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EFFECT OF FOLIAR FERTILIZATION AT EARLY REPRODUCTIVE STAGE ON GROWTH, PRODUCTIVITY AND PROFITABILITY OF SOYBEAN [*Glycine max* (L.) Merrill]

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ABSTRACT

A field experiment was conducted at research farm of PAU, Ludhiana, Punjab (India) for consecutive three years (2015-2017) to study the effect of foliar application of different nutrients at early reproductive stage (R3 stage) on growth, productivity and profitability of soybean. The experiment comprised of eight treatments of foliar nutrient application at pod initiation stage along with the recommended dose of fertilizer (RDF). The treatments were: water spray, urea 2% spray, diammonium phosphate (DAP) 2% spray, muriate of potash (MOP) 0.5% spray, NPK 19:19:19 ($N:P_2O_5:K_2O$) 2% spray, molybdenum 0.1% spray, zinc chelated 0.5% spray and no spray (control). Results revealed that different treatments of foliar nutrients did not significantly influence the growth attributes; however, foliar application of 2% urea yielded significantly higher number of pods plant^{-1} than other treatments and was at par with RDF + 0.5% MOP. Foliar application of 2% urea also gave the highest seed yield, gross returns and net returns and was statistically at par with spray of 0.5% MOP, 2% DAP, 0.5% chelated zinc and 0.1% molybdenum (except net returns). It may be concluded that foliar application of 2% urea at pod initiation stage provides highest seed yield, gross returns, net returns and B:C ratio.

Keywords: Foliar spray, pod initiation stage, seed yield, soybean

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an important oilseed crop grown worldwide. It occupied an area of 123.5 million ha with production of 352.6 million tonnes and productivity of 2854 kg ha^{-1} in the world during 2017 (FAOSTAT, 2019). Soybean is a rich source of fats (20%) and protein (40%) (Carrera *et al.*, 2011). However, the crop faces several constraints during growth including nutrient limitation. Severe depletion of nutrients in leaves limits photosynthesis. Nutrient application is, therefore, essential for optimum seed yield of soybean. The requirement of nutrients is more severe during reproductive stage due to the rapid depletion of nutrients from leaves. Thus, the requirement of nutrients increases during reproductive stage. Further, apart from the basal application of recommended dose of fertilizers, the yield can be enhanced with foliar application of nutrients. Foliar applications of small amounts of macro- and micro-nutrients may stimulate growth and improve the seed yield (Odeleye *et al.*, 2007).

Foliar application of fertilizers/nutrients is one of the efficient methods of fertilizer application to meet crop nutrient demand (Rajasekar *et al.*, 2017). Foliar application facilitates easy and quick nutrient-use by penetration through stomata or leaf cuticle and entering cell (Latha and Nadanassababady, 2003). Foliar application of nutrients is the best way to improve crop growth (Fageria *et al*., 2009; Paikra *et al*., 2018) and achieve higher yield of soybean (Kumar *et al*., 2013; Singh *et al*., 2018). Foliar application of 1% urea (Ashour and Thalooth, 1983) and 2% DAP and 2% NPK (19:19:19) (Dandge *et al*., 2018**)** during pod development stage resulted in better yield of soybean. The study was important to fulfill the nutrient requirement of soybean during reproductive stage. The information on the influence of foliar application of fertilizers/ micronutrients on growth and development of soybean is scarce in Punjab. This study can help us to improve the productivity of soybean by application of foliar nutrients. The crop requires micronutrients also for development. Considering the importance of foliar fertilization to supply the major and minor nutrients at reproductive growth stage of soybean, an experiment was planned to study effect of foliar fertilization with various fertilizer/nutrients such as urea, DAP, MOP, NPK, molybdenum and zinc chelated on growth, productivity and profitability of soybean.

MATERIALS AND METHODS

A field experiment was conducted at research farm of PAU, Ludhiana (30° 54´N, 75° 48´E, altitude 247 m), Punjab (India) for three consecutive years during *kharif* (rainy) season of 2015, 2016 and 2017. The experimental soil was loamy sand in texture, having pH 7.4, organic carbon 0.34%, low in available N (145.1 kg ha^{-1}) and medium in available phosphorus (16.2 kg ha^{-1}) and available potassium (210 kg ha^{-1}). The crop received 575, 499 and 418 mm rainfall during the crop seasons of 2015, 2016 and 2017, respectively. The experiment comprised of eight treatments of foliar application of nutrients along with recommended dose of fertilizer (RDF) *viz*., i) water spray (control), ii) urea 2%, iii) diammonium phosphate (DAP) 2%, iv) muriate of potash (MOP) 0.5%, v) NPK (19 N: 19 P_2O_5: 19 K_2O) 2%, vi) molybdenum 0.1%, vii) zinc chelated 0.5% and viii) no spray (control). All the treatments received RDF @ 31.25 kg N and 60 kg P_2O_5 ha^{-1}, which were applied through urea and single super phosphate, respectively, at sowing time. Molybdenum and zinc chelate were applied through ammonium molybdate and zinc sulphate, respectively. All the foliar applications were done at pod initiation stage (R3) of soybean (Fehr *et al*., 1971). The experiment was laid out in a randomized complete block design with eight treatments, each replicated three times. Sowing of soybean was done on 11, 10 and 6 June in the year 2015, 2016 and 2017, respectively, using variety ‘SL 958’. The seeds were inoculated with *Bradyrhizobium japonicum* culture @ 5 g kg^{-1} seed before sowing. Sowing was done at 45 cm row spacing by using 75 kg ha^{-1} seed rate. The gross plot size was 6.0 m × 3.6 m. The harvesting of soybean was done manually on 3 November in years 2015 & 2016 and on 31 October in year 2017. Data on plant height, number of branches plant^{-1}, number of pods plant^{-1}, seed index and seed yield were recorded at harvest. Harvest index was also calculated as follows:

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Rainwater use efficiency (Dass and Bhattacharya *et al*., 2017) was computed as follows:

$$\text{Rainwater use efficiency (RWUE)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Rainfall (mm)}}$$

Gross returns, net returns and benefit cost ratio were calculated on the basis of the prevailing prices of inputs used in various treatments and output by using the following formulas:

$$\text{Gross returns (Rs ha}^{-1}\text{)} = \text{Grain yield (kg ha}^{-1}\text{)} \times \text{Selling price}$$

Net returns (Rs ha^{-1}) = Gross returns – Cost of cultivation as per the treatment

$$\text{B:C ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

The data were analyzed with analysis of variance (ANOVA). The comparisons of treatment means were made at 5% level of significance (p = 0.05).

RESULTS AND DISCUSSION

The plant height and number of branches $plant^{-1}$ were non-significantly influenced by different treatments of foliar nutrients (Table 1). This was probably due to the fact that the plants had reached the peak of vegetative growth before spraying was done. However, foliar application of 2% NPK and 0.5% zinc chelated recorded the highest plant height followed by foliar application of 2% urea.

Table 1: Growth and yield attributes of soybean as influenced by different treatments of foliar nutrition (pooled mean of 3 years)

Treatments	Plant height (cm)	Branches $plant^{-1}$	Pods $plant^{-1}$	Seed index (g)
No foliar spray (control)	96.0	4.4	70.0	10.3
Water spray	94.1	4.4	71.3	10.6
2% urea spray	96.6	4.5	82.9	10.8
2% DAP spray	93.1	4.4	73.5	10.4
0.5% MOP spray	94.4	4.4	79.4	10.5
2% NPK (19:19:19) spray	96.8	4.3	72.0	10.5
0.1% molybdenum spray	94.7	4.4	75.1	10.5
0.5% zinc chelated spray	96.8	4.1	75.9	10.6
$CD_{0.05}$	ns	ns	6.5	ns

Different treatments of foliar application of nutrients significantly influenced the number of pods $plant^{-1}$ (Table 1). Foliar application of 2% urea recorded significantly higher number of pods $plant^{-1}$ than the other treatments and at par with RDF + 0.5% MOP. Foliar spray of these nutrients might have caused efficient translocation of photosynthates from source to sink. Foliar urea application at flowering and pod initiation stages recorded higher number of pods and reduced flower and pod abortions (Oko *et al*., 2003). This might have increased the number pods $plant^{-1}$. Seed index was non-significantly affected by different treatments of foliar application of nutrients.

The seed yield and harvest index were significantly influenced by different treatments of foliar application of nutrients (Table 2). Foliar application of 2% urea recorded significantly higher seed

Table 2: Seed yield, harvest index and rainwater use efficiency of soybean as influenced by different treatments of foliar nutrition (pooled mean of 3 years)

Treatments	Seed yield (kg ha^{-1})	Harvest index (%)	Rainwater use efficiency (kg ha^{-1} mm^{-1})
No foliar spray (control)	2644	34.2	4.77
Water spray	2673	36.5	4.84
2% urea spray	2852	36.9	5.15
2% DAP spray	2692	36.9	4.86
0.5% MOP spray	2806	35.9	5.04
2% NPK (19:19:19) spray	2648	37.6	4.84
0.1% molybdenum spray	2732	36.4	4.91
0.5% zinc chelated spray	2760	35.7	4.94
$CD_{0.05}$	170	1.8	ns

Table 3: Effect of foliar nutrition on the economics of soybean cultivation (pooled mean of 3 years data)

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
No foliar spray (control)	27696	84485	46819	3.06
Water spray	27846	85359	47469	3.08
2% urea spray	27840	91149	52523	3.29
2% DAP spray	27933	86361	47881	3.10
0.5% MOP spray	27834	89799	51252	3.24
2% NPK (19:19:19) spray	27925	84980	46565	3.05
0.1% molybdenum spray	46563	87431	30432	1.88
0.5% zinc chelated spray	7848	88105	50020	3.17
$CD_{0.05}$	-	4816	4816	0.17

yield than unsprayed control, water spray and 2% NPK which was, however, at par with 0.5% MOP, 0.5% zinc chelated, 0.1% molybdenum and 2% DAP. The increase may be attributed to the improvement in yield attributes like number of pods $plant^{-1}$ and seed index due to increased uptake of nutrients by effective translocation of nutrients from source to reproductive area of crop. At pod development stage, increasing levels of nitrogen in the leaves due to foliar application of urea may result high photosynthesis leading to the reduction of leaf senescence in plants. Aggarwal *et al*. (2015) also reported that foliar spray of 2% urea at pod initiation stage caused significant increase in grain yield over unsprayed control and also improved the chlorophyll kinetics and quantum efficiency of photosystem II in chickpea. Moreover, foliar spraying during pod filling stage is more effective than during vegetative stage because nutrients applied during pod filling are readily used for photosynthesis and assimilates are quickly mobilized for seed filling and protein accumulation in seed (Mannan, 2014). Rainwater use efficiency was non-significantly influenced by different treatments of nutrients (Table 2). However, the treatment of 2% urea recorded the highest rainwater use efficiency followed by 0.5% MOP and 0.5% zinc chelated.

Gross returns, net returns and B:C ratio were varied significantly due to different foliar nutrient applications (Table 3). The treatment of 2% urea spray at pod initiation recorded significantly higher gross returns than unsprayed control, water spray and 2% NPK, which was, however, at par with other treatments. The treatment of 2% urea spray at pod initiation recorded significantly higher net returns than unsprayed control, water spray, 2% NPK and 0.1% molybdenum, which was, however, at par with other treatments. Highest net returns and B:C ratio were obtained with application of 2% urea spray (Singh *et al*., 2018). It might be due to the increase in seed yield with foliar application of 2% urea which involves low input cost. Aggarwal *et al.* (2015) reported higher gross returns, net returns and B:C ratio with foliar spray of 2% urea in chickpea. The lowest net return was noted in 0.1% molybdenum treatment perhaps due to high cost of ammonium molybdate. Application of 2% urea spray gave highest B:C ratio, followed by 0.5% MOP and 0.5% zinc chelated.

It can be concluded that foliar application of 2% urea at pod initiation stage gives the highest seed yield of soybean and provides the highest gross returns, net returns and B:C ratio.

Conflict of interest: The authors declare that there is no conflict of interest.

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