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Impact of bioregulators on groundnut (*Arachis hypogaea* L.) growth under deficit irrigation conditions

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Abstract
A field experiment was conducted during *Rabi* 2024-25 at Professor Jayashankar Telangana State Agricultural University, Hyderabad, to evaluate the effects of irrigation schedules and bioregulator applications on groundnut growth under semi-arid conditions. The experiment was laid out in a split-plot design with three replications. Main plot treatments included four irrigation schedules: full irrigation (I1), irrigation skipped at pre-flowering (I2), irrigation skipped at pre-flowering and pegging (I3) and irrigation skipped at pre-flowering, pegging and pod formation (I4). Sub-plot treatments comprised foliar application of bioregulators: Triacontanol 2 ml l^{-1} (B1), Salicylic acid 2 ml l^{-1} (B2), PPFM 10 ml l^{-1} (B3) and control (B4).
Results revealed that full irrigation (I1) significantly enhanced plant height, dry matter production and leaf area index (LAI) compared to the most stressed treatment (I4). However, growth parameters under I1 and I2 were statistically similar at 60, 80 DAS and harvest, demonstrating the ability of groundnut plants to recover from early-season water stress through compensatory growth. Among the bioregulators, Triacontanol (B1) consistently outperformed other treatments, significantly improving all growth traits compared to the control (B4), owing to its role in promoting photosynthesis, nutrient uptake, and cell elongation. Interaction effects between irrigation schedules and bioregulators were non-significant.
In conclusion, deficit irrigation at the pre-flowering stage (I2) combined with Triacontanol application (B1) provides a sustainable management strategy for enhancing groundnut growth while conserving water under semi-arid conditions.

Keywords: Groundnut, deficit irrigation, bioregulators, triacontanol, dry matter, LAI, compensatory growth

Introduction
Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops in India, ranking first in area and second in production after soybean. It is cultivated on 5.74 million hectares, producing 10.13 million tonnes with an average productivity of 1.77 t ha^{-1}. In Telangana, groundnut is grown on 1.55 lakh hectares with an output of 3.49 lakh tonnes and productivity of 2.26 t ha^{-1} (Indiastat, 2023) [4].
Water is the most limiting input for crop production in semi-arid regions. Efficient water use requires synchronizing irrigation with nutrient supply during critical crop stages (Soni *et al.,* 2019) [8]. Groundnut is particularly sensitive to water deficits during flowering, pegging, and pod filling stages, which can drastically reduce yield (Behera *et al.,* 2015; Balasubramanian *et al.,* 2023) [2, 1]. However, stress during early vegetative growth stages is often less damaging, as plants can recover later through compensatory mechanisms.
Plants produce endogenous bioregulators that mediate stress tolerance, but these are often insufficient under drought. Exogenous application of bioregulators such as Triacontanol, Salicylic acid and PPFM can mitigate moisture stress, enhance flower set, and improve yield stability (Siddik *et al.,* 2016; Wakchaure *et al.,* 2018; Nathawat *et al.,* 2021) [7, 9, 6]. Triacontanol, in particular, is known to enhance photosynthetic activity, assimilate partitioning and cell elongation. Salicylic acid modulates stress signaling, while PPFM (Pink Pigmented Facultative Methylotrophs) promotes plant growth via phytohormone production.
Given the increasing incidence of droughts in Telangana, this study was conducted to evaluate

the effects of deficit irrigation and foliar bioregulator application on the growth performance of groundnut.

Materials and Methods

The field experiment was conducted during *Rabi* 2024-25 at the Student Farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad (17°19′N, 78°24′E, 542 m MSL). The soil was sandy loam, slightly alkaline (pH 6.2), low in available nitrogen (180.4 kg ha⁻¹) and organic carbon (0.39%), medium in phosphorus (24.6 kg ha⁻¹), and high in potassium (302 kg ha⁻¹). The experiment followed a split-plot design with three replications. The treatments were: Irrigation schedules (main plots): I1: Full irrigation (control), I2: Irrigation skipped at pre- flowering, I3: Irrigation skipped at pre-flowering and pegging and I4: Irrigation skipped at pre- flowering, pegging and pod formation. Bioregulators (sub plots): B1: Triacontanol 2 ml l⁻¹, B2: Salicylic acid 2 ml l⁻¹, B3: PPFM 10 ml l⁻¹ and B4: Control (water spray). Bioregulators were sprayed at 30, 50, and 70 DAS. The groundnut variety TCGS-1694 was sown at 22.5 × 10 cm spacing, adopting recommended practices. Growth parameters (plant height, dry matter production, and LAI) were recorded at 20, 40, 60, 80 DAS and harvest, and data were analyzed statistically using Gomez and Gomez (1984) [3].

Results and Discussion Plant Height

Plant height was significantly higher under I1 compared to I4 at all stages (Table 1). However, I1 and I2 recorded statistically similar values at 60, 80 DAS and harvest, indicating that early-stage stress did not cause irreversible damage. The compensatory growth observed after rewatering is likely due to deeper rooting and efficient soil moisture extraction, corroborating Behera *et al.* (2015) [2] and Balasubramanian *et al.* (2023) [1], who emphasized that reproductive-stage stress is more detrimental than early vegetative stress.

Among bioregulators, Triacontanol (B1) significantly improved plant height compared to the control (B4). Its role in stimulating cell division, chlorophyll biosynthesis, and nutrient uptake aligns with findings of Kumar and John (2018) in mustard and Wakchaure *et al.* (2018) [9] in onion. Interaction effects were non-significant.

Dry Matter Production

Dry matter accumulation followed a similar trend (Table 2). I1 produced the highest biomass, while I4 recorded the lowest. I1 and I2 were statistically similar at 60, 80 DAS and harvest, reflecting the crop's resilience to pre-flowering drought through root proliferation and resource reallocation. Soni *et al.* (2019) [8] demonstrated that synchronized irrigation enhances biomass, supporting the present findings.

Bioregulator application of Triacontanol (B1) produced the highest dry matter, followed by Salicylic acid (B2) and PPFM (B3), all of which were superior to the control (B4). Nathawat *et al.* (2021) [6] reported similar improvements in stress tolerance and productivity with exogenous bioregulators, highlighting their role in maintaining biomass under deficit irrigation.

Leaf Area Index (LAI)

LAI was significantly higher under I1 at all stages, with I2 performing on par with I1 at 60, 80 DAS and harvest (Table 3). The reduction in LAI during pre-flowering stress was compensated by rapid leaf expansion upon rewatering, consistent with Wakchaure *et al.* (2018) [9], who observed compensatory leaf growth in onion under deficit irrigation.

Among bioregulators, Triacontanol (B1) produced the highest LAI, followed closely by Salicylic acid (B2) and PPFM (B3), confirming their role in promoting canopy development. Siddik *et al.* (2016) [7] also reported similar improvements in physiological traits of sesame under stress.

Table 1: Plant height of groundnut as influenced by deficit irrigation and bioregulator

Treatments		Plant height (cm)				
		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Deficit Irrigation (I)						
I1: Full irrigation (Control)		11.3	17.7	23.0	26.0	28.3
I2: Irrigation skipped at pre- flowering stage		11.6	16.8	22.4	25.4	27.5
I3: Irrigation skipped at pre- flowering and pegging		11.3	16.5	17.6	20.7	23.3
I4: Irrigation skipped at pre- flowering, pegging and pod formation stage		11.5	16.3	17.3	18.2	21.5
SEm±		0.3	0.2	0.4	0.6	0.7
CD (P=0.05)		NS	0.8	1.5	2.1	2.6
Bioregulators (B)						
B1: Triacontanol 2ml l⁻¹		11.5	17.4	21.3	23.7	26.2
B2: Salicylic acid 2ml l⁻¹		11.5	16.9	20.3	22.7	25.3
B3: PPFM 10 ml l⁻¹		11.3	16.9	20.1	22.6	25.1
B4: Control (Water Spray)		11.4	16.0	18.6	21.3	23.8
SEm±		0.2	0.2	0.3	0.3	0.4
CD (P=0.05)		NS	0.8	0.9	0.9	1.3
Interaction						
B x I	SEm±	0.4	0.5	0.6	0.6	0.9
	CD (P=0.05)	NS	NS	NS	NS	NS
I x B	SEm±	0.5	1.5	0.7	0.8	1.1
	CD (P=0.05)	NS	NS	NS	NS	NS

Table 2: Dry matter production of groundnut as influenced by deficit irrigation and bioregulators

Treatments		Dry matter production (kg ha^{-1})				
		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Deficit Irrigation (I)						
I1: Full irrigation (Control)		356	1532	2974	4733	5811
I2: Irrigation skipped at pre- flowering stage		368	1227	2751	4497	5540
I3: Irrigation skipped at pre- flowering and pegging		320	1233	1895	3528	4237
I4: Irrigation skipped at pre- flowering, pegging and pod formation stage		353	1203	1833	2405	3246
SEm±		12	41	81	83	82
CD (P=0.05)		NS	147	283	239	284
Bioregulators (B)						
B1: Triacontanol 2ml l^{-1}		344	1461	2609	4153	5216
B2: Salicylic acid 2ml l^{-1}		356	1323	2352	3757	4708
B3: PPFM 10 ml l^{-1}		345	1331	2344	3708	4662
B4: Control (Water Spray)		351	1230	2148	3544	4248
SEm±		12	39	77	107	72
CD (P=0.05)		NS	117	231	321	210
Interaction						
B x I	SEm±	22	79	159	215	144
	CD (P=0.05)	NS	NS	NS	NS	NS
I x B	SEm±	23	80	157	204	149
	CD (P=0.05)	NS	NS	NS	NS	NS

Table 3: Leaf area index (LAI) of groundnut as influenced by deficit irrigation and bioregulators

Treatments		LAI				
		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Deficit Irrigation (I)						
I1: Full irrigation (Control)		0.22	1.4	2.3	2.8	2.5
I2: Irrigation skipped at pre- flowering stage		0.24	1.0	2.1	2.6	2.3
I3: Irrigation skipped at pre- flowering and pegging		0.23	1.0	1.4	2.0	1.6
I4: Irrigation skipped at pre- flowering, pegging and pod formation stage		0.23	1.1	1.4	1.7	1.5
SEm±		0.01	0.03	0.06	0.08	0.07
CD (P=0.05)		NS	0.1	0.2	0.3	0.2
Bioregulators (B)						
B1: Triacontanol 2ml l^{-1}		0.22	1.3	2.0	2.5	2.2
B2: Salicylic acid 2ml l^{-1}		0.22	1.2	1.8	2.2	1.9
B3: PPFM 10 ml l^{-1}		0.24	1.2	1.9	2.3	2.0
B4: Control (Water Spray)		0.23	1.1	1.5	1.8	1.5
SEm±		0.01	0.03	0.07	0.08	0.07
CD (P=0.05)		NS	0.1	0.2	0.3	0.2
Interaction						
B x I	SEm±	0.01	0.06	0.14	0.17	0.15
	CD (P=0.05)	NS	NS	NS	NS	NS
I x B	SEm±	0.01	0.06	0.14	0.17	0.15
	CD (P=0.05)	NS	NS	NS	NS	NS

Conclusion

The study concluded that skipping irrigation at the pre-flowering stage (I2) had minimal adverse impact on growth compared to full irrigation (I1), demonstrating the resilience of groundnut to early-season drought. Triacontanol (B1) was the most effective bioregulator, significantly enhancing plant height, dry matter production, and LAI over the control. Interaction effects between irrigation and bioregulators were non-significant.

Thus, a combination of deficit irrigation at pre-flowering (I2) with Triacontanol application (B1) is recommended as a water-saving and growth-enhancing strategy for sustainable groundnut cultivation under semi-arid conditions.

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