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EFFECT OF FOLIAR NUTRITION ON CHLOROPHYLL CONTENT INDEX (SPAD VALUE), ROOT CHARACTERS, SEED YIELD AND NUTRIENT UPTAKE IN IRRIGATED SESAME

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ABSTRACT

A field experiment was carried out in 2024 at the Experimental Farm of the Department of Agronomy, Faculty of Agriculture, Annamalai University, located in Annamalai Nagar, Tamil Nadu. The objective of the study was to examine the impact of foliar nutrition on chlorophyll content index (SPAD value), root characters, seed yield and nutrient uptake in irrigated sesame. The experiment was laid out in a randomized block design with eleven treatments, each replicated three times. The sesame variety TMV 4 was chosen for the study. The treatments involved foliar applications of macronutrients such as DAP, KCl, and NPK (19:19:19), as well as micronutrients like $ZnSO_4$ and $MnSO_4$, applied both individually and in combinations at 30 and 45 days after sowing (DAS). Based on the results, foliar application of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ at 30 and 45 days after sowing (DAS) significantly registered higher root characters *viz*., root length (17.63 cm), root volume (18.83 cc), root dry weight (4.01 g $plant^{-1}$), and chlorophyll content index (43.18), seed yield (877 kg ha^{-1}) and NPK uptake (31.58, 10.42 and 35.25 kg ha^{-1}). The same treatment also registered lowest levels of post-harvest soil available nitrogen (200.04 kg ha^{-1}), phosphorus (13.46 kg ha^{-1}) and potassium (295.72 kg ha^{-1}).

Keywords : Chlorophyll content index (SPAD value), DAP, foliar nutrition, KCl, $MnSO_4$ nutrient uptake, sesame, $ZnSO_4$.

Introduction

Sesame (*Sesamum indicum* L.), often lauded as the "Queen of Oilseeds," holds significant global importance due to its rich composition of high-quality polyunsaturated fatty acids. These include palmitic acid (16%), stearic acid (18%), oleic acid (18.1%), and linoleic acid (18.2%), which naturally contribute to its resistance to rancidity (Taware *et al*., 2006). Globally, sesame cultivation spans approximately 12.84 million hectares, yielding 6.74 million tonnes with an average productivity of 525 kg per hectare. India contributes significantly to this global landscape, cultivating 1.627 million hectares and producing 789,000 tonnes, albeit with a lower average yield of 485 kg per hectare (FAOSTAT, 2023). Despite its established importance as an oilseed crop, sesame's average productivity remains comparatively low when benchmarked against leading sesame-producing nations. For instance, countries like China (1,393 kg per hectare), Egypt (1,315 kg per hectare), and Nigeria (1,063 kg per hectare) consistently achieve significantly higher yields, highlighting a considerable opportunity for enhancing sesame productivity in other regions, including India. This lower yield is primarily due to poor management practices and cultivation on less fertile, marginal, and sub-marginal lands. Yield is a result of various physiological processes in plants, which are often influenced by management practices and environmental conditions. Among these, nutrient management, especially through foliar nutrition, is crucial in determining sesame yields. Applying essential nutrients via foliar feeding, along with soil application, is vital for sesame production as it promotes better root development, energy transformation, metabolic processes, and nutrient translocation, and improves capsule setting, all of which contribute to increased growth and yields (Dutta and Bera, 2021). Applying DAP as a foliar spray at critical stages of the crop has been shown to enhance the growth and yield of the crop, as reported by Ramesh *et al.* (2015). Potassium (K) is a vital nutrient required for plant growth and physiological functions. It also contributes to cellular signaling, either independently or in combination with other signaling molecules and phytohormones . Zinc and manganese are crucial for several enzymatic activities necessary for the growth and development of sesame plants (Elayaraja and Singaravel, 2017). Therefore, the current study aimed to "examine the effects of foliar applications of macronutrients, such as NPK fertilizers and micronutrients like zinc and manganese on chlorophyll content index (SPAD value), root characters and nutrient uptake of sesame under irrigated conditions".

Materials and Methods

A field experiment was conducted from January to April 2024 at the Experimental Farm of the Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu. The soil at the experimental site was classified as clay loam, with a pH of 7.4 and an electrical conductivity (EC) of 0.46 dS m^{-1}. It was low in available nitrogen (215.6 kg ha^{-1}), had a moderate level of available phosphorus (18.84 kg ha^{-1}) and was rich in available potassium (316.4 kg ha^{-1}). The experiment used a randomized block design **with** eleven distinct treatments, each replicated three times. The treatments were: T_1 - Control (water spray), T_2 - Foliar spray of 2% DAP + 0.5% KCl (30 and 45 DAS), T_3 - Foliar spray of 2% NPK (19:19:19) (30 and 45 DAS), T_4 - Foliar spray of 0.5% $MnSO_4$ (30 and 45 DAS), T_5 - Foliar spray of 0.5% $ZnSO_4$ (30 and 45 DAS), T_6 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ (30 and 45 DAS), T_7 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% $MnSO_4$ (30 and 45 DAS), T_8 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (30 and 45 DAS), T_9 - Foliar spray of 2% NPK (19:19:19) + 0.5% $ZnSO_4$ (30 and 45 DAS), T_{10} - Foliar spray of 2% NPK (19:19:19) + 0.5% $MnSO_4$ (30 and 45 DAS) and T_{11} - Foliar spray of 2% NPK (19:19:19) + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (30 and 45 DAS). The sesame variety TMV 4 was used for the study. Fertilization followed the recommended schedule of 35:23:23 kg N, P2O5, and K2O ha^{-1}, with the entire amount of nitrogen, phosphorus and potassium applied as a basal dose. Urea, single super phosphate and muriate of potash were used for nitrogen, phosphorus and potassium, respectively. According to the treatment plan, DAP (2%), KCl (0.5%), NPK (19:19:19) (2%), $MnSO_4$ (0.5%) and $ZnSO_4$ (0.5%) were sprayed at 30 and 45 days after sowing (DAS) using a hand-operated knapsack sprayer, with a spray volume of 500 litres per hectare, during the morning hours. SPAD values were measured following the method outlined by Peng *et al*. (1993) using a chlorophyll meter (SPAD - 502, Soil Plant Analysis Development Section, Minolta Camera Co. Ltd., Japan). Readings were taken from the third leaf from the top of five randomly selected plants during the flowering stage of the crop. At harvest, sample plants collected from each plot were dried in an oven at 80 ± 5 °C, ground into a powder using a Willey mill and then used for chemical analysis of N, P_2O_5 and K_2O. The nutrient values obtained from the analysis were multiplied by the corresponding dry matter production (DMP) for each treatment, and the total nutrient uptake was calculated and expressed in kg ha^{-1}. The analysis followed the standard procedures outlined in Table 1a. After the harvest of crop, the soil samples were analyzed for available nitrogen, phosphorus and potassium, following the standard procedures described in Table 1b.

Table 1a : Analytical methods used for plant analysis

S. No	Nutrients	Method	Reference
1.	Nitrogen	Microkjeldhal method	Yoshida *et al.* (1976)
2.	Phosphorus	Triple acid digestion with calorimeter method	Jackson, (1973)
3.	Potassium	Triple acid digestion with flame photometry method	Jackson, (1973)

Table 1b: Analytical methods used for soil analysis

S. No	Nutrients	Method	Reference
1.	Available Nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
2.	Available Phosphorus	Calorimetry method	Olsen *et al.* (1954
3.	Available Potassium	Flame photometric method	Stanford and English (1949)

Results and Discussion

Chlorophyll content index (SPAD value)

Among the various treatments, the foliar application of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ at 30 and 45 DAS (T_8) resulted in the highest SPAD value of 43.18. The increased chlorophyll content index could be attributed to the synergistic effects of the combined inputs (DAP + KCl + $ZnSO_4$ + $MnSO_4$), which enhance nutrient uptake, especially nitrogen, and promote chlorophyll synthesis. This plays a role in the assimilation of various amino acids that are later integrated into proteins and nucleic acids, forming the structural framework for chloroplasts. This leads to higher chlorophyll content in the leaves of plants under this treatment, supporting the findings of Jaybhay *et al.* (2021). Additionally, micronutrients like zinc and manganese provided in this treatment promote auxin synthesis, which helps delaying processes such as senescence and abscission, ultimately raising the chlorophyll content index, as noted by Gowthami *et al.* (2018). This was followed by the application of 2% NPK (19:19:19) combined with 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ at 30 and 45 days after sowing (T_{11}), which resulted in a SPAD value of 41.40. The lowest SPAD value of 27.14 was recorded in the control treatment (T_1).

Root characters

Foliar spray of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (30 and 45 DAS) (T_8) had significantly recorded the highest root length of 17.63 cm, root volume of 18.83 cc and root dry weight of 4.01 g $plant^{-1}$ which were 43.80 per cent, 42.65 per cent and 90.04 per cent, respectively over control at flowering stage (Table 2). This improvement can be attributed to the application of macronutrients (NPK) and micronutrients (Zn and Mn) through foliar feeding, which tends to enhance the synthesis of enzymes such as auxins, cytokinins, and IAA. These compounds support root growth, resulting in increased root length, volume and dry weight (Sachin *et al.*, 2022). Additionally, applying DAP, KCl, zinc, and manganese in the right quantities, at the correct times and using appropriate methods boosts photosynthetic activity, accelerates nutrient transport and enhances the efficiency of photosynthetic product utilization. This results in cell elongation and rapid cell division in the root area, which contributes to greater root length, volume and dry weight. These findings are consistent with the research of Harisudan *et al.* (2023). The foliar spray of 2% NPK (19:19:19) + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (30 and 45 DAS) (T_{11}) achieved the second-highest root length of 16.98 cm, root volume of 18.09 cc and root dry weight of 3.81 g $plant^{-1}$. The lowest root length, root volume and root dry weight were observed in the control (T_1), which had a root length of 12.26 cm, root volume of 13.20 cc and root dry weight of 2.11 g $plant^{-1}$.

Seed yield

Among the treatments, the foliar application of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$, applied at 30 and 45 days after sowing (T_8), resulted in a significantly higher seed yield of 877 kg per hectare. The improvement in seed yield is likely due to the combined effects of macronutrients (NPK) and micronutrients (zinc and manganese). The notable increase in yield was primarily attributed to enhanced dry matter accumulation, a greater number of branches per plant and more capsules per plant (Mahajan *et al.*, 2016). Improved nutrient uptake, supported by effective nutrient translocation from the source to the reproductive parts, seems to be a crucial factor in achieving these higher yields, as highlighted by Dhayanethi *et al.* (2024a). Additionally, It's probable that the foliar application of zinc and manganese activated a range of enzymes, enhanced metabolic processes, facilitated nucleic acid and hormone synthesis, and alleviated water stress. These combined effects likely optimized the conversion of photosynthates into characteristics favourable for increased yield. These observations are consistent with the work of Elayaraja *et al.* (2019). Following this, the foliar application of 2% NPK (19:19:19) combined with 0.5% $ZnSO_4$ + 0.5% $MnSO_4$, applied at 30 and 45 days after sowing (T_{11}), resulted in a seed yield of 841 kg per hectare. The lowest seed yield was recorded in the control treatment (T_1), with 522 kg per hectare.

Nutrient uptake

Among the different treatments, the foliar application of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ at 30 and 45 days after sowing (T_8) resulted in significantly higher uptake of 31.58 kg ha^{-1} of nitrogen (N), 10.42 kg ha^{-1} of phosphorus (P) and 35.25 kg ha^{-1} of potassium (K). This might be due to the availability of native and applied nutrients being higher, which is favourable for the better nutrient uptake by the plant system. Moreover, the enhanced uptake of major nutrients (NPK) can be attributed to the role of micronutrients such as zinc and manganese in facilitating the translocation of nitrogen from the soil to various plant parts, which likely contributed to increased dry matter production. The higher nitrogen absorption might also be a result of the stimulatory effects of zinc and manganese on nitrogen uptake (Girish Chandra Pathak *et al.*, 2012). The increased phosphorus uptake could be due to the foliar application of micronutrients, which improved root growth and physiological activity, allowing the roots to absorb more phosphorus. The greater potassium uptake may be linked to enhanced plant growth, which improves nutrient absorption, as well as the stimulatory effects of zinc and magnesium on potassium uptake. These findings align with the results of Dhayanethi *et al*. (2024b). Statistically, the next highest nutrient uptake was achieved with the foliar application of 2% NPK (19:19:19) combined with 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ at 30 and 45 days after sowing (T_{11}), resulting in uptake of 30.53 kg ha^{-1} of nitrogen (N), 10.06 kg ha^{-1} of phosphorus (P) and 34.08 kg ha^{-1} of potassium (K). The lowest nutrient uptake values were observed in the control treatment (T_1), with 22.10 kg ha^{-1} of nitrogen, 7.06 kg ha^{-1} of phosphorus and 24.45 kg ha^{-1} of potassium.

Post-harvest soil nutrient status

Among the different treatments, the control (T_1) showed the highest post-harvest soil availability of nitrogen (N), phosphorus (P) and potassium (K), with values of 212.93, 17.47, and 310.77 kg per hectare, respectively. This could be due to the lower dry matter production (DMP) and the minimal nutrient uptake observed in this treatment, leading to higher post-harvest soil availability of NPK at the end of the experiment. A similar finding was reported by Stanley and Basavarajappa (2014). The lowest post-harvest soil availability of nitrogen (N), phosphorus (P) and potassium (K) was observed with the foliar application of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ at 30 and 45 days after sowing (T_8), with values of 200.04, 13.46 and 295.72 kg per hectare, respectively. This could be attributed to the crop's nutrient uptake in those plots, associated with higher biomass production. Greater biomass production leads to increased nutrient uptake, resulting in the depletion of nutrients in the post-harvest soil (Kumar *et al*., 2023).

Conclusion

Based on a one-year field study conducted in the Cauvery Delta region of Tamil Nadu, the foliar application of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ applied at 30 and 45 days after sowing (DAS) appears to be the most effective treatment. This specific combination significantly improved root characteristics, enhanced seed yield, and optimized nutrient uptake in irrigated sesame.

Table 2 : Effect of foliar nutrition on chlorophyll content index (SPAD value), root characters and seed yield (kg ha^{-1}) in sesame

Treatments	Chlorophyll content index SPAD value	Root characters			Seed yield (kg ha^{-1})
		Root length (cm)	Root volume (cc)	Root dry weight (g $plant^{-1}$)	
T1 - Control (Water spray)	27.14	12.26	13.20	2.11	522
T2 - Foliar spray of 2% DAP + 0.5% KCl(30 & 45 DAS)	33.56	14.42	15.63	2.97	645
T3 - Foliar spray of 2% NPK (19:19:19) (30 & 45 DAS)	31.86	13.78	14.86	2.73	608
T4 - Foliar spray of 0.5% $MnSO_4$ (30 & 45 DAS)	28.93	12.93	13.92	2.35	560
T5 - Foliar spray of 0.5% $ZnSO_4$ (30 & 45 DAS)	30.08	13.15	14.08	2.44	569
T6 - Foliar spray of 2% DAP + 0.5% KCl +0.5% $ZnSO_4$ (30 & 45 DAS)	39.69	16.30	17.36	3.59	780
T7 - Foliar spray of 2% DAP + 0.5% KCl +0.5% $MnSO_4$ (30 & 45 DAS)	38.39	16.03	17.25	3.57	756
T8 - Foliar spray of 2% DAP + 0.5% KCl +0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (30 & 45 DAS)	43.18	17.63	18.83	4.01	877
T9 - Foliar spray of 2% NPK (19:19:19) + 0.5% $ZnSO_4$ (30 & 45 DAS)	36.67	15.29	16.53	3.34	719
T10 - Foliar spray of 2% NPK (19:19:19) +0.5% $MnSO_4$ (30 & 45 DAS)	35.39	15.07	16.37	3.27	696
T11 - Foliar spray of 2% NPK (19:19:19) + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (30 & 45 DAS)	41.40	16.98	18.09	3.81	841
S.Ed	**0.66**	**0.28**	**0.30**	**0.06**	**12.12**
CD (p=0.05)	**1.38**	**0.58**	**0.62**	**0.13**	**25.46**

Table 3 : Effect of foliar nutrition on N, P and K uptake and post-harvest soil available nutrients status (kg ha^{-1}) in sesame

Treatments	Nutrient uptake (kg ha^{-1})			Post-harvest soil available nutrient status (kg ha^{-1})		
	N	P	K	N	P	K
T1 - Control (Water spray)	22.10	7.06	24.45	212.93	17.47	310.77
T2 - Foliar spray of 2% DAP + 0.5% KCl (30 & 45 DAS)	26.00	8.47	28.83	207.62	15.82	304.71
T3 - Foliar spray of 2% NPK (19:19:19) (30 & 45 DAS)	24.94	8.02	27.66	209.14	16.38	306.48
T4 - Foliar spray of 0.5% $MnSO_4$ (30 & 45 DAS)	23.16	7.42	25.63	211.41	17.01	309.15

T5 - Foliar spray of 0.5% $ZnSO_4$ (30 & 45 DAS)	23.89	7.66	26.48	210.77	16.83	308.17
T6 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ (30 & 45 DAS)	29.47	9.69	32.90	203.20	14.43	299.13
T7 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% $MnSO_4$ (30 & 45 DAS)	28.80	9.45	32.00	203.73	14.58	300.22
T8 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (30 & 45 DAS)	31.58	10.42	35.25	200.04	13.46	295.72
T9 - Foliar spray of 2% NPK (19:19:19) + 0.5% $ZnSO_4$ (30 & 45 DAS)	27.74	9.08	30.82	205.37	15.12	301.96
T10 - Foliar spray of 2% NPK (19:19:19) + 0.5% $MnSO_4$ (30 & 45 DAS)	27.05	8.83	30.01	205.89	15.28	302.99
T11 - Foliar spray of 2% NPK (19:19:19) + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (30 & 45 DAS)	30.53	10.06	34.08	201.56	13.89	297.42
S.Ed	**0.50**	**0.16**	**0.55**	**0.51**	**0.17**	**0.57**
CD (p=0.05)	**1.04**	**0.34**	**1.16**	**1.07**	**0.37**	**1.18**

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