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Effect of foliar application of water-soluble fertilizers on yield and economics of soybean

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Abstract
A field investigation entitled "Effect of Foliar Application of Water-Soluble Fertilizers on Growth, Yield and Quality of Soybean" was conducted in *kharif* season of 2024 at the PGI farm, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was laid out in randomized block design (RBD) with three replications. The experiment consists of eight treatments *viz* T_1: Absolute control, T_2: RDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O), T_3: GRDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O + 10 t FYM ha^{-1}), T_4: GRDF + Urea @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS, T_5: GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS, T_6: GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS, T_7: GRDF + 13:00:45 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS, T_8: GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS.As regards yield attributing characters, number of pods plant^{-1} (50.76), weight of pods plant^{-1} (42.46 g), number of grains pod^{-1} (2.99), weight of grains plant^{-1} (24.39 g), grain yield (2933 kg ha^{-1}) and stover yield (3898 kg ha^{-1}) of soybean were recorded significantly the highest under treatment T_6 (GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS). Significantly the highest gross monetary returns (₹171060 ha^{-1}), net monetary returns (₹ 106691 ha^{-1}) and B:C ratio (2.65) was obtained in treatment T_6 (GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS). While, T_1: Absolute control obtained minimum gross monetary returns, net monetary returns and B:C ratio among all the treatments.

Keywords: Soybean, foliar application, water soluble fertilizers, yield, economics

1. Introduction
Soybean, often known as poor man's meat, or golden bean (*Glycine max* L. Merrill) is a significant oil seed crop that has been farmed in China since 2800 BC. It contains 60% protein, which includes well-balanced essential amino acids, 20% oil, which includes polyunsaturated fatty acids, 6-7% minerals, 5-6% crude fiber, and 17-19% carbs. According to Sharifi *et al*. (2018) [10], soybean has protein qualities comparable to those of meat, milk, and eggs, and they are acknowledged as possible additional sources of oil.

The world's oilseed farming scenario depends heavily on soybean because of their high production, profitability, and essential role in preserving soil fertility. The crop holds a significant position as the most important seed legume globally, accounting for 25% of vegetable oil output worldwide, producing almost two thirds of the world's protein concentrate used in animal feed, and serving as a crucial component in fish and poultry formulas. Every year, around 85% of the world's soybean is processed to make oil and meal. Symbiotically soybean fixes 125-150 kg N ha^{-1} (Chandel *et al*., 1989) [3]. It also enriches the soil through atmospheric nitrogen fixation and leaves about 30-40 kg N (Nitrogen) per hectare for succeeding crop (Saxena and Chandel, 1992) [9].

Applying fertilizer directly to the leaves of plants is known as foliar feeding. Through their leaves, plants are able to take in necessary nutrients. Both the epidermis and the stomata allow for the absorption to occur. Although stomata often allow for faster transport, the epidermis can nevertheless absorb a same amount of material. Through their bark, plants can also receive nutrients. Foliar application is seen to be the best course of action in situations when the soil's ability to absorb nutrients is compromised or where the fast delivery of nutrients is delayed

(Salisbury and Ross, 1985) [8]. Studies have shown that foliar nutrition has a positive impact on crop output and quality. The crop may experience nutrient shortages later on because nutrients given through fertilizers at the time of planting are not completely utilized by the crop and are lost through leaching, fixation, etc. The foliar application of N, P, K and S during the pod filling stage has been shown to boost soybean production by up to 31%, according to Garcia and Hanway (1976) [4]. According to Palta *et al*. (2005) [7] and Zeidan (2003) [12], urea applied topically at 50% flowering boosted seed protein and yield.

2. Materials and Methods

The field experiment was conducted during *kharif* season of 2023 at PGI Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India). Before laying out the experiment, soil sample from 0-30 cm depth were taken from the well drained experimental area at randomly selected places in order to evaluate physical and chemical properties of soil. The soil texture of the experimental site was found to be medium deep clay. Soil was low in available nitrogen, medium in available phosphorus and high in potassium. The soil was slightly alkaline in reaction (pH 7.8) with normal in electrical conductivity (0.31 dS m^{-1}). Geographically, the Central Campus Farm of Mahatma Phule Krishi Vidyapeeth, Rahuri is situated between the 190 18'North and 190 57'North latitude and 740 35'East and 740 19'East longitude. The altitude of the field varies from 495 to 556 m above mean sea level. This area falls in the semi-arid tropics region with an annual rainfall ranging from 307 to 619 mm. The average rainfall of the area is 520 mm. Rainfall is erratic and unevenly distributed within 15 to 45 rainy days. The annual rainfall, about 80% receives from South-West monsoon from June to September and rest of the rainfall receives from North-East monsoon during October to November and practically negligible rains receive during summer. Agro-climatically location is in drought-prone area of scarcity zone of Maharashtra state, characterized by the low and erratic rainfall with less rainy days and long dry spell. The seeds of soybean variety Phule Sangam (KDS-726) were procured from the MPKV, Rahuri (M.S.) for the experiment. The variety was recommended for both *kharif* as well as summer season. The lines were first marked out with the help of marker at 45 cm distance. Seed was then dibbled in these lines at distance of 5 cm with recommended seed rate (75 kg ha^{-1}). Sowing was done by dibbling method with spacing 45 cm x 5 cm.

3. Results and Discussion

3.1 Yield Characters

Data regarding to yield contributing characters *viz.*, numbers of pods $plant^{-1}$, weight of pods $plant^{-1}$ (g)**,** number of seeds pod^{-1}, weight of seeds $plant^{-1}$ (g) and 100 seed weight (g) are presented in table 1.

3.2 Number of pods $plant^{-1}$

Number of pods $plant^{-1}$ of soybean recorded at harvest differed significantly because of different treatments. The mean number of pods $plant^{-1}$ at harvest was 45.51. The number of pods $plant^{-1}$ (50.76) found under treatment GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS was significantly superior among all the treatments. Among various treatments application of GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (49.70) and GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (47.47) were found at par to the superior treatment. The least number of pods $plant^{-1}$ was documented in the absolute control treatment (40.50). Foliage applied nitrogen and phosphorus at initial stages was effectively absorbed and translocated to the pods resulting in more number of pods $plant^{-1}$. These results are parallel with the findings of Gutte *et al*. (2019) [5], Warpe *et al*. (2022) [11] and Biradar *et al*. (2023) [2].

Table 1: Yield contributing characters of soybean as influenced by different treatment

Tr. No.	Treatments	Number of pods $plant^{-1}$	Weight of pods $plant^{-1}$ (g)	Number of seeds pod^{-1}	Weight of seeds $plant^{-1}$ (g)	100 seed weight (g)
T_1	Absolute control	40.50	32.87	2.36	14.00	12.08
T_2	RDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O)	41.17	34.87	2.45	15.67	13.07
T_3	GRDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O + 10 t FYM ha^{-1})	43.80	36.27	2.48	16.57	13.20
T_4	GRDF + Urea @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	44.57	36.63	2.54	16.87	13.47
T_5	GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	47.47	40.97	2.88	22.83	13.67
T_6	GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	50.76	42.46	2.99	24.96	14.21
T_7	GRDF + 13:00:45 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	46.16	38.16	2.73	19.07	13.66
T_8	GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	49.70	41.56	2.91	23.87	14.09
S. E.(m) ±		1.38	1.13	0.07	0.84	0.43
C. D. at 0.05		4.19	3.43	0.23	2.56	NS
General Mean		45.51	37.97	2.66	19.22	13.43

3.3 Weight of pods $plant^{-1}$ (g)

Weight of pods $plant^{-1}$ of soybean recorded at harvest differed significantly by different treatments. The weight of pods $plant^{-1}$ at harvest was 37.97 g. The highest weight of pods $plant^{-1}$ (42.46 g) was found under GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS treatment. Among different treatments, application of GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (41.56 g) and GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (40.97 g) were found at par to the superior treatment. The least number of seeds pod^{-1} was documented from the absolute control treatment (32.87 g). These results are in the agreement with those of Gutte *et al*. (2019) [5], Warpe *et al*. (2022) [11] and Biradar *et al*. (2023) [2].

3.4 Number of seeds pod^{-1}

Number of seeds pod^{-1} of soybean recorded at harvest differed significantly by different treatments. The mean number of seeds

pod^{-1} at harvest was 2.66. The numerically highest number of seeds pod^{-1} (2.99) was found under GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS treatment. Among various treatments, application of GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (2.91) and GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (2.88) were found at par to the superior treatment. The least number of seeds pod^{-1} was documented from the absolute control treatment (2.36). The result is due to better absorption of nutrients applied through foliage leading to more uptake of nutrients and more flower production and subsequently pod formation. These results are in the agreement with those of Gutte *et al*. (2019) [5], Warpe *et al*. (2022) [11] and Biradar *et al*. (2023) [2].

3.5 Weight of seeds plant^{-1} (g)

Weight of seeds plant^{-1} of soybean recorded at harvest differed significantly due to various treatments. The mean weight of seeds plant^{-1} at harvest was 19.22 g.The numerically highest weight of seeds plant^{-1} (24.96 g) was found under GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS treatment. Among various treatments, application of GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (23.87 g) and GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (22.83 g) were found at par to the superior treatment.The least weight of seeds plant^{-1} was documented from the absolute control treatment (14.00 g).

3.6 100 seed weight (g)

The difference in 100 seed weight because of various treatments was observed to be non-significant. The mean 100 seed weight of soybean at harvest was 13.43 g.

3.7 Yield studies

The data pertaining to seed yield, stover yield and harvest index of soybean as affected by different treatments are presented in table 2.

3.8 Seed yield (kg ha^{-1})

The highest seed yield was obtained in GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS treatment (2933 kg ha^{-1}). However, among the various treatments, application of GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (2826 kg ha^{-1}) and GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (2802 kg ha^{-1}) recorded statistically similar seed yield of soybean at par with the superior treatment. The higher seed yield in the above treatments was obtained due to increased uptake of nutrients by soybean and effective translocation of nutrients from sink to reproductive area of crop. These results are in the agreement with those of Das *et al*. (2015), Gutte *et al*. (2019) [5], Warpe *et al*. (2022) [11] and Biradar *et al*. (2023) [2].

Table 2: Seed yield, stover yield and harvest index of soybean as influenced by different treatment

Tr. No.	Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1	Absolute control	1284	1926	40.00
T_2	RDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O)	1836	2590	41.20
T_3	GRDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O + 10 t FYM ha^{-1})	2398	3406	41.29
T_4	GRDF + Urea @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	2412	3448	41.45
T_5	GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	2802	3752	42.78
T_6	GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	2933	3898	43.26
T_7	GRDF + 13:00:45 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	2540	3607	41.67
T_8	GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	2826	3821	42.84
S. E.(m) ±		79.01	106.08	-
C.D. at 0.05		239.65	321.76	-
General Mean		2377	3306	41.86

3.9 Stover yield (kg ha^{-1})

Significantly maximum stover yield (3898 kg ha^{-1}) was found in GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS treatment which was found at par with application of GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (3821 kg ha^{-1}), GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (3752 kg ha^{-1}) and GRDF + 13:00:45 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (3607 kg ha^{-1}). The lowest value of stover yield was documented from the absolute control treatment (1926 kg ha^{-1}).The higher stover yield might be due to the increase in uptake of nutrients resulting in faster synthesis and translocation of photosynthesis which influences the stover yield. These results are in the agreement with those of Singh *et al*. (2018), Dandge *et al*. (2018), Warpe *et al*. (2022) [11] and Biradar *et al*. (2023) [2].

3.10 Harvest Index (%)

It is obvious from the data that the difference in harvest index was observed to be non-significant as a result of different treatments. The mean harvest index was 41.86 per cent.

3.11 Economic studies

The economic evaluation of soybean crop was assessed in terms of gross monetary returns, cost of cultivation, net monetary returns and benefit cost ratio during *kharif* season of 2023-24 are presented in table 3.

3.12 Gross monetary returns

GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS treatment registered significantly the highest gross monetary returns (₹ 171060 ha^{-1}) but statistically at par with application of GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (₹ 164983 ha^{-1}) and GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (₹ 163490 ha^{-1}). The lowest gross monetary returns were documented from the absolute control (₹ 75435 ha^{-1}). Higher gross monetary returns are accounted due to higher seed and stover yield in the given treatments.

3.13 Net monetary returns

Statistics relating to net monetary returns recorded that among treatments, GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS documented significantly the

highest net monetary returns (₹ 106691 ha^{-1}). The net monetary returns were significantly lowest in absolute control treatment (₹ 38920 ha^{-1}). Higher seed and stover yields as well as lower cost of cultivation costs, were responsible for the higher net monetary returns in treatment GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34@ 1% spray at 45 DAS. The above findings are consistent with the results of Jadhav *et al*. (2016) [6] and Ahmad *et al*. (2019) [1].

3.14 Cost of cultivation

Among all the treatments, GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS documented the highest cost of cultivation (₹ 64470 ha^{-1}). The lowest cost of cultivation was documented from the absolute control (₹ 36515 ha^{-1}). The higher cost of cultivation for GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS treatment was due to fertilizers and more number of labour required for foliar spraying operation in the plot.

Table 3: Gross monetary returns, Cost of cultivation, Net monetary returns and B:C ratio as influenced by different treatment

Tr. no.	Treatments	Gross monetary returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net monetary returns (₹ ha^{-1})	B:C ratio
T_1	Absolute control	75435	36515	38920	2.06
T_2	RDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O)	107455	50470	56985	2.12
T_3	GRDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O + 10 t FYM ha^{-1})	140405	64030	76375	2.19
T_4	GRDF + Urea @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	140920	64267	76653	2.20
T_5	GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	163490	64470	99020	2.53
T_6	GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	171060	64369	106691	2.65
T_7	GRDF + 13:00:45 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	148718	64369	84349	2.31
T_8	GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS	164983	64284	100699	2.56
S. E.(m) ±		2633	-	1512	-
C.D. at 0.05		7986	-	4586	-
General Mean		139058	-	79981	-

3.15 Benefit: cost ratio

The maximum B: C ratio (2.65) was attained under application of GRDF + 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS because of higher seed yield resulted in more gross monetary returns and less cost of cultivation. This treatment followed by application of GRDF + 12:61:00 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (2.56) and GRDF + DAP @ 2% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS (2.53). Minimum B: C ratio (2.06) was found from the absolute control. These results are in agreement with those of Jadhav *et al*. (2016) [6], Ahmad *et al*. (2019) [1] and Gutte *et al*. (2019) [5].

4. Conclusion

On the basis of one year experimental study, it can be concluded that application of GRDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O + 10 t ha^{-1} FYM) along with foliar spray of 19:19:19 @ 1% spray at 30 DAS and 00:52:34 @ 1% spray at 45 DAS to *kharif* soybean found beneficial for increase in yield contributing characters, yield of soybean and monetary returns of *kharif* soybean grown in medium deep soil.

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