop of majority of poor and small land holders in Asia and Africa continent. It is also consumed as feed and fodder for livestock. India accounts for half of global millet production in the country. It is good source of energy, carbohydrate, fat (5-7%), ash, dietary fibre (1.2 g/100 g), protein (9-13%), antioxidant such as coumaric acids with better digestibility. Pearl millet cultivation in India is mostly confined to coarse textured soils having the problem of poor moisture retention capacity and low soil fertility. Lack of improved practices, cultivation on poor and marginal lands of low fertility and poor and delayed germination due to soil crusting are some of the major constraints responsible for its poor yield. This gap between nutrient removal and supply cannot be bridged by fertilizer and manure alone. It can be supported by foliar nutrition also. Foliar nutrition is a method of feeding plants by applying liquid fertilizers directly to their leaves. Plants are able to absorb essential elements through their leaves and bark. Foliar uptake is a means of rapid nutrient supply, especially when soil nutrient availability or root activity is reduced. Quick recovery from N deficiency is possible in dry farming areas where uptake of soil nutrient is a constraint due to moisture deficiency.

Keywords: Foliar, nutrition, pearl, millet, performance

Introduction

Effect of foliar nutrition

Growth parameters

Nehra *et al.* (2001) [34] while working on wheat found maximum values of dry matter accumulation, leaf area index and chlorophyll content with recommended dose of NPK (120 kg N, 60 kg P_2O_5 and 60 kg K_2O /ha). Application of 100% recommended dose of NPK fertilizer (80:40:0 kg/ha) produced taller plants and more number of tillers in oat as observed by Jayanti *et al.* (2002). Increase in NPK dose from 0 to 100% resulted in significant improvement in both below and above ground dry matter in sorghum at 60 DAS and at harvest (Ghosh *et al.*, 2003). Singh and Pareek (2003) carried out a field experiment on mung bean at Jobner on loamy sand soil and reported that application of 30 kg P_2O_5 / ha along with a uniform basal dose of 25 kg N/ha significantly increased plant height, branches per plant, number of nodules and nodule weight per plant over 15 kg P_2O_5 / ha and control. Ram Pratap (2005) [46] at Fatehpur Shekhawati reported that application of poultry manure @ 2 t/ha + 50% RDF remained at par with FYM 5 t/ha + 50% RDF and significantly increased the plant height, number of tillers per meter row length, dry matter accumulation, chlorophyll content and LAI over control. Singh *et al.* (2005) at Hisar further reported significant increase in total tillers per plant and plant height in pearl millet by applying 10 t FYM in integration with recommended dose of nitrogen over alone application of 100% RDF, 10 and 20 t FYM/ha. Jakhar (2006) a pot experiment on fenugreek was conducted in green house at Jobner and reported that increasing levels of zinc (0, 10 and 20 mg / kg) significantly increased the plant height, number of pods per plant, number of seeds per pod, test weight, seed and straw yield of fenugreek.

Bhowmick (2006) [13] at Berhampore (W.B.) observed that foliar spray of either urea or DAP @ 2% solution twice at flower initiation and 10 days thereafter remarkably increased the crop growth of chickpea compared with absolute control. Dixit and Elamathi (2007) at Allahabad observed that foliar spray of 2% DAP on green gram at 30 DAS significantly increased the plant height and dry weight of plants over the control. Ram and Punia (2007) reported in an experiment conducted on *lentil* at Kota, it was observed that foliar spray of 2% urea showed

beneficial effect on growth parameters like plant height, branches per plant and pods per plant. Venkatesh *et al.* (2007) [69] an experiment conducted on a Typic Ustochrept at, Kanpur to study the effect of foliar application of urea on chickpea under rain fed condition, it was noted that spraying of urea @ 2% at 75 DAS resulted in significant increase of growth parameters like number of tertiary branches per plant, number of pods per plant and number of seeds per pod.

Ravi *et al.* (2008) found that combined foliar application of iron 0.5% + zinc 0.5% at 30 and 60 DAS in safflower recorded significantly higher growth parameters like plant height, number of leaves, primary and secondary branches/ plant and dry matter accumulation as compared to control. Bagla *et al.* (2008) studied that application of potassium through 50% RDF and 50% through FYM significantly increased the number of tillers per metre row length, dry matter accumulation and leaf area over control in pearl millet. Tiwari and Kumar (2009) reported that application of 60 kg P_2O_5/ha in green gram along with recommended dose (20 kg N and 20 kg K_2O_5/ha) resulted in increased number of nodules per plant. Choudhary *et al.* (2010) reported that foliar application of zinc sulphate @ 0.5% at star bud stage + borax spray @ 0.20% at ray floret initiation stage in sunflower recorded significantly higher filled seeds/head (594.56), lower % chaffiness (6.33) and seed yield (53.80 g/plant) as compared to other treatments. Kumar *et al.* (2010) foliar application of zinc @ 0.5% at 35 and 55 DAS in sunflower recorded significantly higher plant height, number of leaves and stem girth but it was statistically at par with boron application.

The plant height is indicative of the vigour and growth of plant. The application of foliar spray of nutrients in pearlmillet at both tillering and flowering stages significantly recorded highest plant height (160.3 cm) over all other stages. Among the treatments, foliar spray of water soluble complex fertilizer (19:19:19) and $ZnSO_4$ @ 0.5% registered appreciably higher plant height (163.9 cm) compared to other treatments. The highest plant height recorded might be due to the better nutrition, which plays a vital role in cell division and growth of the plant. Sharn Kumar *et al.* (2012) [62] reported significant response in sorghum where 2% urea spray was done over other foliar treatments. Boron concentration in younger leaves, at flowering stage and harvest stage, ranged from 7.8-2.3 mg B /kg soil with an average of 11.4 mg B /kg soil, whereas, only one of the thirteen samples had adequate B concentration (15 mg B /kg soil). Boron concentration in lentil seed increased from 12.2 mg /g in control treatment to the maximum of 24.1 mg /g with the application of 1.25 kg B /ha through granubore. There was 24.6 per cent increase in seed yield of soybean with the application of 1.25 kg B /ha through either of fertilizer source. Total B content increased to the maximum of 59.8 per cent over control when B was applied through borax (Khurana and Arora) 2012 [24].

Singh and Singh (2015) working on pearl millet reported that application of 75% RDF + 25% RDF through FYM+ Azotobacter recorded higher values of growth attributes of pearl millet. Shakoor *et al.* (2017) [59] conducted a field experiment with the objective to optimize methods of B and Zn application in maize and found that foliar application of Zn and B produced more plant height, cob length and stem girth compared to soil application. Rundla and Bairwa (2018) revealed that the application of 75% N (50% basal + 25% top dressing at 25 DAS) P: K+1.5% spray of NPK (18:18) at 35 DAS (T_{11}) recorded significantly higher total number of tillers/plant at 60 DAS, number of effective tillers/ plant of pearl millet.

Yield attributes and yield

Nehra and Hooda (2000) [36] obtained highest values of yield attributes and yield with full dose of RDF (120: 60: 60 NPK kg/ha) in wheat. Yadav (2002) reported that seed and stover yield of mung bean increased significantly with the application of 4 kg Fe /ha as $FeSO_4$. Recommended dose of fertilizer (20:60:40 kg /ha) resulted in significantly higher pods per plant, 100 grain weight and harvest index than the control in soybean as reported by Chaturvedi and Chandel (2005).

Singh *et al.* (2005) on sandy loam soil observed that FYM at 10 or 20 t/ha increased the yield of pearl millet significantly over control. However, the maximum yield (32.45 q/ha) obtained with FYM at 10 t/ha in integration with recommended dose of nitrogen was significantly higher than rest of the treatments. The increase in the yield with 10 t FYM + RDN was 19.7, 36.1, 26.9 per cent over sole application of RDF, 10 and 20 t FYM/ha, respectively. This treatment also fetched the highest gross and net returns of ` 23210 / ha and ` 9123 / ha respectively. Ram Pratap (2005) [46] at Fatehpur Shekhawati reported that application of poultry manure @ 2 t/ha + 50% RDF being at par with FYM 5 t/ha + 50% RDF significantly increased grain yield of pearl millet. Raman and Venkataramana (2006) in a field experiment at Annamalainagar (Tamil Nadu) studied the effect of foliar nutrition on yield of green gram (*Vigna radiata*) and found that foliar spray of 2% DAP significantly increased yield attributes and yield. The highest grain yield of 1529 kg/ha was recorded with this treatment.

Singh *et al.* (2011) observed that application of 12.5 kg N and 60 kg P_2O_5/ha significantly increased the number of pods per plant, seeds per pod and 100 - seed weight of mung bean than lower doses of N and P. Bameri *et al.* (2012) revealed that foliar application of iron sulphate significantly increased plant height, yield attributes and yield of wheat over control. Parihar *et al.* (2012) reported that the application of 30 kg N and 20 kg P_2O_5/ha along with 6 t/ha FYM produced significantly higher yield of pearl millet over control, 30 kg N + 20 kg P_2O_5/ ha and sole application of 6 t/ha FYM and it was at par with 60 kg N + 40 kg P_2O_5/ha. Thenu *et al.* (2014) conducted an experiment at Bulandshar with five levels of sulphur (0, 10, 20 and 30 kg S/ha) and four levels of zinc (0, 10, 20, 30 kg Zn/ha) to study the sulphur and zinc requirement of soybean and its effect on yield and their availability status in the soil. The result showed that highest yield was recorded under 40 kg S/ha followed by 30 kg S/ha of zinc @30 kg/ha recorded highest yield as compared to its lower levels. Manoj *et al.* (2014) reported that application of 20 kg N/ha as basal + 20 kg N/ha as split + one irrigation at flower initiation significantly increased number of pods per plant, seeds per pod, test weight and seed yield (16.6 q/ha) of mung bean over control.

Puniya *et al.* (2014) [44] at Bikaner observed that application of phosphorus at 40 kg P_2O_5/ha significantly increased the seed and straw yield of moth bean than lower levels of fertilizers. Rahman *et al.* (2014) has also reported highest seed and straw yield for wheat with 2% urea spray. Yadav *et al.* (2014) reported that increase in foliar application of $FeSO_4$ from 2% significantly increase the grain yield, straw yield of

wheat from 94.06 cm, 572.18,4.19 ton/ha, 4.65 ton/ha respectively than 1% $FeSO_4$, 0.5% $MnSO_4$ and 1% $MnSO_4$ treatments. Arabhavi *et al.* (2015) noted that micro-nutrients are essential for plant growth but plant required relatively in smaller quantity. They include iron (Fe), manganese (Mn), boron (B), copper (Cu), molybdenum (Mo). Ehanullah *et al.* (2015) observed the comparative efficacy of micronutrient application method in three maize hybrids (Pioneer-32, Monsanto-6525 and Hycorn-8288) though the soil and foliar application indicated that Monsanto-6525 and Pioneer-32 produced 80% and 50% higher grain yield, respectively than Hycorn-8288 hybrid. Moreover, foliar application of $ZnSO_4$ at 9 leaf stage (vegetative stage) gave 12% more grain yield than soil applied and 38% higher than control. Houimli *et al.* (2015) [20] applied 5 concentration of iron i.e. 0,500.1000, 1500, 2000 mg/l. $FeSO_4$were applied exogenously after 40 days transplantation by hand sprayer. Results showed that, foliar spray of 500 and 1000 mg/l $FeSO_4$ solution was found to be effective for enhancing physiological and yield parameters, such as yield /plant (17.2kg), fruit weight (193.8g), fruit length (66.2mm) and fruit diameter (76.0 mm) respectively.

Khan *et al.* (2017) [15] reported that application of micro nutrients (Zn, B,) increased capsule length, capsule weight capsules/plant, seeds/capsule, test weight, test weight, seed yield and oil yield of sesame. It was concluded that micro nutrients fertilization @ 10 kg /ha and 5 kg /ha would enhance yield and yield related traits providedproper cultivar is selected to other treatment. Shakoor *et al.* (2017) [59] in a field experiment with the objective to optimize methods of Zn and B application in maize found that foliar application of Zn and B produced more 1000-grain weight, harvest index, grain and biological yield compared to soil application. Shankar *et al.* (2017) in a field experiment to study the comparative efficiency of boron as foliar spray and soil application on performance of finger millet concluded that foliar application of boron @ 0.5 kg/ha recorded significantly higher grain yield (3498 kg/ha) and straw yield (4640 kg/ha) as compared to control (3083 kg/ha, 4118 kg/ha, respectively) and it was on par with soil application of boron @ 0.5 kg/ha (3466 and 4529 kg/h). The per cent increase in yield was 13.4 per cent with foliar application of boron @ 0.5 kg/ha as compared to control. Shirazy *et al.* (2017) [63] conducted an experiment and found that the useof 60 kg N/ha and 150 ppm micro nutrient (as the source of Fe, Zn, Mn, and Cu) three nitrogen levels and four micro nutrients levels. Foliar application of different micro nutrient also improved morphological characters *viz.*, plant height, number of leaves/plant, number of branches/plant, fresh and dry weight of shoots and root, pod diameter, pod length, seed weight/plot as compared to control and seed yield of sesame as nitrogen.

Kadivala *et al.* (2019) revealed that the higher grain yield was obtained with the 1% foliar spray of multi-micronutrient mixture grade-III (for Fe deficiency) having concentration of Fe-6.0%, Mn 1.0%, Zn 4.0, Cu 0.3% and B 0.5% at 15, 30 and 45 DAT (days after transplanting). While straw and total yield was higher under the soil application of micronutrients of 50 kg $FeSO_4.5H_2O$/ha and 40 kg $MnSO_4.3H_2O$ /ha as per Soil test value. Micronutrient supplementation through 1.0% foliar application of the mixture having concentration of Fe-4.0%. Mn-1.0%, Zn-6.0%, Cu-0.5% and B-0.5% (Grade-IV for Zn and Fe deficiency) was also found beneficial in increasing ear head length, grain, straw and total yield of summer pearl millet. Patel *et al.* (2019) indicated that application of foliar nutrients at tillering and flowering stages significantly recorded highest plant height (160.3 cm), number of effective tillers (1.68), length of ear head (25.6 cm), seed yield (1300 kg/ha) a straw yield (2945 kg/ha). Further, foliar spray of water soluble complex fertilizer (19:19:19) and $ZnSO_4$ @ 0.5% produced higher plant height (163.9 cm), number of effective tillers (1.57), length of ear head (25.7 cm), grain yield (1383 kg/ha) and straw yield (2998 kg/ha) were recorded under foliar sprays of fertilizer (19:19:19) and $ZnSO_4$ @ 0.5%. Foliar sprays of water soluble complex fertilizer (19:19:19) and $ZnSO_4$ @ 0.5% at both the tillering and flowering stages of pearl millet improved the growth, yield components and yield.

Nutrient concentration, uptake and quality

Niaz *et al.* (2002) [37] conducted a field experiment on cotton at 13 different sites in Punjab, Pakistan, five were medium textured (clay loam), two were silty, clay, one was loam and five were coarse texture (sandy loam and loamy sand). Out of the thirteen soils, twelve were found deficient in boron (less than 0.5 mg B /kg 0.05M HCL extractable). Singaravel *et al.* (2002) conducted an experiment to study the effect of manganese and zinc on the yield and nutrient uptake of sesame in vertisol soil. Seven treatment comprised control (recommended NPK), NPK + $ZnSO_4$ at 25 kg /ha (soil) NPK + $MnSO_4$ at 5 kg /ha (soil), NPK + 0.5% $ZnSO_4$ (Foliar), NPK + 0.5% $MnSO_4$ (foliar), NPK + $ZnSO_4$ at 25 kg /ha + $MnSO_4$ at 5 kg /ha (soil) and NPK + 0.5% ZnSO4 + 0.5% (foliar). The results revealed that combined application of $ZnSO_4$ at 25 kg /ha + MnSO4 at 5 kg /ha was significantly superior in enhancing the growth, yield and nutrient uptake of sesame. Katiyar and Uttam (2003) opined that increase in fertility levels increased the concentration and uptake of N. P and K in grains and straw. The highest value observed with application of 60 kg N + 30 kg P+ 30 kg k/ha. Application of 60 kg N + 30 kg POs + 30 kg K/ha also recorded the highest net returns. Jain (2007) concluded that the application of 5 kg Zn/ha being at par with 7.5 kg Zn/ha significantly increased the content of N and Zn in seed and straw of wheat and their uptake and protein content. However, 5 kg Zn/ha significantly decreased the P content in seed and straw with increased levels of zinc up to 7.5 kg/ha. Dange *et al.* (2008) was conducted a field experiment at Akola(Maharashtra) to studied the effect of sulphur and zinc on nutrient uptake of sesame reported that maximum uptake of zinc by grain was recorded with 20 kg /ha elemental sulphur + 5 kg /ha $ZnSO_4$ + 1 t/ha FYM which was significantly higher than rest of the treatments.

Bhadauria *et al.* (2012) [12] also reported that soil application of zinc @ 10 kg/ha recorded significantly higher iron, manganese, copper and zinc uptake as compared to control in oilseed crops. Khurana and Arora (2012) [24]. Boron concentration in younger leaves, flowering stage and harvest stage, ranged from 7.8-2.3 mg B /kg soil with an average of 11.4 mg B /kg soil, whereas, only one of the thirteen samples had adequate B concentration (15 mg B /kg soil). Boron concentration in lentil seed increased from 12.2 mg /gin control treatment to the maximum of 24.1 mg /gwith the application of 1.25 kg B /ha through granubore. There was 24.6 per cent increase in seed yield of soybean with the application of 1.25 kg B/ha through either of fertilizer source. Total B content increased to the maximum of 59.8 per cent

over control when B was applied through borax. Puniya *et al.* (2014) [44] reported that the application of phosphorus at 40 kg P_2O_5/ha significantly increased protein content in seed, phosphorus and zinc content in seed and straw and nitrogen, phosphorus and zinc uptake by moth bean over preceding levels. Chatra Ram *et al.* (2015) [16] showed that the effect of bio-fertilizers were not found significant in increasing the yield as well as soil available nutrients after harvest of the pearl millet during all the years and on pooled basis. In terms of soil available nitrogen, phosphorus and potash, the treatment 50% N through urea +50% N through FYM obtained significant improvement in soil fertility status of available N (174 kg/ha), phosphorus(48 kg/ha) and potash (204.8 kg/ha).

Manasa and Devaranavadagi (2015) revealed that soil application of recommended dose of N, P_2O_5 and K_2O along with foliar application of $ZnSO_4$ @ 1.0 per cent during grand growth stage recorded grain yield was significantly higher zinc, Iron and boron content in leaf was observed in foliar application of micronutrient compare to soil application of maize. Vannila *et al.* (2017) the study indicates that inclusion of organic source of nutrients along with inorganic source of nutrients to bajra napier hybrid grass results in increased nutrient uptake. Application of recommended dose of nutrients (FYM 25 t/ha + 150:50:40 kg NPK/ha) through drip would be an ideal practice to achieve higher biomass and in turn resulting in higher uptake of bajra napier hybrid grass.

Economics

Manaria (2005) reported that maximum net returns and B: C ratios of fennel with the application of N,P,K,S and Zn treatment, which was significantly higher over NPK, NPKZn and NPKS during both the years. Sammauria and Yadav (2010) conducted a field experiment on fenugreek (*Trigonella foenum-graecum*) – pearl millet (*Pennisetum glaucum*) cropping system and reported that the highest net returns and B: C ratios were in 7.5 kg Zn/ ha. Gupta (2012) reported that significantly higher net returns and B:C ratio was recorded with the application of 6 kg Zn/ha in fennel. Choudhary (2013) revealed that 0.5% foliar spray of iron significantly increased net returns and B: C ratio of barley compared to control. Togas (2016) reported that application of poultry manure @ 2 t/ha +½RDF increased N, K content in grain, however, phosphorus content in grain N, P, K content in Stover and their uptake was significantly increased due to application of vermicompost @ 2.5 t/ha + ½ RDF. Application of poultry manure @ 2 t/ha + ½ RDF gave highest net returns of Rs 34898/ha. Shankar *et al.* (2017) in a field experiment to study the comparative efficiency of boron as foliar spray and soil application on performance of finger millet concluded that foliar application of boron @ 0.5 kg /ha recorded higher benefit cost ratio (1.46) as well as higher uptake of micronutrient (142,680 and 87 g/ha of Zn, Fe and B, respectively) compared to soil application of boron @ 1 kg /ha.

Rundla and Bairwa (2018) reported that the significantly highest gross return (42798/ha), net return (Rs 23025/ha) and benefit cost ratio (2.16) were also obtained with the application of 75% N (50% basal+25% top dressing at 25 DAS): P: K+15% spray of NPK (18 18.18) at 35 DAS. Patel *et al.* (2019) result indicated that application of foliar nutrients at tillering and flowering stages significantly recorded the higher net return (Rs.23762/ha) with highest B/C ratio (1.92) were observed when foliar spray of nutrients were applied at both the tillering and flowering stages of pearl millet. Significantly higher net return (Rs 25411/ha) and B: C ratio (2.03) were recorded under foliar sprays of water soluble complex fertilizer (19:19:19) and $ZnSO_4$ @ 0.5%. Foliar sprays of water soluble complex fertilizer (19:19:19) and $ZnSO_4$ @ 0.5% at both the tillering and flowering stages of pearl millet improved the growth, yield components and yield.

Conclusion

Foliar nutrition is a method of feeding plants by applying liquid fertilizers directly to their leaves. Plants are able to absorb essential elements through their leaves and bark. Quick recovery from N deficiency is possible in dry farming areas where uptake of soil nutrient is a constraint due to moisture deficiency. Foliar nutrition specially for micronutrients provide sufficient nutrition to pearl millet for better growth and development

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