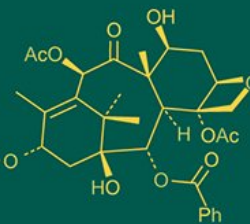
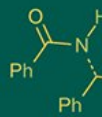


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Impact of plant growth regulators on morphological, yield and quality of black gram (*Vigna Mungo* L.) under drought stress during different growth stages

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Abstract

To assess the effect of growth stage specific water stress and plant growth regulators on the growth, yield and seed quality of black gram and their potential role in mitigating moisture stress. A field experiment was conducted during 2025 at Department of Plant Physiology, Anand Agricultural University, Anand. The treatments comprised water stress imposed at vegetative (I₁), flowering (I₂) and reproductive (I₃) stages along with no stress (I₄), and foliar application of control (F₀), NAA @ 75 ppm (F₁) and paclobutrazol (PBZ) @ 75 ppm (F₂) at 30 and 40 DAS with split plot design. Water stress significantly affected major growth and yield attributes, with no stress (I₄) recording the highest number of pods per plant (35.27), 100 seed weight (6.12 g) and seed yield (925.50 kg ha⁻¹). Conversely, flowering stage stress (I₂) caused the greatest reduction in productivity, recording the lowest number of pods per plant (29.65), 100-seed weight (4.20 g) and seed yield (653.41 kg ha⁻¹). Among the plant growth regulators, NAA @ 75 ppm promoted plant height, whereas PBZ @ 75 ppm enhanced branching and reproductive performance. PBZ recorded the highest number of pods per plant (33.51), 100-seed weight (5.44 g), seed yield (829.72 kg ha⁻¹) and harvest index (38.61%), compared with 28.97, 5.05 g, 704.39 kg ha⁻¹ and 33.89%, respectively, under the control. Significant interaction effects between water stress and plant growth regulators were observed for important yield attributes. The results indicate that flowering is a particularly sensitive stage to water deficit in black gram and that foliar application of PBZ @ 75 ppm can improve reproductive efficiency and productivity under varying moisture regimes.

Keywords: Black gram, water stress, paclobutrazol, naa, plant growth regulators, seed yield, moisture stress

Introduction

Black gram [*Vigna mungo* (L.)] is an important short-duration pulse crop well suited to intensive and rainfed cropping systems. India accounts for more than 70% of global black gram production (Anonymous, 2026) ^[1]. Besides its agronomic importance, black gram contributes substantially to nutritional security owing to its high protein (about 25%), carbohydrate and mineral contents (Panigrahi *et al.*, 2015) ^[2]. As a leguminous crop, it also contributes to soil fertility through biological nitrogen fixation and fits effectively into cereal-pulse cropping systems (Ramesh *et al.*, 2020) ^[3]. However, its productivity remains relatively low due to several biotic and abiotic constraints, among which water stress is a major limitation.

Drought is one of the most severe and unpredictable environmental stresses affecting crop productivity, and its impact is becoming increasingly important under changing climatic conditions. Water deficit adversely affects seed germination, vegetative growth, photosynthesis and reproductive development. In black gram, prolonged moisture stress restricts root and shoot growth, branching and flower production, while water deficiency during reproductive development can reduce pod formation and ultimately result in substantial yield losses. The magnitude of these effects largely depends on the intensity, duration and developmental stage at which water stress occurs.

The use of plant growth regulators (PGRs) through foliar application offers a potential approach for improving crop performance under water-limited conditions. Foliar application facilitates rapid absorption and utilization of applied compounds and can improve

physiological efficiency and assimilate translocation from source to sink (Manonmani and Srimathi, 2009 ^[4]; Beulah and Ghosh, 2020) ^[5]. Among various PGRs, naphthalene acetic acid (NAA) and paclobutrazol (PBZ) have shown potential for regulating plant growth and improving responses to water stress. NAA, a synthetic auxin, promotes growth and nutrient mobilization and has been reported to improve leaf water status, chlorophyll content, osmolyte accumulation and antioxidant activity under short-term drought conditions (Khan *et al.*, 2019 ^[6]; Ullah *et al.*, 2023)^[7]. Paclobutrazol, a triazole growth regulator, inhibits gibberellin biosynthesis and restricts excessive shoot elongation, thereby promoting compact plant growth and water conservation. It can also enhance abscisic acid-mediated stomatal regulation, root development, osmolyte accumulation and antioxidant activity under water deficit (Soumya *et al.*, 2017 ^[8]; Maheshwari *et al.*, 2022 ^[9]; Hütsch *et al.*, 2023)^[10]. These physiological modifications may contribute to improved water status, photosynthetic efficiency and assimilate partitioning under moisture stress. Although NAA and PBZ have demonstrated potential in alleviating drought-induced effects in different crops, their comparative effectiveness under water stress occurring at different developmental stages of black gram requires further evaluation. Therefore, the present investigation was undertaken to assess the effects of growth-stage-specific water stress and foliar application of NAA and PBZ on the morpho-physiological traits, yield attributes and biochemical responses of black gram.

Materials and Methods

Experimental site

An experiment was carried out at Department of Plant Physiology, BACA and an experiment conducted at Regional Research Station, AAU, Anand, India during summer 2025.

Details of treatments

Twelve treatment combinations involving four levels of irrigation and three levels of plant growth regulators (PGRs) treatments were incorporated in the study. Four irrigation treatments were allotted to the main plot, while three treatments of plant growth regulators were embedded as subplots in split plot design with three replications. Details of the treatments with their symbols are given as follows.

A. Main plot treatments

- I₁: Stress given at Vegetative stage (Withhold Irrigation about 15-20 DAS)
- I₂: Stress given at Flowering stage (Withhold Irrigation about 30-35 DAS)
- I₃: Stress given at Reproductive stage (Withhold Irrigation about 45-50 DAS)
- I₄: No stress

B. Sub plot treatments

- F₀: Control (No Spray)
- F₁: NAA @ 75 ppm
- F₂: PBZ @ 75 ppm

Note:

- First foliar spray in all treatments was given at 30 DAS
- Second foliar spray at 40 DAS in all plot i.e., at reproductive stage

Methods

Plant height

The five randomly tagged plants were uprooted at maturity

and measure the height from bottom of stem to the tip of upper most fully opened leaf and finally the mean height of plant in centimetre (cm) in each treatment was calculated and were recorded for statistical analysis.

Number of branches per plant

The number of branches per plant was counted from previously selected five plants from each plot at harvest of the crop. The mean number of branches per plant was worked out and recorded separately for each treatment.

Leaf area per plant (cm²)

Five plants were randomly uprooted from the gross plot at 35, 50, 65 DAS and at harvest and the leaves were separated and the total leaf area per plant was calculated with the help of Leaf Area Meter (CI-203) and the mean were calculated and expressed in cm².

Number of pods per plant

Total filled pods present in tagged plants were counted and the mean were calculated and expressed as the number of pods per plant.

100 seed weight (g)

The weight of 100 seeds drawn at random from the seed yield of plants were recorded and expressed in grams.

Moisture content (%)

Moisture content was estimated as per procedure developed by Anonymous, (2000) ^[11].

10 grams of seeds of each treatment were kept in the small aluminum boxes. The weight of each box with seeds was prerecorded then the boxes were kept in the hot air oven at 105 °C for 6 hrs. All boxes were taken out of the oven and allowed to cool at room temperature. All the boxes were weighed to measure the moisture loss from the seeds. The amount of total moisture was calculated as,

$$\text{Moisture \%} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Crude protein (%)

The estimation of crude protein content of harvested seeds was done at Department of Biochemistry, BACA, AAU, Anand by following proper procedure.

Protein content from seed powder was estimated as per the Standard Kjeldhal method described by Anonymous, (2000) ^[11].

Forty mg of sample was digested in digestion tube with one gram of digestion mixture (prepared by addition of 99 g of K₂SO₄, 4.1 g of HgO and 0.8 g of CuSO₄) and 2 mL of concentrated H₂SO₄. These tubes were allowed to digest in digestion chamber for 40 minutes, till color turns to blue or slight greenish. On completion of digestion color solution becomes colourless. To this, 10 mL 40% sodium hydroxide solution was added to each tube and kept for distillation in distillation unit, at the same time 10 mL boric acid with 2-3 drops of methyl-red-bromocresol green indicator in another 100 mL volumetric flask was taken and it was placed the flask under condenser extending below the surface of the solution for 7 min. The ammonia present in digestion tube is distilled off and absorbed in the boric acid solution. Then boric acid solution in the receiving flask was removed and titrated against standard sulphuric acid solution till first appearance of violet color.

Blank determination was made (without sample) by using the same quantity of reagents, same digestion and distillation period as for the sample determination. The %

nitrogen and the % protein in the samples were calculated using the following formula.

$$\% N = \frac{(\text{mL of H}_2\text{SO}_4 \text{ determination} - \text{mL blank}) \times \text{Normality} \times 14.007 \times 100}{\text{Weight of sample taken (mg)}}$$

$$\text{Protein (\%)} = N (\%) \times 6.25$$

Results and Discussion

Effect of water stress

The data regarding plant height (Table 1) was not significantly influenced by irrigation levels at harvest. However, numerical differences were observed among the treatments, plants maintained under no stress (I₄) recorded the numerically highest plant height (31.05 cm), followed by vegetative-stage stress (I₁; 29.91 cm), reproductive-stage stress (I₃; 29.27 cm) and flowering-stage stress (I₂; 28.35 cm). The absence of a significant irrigation effect indicates that the imposed moisture stress did not produce sufficient differences in final plant height under the conditions of the experiment. However, the numerical reduction under flowering-stage stress suggests that water deficit during active reproductive development may restrict cell expansion and internodal growth. Similar stage-dependent effects of water stress on black gram growth have been reported, with moisture stress reducing morphological growth and reproductive performance. The present findings are in close agreement with reported by Manivannan *et al.*, (2007) [12] in sunflower, Baroowa and Gogoi (2012) [13] in black gram, Baroowa *et al.*, (2012) [14], Uddin *et al.*, (2013) [15] in green gram, Dahanayake *et al.*, (2015) [16], Baroowa and Gogoi (2016) [17] and Kumar *et al.*, (2020) [18] in black gram.

Number of primary branches per plant (Table 1) was significantly affected by both irrigation and PGR treatments. Among irrigation treatments, no stress (I₄) recorded the maximum number of primary branches (5.16 plant⁻¹), followed by reproductive-stage stress (I₃; 4.58), vegetative-stage stress (I₁; 4.21) and flowering-stage stress (I₂; 3.85). The lower branching under flowering-stage stress may be attributed to restricted assimilate availability and impaired meristematic activity under moisture deficit. Water stress is known to reduce vegetative growth and branching in black gram by limiting cell expansion and overall carbon assimilation. Similar findings reported by Kumar *et al.*, (2020) [18] in black gram. Leaf area (Table 1) was significantly influenced by both irrigation and PGR treatments. Among the irrigation regimes, no stress (I₄) recorded the highest leaf area (230.33 cm²), followed by vegetative-stage stress (I₁; 191.00 cm²), reproductive-stage stress (I₃; 175.00 cm²) and flowering-stage stress (I₂; 157.67 cm²). The significantly lower leaf area under flowering-stage stress indicates that moisture deficit during this critical stage restricted leaf expansion and probably promoted premature leaf senescence. Reduced leaf area under drought is a well-established adaptive response that limits transpirational water loss but simultaneously reduces the photosynthetic surface available for carbon assimilation. Similar reductions in leaf area and other growth attributes under moisture stress have been reported in black gram. The present findings are in close agreement with reported by Manivannan *et al.*, (2007) [12] in sunflower, Baroowa *et al.*, (2012) [14] in black gram and Baroowa and Gogoi (2016) [17] in black gram. The number of pods per plant (Table 2) was significantly influenced by both irrigation regimes and plant growth regulator treatments. Among the irrigation

treatments, no-stress condition (I₄) recorded the highest number of pods per plant (35.27), followed by vegetative-stage stress (I₁; 32.08) and reproductive-stage stress (I₃; 30.18), whereas flowering-stage stress (I₂) recorded the lowest number of pods per plant (29.65). The reduction in pod formation under flowering-stage stress indicates the greater sensitivity of reproductive development to water deficit. Moisture stress during flowering can impair flower retention and pod set, ultimately reducing the number of pods formed. Similar stage-specific effects of water stress have been reported in black gram, where stress imposed during flowering caused a pronounced reduction in pod number. The present findings are in close agreement with reported by Baroowa and Gogoi (2012) [13] in black gram, Dahanayake *et al.*, (2015) [16] in black gram, Rai *et al.*, (2019) [19] and Pavithra *et al.*, (2021) [20] in black gram. Irrigation treatments significantly affected 100-seed weight. The data furnished in Table 2. The highest 100-seed weight was recorded under no stress (I₄; 6.12 g), followed by vegetative-stage stress (I₁; 5.64 g) and reproductive-stage stress (I₃; 5.19 g), while flowering-stage stress (I₂) recorded the lowest value (4.20 g). The reduction in seed weight under flowering-stage stress indicates that moisture deficit during flowering adversely affected subsequent seed development and assimilate accumulation. Adequate moisture availability favours continued photosynthesis and translocation of assimilates to developing seeds, thereby supporting greater seed filling. Similar reductions in seed weight under moisture stress have been documented in black gram. The present findings are in close agreement with reported by Allahmoradi *et al.*, (2011) [21] in green gram.

Seed moisture content at harvest (Table 2) was significantly affected by irrigation treatments. The no-stress treatment (I₄) recorded the highest seed moisture content (10.41%), followed by vegetative-stage stress (I₁; 8.90%) and reproductive-stage stress (I₃; 8.60%), whereas flowering-stage stress (I₂) recorded the lowest value (8.30%). The lower moisture content under stressed treatments may reflect reduced water availability during seed development and maturation. Moisture deficit during reproductive development can also accelerate seed maturation and reduce water accumulation in developing seeds. The data revealed (Table 2) that water stress treatments significantly influenced crude protein content. Significantly higher crude protein content (21.25%) was recorded under no stress treatment (I₄), which remained at par with stress at reproductive stage (I₃) recording 21.12%. The lowest crude protein content (16.09%) was recorded under flowering stage stress (I₂), while vegetative stage stress (I₁) recorded 18.25%. The higher crude protein content under no stress condition may be attributed to adequate soil moisture availability, which enhanced nitrogen uptake, amino acid synthesis and protein accumulation in seeds. Sufficient moisture supply improves metabolic activity and facilitates efficient translocation of nitrogenous compounds towards developing grains. Moisture stress, particularly during flowering stage, reduced crude protein content due to impaired nitrogen metabolism, restricted nutrient uptake and reduced assimilate translocation under water deficit conditions. The present findings are in close agreement with reported by Baroowa and Gogoi (2015) [22] in black gram.

Effect of plant growth regulators

The data regarding plant height (Table 1) among the PGR

treatments, NAA @ 75 ppm (F₁) produced the highest plant height (31.34 cm), which was significantly superior to PBZ @ 75 ppm (F₂; 27.49 cm) and the control (F₀; 30.11 cm). The increase in plant height with NAA may be associated with auxin-mediated stimulation of cell division and elongation. Similar beneficial effects of NAA on growth attributes of black gram and related pulse crops have been reported. In contrast, PBZ markedly reduced plant height. This response is consistent with the known growth-retarding action of PBZ through suppression of gibberellin biosynthesis, thereby restricting internodal elongation. The present findings are in close agreement with reported by Bekheta and Talaat (2009) ^[23] in green gram, Mona *et al.*, (2013) ^[24], Rajesh *et al.*, (2014) ^[25] in green gram, Rai *et al.*, (2019) ^[19] in green gram, Karthikeyan *et al.*, (2020) ^[26] in black gram, Singh and Jambukiya (2020) ^[27] in green gram, Beulah and Ghosh (2020) ^[5] and Gimhavanekar *et al.*, (2020) ^[28] in pigeon pea, Hütsch *et al.*, (2023) ^[10] in maize cultivar.

Number of branches (Table 1) among PGR treatments, PBZ @ 75 ppm (F₂) produced the highest number of primary branches (4.96 plant⁻¹), followed by NAA @ 75 ppm (F₁; 4.58) and the control (F₀; 3.80). The greater branching under PBZ may be associated with its growth-retarding action, which suppresses apical dominance and redirects assimilates towards lateral growth. PBZ-induced changes in plant architecture, including reduced vertical growth and increased lateral development, have been reported in several crops. The present findings are in close agreement with reported by Bekheta and Talaat (2009) ^[23] in green gram, Rajesh *et al.*, (2014) ^[25] in green gram, Rai *et al.*, (2019) ^[19] in green gram, Beulah and Ghosh (2020) ^[5] in black gram and Karthikeyan *et al.*, (2020) ^[26] in black gram.

Leaf area (Table 1) among the PGR treatments, NAA @ 75 ppm (F₁) recorded the highest leaf area (217.25 cm²), significantly exceeding the control (186.00 cm²) and PBZ @ 75 ppm (162.25 cm²). The greater leaf area under NAA may be attributed to its role in promoting cell division and cell expansion, resulting in greater development of leaf lamina. In contrast, PBZ substantially reduced leaf area, which is consistent with the reported ability of triazole growth retardants to restrict leaf expansion and reduce leaf size. Despite the reduction in leaf area under PBZ, its higher branching observed in the present study indicates a shift from excessive vertical and leaf expansion towards a more compact plant architecture. Such morphological modification is important when interpreting PBZ responses, because reduced leaf area does not necessarily indicate poorer physiological performance; PBZ can also improve leaf longevity and photosynthetic efficiency in some crops. The present findings are in close agreement with reported by Mona *et al.*, (2013) ^[24], Samanta and Bordolui (2026) ^[29].

The number of pods per plant (Table 2) among the PGR treatments, PBZ @ 75 ppm (F₂) recorded the highest number of pods per plant (33.51), followed by NAA @ 75 ppm (F₁; 32.90), while the control (F₀) recorded the lowest value (28.97). The significant increase under PBZ may be associated with improved assimilate partitioning towards reproductive sinks and greater branching, which provides more sites for pod formation. The present finding is also consistent with the broader observation that increasing productive branches and pods contributes substantially to black gram yield. The present findings are in close

agreement with reported by Bekheta and Talaat (2009) ^[23] in black gram.

100 seed weight (Table 2) among the PGR treatments, PBZ @ 75 ppm (F₂) recorded the highest 100-seed weight (5.44 g), followed by NAA @ 75 ppm (F₁; 5.37 g), whereas the control recorded the lowest value (5.05 g). The significant improvement with PBZ may be related to enhanced assimilate availability and improved partitioning towards developing seeds. The positive response of yield components to growth-regulating treatments is consistent with reports that foliar growth-regulator applications can improve seed weight and other yield attributes in black gram. The present findings are in close agreement with reported by Panda *et al.*, (2024) ^[30] in chickpea and Yadav *et al.*, (2024) ^[31] in green gram.

Seed moisture content (Table 2) among the PGR treatments, PBZ @ 75 ppm (F₂) recorded the highest seed moisture content (9.57%), followed by NAA @ 75 ppm (F₁; 9.05%) and the control (F₀; 8.53%). The significant increase under PBZ may be associated with improved plant water relations and maintenance of physiological activity during seed development.

The data presented in Table 4.21 indicated that the effect of plant growth regulators on crude protein content was found non-significant. However, numerically higher crude protein content (19.49%) was recorded with PBZ @ 75 ppm (F₂), followed by NAA @ 75 ppm (F₁) with 19.40%, whereas the lowest value (18.65%) was observed under control treatment (F₀). The increased crude protein content under PBZ application might be attributed to improved nitrogen assimilation, enhanced stress tolerance and efficient partitioning of assimilates towards seed development. Paclobutrazol improves physiological efficiency and maintains better metabolic activity under moisture stress conditions, thereby enhancing protein synthesis. NAA application also improved crude protein content over control through enhanced nutrient mobilization and better physiological functioning. The present findings are in close agreement with reported by Ingale *et al.*, (2007) ^[32], Bekheta and Talaat (2009) ^[23] in green gram, Mona *et al.*, (2013) ^[24], Beulah and Ghosh (2020) ^[5] in black gram, Singh and Jambukiya (2020) ^[27] in green gram, Kumar *et al.*, (2023) ^[33] in green gram and Yadav *et al.*, (2024) ^[31] in green gram.

Interaction effect

The interaction between irrigation levels and plant growth regulators (Table 3) was significant for the number of pods per plant. The highest number of pods per plant was recorded under I₁F₁ (45.49 pods plant⁻¹), followed by I₄F₂ (44.44 pods plant⁻¹). The lowest number was observed under I₁F₀ (23.40 pods plant⁻¹). At the vegetative-stage stress level (I₁), application of NAA @ 75 ppm (F₁) markedly increased pod production compared with the control and PBZ. In contrast, under no-stress conditions (I₄), PBZ @ 75 ppm (F₂) produced the highest number of pods. Since the interaction CD at 5% was 3.64, these differences indicate a strong differential response of PGR treatments to the prevailing moisture regime. The results suggest that NAA was particularly effective in improving reproductive development when stress occurred at the vegetative stage, whereas PBZ performed better under adequate moisture availability.

A significant interaction between irrigation levels and PGR treatments (Table 4) was observed for 100-seed weight. The

maximum 100-seed weight was recorded with I₄F₂ (6.72 g), followed by I₄F₁ (5.94 g) and I₁F₁ (5.78 g), whereas the minimum value was recorded under I₂F₀ (3.95 g). Under flowering-stage stress, both NAA and PBZ improved seed weight over the untreated control, although the values remained lower than those obtained under no-stress conditions. The interaction CD at 5% was 0.52 g, indicating that the differences between the higher-performing and lower-performing combinations were statistically meaningful. The superior seed weight under I₄F₂ may be associated with favourable moisture availability combined with PBZ-mediated improvement in assimilate partitioning towards developing seeds. The particularly low seed weight under I₂F₀ indicates the severe adverse effect of flowering-stage moisture stress when no growth regulator was applied. The interaction effect of irrigation and PGR treatments on seed moisture content (Table 5) was also significant. The highest seed moisture content was recorded under I₄F₂ (11.05%), followed by I₄F₁ (10.40%), while the lowest value was observed under I₂F₀ (7.81%). Within each irrigation regime, PGR application generally increased seed moisture

content compared with the corresponding control, with PBZ recording the highest value under I₁, I₂, I₃ and I₄. The interaction CD at 5% was 0.13%, indicating that the observed differences among treatment combinations were statistically significant. The higher seed moisture content under I₄F₂ may reflect better plant water status and continued assimilate and water supply during seed development, whereas the lower value under I₂F₀ reflects the combined adverse effect of flowering-stage water stress and absence of PGR protection.

The interaction effect between water stress and plant growth regulator levels ($I \times T$) was found significant with respect to crude protein content (Table 6). Significantly higher crude protein content (22.73%) was recorded under no stress + PBZ @ 75 ppm (I₄F₂), which was statistically at par with reproductive stage stress + PBZ @ 75 ppm (I₃F₂; 22.03%), no stress + NAA @ 75 ppm (I₄F₁; 21.19%) and reproductive stage stress + NAA @ 75 ppm (I₃F₁; 21.01%). The lowest crude protein content (15.70%) was recorded under flowering stage stress + PBZ @ 75 ppm (I₂F₂).

Table 1: Effect of water stress and plant growth regulators on plant height, number of branches per plant and leaf area

Treatments	Parameters		
	Plant height (cm)	Number of brances per plant	Leaf area (cm ²)
Main plot (Irrigation Level)			
I ₁ : Stress given at vegetative stage	29.91	4.21	191.00
I ₂ : Stress given at flowering stage	28.35	3.85	157.67
I ₃ : Stress given at reproductive stage	29.27	4.58	175.00
I ₄ : No stress given	31.05	5.16	230.33
S.Em. $\pm$	1.00	0.13	7.41
CD at 5%	NS	0.44	25.66
CV%	9.84	8.49	11.80
Sub plot (PGR Level)			
F ₀ : Control	30.11	3.80	186.00
F ₁ : Naphthalene Acetic Acid	31.34	4.58	217.25
F ₂ : Paclobutrazol @ 75 ppm	27.49	4.96	162.25
S.Em. $\pm$	0.42	0.07	5.34
CD at 5%	1.27	0.20	16.00
CV%	4.95	5.16	9.81
Interaction effect			
$I \times T$	NS	NS	NS

Table 2: Effect of water stress and plant growth regulators on number of pods per plant, 100 seed weight and moisture content

Treatments	Parameters			
	Number of pods per plant	100 seed weight (g)	Moisture content (%)	Crude protein (%)
Main plot (Irrigation Level)				
I ₁ : Stress given at vegetative stage	32.08	5.64	8.90	18.25
I ₂ : Stress given at flowering stage	29.65	4.20	8.30	16.09
I ₃ : Stress given at reproductive stage	30.18	5.19	8.60	21.12
I ₄ : No stress given	35.27	6.12	10.41	21.25
S.Em. $\pm$	1.08	0.21	0.06	0.40
CD at 5%	3.72	0.71	0.20	1.37
CV%	10.15	11.71	1.87	6.19
Sub plot (PGR Level)				
F ₀ : Control	28.97	5.05	8.53	18.65
F ₁ : Naphthalene Acetic Acid	32.90	5.37	9.05	19.40
F ₂ : Paclobutrazol @ 75 ppm	33.51	5.44	9.57	19.49
S.Em. $\pm$	0.61	0.09	0.02	0.28
CD at 5%	1.82	0.26	0.07	NS
CV%	6.62	5.73	0.86	5.10
Interaction effect				
$I \times T$	Sig	Sig	Sig	Sig

Table 3: Interaction effect of water stress and plant growth regulators on number of pods per plant

Treatments	F ₀	F ₁	F ₂
I ₁	23.40	45.49	27.34
I ₂	33.60	26.09	29.25
I ₃	33.50	24.02	33.03
I ₄	25.38	35.99	44.44
S.Em. ±		1.22	
CD at 5%		3.64	

Table 4: Interaction effect of water stress and plant growth regulators on 100 seed weight

Treatments	F ₀	F ₁	F ₂
I ₁	5.67	5.78	5.46
I ₂	3.95	4.38	4.26
I ₃	4.86	5.39	5.31
I ₄	5.70	5.94	6.72
S.Em. ±		0.18	
CD at 5%		0.52	

Table 5: Interaction effect of water stress and plant growth regulators on moisture content

Treatments	F ₀	F ₁	F ₂
I ₁	8.41	8.90	9.38
I ₂	7.81	8.30	8.78
I ₃	8.11	8.60	9.08
I ₄	9.77	10.40	11.05
S.Em. ±		0.05	
CD at 5%		0.13	

Table 6: Interaction effect of water stress and plant growth regulators on crude protein

Treatments	F ₀	F ₁	F ₂
I ₁	18.36	18.89	17.48
I ₂	16.05	16.52	15.70
I ₃	20.31	21.01	22.03
I ₄	19.84	21.19	22.73
S.Em. ±		0.57	
CD at 5%		1.69	

Conclusion

The present study demonstrated that moisture stress imposed at different growth stages and foliar application of plant growth regulators significantly modified the growth and reproductive performance of black gram. Among the irrigation regimes, continuous availability of moisture (I₄) resulted in superior plant height, branching, leaf area, pod production, seed weight and seed moisture, whereas flowering-stage stress (I₂) generally caused the greatest reduction in these traits. NAA @ 75 ppm promoted vegetative attributes, particularly plant height and leaf area, while PBZ @ 75 ppm enhanced branching and reproductive traits. Significant irrigation × PGR interactions for pods per plant, 100-seed weight and seed moisture content further demonstrated that PGR responses were dependent on the prevailing moisture regime. The combination I₁F₁ produced the maximum number of pods per plant, whereas I₄F₂ recorded the highest 100-seed weight, seed moisture content and crude protein. Overall, the results indicate that maintaining adequate moisture and judicious use of PGRs, particularly PBZ for reproductive performance, can improve growth and yield-related attributes of black gram under moisture stress conditions.

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