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Effect of potassium fulvate, Iron and Zinc as foliar spray on growth, yield and quality of spinach (*Spinacia oleracea* L.)

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Abstract
A field experiment conducted during *Rabi* 2024-25 at the Research Farm, College of Agriculture, Karad, evaluated the effect of foliar application of potassium fulvate, Fe, and Zn on the yield and quality of spinach (*Spinacia oleracea* L.) under Inceptisol conditions. Among nine treatments tested in a randomized block design, GRDF + potassium fulvate 0.4% + $FeSO_4$ 0.5% + $ZnSO_4$ 0.5% recorded the highest green leaf yield (200.46 q ha^{-1}), plant height, number of leaves, leaf area, ascorbic acid, chlorophyll and protein content. This treatment also produced superior quality, with maximum ascorbic acid (33.73 mg 100 g^{-1}) and protein content (23.10%), owing to improved nutrient absorption, chlorophyll synthesis and metabolic activity, making it an effective strategy for enhancing spinach yield and quality under Inceptisol conditions.

Keywords: Potassium fulvate, foliar spray, zinc sulphate, ferrous sulphate, spinach

Introduction
Leafy vegetables are nutritionally significant because they grow quickly, yield well in limited space, and provide essential vitamins, minerals, and antioxidants. Among these, spinach (*Spinacia oleracea* L.) of the Amaranthaceae family is widely cultivated and consumed in India and globally. It is valued for its rich composition of vitamin A, vitamin C, iron, calcium, riboflavin, and dietary fiber, which support immune function, eye health, and metabolic activities (Mursia *et al.*, 2020) [7]. To enhance growth and quality, effective nutrient management is essential. Recently, biostimulants, particularly humic substances, have gained attention as sustainable inputs. These substances originate from decomposition of organic matter and are categorized into humic acid, fulvic acid, and humin (Stevenson, 1994) [10]. Fulvic acid, due to its low molecular size and high solubility, improves nutrient uptake, enzyme activity, and photosynthesis. Its potassium salt, potassium fulvate, is widely used as a foliar spray to stimulate growth (Ali *et al.*, 2015; Monda *et al*., 2021) [2, 6]. Iron and zinc, vital for chlorophyll synthesis and enzyme functioning, are often deficient in soils, and foliar application with potassium fulvate enhances their absorption and utilization (Tavanti *et al*., 2020; Saudy *et al.*, 2021) [11, 9].

Materials and Methods
The experiment was conducted on spinach (*Spinacia oleracea* L.) variety Pusa Jyoti during the Rabi season at the Government College of Agriculture, Karad (Dist. Satara, Maharashtra) on Inceptisol. The crop was sown on 12 December 2024 with a seed rate of 8-10 kg ha^{-1}, and two cuttings were taken at 37 and 52 days after sowing, respectively**.** The experiment consisted of nine treatments: T_1 - Absolute control; T_2 - GRDF (FYM 10 t ha^{-1} + 80:40:40 kg ha^{-1} N:P_2O_5:K_2O); T_3 - GRDF + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%; T_4 - GRDF + 0.4% foliar spray of potassium fulvate; T_5 - GRDF + 0.6% foliar spray of potassium fulvate; T_6 - GRDF + 0.8% foliar spray of potassium fulvate; T_7 - GRDF + 0.4% foliar spray of potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%; T_8 - GRDF + 0.6% foliar spray of potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%; and T_9 - GRDF + 0.8% foliar spray of potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%. The GRDF (FYM 10 t ha^{-1} + 80:40:40 kg ha^{-1} N:P_2O_5: K_2O) was applied to all treatments except T_1, with potassium fulvate sourced from vermicompost. Foliar sprays of potassium fulvate, zinc sulphate, and ferrous were applied at 30 and 45 days after sowing

Results and Discussion

Growth Attributes

Foliar application of potassium fulvate, either alone or in combination with iron and zinc, significantly improved the growth attributes of spinach compared to the control (T_1). The combined application of GRDF + 0.4% potassium fulvate + 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ (T_7) consistently recorded the highest plant height, number of leaves, and leaf area at both 37 and 52 DAS. Foliar application of potassium fulvate at 0.4-0.6% concentration also enhanced growth parameters; however, its efficiency declined at higher concentrations (>0.6%). The improvement in growth may be attributed to the role of fulvic acid in enhancing nutrient absorption, enzyme activity, and photosynthetic efficiency, while Fe and Zn contribute to chlorophyll synthesis and metabolic functioning. These results suggest that foliar application of potassium fulvate in combination with Fe and Zn serves as an effective biostimulant for improving vegetative growth in spinach. Similar results were reported by Abdel-Baky *et al*. (2019) [1] in faba bean, Wang *et al.* (2019) [13] in lettuce, El-Sawy *et al.* (2020) [3] in snap bean, Nimmala *et al*. (2021) [8] in chilli, and Turan *et al.* (2022) [12] in spinach, indicating that fulvic acid combined with micronutrients effectively enhances vegetative growth and nutrient uptake.

Quality Parameters

Foliar application of potassium fulvate in combination with iron and zinc markedly enhanced the total chlorophyll content in spinach leaves. The treatment comprising GRDF + 0.4% potassium fulvate + 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ recorded the highest chlorophyll levels at both first and second cuttings, indicating improved photosynthetic efficiency. Sole application of potassium fulvate also increased chlorophyll content, with 0.4-0.6% being the most effective range; however, concentrations above 0.6% showed a slight decline, suggesting possible antagonistic effects at higher doses. The enhancement in chlorophyll may be attributed to improved micronutrient availability, stimulation of chloroplast development, and delayed leaf senescence due to humic-substance activity. Overall, the combined application of potassium fulvate with Fe and Zn proved more beneficial than individual applications. Similar result were reported by (Gabr *et al.* 2022) [4] in spinach and (Wang *et al.* 2019) [13].

Foliar application of potassium fulvate in combination with iron and zinc markedly improved the quality attributes of spinach. The treatment consisting of GRDF + 0.4% potassium fulvate + 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ consistently recorded the highest ascorbic acid (33 mg 100 g^{-1}) and protein content (23%) at both cuttings, outperforming both the control and sole nutrient applications. Although potassium fulvate alone enhanced ascorbic acid and protein levels compared to control, concentrations beyond 0.4% showed a slight decline, indicating reduced efficiency at higher doses. The improvement in quality may be attributed to enhanced micronutrient uptake, improved metabolic activity, and increased nitrogen assimilation facilitated by fulvic substances. Overall, the combined foliar application of potassium fulvate with Fe and Zn proved more effective than individual treatments in enhancing the nutritional quality of spinach. The similar trend of observation was reported by (Gabr *et al.* 2022) [4] for spinach.

Yields

Foliar application of potassium fulvate significantly enhanced the fresh yield of spinach, particularly when combined with iron and zinc. The treatment comprising GRDF + 0.4% potassium fulvate + 0.5% $FeSO_4$ + 0.5 % $ZnSO_4$ produced the highest total fresh yield (200 q ha^{-1}), nearly double that of the absolute control. Sole application of potassium fulvate also improved yield, with 0.4-0.6% concentrations showing greater effectiveness than higher doses. The increased yield is attributed to improved nutrient uptake, enhanced root growth, and greater photosynthetic efficiency stimulated by fulvic substances. Overall, the combined foliar application of potassium fulvate with Fe and Zn proved superior in promoting higher biomass production in spinach. The results obtained in present study are in confirmation with the results reported by by Turan *et al.* (2022) [12] for spinach.

Table 1: Effect of foliar application of potassium fulvate, iron and zinc on plant height, number of leaves, leaf area and fresh yield of spinach

Tr. No.	Treatment	Plant height (cm)		Number of leaves		Leaf Area (cm^2)		Total fresh yield (q ha^{-1})
		1st cutting (37DAS)	2nd cutting (52 DAS)	1st cutting (37DAS)	2nd cutting (52 DAS)	1st cutting (37DAS)	2nd cutting (52 DAS)	
T_1	Absolute control	14.51	20.71	7.07	9.93	74.49	81.32	97.49
T_2	GRDF (FYM 10 t ha^{-1} + 80:40:40 kg ha^{-1} N: P_2O_5:K_2O)	18.43	24.51	9.93	13.13	96.18	100.74	149.59
T_3	GRDF + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	21.29	25.38	13.00	16.60	108.44	116.53	168.22
T_4	GRDF + 0.4 % foliar spray potassium fulvate	22.76	25.59	15.33	18.80	112.54	126.83	171.37
T_5	GRDF + 0.6 % foliar spray potassium fulvate	24.16	27.62	16.87	21.20	116.89	128.41	175.46
T_6	GRDF + 0.8 % foliar spray potassium fulvate	24.17	27.71	15.03	20.87	118.01	128.38	172.40
T_7	GRDF + 0.4 % foliar spray potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	26.56	32.13	19.20	22.97	127.12	143.40	200.46
T_8	GRDF + 0.6 % foliar spray potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	26.35	31.19	19.10	22.07	126.70	141.86	199.55
T_9	GRDF + 0.8 % foliar spray potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	26.34	30.19	19.03	21.93	126.51	139.37	198.83
	S.E ±	0.79	0.65	0.66	0.39	2.80	3.66	2.98
	C.D. at 5%	2.38	1.18	1.98	1.19	8.42	10.99	8.94

Table 2: Effect of foliar application of potassium fulvate, iron and zinc on total chlorophyll, ascorbic acid and Protein content of spinach

Tr. No	Treatment	Total chlorophyll (mg g^{-1} of fresh tissue)		Ascorbic acid (mg $100g^{-1}$)		Protein %	
		1st cutting (37DAS)	2nd cutting (52 DAS)	1st cutting (37DAS)	2nd cutting (52 DAS)	1st cutting (37 DAS)	2nd cutting (52 DAS)
T_1	Absolute control	1.55	1.66	22.17	24.43	17.27	16.82
T_2	GRDF (FYM 10 t ha^{-1} + 80:40:40 kg ha-1 N: P_2O_5:K_2O)	1.71	1.86	23.43	25.43	20.96	21.23
T_3	GRDF + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	1.87	2.01	25.37	27.40	21.67	21.85
T_4	GRDF + 0.4 % foliar spray potassium fulvate	1.97	2.09	26.27	27.73	21.63	21.92
T_5	GRDF + 0.6 % foliar spray potassium fulvate	2.03	2.19	29.13	29.13	22.08	22.21
T_6	GRDF + 0.8 % foliar spray potassium fulvate	1.97	2.15	29.33	28.03	22.00	22.15
T_7	GRDF + 0.4 % foliar spray potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	2.17	2.28	32.80	33.73	22.79	23.10
T_8	GRDF + 0.6 % foliar spray potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	2.13	2.22	32.00	31.83	22.71	22.81
T_9	GRDF + 0.8 % foliar spray potassium fulvate + $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	2.12	2.21	31.13	31.43	22.35	22.56
	S.E ±	0.019	0.028	0.744	0.785	0.14	0.25
	C.D. at 5%	0.06	0.08	2.23	2.35	0.42	0.76

Conclusion

Foliar application of potassium fulvate in combination with iron and zinc proved highly effective in improving the growth, yield, and quality of spinach. The treatment GRDF + 0.4% potassium fulvate + 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ consistently recorded the highest plant height, leaf area, number of leaves, chlorophyll content, ascorbic acid, protein content, and total fresh yield. The beneficial effects may be attributed to enhanced nutrient uptake, improved photosynthetic activity, and stimulation of metabolic processes by fulvic substances and micronutrients. Overall, 0.4% potassium fulvate with Fe and Zn as foliar spray is recommended as an efficient and eco-friendly nutrient management approach for maximizing spinach productivity and nutritional quality.

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