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Impact of zinc and iron foliar application on growth analysis study of Urdbean (*Vigna mungo* L. Hepper)

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Abstract
Urdbean (*Vigna mungo* L. Hepper) is a significant warm-season legume crop in South Asia, particularly in India, known for its high nutritional value. This study explores the influence of iron and zinc foliar applications on the growth parameters of Urdbean, focusing on parameters like Leaf Area Index (LAI), Leaf Area Ratio (LAR), Leaf Area Duration (LAD), Absolute Growth Rate (AGR), Relative Growth Rate (RGR), and Net Assimilation Rate (NAR). The experiment, conducted during the kharif season of 2023, employed a randomized block design with genotypes AKU 10 01 and ten combination treatments, including various stages of micronutrient foliar application.
Results revealed nuanced effects on growth parameters, with significant variations observed at different growth stages. However, post-vegetative stage applications of zinc and iron did not yield statistically significant differences in growth parameters. The findings emphasize the complexity of nutrient management and its implications for crop growth, providing valuable insights for sustainable agricultural practices in Urdbean cultivation.

Keywords: Urdbean, micronutrient foliar application, growth parameters, Leaf Area Index (LAI), Leaf Area Ratio (LAR), Leaf Area Duration (LAD), Absolute Growth Rate (AGR), Relative Growth Rate (RGR), Net Assimilation Rate (NAR), kharif season, randomized block design, sustainable agriculture

Introduction
Urdbean, scientifically termed *Vigna mungo* L. Hepper, is a warm-season legume extensively cultivated across South Asia, with India standing as its primary producer and consumer. This leguminous crop is highly valued for its nutritional density, boasting approximately 24% protein, 62% carbohydrate, and 1.7% fats per 100 grams. Notably rich in phosphoric acid, it also contains significant quantities of essential nutrients such as 7.2 mg Iron, 3 mg Zinc, 360 mg phosphorus, and 1240 mg Potassium, surpassing other pulses in nutrient content by 5 to 10 times [1]. In India, the Kharif Urdbean cultivation area spans 32.13 million hectares, yielding around 15.07 million tons with a productivity rate of 469 Kg/ha [2].
Growth analysis serves as a quantitative representation of environmental influences on crop growth and development. It proves invaluable in unravelling the intricate dynamics between plant growth and the surrounding environment. The complexity of accounting for yield variation stems from several factors: the impact of external environmental conditions on plant physiological processes, the interconnectedness of various physiological processes, and the influence of internal factors governed by the plant's genetic makeup. The fundamental principle behind growth analysis is to estimate crop growth at different stages and decipher yield variations, offering insights into both genotype performance and the effects of agronomic practices at various growth stages and final yield.
These parameters play a pivotal role in understanding plant development, productivity, and overall well-being. They are crucial for Assessing Crop Performance as they provide a comprehensive evaluation of how effectively a crop is growing. Biomass accumulation, leaf area, and photosynthetic efficiency are among the factors measured, offering a holistic perspective on crop health. Researchers, agronomists, and farmers leverage this information to make informed decisions about crop management practices [3].

Furthermore, these parameters aid in Predicting Yield Potential by estimating a crop's potential yield through metrics like Absolute Growth Rate (AGR) and Relative Growth Rate (RGR). Understanding the growth rate and resource utilization efficiency helps in projecting future yields. They also contribute to Optimizing Resource Allocation by guiding resource distribution within the plant, as evidenced by metrics like Leaf Area Ratio (LAR) and Leaf Area Index (LAI), which balance leaf area with total biomass and quantif leaf area per unit ground area, respectively.

Additionally, growth analysis helps in Monitoring Environmental Impact by tracking the Net Assimilation Rate (NAR), reflecting the plant's carbon assimilation capacity through photosynthesis. This allows for an assessment of how environmental factors like light, temperature, and CO_2 levels affect crop growth. Ultimately, growth analysis aids in Improving Sustainable Practices by identifying growth-limiting factors. For instance, a low AGR may indicate nutrient deficiencies or other stressors, prompting the implementation of sustainable practices to boost crop productivity.

In this study, we are focusing the impact of iron and zinc foliar application on urdbean and their impact on growth parameters *viz*. LAD, LAI, LAR, AGR, RGR.

Materials and Methods

The field experiment took place at the Research Farm within the Department of Agronomy at Dr. Panjabrao Deshmukh Krishi Vidyapeeth in Akola. The farm's geographic coordinates are approximately 17°32'N latitude and 78°41'E longitude, with an altitude of 542.6 meters above sea level. The soil composition at the experimental site was identified as clayey, slightly alkaline, and saline. Regarding soil fertility, it exhibited low organic carbon levels at 0.42%, medium availability of nitrogen (198 kg ha^{-1}), low phosphorus content (19 kg ha^{-1}), and high potassium content (396 kg ha^{-1}).

The experiment was carried out during the kharif season of 2023 using a randomized block design with genotypes AKU 10 01 and ten combination and various stages of foliar application of zinc and iron. Fertilization management adhered to the Recommended Dose of Fertilizers (RDF) provided by Dr. PDKV Akola, which consisted of a ratio of 20:40:20 of nitrogen, phosphorus, and potassium per hectare. The sources used for nitrogen, phosphorus (P2O5), and potassium (K2O) were Urea, DAP, and MOP, respectively. Zinc and iron were applied in their septa hydrate and sulphate forms, respectively, as foliar sprays during the flower and pod development stages according to the prescribed treatment regimen.

Basic parameters such as plant height, leaf area per plant, and dry matter were recorded at intervals of 15, 30, 45, and 60 days after sowing, as well as at harvest. Yield observations were also taken into account.

Other growth-related observations were noted throughout the experiment and included:

Leaf Area Index

This is the area of photosynthetic surface produced by the individual plant over a period of interval of time and expressed in cm2 plant-The leaf area index of the plant is determined at 15, 30, 45, and 60 DAS (days after sowing) using the fundamental formula [4].

$$\frac{Total\ leaf\ area\ (dsm)}{Ground\ area\ occupied\ yb\ plant}$$

Leaf area ratio

It expresses the ratio between the area of leaf lamina to the total plant biomass or the LAR reflects the leafiness of a plant or amount of leaf area formed per unit of biomass and expressed in cm^{-2} g^{-1} of plant dry weight.

It can be calculated by formula

$$\frac{Leaf\ area\ per\ plant}{plant\ dry\ matter}$$

Leaf Area Duration

To correlate dry matter yield with LAI, Power *et al.* (1967) integrated the LAI with time and called as Leaf Area Duration. LAD takes into account, both the duration and extent of photosynthetic tissue of the crop canopy. The LAD is expressed in days

$$\frac{L1 + L2}{2} X(t2 - t1)$$

Where, L2 is leaf area of later stage time T_2 and L1 is leaf Area of time T_1

Absolute growth rate

The rate of increasing growth variable (w)at the time (t)is called as absolute growth rate. AGR of two variable is compounded using formula [5].

AGR for Plant Height

$$\frac{H2 - H1}{T2 - T1}$$

Where H2 and W2 are height and dry matter at time T_2 and H1 and W1 are height and dry matter at time T_1

Relative growth rate

This parameter indicates the rate of growth per unit dry matter and have unit g g-1 day-1 (6&7)

$$\frac{Log(W2) - Log(W1)}{T2 - T1}$$

Where

W2 is dry matter at time T_2 and W_1 is dry matter at time T_1

Results and Discussion

Table 1 presents the values of AGR calculated using specified formulas. The average AGR values are 0.58, 0.812, 0.720, and 0.538 at 15, 30, 45, and 60 days after sowing (DAS) and at harvest. The increase in AGR up to 60 DAS indicates height growth, while a decline in AGR is observed at harvest due to the crop transitioning to the maturity phase followed by senescence. None of the treatments were found to be significant, as zinc and iron were applied post-vegetative stage. (Stat done by Gomez *et al.* [9].

For LAI (Leaf Area Index), the values in Table 2 were calculated using specified formulas. The average LAI values are 0.12, 0.33, 1.27, and 1.28 at 15, 30, 45, and 60 DAS. The increase in LAI up to 45 DAS indicates plant area growth and positive crop development, with a lower increase in LAI at 60 DAS due to the crop transitioning to maturity and eventual death. Similar to AGR, treatments were not significant as zinc and iron were applied post-vegetative stage.

Regarding LAR (Leaf Area Ratio), values in Table 2 were calculated using specified formulas. The average LAR values are 1.93, 1.57, 2.28, and 1.85 at 15, 30, 45, and 60 DAS. The increase in LAR up to 45 DAS indicates plant area growth and positive crop development, with a lower increment at 60 DAS due to the crop transitioning to maturity and eventual death. As with AGR and LAI, treatments showed no significance due to post-vegetative stage application of zinc and iron.

Similarly, for LAD (Leaf Area Duration), values in Table 3 were calculated using specified formulas. The average LAD values are 0.92, 3.41, 12.01, and 23.09 at 15, 30, 45, and 60 DAS. The increase in LAD up to 45 DAS indicates plant area growth and positive crop development, with no further increase at 60 DAS due to the crop reaching maturity and eventual senescence. Treatments were not significant, attributed to post-vegetative stage application of zinc and iron.

Finally, Table 3 provides RGR (Relative Growth Rate) values calculated using prescribed values. The average RGR values are 0.5, 0.57, and 0.2 at 30, 45, 60 DAS, and at harvest. The increase in RGR up to 60 DAS indicates height growth, with a decrease at harvest due to the crop transitioning to maturity followed by senescence. Similar to other parameters, treatments were not significant due to post-vegetative stage application of zinc and iron.

Tables 1: Effect of various treatment on AGR of Urdbean crop

Symbol	Treatment Details	AGR- Height (cm/day)				
		15 DAS	30 DAS	45 DAS	60 DAS	AH
T_1	RDF + FA of 0.50% $ZnSO_4$ at FI	0.536	0.830	0.619	0.526	0.020
T_2	RDF + FA of 0.50% $FeSO_4$ at FI	0.546	0.791	0.835	0.762	0.163
T_3	RDF + FA of 0.50% $ZnSO_4$ at PI	0.600	0.774	0.672	0.450	0.111
T_4	RDF + FA of 0.50% $FeSO_4$ at PI	0.536	0.831	0.904	0.448	0.035
T_5	RDF + FA of 0.50% $ZnSO_4$ + 0. 50% $FeSO_4$ at FI	0.564	0.872	0.738	0.543	0.119
T_6	RDF + FA of 0.50% $ZnSO_4$ + 0. 50% $FeSO_4$ at PI	0.556	0.901	0.469	0.514	0.123
T_7	RDF + FA of 0.50% $ZnSO_4$ + 0.50% $FeSO_4$ at FI & PI	0.544	1.023	0.723	0.473	0.178
T_8	RDF + FA of "PDKV Liquid Micro Grade X" at FI & PI	0.509	0.799	0.905	0.465	0.107
T_9	75% RDF + FA of 0.50% $ZnSO_4$ + 0.50% $FeSO_4$ at FI and PI	0.551	0.544	0.645	0.621	0.154
T_{10}	RDF (Control)	0.540	0.748	0.721	0.578	0.115
	S.E. (m)+	0.03	0.06	0.09	0.19	0.22
	CD (P=0.05)	NS	NS	NS	NS	NS
	CV (%)	10.09	12.85	22.39	62.57	343.67
	GM	0.548	0.812	0.72	0.538	0.112
	Where, FI : Flower Initiation, PI : Pod Initiation, RDF,: Recommended dose of Fertilizers, FA : Foliar Application					

Tables 2: Effect of various treatment on Leaf Area Index and Leaf Area Ratio of Urdbean crop

Symbol	Treatment Details	Leaf Area Index				Leaf Area Ratio			
		15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
T_1	RDF + FA of 0.50% $ZnSO_4$ at FI	0.128	0.339	1.326	1.377	1.92	1.52	2.25	1.95
T_2	RDF + FA of 0.50% $FeSO_4$ at FI	0.121	0.322	1.250	1.215	2.01	1.64	2.40	1.95
T_3	RDF + FA of 0.50% $ZnSO_4$ at PI	0.129	0.393	1.295	1.372	1.85	1.85	2.24	1.74
T_4	RDF + FA of 0.50% $FeSO_4$ at PI	0.123	0.325	1.255	1.235	2.22	1.63	2.32	2.07
T_5	RDF + FA of 0.50% $ZnSO_4$ + 0. 50% $FeSO_4$ at FI	0.120	0.319	1.363	1.403	1.91	1.40	2.22	1.79
T_6	RDF + FA of 0.50% $ZnSO_4$ + 0. 50% $FeSO_4$ at PI	0.127	0.331	1.402	1.411	1.78	1.41	2.34	1.91
T_7	RDF + FA of 0.50% $ZnSO_4$ + 0.50% $FeSO_4$ at FI & PI	0.121	0.319	1.420	1.419	1.90	1.35	2.47	1.63
T_8	RDF + FA of "PDKV Liquid Micro Grade X" at FI & PI	0.127	0.337	1.245	1.158	1.81	1.72	2.33	2.03
T_9	75% RDF + FA of 0.50% $ZnSO_4$ + 0.50% $FeSO_4$ at FI and PI	0.115	0.304	1.052	1.089	1.91	1.47	2.00	1.71
T_{10}	RDF (Control)	0.122	0.324	1.094	1.140	1.94	1.67	2.21	0.99
	S.E. (m)+	0.01	0.02	0.11	0.09	0.15	0.10	0.21	0.21
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
	CV (%)	9.95	10.84	14.90	12.76	13.90	11.17	22.45	19.23
	GM	0.12	0.33	1.270	1.28	1.93	1.57	2.28	1.85

Tables 3: Effect of various treatment on leaf area duration and relative growth rate of Urdbean crop

Symbol	Treatment Details	Leaf Area Duration				Relative Growth Rate		
		15 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1	RDF + FA of 0.50% $ZnSO_4$ at FI	0.96	3.50	12.49	23.79	0.053	0.048	0.021
T_2	RDF + FA of 0.50% $FeSO_4$ at FI	0.91	3.33	11.79	21.81	0.052	0.050	0.020
T_3	RDF + FA of 0.50% $ZnSO_4$ at PI	0.96	3.91	12.66	22.53	0.050	0.050	0.020
T_4	RDF + FA of 0.50% $FeSO_4$ at PI	0.92	3.36	11.85	22.01	0.056	0.050	0.020
T_5	RDF + FA of 0.50% $ZnSO_4$ + 0. 50% $FeSO_4$ at FI	0.90	3.29	12.61	24.48	0.056	0.049	0.021
T_6	RDF + FA of 0.50% $ZnSO_4$ + 0. 50% $FeSO_4$ at PI	0.95	3.43	13.00	24.64	0.053	0.048	0.021
T_7	RDF + FA of 0.50% $ZnSO_4$ + 0.50% $FeSO_4$ at FI & PI	0.91	3.30	13.04	26.10	0.056	0.048	0.021
T_8	RDF + FA of "PDKV Liquid Micro Grade X" at FI & PI	0.95	3.48	11.86	24.16	0.048	0.050	0.020
T_9	75% RDF + FA of 0.50% $ZnSO_4$ + 0.50% $FeSO_4$ at FI and PI	0.86	3.14	10.18	19.93	0.054	0.046	0.018
T_{10}	RDF (Control)	0.92	3.35	10.63	21.47	0.051	0.049	0.021
	S.E. (m)+	0.05	0.18	0.80	1.58	0.00	0.002	0.001
	CD (P=0.05)	0.16	0.53	2.36	4.68	0.00	0.005	0.004
	CV (%)	9.95	9.02	11.48	11.82	4.48	5.523	11.809
	GM	0.92	3.41	12.01	23.09	0.05	0.05	0.02

Conclusion

These experimental findings indicate that applying micronutrients after the vegetative stages yields better results, especially when applied in combination. However, these effects are not statistically significant in terms of growth based on analytical studies. These studies also suggest that fundamental parameters are not significantly affected by these treatments.

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