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Effect of foliar nutrition on growth analysis, productivity and profitability of irrigated sesame in Cauvery delta zone of Tamil Nadu

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Abstract

A field experiment was conducted in 2024 at the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, and Tamil Nadu to study the effect of foliar nutrition on the growth analysis, productivity and profitability of sesame. The field experiment was laid out in a randomized block design with eleven treatments and replicated thrice. The treatments included foliar applications of macronutrients such as DAP, KCl, NPK (19:19:19), as well as micronutrients like ZnSO₄ and MnSO₄, applied individually and in combinations at 30 and 45 days after sowing (DAS). Growth analysis viz., LAI, CGR and AGR was significantly improved with the foliar application of 2% DAP + 0.5% KCl + 0.5% ZnSO₄ + 0.5% MnSO₄ at 30 and 45 DAS (T8). This treatment also led to increased seed and stalk yields and gross income, net income, and BCR. The control treatment recorded the lowest values of growth analysis, seed and stalk yields, gross and net income, and BCR.

Keywords: AGR, CGR, Economics, Foliar nutrition, Gross income, Growth analysis, Net income, Sesame and productivity.

Introduction

Sesame (*Sesamum indicum* L.) is an important oilseed crop with an ancient history of origin. Sesame seeds are highly valued for their nutritional content, edible oil and medicinal properties. Often referred to as the “Queen of Oilseeds”, sesame is rich in high-quality polyunsaturated stable fatty acids, such as palmitic acid (16%), stearic acid (18%), oleic acid (18.1%) and linoleic acid (18.2%), which provide natural resistance to rancidity. Sesame is grown worldwide on 12.84 million hectares, producing 6.74 million tonnes with an average yield of 525 kg per hectare. In India, sesame is cultivated on 1.627 million hectares, with a production of 7,89,000 tonnes and a productivity of 485 kg per hectare. In Tamil Nadu, sesame is grown on 4,72,000 hectares, yielding of 2,79,000 tonnes with an average productivity of 585 kg per hectare (FAOSTAT, 2023) [5]. Foliar application of NPK and micronutrients is more effective than soil application, as leaves absorb the nutrients more rapidly and transport them more efficiently to crucial plant areas. This method promotes rapid growth and development by correcting nutrient deficiencies, enhancing pest and disease resistance, sustaining plant health, improving growth and yield traits and increasing crop yield (Bhavaya *et al.*, 2020) [2].

Applying DAP as a foliar spray at critical stages of the crop has been shown to enhance photosynthetic activity, as reported by Ramesh *et al.* (2015) [14]. 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 (Hasanuzzaman *et al.*, 2018) [8]. The NPK (19:19:19) fertilizer is a fully water-soluble and balanced blend, featuring nitrogen in three different forms: NO₃-N (45.0%), NH₄-N (4.5%), and NH₂-N (10.5%). This composition supports rapid and vigorous crop growth, effectively correcting nutrient deficiencies and enhancing their resistance to pests and diseases, thereby reducing the need for pesticides and fungicides. This leads to more consistent flowering, fewer flower drop-offs and ultimately higher crop yields (Dhayanethi *et al.*, 2024a) [3].

Zinc is an essential micronutrient that is a structural component or regulatory cofactor for numerous enzymes and proteins involved in critical biochemical processes viz., carbohydrate metabolism, photosynthesis, sugar-to-starch conversion, protein metabolism, auxin metabolism (a growth regulator), pollen formation, maintenance of biological membrane integrity, and defense against pathogens (Gupta *et al.*, 2006) [7]. Manganese fertilization improves crop yield and quality by enhancing plant nutrition and boosting photosynthesis, which increases photosynthetic efficiency and ultimately results in higher crop yield and quality (Mousavi *et al.*, 2007) [10]. Considering the above, the present experiment was conducted to study the effect of foliar applications of macronutrients, including NPK fertilizers, and micronutrients like zinc and manganese on the growth analysis, productivity and profitability of sesame under irrigated conditions.

Materials and Methods

A field experiment was conducted during January to April 2024 at the Experimental Farm, Department of Agronomy, Annamalai University, Annamalai Nagar, Tamil Nadu. The soils in the experimental field was classified as clay loam, with a pH of 7.4 and an electrical conductivity (EC) of 0.46 dS m⁻¹. The soil 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 field experiment was laid out in a randomized block design with eleven treatments, each replicated three times. The treatments included: T₁ - Control (water spray), T₂ - Foliar spray of 2% DAP + 0.5% KCl (30 and 45 DAS), T₃ - Foliar spray of 2% NPK (19:19:19) (30 and 45 DAS), T₄ - Foliar spray of 0.5% MnSO₄ (30 and 45 DAS), T₅ - Foliar spray of 0.5% ZnSO₄ (30 and 45 DAS), T₆ - Foliar spray of 2% DAP + 0.5% KCl + 0.5% ZnSO₄ (30 and 45 DAS), T₇ - Foliar spray of 2% DAP + 0.5% KCl + 0.5% MnSO₄ (30 and 45 DAS), T₈ - Foliar spray of 2% DAP + 0.5% KCl + 0.5% ZnSO₄ + 0.5% MnSO₄ (30 and 45 DAS), T₉ - Foliar spray of 2% NPK (19:19:19) + 0.5% ZnSO₄ (30 and 45 DAS), T₁₀ - Foliar spray of 2% NPK (19:19:19) + 0.5% MnSO₄ (30 and 45 DAS) and T₁₁ - Foliar spray of 2% NPK (19:19:19) + 0.5% ZnSO₄ + 0.5% MnSO₄ (30 and 45 DAS). The sesame variety TMV 4 was chosen for the study. According to the treatment plan, DAP (2%), KCl (0.5%), NPK (19:19:19) (2%), MnSO₄ (0.5%), and ZnSO₄ (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.

Growth Analysis

Leaf Area Index (LAI)

The Leaf Area Index (LAI) was recorded at the flowering stage and calculated using the formula provided by Watson (1947) [17].

$$LAI = \frac{\text{Leaf Area}}{\text{Ground Area}}$$

Leaf area per unit area (m²) = L × W × CF × A × B

Where,

L = Length of the leaf in cm

W = Maximum width of the leaf in cm

CF = Correction Factor (0.7231)

A = Number of leaves plant⁻¹

B = Number of plants m⁻²

Crop growth rate (CGR)

The Crop Growth Rate (CGR) indicates the amount of dry

matter accumulated per unit area per unit time, and is measured in grams per square meter per day (g m⁻² day⁻¹). It was calculated using the formula provided by Watson (1958) [18].

$$CGR = \frac{W_2 - W_1}{S (t_2 - t_1)}$$

Where,

S = Ground area

W₁ = Dry weight of plant m⁻² at time t₁

W₂ = Dry weight of plant m⁻² at time t₂

t₁ and t₂ are the time interval

Absolute growth rate (AGR)

The Absolute Growth Rate (AGR) is defined as the irreversible increase in dry weight over a given period. It was calculated using the formula provided by Radford (1967) [12].

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W₁ = Dry weight of plant m⁻² at time t₁

W₂ = Dry weight of plant m⁻² at time t₂

t₁ and t₂ are the time interval

After physiological maturity, each plot's crop was harvested. The seeds and stalks were then cured, threshed, cleaned, and dried, with their weights recorded in kg per hectare. The data collected on various traits during the field study were statistically analyzed using the method outlined by Panse and Sukhatme (1978) [11]. Significant results were evaluated by calculating the critical differences at a five percent probability level for statistical inference. Differences between treatments that were not significant were noted as "NS".

Results and Discussion

Leaf area index

Among the various treatments evaluated, the foliar application of 2% DAP + 0.5% KCl + 0.5% ZnSO₄ + 0.5% MnSO₄ (at 30 and 45 DAS) (T₈) achieved the highest Leaf Area Index (LAI) of 4.01 at the flowering stage. This might be due to the higher nitrogen availability directly translates to increased chlorophyll content, leading to more efficient photosynthesis. More photosynthesis means more energy production and, consequently, greater biomass accumulation and leaf development, directly contributing to a higher LAI. The addition of phosphorus and potassium enhances larger root systems, which in turn increase water and nutrient uptake from the soil, raise plant vigour and stress tolerance, resulting in increased the growth and development of the plant, especially in terms of LAI. This finding aligns with the results reported by Reddy *et al.* (2020) [15]. Furthermore, the foliar application of zinc and manganese might have helps in the synthesis of auxins, which play a key role in chlorophyll formation and carbohydrate metabolism, resulting in higher LAI. These results are consistent with the findings of Gowthami and Rao (2014) [6].

Growth analysis

The foliar application of 2% DAP + 0.5% KCl + 0.5% ZnSO₄ + 0.5% MnSO₄ (30 and 45 DAS) (T₈) recorded a higher crop growth rate of 2.69 g m⁻² day⁻¹ at 30 - 60 DAS and 2.37 g m⁻² day⁻¹ at 60 DAS - harvest stage and absolute growth rate of 26.90 g day⁻¹ at 30 - 60 DAS and 23.73 g day⁻¹ at 60 DAS -

harvest stage. The significant impact on Crop Growth Rate (CGR) and Absolute Growth Rate (AGR) is likely due to improved photosynthetic efficiency and a better source-to-sink relationship in the plant, along with increased nutrient and water uptake, reduced transpiration and respiration and enhanced translocation and accumulation of sugars and other metabolites. Furthermore, critical role of nitrogen (from DAP) in metabolic activities and vegetative growth. Additionally, the presence of zinc and manganese throughout the plant's life cycle enhanced solar energy utilization, leading to increased photosynthetic activity and the transfer of more photosynthates to different plant parts. This resulted in the highest observed DMP, which directly reflected on CGR and AGR with this treatment, consistent with the findings of Aruna *et al.* (2022) [1]. The foliar application of 2% NPK (19:19:19) + 0.5% ZnSO₄ + 0.5% MnSO₄ (30 and 45 DAS) (T₁₁) ranked next, achieving a crop growth rate of 2.55 g m⁻² day⁻¹ at 30 - 60 DAS and 2.22 g m⁻² day⁻¹ at 60 DAS - harvest stage and absolute growth rate of 25.47 g day⁻¹ at 30 - 60 DAS and 22.23 g day⁻¹ at 60 DAS - harvest stage. The control treatment (T₁) recorded the lowest crop growth rate of 1.52 g m⁻² day⁻¹ at 30 - 60 DAS and 1.50 g m⁻² day⁻¹ at 60 DAS - harvest stage and absolute growth rate of 15.20 g day⁻¹ at 30 - 60 DAS and 14.97 g day⁻¹ at 60 DAS - harvest stage.

Seed and stalk Yields

Among the treatments, the foliar application of 2% DAP + 0.5% KCl + 0.5% ZnSO₄ + 0.5% MnSO₄ (applied at 30 and 45 DAS) (T₈) significantly recorded higher seed yield of 877 kg ha⁻¹ and stalk yield of 1885 kg ha⁻¹, representing increases of 68.00% and 53.25%, respectively, compared to the control (Table 2). This improvement is likely due to the combined effects of macronutrients (NPK) and micronutrients (zinc and manganese). The significant increases in seed and stalk yields were primarily driven by enhanced dry matter accumulation, a greater number of branches plant⁻¹ and more capsules plant⁻¹

(Mahajan *et al.*, 2016) [9]. Improved nutrient uptake, facilitated by effective nutrient translocation from source to reproductive parts, appears to be a key factor in achieving these higher values, as noted by Dhayanethi *et al.* (2024b) [4]. Additionally, the foliar application of zinc and manganese likely activated various enzymes, increased basic metabolic rates, supported nucleic acid and hormone synthesis, and alleviated the effects of water stress. This probable led to more efficient conversion of photosynthates into yield-enhancing traits, ultimately boosting both seed and stalk yields. These results align with the observations of Ramesh (2017) [13]. This treatment was followed by the foliar application of 2% NPK (19:19:19) + 0.5% ZnSO₄ + 0.5% MnSO₄ (applied at 30 and 45 DAS) (T₁₁), which resulted in a seed yield of 841 kg ha⁻¹ and stalk yield of 1812 kg ha⁻¹. The lowest seed yield of 522 kg ha⁻¹ and stalk yield of 1230 kg ha⁻¹ were observed in the control treatment (T₁). This result can be attributed to the lack of NPK, zinc, and manganese provided to the crop, which led to the poorest growth and yield characteristics observed in the control treatment, resulting in a lower yield compared to the other treatments. These findings align with those reported by Siva *et al.* (2017) [16].

Economics

The highest gross income of Rs. 1,09,625 ha⁻¹, net income of Rs. 65,696 ha⁻¹, and a BCR of 2.50 were obtained with the foliar application of 2% DAP + 0.5% KCl + 0.5% ZnSO₄ + 0.5% MnSO₄ (at 30 and 45 DAS) (T₈). This can be attributed to the balanced application of macro and micronutrients through the foliar spray at the appropriate growth stage, which significantly boosted the seed and stalk yields of sesame. As a result, this led to higher gross income, net income, and benefit-cost ratio (BCR). The control treatment (T₁) resulted in the lowest gross income of Rs. 65,250 ha⁻¹, net income of Rs. 24,276 ha⁻¹ and a benefit-cost ratio (BCR) of 1.59.

Table 1: Effect of foliar nutrition on LAI, CGR (g m⁻² day⁻¹) and AGR (g day⁻¹) in sesame

Treatments	LAI	CGR (g m ⁻² day ⁻¹)		AGR (g day ⁻¹)	
	Flowering stage	30 - 60 DAS	60 DAS - harvest	30 - 60 DAS	60 DAS - harvest
T1 - Control (Water spray)	2.53	1.52	1.50	15.20	14.97
T2 - Foliar spray of 2% DAP + 0.5% KCl (30 & 45 DAS)	3.13	2.01	1.88	20.10	18.77
T3 - Foliar spray of 2% 19:19:19 (NPK) (30 & 45 DAS)	2.96	1.87	1.75	18.67	17.53
T4 - Foliar spray of 0.5% MnSO ₄ (30 & 45 DAS)	2.69	1.66	1.61	16.60	16.13
T5 - Foliar spray of 0.5% ZnSO ₄ (30 & 45 DAS)	2.80	1.72	1.64	17.17	16.37
T6 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% ZnSO ₄ (30 & 45 DAS)	3.67	2.40	2.12	24.03	21.20
T7 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% MnSO ₄ (30 & 45 DAS)	3.57	2.36	2.11	23.57	21.13
T8 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% ZnSO ₄ + 0.5% MnSO ₄ (30 & 45 DAS)	4.01	2.69	2.37	26.90	23.73
T9 - Foliar spray of 2% 19:19:19 (NPK) + 0.5% ZnSO ₄ (30 & 45 DAS)	3.40	2.21	2.02	22.07	20.20
T10 - Foliar spray of 2% 19:19:19 (NPK) + 0.5% MnSO ₄ (30 & 45 DAS)	3.31	2.17	1.99	21.67	19.90
T11 - Foliar spray of 2% 19:19:19 (NPK) + 0.5% ZnSO ₄ + 0.5% MnSO ₄ (30 & 45 DAS)	3.85	2.55	2.22	25.47	22.23
S.Ed	0.06	0.04	0.03	0.39	0.36
CD (p=0.05)	0.13	0.08	0.07	0.83	0.75

Table 2: Effect of foliar nutrition on seed and stalk yield and economics in sesame

Treatments	Yields		Economics			
	Seed yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Cost of Cultivation (Rs. ha ⁻¹)	Gross Income (Rs. ha ⁻¹)	Net income (Rs. ha ⁻¹)	B:C ratio
T1 - Control (Water spray)	522	1230	40974	65250	24276	1.59
T2 - Foliar spray of 2% DAP + 0.5% KCl (30 & 45 DAS)	645	1480	42629	80625	37996	1.89
T3 - Foliar spray of 2% 19:19:19 (NPK) (30 & 45 DAS)	608	1405	44854	76000	31146	1.69
T4 - Foliar spray of 0.5% MnSO ₄ (30 & 45 DAS)	560	1309	42754	70000	27246	1.64
T5 - Foliar spray of 0.5% ZnSO ₄ (30 & 45 DAS)	569	1329	42254	71125	28871	1.68
T6 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% ZnSO ₄ (30 & 45 DAS)	780	1734	43029	97500	54471	2.27
T7 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% MnSO ₄ (30 & 45 DAS)	756	1681	43529	94500	50971	2.17
T8 - Foliar spray of 2% DAP + 0.5% KCl + 0.5% ZnSO ₄ + 0.5% MnSO ₄ (30 & 45 DAS)	877	1885	43929	109625	65696	2.50
T9 - Foliar spray of 2% 19:19:19 (NPK) + 0.5% ZnSO ₄ (30 & 45 DAS)	719	1606	45254	89875	44621	1.99
T10 - Foliar spray of 2% 19:19:19 (NPK) + 0.5% MnSO ₄ (30 & 45 DAS)	696	1556	45754	87000	41246	1.90
T11 - Foliar spray of 2% 19:19:19 (NPK) + 0.5% ZnSO ₄ + 0.5% MnSO ₄ (30 & 45 DAS)	841	1812	46154	105125	58971	2.28
S.Ed	12.12	28.74	-	-	-	-
CD (p=0.05)	25.46	60.37	-	-	-	-

Conclusion

From this study, it is concluded that foliar application of 2% DAP + 0.5% KCl + 0.5% ZnSO₄ + 0.5% MnSO₄ at 30 and 45 days after sowing (DAS) recorded significantly higher seed and stalk yields, gross and net returns and BC ratio in irrigated sesame under the Cauvery Delta zone of Tamil Nadu.

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