Original Research Article

Effectiveness of Paclobutrazol Application on Improvement of Groundnut (*Arachis hypogaea* L.) Yield Under Water Deficit Conditions

ABSTRACT

An experiment was carried out during the summer seasons of the year 2021 and 2022.A split plot design with three replications was used for experiment which included irrigation as main faction with three levels while paclobutrazole foliar spray as a sub-factor with four levels. Pod yield per plant, seed yield per plant, and harvest index was significantly higher with irrigation at 15 days interval (I_2) in the pooled data, whereas minimum recorded when irrigation at 20 days interval (I_3) was given.The significantly higher harvest index, pod yield per plant and seed yield per plant was recorded with application of PBZ @ 200 mg/l (T_3), whereas a minimum harvest index was noted with control (T_1).

Keywords: Pod yield, seed yield, harvest index, 100 kernel weight,Paaclobutrazol, water stress, Groundnut

1. INTRODUCTION

Groundnut is an important oilseed crop of tropical and subtropical areas and now being cultivated on about 25 million hectares of land in about 100 countries in the world, under different agro-climatic regions where rainfall during the growing season exceeds 500 mm.Groundnuts in India are available throughout the year because it's grown in two seasons but in India grown mostly under rain-fed conditions.

Several biotic and abiotic stress factors have been identified as key contributors to India's appallingly poor yield. Furthermore, around 70% of the agricultural area is exposed to drought. Because of the limitation caused by scarcity of water, this vast area produces only 38% of world agricultural production (Dilley *et al.*, 2005). Recent years have seen a growing scarcity of water worldwide and is estimated that by 2050, as much as two-third of the global production will live in water scarce areas (Wallace, 2000).Plant growth is severely affected by water stress. In India, rainfall accounts for over 50% of variance in yield (Challinor *et al.,* 2009). The average peanut yield in our country is very low because of moisture stress faced at various growth stages, irrespective of the other factors of the crop production package (Singh *et al*., 2013).

Paclobutrazol can provides significant benefit to plants subjected to water stress. It limits elongation, increase nutrient uptake and enhance osmotic adjustment, PBZ helps to reduce the effects of water stress on the plant, protects it from serious damage and allowing it to produce a viable crop in the face of tough environmental conditions.Paclobutrazole is a plant growth retardant that inhibits the production of gibberellins, a hormone that leads to plant growth and elongation. By inhibiting this hormone, PBZ can help plants to withstand environmental stresses better, such as water stress. When applied as a foliar spray, PBZ is absorbed by petioles and stems and is translocated through the xylem to the growing tip. When applied as a soil drench, it is taken up through the roots and then translocated through the xylem to the apical meristems. (Million *et al.,* 1999). This study aimed to evaluate the ability of PBZ by counteracting the water stress and improve the yield in water stressed groundnut plants.

2. METHODOLOGY

2.1 Experimental Site

An experiment was carried out at Department of Plant Physiology, BACA and an experiment conducted at Regional Research Station, AAU, Anand during summer 2021 and 2022.

2.2 Details of Treatments and Statistical Design

Twelve treatment combinations) involving three levels of irrigation and four levels of paclobutrazole treatments were incorporated in the study. Three irrigation treatments were allotted to main plot while four treatments of paclobutrazole treatments were embedded as sub plot in split plot design with three replications. Details of the treatments with their symbols are given as under:

A. .**Main plot treatments**
   I_1:Irrigation at 10 days interval
   I_2:Irrigation at 15 days interval
   I_3:Irrigation at 20 days interval
B. **Sub plot treatments**
   T_1: CONTROL (No application of PBZ)
   T_2: PBZ @ 100 mg/l

T_3: PBZ @ 200 mg/l

T_4: PBZ @ 300 mg/l

*Foliar spray of PBZ was given at 35 and 55 DAS in all the treatments.

There were twelve treatment combinations were evaluated in the present study *viz*.,I_1T_1: Irrigation at 10 days interval + Control (No PBZ), I_1T_2: Irrigation at 10 days interval + PBZ @ 100 mg/l, I_1T_3: Irrigation at 10 days interval + PBZ @ 300 mg/l, I_1T_4: Irrigation at 10 days interval + PBZ @ 300 mg/l , I_2T_1: Irrigation at 15 days interval + Control (No PBZ) , I_2T_2: Irrigation at 15 days interval + PBZ @ 100 mg/l, I_2T_3: Irrigation at 15 days interval + PBZ @ 200 mg/l, I_2T_4: Irrigation at 15 days interval + PBZ @ 300 mg/l , I_3T_1: Irrigation at 20 days interval + Control (No PBZ), I_3T_2: Irrigation at 20 days interval + PBZ @ 100 mg/l, I_3T_3: Irrigation at 20 days interval + PBZ @ 200 mg/l , I3T4: Irrigation at 20 days interval + PBZ @ 300 mg/l.

2.3Methodology

The five randomly tagged plants were uprooted at maturity and weighed for pod yield from which the average was calculated and expressed as pod yield per plant.A composite sample of kernels was drawn from shelled pods of each net plot and 100 kernels were counted and weighed and recorded separately for each plot.The Harvest index is the ratio of economic yield to biological yield per plot.The harvest index for each treatment was worked out by using the formula (Donald and Hablin, 1976).

$$\text{HI (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

3. RESULT AND DISCUSSION

The observations recorded were analyzed statistically and presented and discussed under the following heads:

3.1 Effect of Water Stress on Yield and Yield attributes

3.1.1 Effect of water stress on pod yield per plant

The significantly higher pod yield per plant (29.94, 28.25 and 29.10g/plant) was recorded with irrigation at 15 days interval (I_2) in the years 2021, 2022 and pooled data, respectively which was at par with T_1 during the year 2021, 2022 and in pooled data (Table 1).

The treatment irrigation at 20 days interval (I_3) resulted minimum pod yield per plant (19.57, 19.80 and 19.68 g/plant) during both the years 2021, 2022 and pooled data, respectively. Water stress disrupts various essential physiological processes in groundnut plants, leading to reduced photosynthesis, impaired nutrient uptake, limited growth, flower and pod abortion, early maturity, and poor kernel formation. All these factors collectively contribute to lower yield in treatment I_3. Proper irrigation management and providing sufficient water during critical growth stages can help mitigate the negative impacts of water stress and promote higher yields. These findings are in agreement with the results of Chandini *et al.* (2023),Abdoul Karim *et al.* (2020) and Nautiyal *et al.* (2017)

3.1.2 Effect of water stress on seed yield per plant

The data (Table 2) regarding seed yield per plant (20.65, 19.45 and 20.05 g/plant) showed that significantly higher with irrigation at 15 days interval (I_2)during 2021, 2022 and in pooled results, respectively which was at par with I_1 during the years 2021, 2022 and in pooled results. Whereas, minimum seed yield per plant (13.02, 13.30 and 13.16 g/plant) was recorded with irrigation at 20 days interval (I_3) during both the years and in pooled results, respectively.Water stress disrupts various essential physiological processes in groundnut plants, leading to reduced photosynthesis, impaired nutrient uptake, limited growth, flower and pod abortion, early maturity, and poor kernel formation. All these factors collectively contribute to lower yield in treatment I_3. Proper irrigation management and providing sufficient water during critical growth stages can help mitigate the negative impacts of water stress and promote higher yields.Water stress can lead to uneven seed development within the same plant, resulting in a mixture of mature and immature seeds. In extreme water stress conditions, the plant may undergo reproductive abortion, where developing pods and seeds are aborted or not filled properly due to limited resources and stress-induced physiological changes.The results are similar to Abdoul Karim *et al.* (2020), Koolachart*et al.* (2013), Painawadee*et al.* (2009) and Bootang*et al*. (2010)

3.1.3 Effect of water stress on 100 kernels weight

The data presented in showed that the effect of water stress on 100 kernels weight was found to be non-significant during both the years and in pooled results.

3.1.4 Effect of water stress on harvest index

The harvest index (Table 4) was not significantly affected by water stress treatments during the years 2021. In the year 2022 and pooled results, harvest index was found to be significant.Significantly higher harvest index (33.63, 32.71 and 33.17 %) was recorded with irrigation at 15 days interval (I_2) in the year 2022 and pooled data, respectively. Minimum harvest index (26.99, 26.77 and 26.88 %) was observed with irrigation at 20 days interval (I_3) during the year 2022 and pooled data, respectively.

The higher harvest index of treatments I_1 and I_2 represents an increased physiological capacity to mobilize photosynthates and translocate them efficiently to pods of economic value compared to I_3. When groundnut plants experience water stress, their ability to produce and allocate assimilates towards seed production is negatively impacted. Water-stressed plants prioritize survival over reproduction. During water stress, plants may allocate more resources to maintaining essential physiological processes and stress responses, such as root growth to access water, rather than investing in reproductive structures like seeds. Abdoul Karim *et al.* (2020), Pervin *et al.* (2014), Patel (2011)and Vaghasia*et al.* (2010)observed decrease in harvest index in water stress conditions.

3.2 Effect of Paclobutrazol on Yield and Yield attributes

3.2.1 Effect of paclobutrazol on pod yield per plant

Results indicated that the significantly higher pod yield per plant (30.29, 29.36 and 29.82 g/plant) was recorded with application of PBZ @ 200 mg/l (T_3) during both the years and in pooled analysis, respectively. It was at par with T_2 in the year 2021 and 2022. Whereas, minimum pod yield per plant (21.39 and 22.38 g/plant) was recorded with application of PBZ @ 300 mg/l (T_4) in the year 2022 and in pooled data, respectively. During the year 2021 minimum pod yield per plant (22.91 g/plant) was noted with control (T_1).

Paclobutrazol can be used in order to maintain the balance between vegetative and reproductive growth by reducing the competition for assimilate. As a result, more distribution of assimilates to pods during reproductive stage help in increment of yield (Arzani and Roosta, 2004). The effects of PBZ on pod yield in groundnut are dose-dependent. Higher doses of PBZ will produce greater increases in pod yield. However, it is important to note that too high a dose of PBZ can also reduce pod yield.Similar findings were reported by Barman *et al.* (2018),Lubis *et al.* (2013), Almeida *et al.* (2016), Gatan and Gonzales (2015)

3.2.2 Effect of paclobutrazol on seed yield per plant

Seed yield per plantwas recorded significantly higher (21.00, 20.28 and 20.64 g/plant) with application of PBZ @ 200 mg/l (T_3) during 2021, 2022 as well as in pooled results, respectively. It was at par with T_2 in the year 2021. While, minimumseed yield per plant (15.45, 14.96 and 15.20 g/plant) were recorded with control (T_1) during 2021, 2022 and in pooled results, respectively.Paclobutrazole-treated groundnut plants often exhibit a stronger source-sink relationship. This means that there is a more efficient flow of photosynthates from leaves to developing seeds, leading to higher dry matter partitioning and seed yield. PBZ can optimize nutrient use efficiency in groundnut plants, directing more nutrients towards reproductive processes, such as seed development. This improved nutrient utilization contributes to higher seed yield.This can result in higher seed yield. The results are similar to those reported by Barman *et al.* (2018)**,** Win *et al.* (2017) and Lubis *et al.* (2013).

3.2.3 Effect of paclobutrazol on 100 kernels weight

The data illustrated in Table 4 showed that the varying paclobutrazole levels failed to exert their significant effect on 100 kernels weight during individual years and in pooled results.

3.2.4 Effect of paclobutrazol on harvest index

Results indicated that the significantly higher harvest index (33.60, 33.94 and 33.77 %) was recorded with application of PBZ @ 200 mg/l (T_3) during both the years and in pooled analysis, respectively. It was at par with T_2 and T_4 in the year 2021. During the year 2022 and in pooled it was at par with T_2. Whereas, minimum harvest index (23.35, 23.15 and 23.25 %) was noted with control (T_1) during the years 2021, 2022 and pooled results, respectively.

The harvest index represents the proportion of total biomass allocated to the harvestable yield relative to the total biomass. PBZ reduces total biomass and increase pod yield by diverting photosynthates to pod development which ultimately leads to increase in harvest index. Similar results were reported by Dwivedi *et al.* (2018) and Win *et al.* (2017).

3.3 Interaction Effect of Water Stress and Paclobutrazol

3.3.1 Interaction effect of water stress and paclobutrazol on pod yield per plant

Data shown in Table 2 showed that the interaction effect of water stress and paclobutrazole levels on pod yield per plant was found to be significant during both the years 2021, 2022 and pooled results.

The combine application of irrigation at 10 days interval and PBZ @ 200 mg/l (I_1T_3) recorded significantly higher pod yield per plant (34.76 g/plant) during the year 2021, which was remained statistically at par with treatment combination I_2T_2 and I_2T_3. The combine application of irrigation at 20 days interval and PBZ @ 300 mg/l (I_3T_4) recorded significantly minimum pod yield per plant (16.09 g/plant) in the year 2021.During the year 2022, combine application of irrigation at 10 days interval and PBZ @ 200 mg/l (I_1T_3) noted significantly higher pod yield per plant (33.27 g/plant) and whichwas remained statistically at par with treatment combination I_2T_2 and I_2T_3 during 2022. Whereas, significantly lower pod yield per plant (15.72 g/plant) was observed under the treatment combination of irrigation at 20 days interval and PBZ @ 300 mg/l (I_3T_4) in the year 2022. Significantly higher pod yield per plant (34.02 g/plant) was noted in treatment combination of irrigation at 10 days interval and PBZ @ 200 mg/l (I_1T_3) during pooled analysis, which was remained at par with the treatment combinations I_2T_2 and I_2T_3. While, significantly minimum pod yield per plant (15.90 g/plant) was observed under the treatment combination of irrigation at 20 days interval and PBZ @ 300 mg/l (I_3T_4) in pooled analysis.

. When water-stressed, plants may have limited access to nutrients due to reduced root activity. PBZ-treated plants tend to have a more compact root system that can better explore the soil for nutrients, improving nutrient uptake efficiency even under water stress conditions.The controlled growth and hormonal regulation induced by PBZ enable the plant to better manage limited water availability, minimizing the negative effects of water stress on pod formation and yield. These findings are in agreement with the results of Win *et al.* (2017), Babarashi*et al.* (2021), Soumya and Kumar (2017), Yooyongwech*et al.* (2017), Dwivedi *et al*. (2018) and Pal *et al.* (2016).

3.3.2 Interaction effect of water stress and paclobutrazolon seed yield per plant

Interaction effect of water stress and paclobutrazole levels (I × T) was found significant with respect to seed yield per plant during the year 2022 and in pooled results. In the year 2021, seed yield per plant was found non-significant.

During the year 2022, combine application of irrigation at 10 days interval and PBZ @ 200 mg/l (I_1T_3) noted significantly higher seed yield per plant (23.34 g/plant) and which was remained statistically at par with treatment combination I_2T_2 and I_2T_3 during 2022. Whereas, significantly lower seed yield per plant (11.20 g/plant) was observed under the treatment combination of irrigation at 20 days interval and PBZ @ 300 mg/l (I_3T_4) in the year 2022. Significantly higher seed yield per plant (23.83 g/plant) was noted in treatment combination of irrigation at 10 days interval and PBZ @ 200 mg/l (I_1T_3) during pooled analysis, which was remained at par with the treatment combinations I_2T_2 and I_2T_3. While, significantly minimum seed yield per plant (10.81 g/plant) was observed under the treatment combination of irrigation at 20 days interval and PBZ @ 300 mg/l (I_3T_4) in pooled analysis.

During seed development, high temperature that inhibit photosynthesis (>30ºC) and water deficit could affect seed quality by reducing photosynthates and other metabolites required for seed formation. Insufficient water can hinder the expansion of seeds within the pods, leading to smaller seed size. This can directly reduce the overall seed yield as smaller seeds weigh less. Water stress can lead to uneven seed development within the same plant, resulting in a mixture of mature and immature seeds. In extreme water stress conditions, the plant may undergo reproductive abortion, where developing pods and seeds are aborted or not filled properly due to limited resources and stress-induced physiological changes. The results are similar to Abdoul Karim *et al.* (2020), Koolachart*et al.* (2013), Painawadee*et al.* (2009), Bootang*et al*. (2010), Girdthai*et al.* (2010)

3.3.3 Interaction effect of water stress and paclobutrazol100 kernels weight

An examination of results given in Table 4 indicated that the interaction effect of water stress and paclobutrazole levels on 100 kernels weight remained unaffected during both the years 2021, 2022 and pooled results.

4.3.4 Interaction effect of water stress and paclobutrazolon harvest index

Interaction effect of water stress and paclobutrazole levels (I × T) was found significant with respect to harvest index during individual year as well as pooled basis. The bird-eye view of the experimental site represents the interaction effect of water stress and paclobutrazole levels and their effect on morpho-physiological growth as shown in the plate no. 4.3.

The combine application of irrigation at 10 days interval and PBZ @ 200 mg/l (I_2T_3) recorded significantly higher harvest index (37.62 %) during the year 2021, which was remained statistically at par with treatment combination I_2T_2, I_3T_2, I_1T_3, I_1T_4 and I_2T_4. The combine application of irrigation at 20 days interval and control (I_3T_1) recorded significantly minimum harvest index (22.39 %) in the year 2021.During the year 2022, combine application of irrigation at 10 days interval and PBZ @ 200 mg/l (I_1T_3) noted significantly higher harvest index (36.86 %) and which was remained statistically at par with treatment combination I_2T_2, I_3T_2 and I_2T_3 during 2022. Whereas, significantly lower harvest index (21.20 %) was observed under the treatment combination of irrigation at 10 days interval and control (I_1T_1) in the year 2022.Significantly higher harvest index (37.34 %) was noted in treatment combination of irrigation at 15 days interval and PBZ @ 100 mg/l (I_2T_2) during pooled analysis, which was remained at par with the treatment combinations I_3T_2, I_1T_3 and I_2T_3. While, significantly minimum harvest index (21.97 %) was observed under the treatment combination of irrigation at 10 days interval and control (I_1T_1) in pooled analysis.Interaction effect of harvest index shows that harvest index is increase in all water stress treatment due to application of the paclobutrazole.Thisresults shows that paclobutrazole helps in mitigating water stress.

CONCLUSION

From the results it is concluded that there is no difference in irrigation I_1 (irrigation at 10 days interval) and I_2 (irrigation at 15 days interval) when treated with paclobutrazole in case of yield. Water stress with the 15-day irrigation interval was reported and improved pod yield by foliar spraying of paclobutrazole @ 200 mg/l as well as 100 mg/l. In 20 days irrigation interval water stress, there is no ameliorative effect of paclobutrazole was observed.In short it was concluded that when 15 days irrigation interval during crop growth period with 100 mg/l paclobutrazole foliar spraying at 35 & 55 DAS is recommended for higher yield with reduced number of irrigation ultimately benefiting farmers.

Table 1: Effect of water stress and paclobutrazole on number of pods per plant, pod yield per plant and seed yield per plant in groundnut during 2021, 2022 and pooled analysis

Treatments		Pod yield per plant (g/plant)			Seed yield per plant (g/plant)		
		2021	2022	Pooled	2021	2022	Pooled
I_1	Irrigation at 10 days interval (10 irrigation)	29.63	27.34	28.49	20.54	19.15	19.84
I_2	Irrigation at 15 days interval (8 irrigation)	29.94	28.25	29.10	20.65	19.45	20.05
I_3	Irrigation at 20 days interval (6 irrigation)	19.57	19.80	19.68	13.02	13.30	13.16
S.Em. ±		0.98	0.76	0.62	0.75	0.63	0.49
C.D. at 5%		3.84	2.98	2.02	2.96	2.48	1.60
C.V.%		12.86	10.46	11.78	14.46	12.65	13.62
T_1	CONTROL (No application of PBZ)	22.91	22.10	22.51	15.45	14.96	15.20
T_2	PBZ @ 100 mg/l	28.94	27.67	28.30	19.76	18.85	19.31
T_3	PBZ @ 200 mg/l	30.29	29.36	29.82	21.00	20.28	20.64
T_4	PBZ @ 300 mg/l	23.38	21.39	22.38	16.07	15.12	15.59
S.Em. ±		0.55	0.58	0.40	0.44	0.43	0.31
C.D. at 5%		1.62	1.74	1.15	1.32	1.30	0.89
I × T		Sig.	Sig.	Sig.	NS	Sig.	Sig.
C.V.%		6.22	6.97	6.59	7.36	7.56	7.46

Table 2: Interaction effect of water stress and paclobutrazole on pod yield per plant in groundnut

Pod yield per plant (g/plant)				
2021				
I \ T	**T_1**	**T_2**	**T_3**	**T_4**
I_1	26.19	30.17	34.76	27.39
I_2	25.70	32.77	34.64	26.66
I_3	16.85	23.87	21.47	16.09
S.Em. ±	0.95			
C.D. at 5%	2.81			

2022				
I \ T	T_1	T_2	T_3	T_4
I_1	24.18	27.68	33.27	24.24
I_2	24.10	32.06	32.64	24.21
I_3	18.03	23.28	22.16	15.72
S.Em. ±	1.01			
C.D. at 5%	3.01			
Pooled				
I \ T	T_1	T_2	T_3	T_4
I_1	25.19	28.92	34.02	25.82
I_2	24.90	32.41	33.64	25.43
I_3	17.44	23.58	21.82	15.90
S.Em. ±	0.69			
C.D. at 5%	1.99			

Table 3: Interaction effect of water stress and paclobutrazole on seed yield per plant in groundnut

Seed yield per plant (g/plant)				
2022				
I \ T	T_1	T_2	T_3	T_4
I_1	16.82	19.12	23.34	17.30
I_2	16.21	22.17	22.58	16.85
I_3	11.84	15.25	14.91	11.20
S.Em. ±	0.76			
C.D. at 5%	2.24			
Pooled				
I \ T	T_1	T_2	T_3	T_4
I_1	17.27	19.99	23.83	18.28
I_2	16.86	22.30	23.36	17.69
I_3	11.48	15.63	14.72	10.81
S.Em. ±	0.54			
C.D. at 5%	1.54			

Table 4: Effect of water stress and paclobutrazole on 100 kernels weight and harvest index in groundnut during 2021, 2022 and pooled analysis

Treatments		100 kernels weight (g)			Harvest index (%)		
		2021	2022	Pooled	2021	2022	Pooled
I_1	Irrigation at 10 days interval (10 irrigation)	51.34	49.65	50.49	30.26	28.68	29.47
I_2	Irrigation at 15 days interval	50.94	50.30	50.62	33.63	32.71	33.17

	(8 irrigation)						
I_3	Irrigation at 20 days interval (6 irrigation)	47.67	49.62	48.65	26.99	26.77	26.88
S.Em. ±		0.77	0.75	0.54	1.95	0.95	1.09
C.D. at 5%		NS	NS	NS	NS	3.74	3.54
C.V.%		5.31	5.21	5.26	22.30	11.22	17.81
T_1	CONTROL (No application of PBZ)	50.90	50.56	50.73	23.35	23.15	23.25
T_2	PBZ @ 100 mg/l	50.57	50.09	50.33	33.52	32.87	33.19
T_3	PBZ @ 200 mg/l	49.56	49.54	49.55	33.60	33.94	33.77
T_4	PBZ @ 300 mg/l	48.91	49.24	49.07	30.70	27.59	29.15
S.Em. ±		0.87	0.71	0.56	0.99	0.88	0.66
C.D. at 5%		NS	NS	NS	2.93	2.63	1.90
I × T		NS	NS	NS	Sig.	Sig.	Sig.
C.V.%		5.20	4.26	4.75	9.76	9.02	9.41

Table 5: Interaction effect of water stress and paclobutrazole on harvest index in groundnut

Harvest index (%)				
2021				
I \ T	**T_1**	**T_2**	**T_3**	**T_4**
I_1	22.75	28.87	35.94	33.49
I_2	24.92	36.59	37.62	35.37
I_3	22.39	35.09	27.25	23.23
S.Em. ±	1.71			
C.D. at 5%	5.07			
2022				
I \ T	**T_1**	**T_2**	**T_3**	**T_4**
I_1	21.20	27.17	36.86	29.51
I_2	25.40	38.08	36.83	30.54
I_3	22.87	33.35	28.12	22.74
S.Em. ±	1.53			

C.D. at 5%	4.55

Pooled				
I \ T	**T_1**	**T_2**	**T_3**	**T_4**
I_1	21.97	28.02	36.40	31.50
I_2	25.16	37.34	37.23	32.96
I_3	22.63	34.22	27.69	22.98
S.Em. ±	1.15			
C.D. at 5%	3.29			

REFERENCES

Abdoul Karim, T. D., Sanoussi, A., Maman Maârouhi, I., Falalou, H., & Yacoubou, B. (2020). Agro-morphological response of some groundnut genotypes (*Arachis hypogaea* L.) in water deficit conditions. *African Journal of Agricultural Research*, 16(5), 622-631.

Almeida, O., Melo, H. C. D., & Portes, T. D. A. (2016). Growth and yield of the common bean in response to combined application of nitrogen and paclobutrazol. *Revista Caatinga*, 29, 127-132.

Babarashi, E., Rokhzadi, A., Pasari, B., & Mohammadi, K. (2021). Ameliorating effects of exogenous paclobutrazol and putrescine on mung bean [*Vigna radiata* (L.) Wilczek] under water deficit stress. *Plant, Soil and Environment*, 67(1), 40-45.

Barman, M., Gunri, S. K., Puste, A. M., & Das, P. (2018). Effects of paclobutrazol on growth and yield attributes of groundnut (*Arachis hypogaea*L.). *Indian Ecological Society*, 45(2), 321-324.

Boontang, S., Girdthai, T., Jogloy, S., Akkasaeng, C., Vorasoot, N., Patanothai, A., &Tantisuwichwong, N. (2010). Responses of released cultivars of peanut to terminal drought for traits related to drought tolerance. *Asian Journal of Plant Sciences*, 9(7), 423-431.

Challinor, A. J., Ewert, F., Arnold, S., Simelton, E., & Fraser, E. (2009). Crops and climate change: progress, trends, and challenges in simulating impacts and informing adaptation. *Journal of experimental botany*, 60(10), 2775-2789.

Chandini, S. K., Venkata Lakshmi, N., Sree Rekha M., & Ravi Babu, M. (2023). Performance of different groundnut (*Arachis hypogaea* L.) varieties and economics under different irrigation schedules. *Journal of Research ANGRAU*,51(1), 38-45.

Dilley, M., Chen, R. S., Deichmann, U., Lerner-Lam, A. L., Arnold, M., Agwe, J., Buys, P., Kjekstad, O., Lyon, B., &Yetman, G. (2005). Natural disaster hotspots: a global risk analysis. International Bank for Reconstruction and Development/the World Bank and Columbia University. Washington, DC.

Donald, C. M., & Hamblin, J. (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Advances in Agronomy*, 28, 361-405.

Dwivedi, S. K., Arora, A., Singh, V. P., & Singh, G. P. (2018). Induction of water deficit tolerance in wheat due to exogenous application of plant growth regulators membrane stability, water relations and photosynthesis. *Photosynthetica*, 56, 478-486.

Dwivedi, S. K., Arora, A., Singh, V. P., & Singh, G. P. (2018). Induction of water deficit tolerance in wheat due to exogenous application of plant growth regulators membrane stability, water relations and photosynthesis. *Photosynthetica*, 56, 478-486.

Gatan, M. G., & Gonzales, V. (2015). Effect of different levels of paclobutrazol on the yield of asha and farmers' variety of peanut. *JPAIR Multidisciplinary Research*, 21(1), 1-15.

Girdthai, T., Jogloy, S., Vorasoot, N., Akkasaeng, C., Wongkaew, S., Holbrook, C. C., &Patanothai, A. (2010). Heritability of, and genotypic correlations between, aflatoxin traits and physiological traits for drought tolerance under end of season drought in peanut (*Arachis hypogaea* L.). *Field crops research*, 118(2), 169-176.

Koolachart, R., Suriharn, B., Jogloy, S., Vorasoot, N., Wongkaew, S., Holbrook, C. C., Jongrungklang, N., Kesmala, T. and Patanothai, A. (2013). Relationships between physiological traits and yield components of peanut genotypes with different levels of terminal drought resistance *SABRAO Journal of Breeding and Genetics*, 45(3), 422-446.

Lubis, I., Kusumawati, A., Ghulamahdi, M., Purnamawati, H., Kusumo, Y. W. E., Mansyuri, A. G., & Rais, S. A. (2013). Paclobutrazol application effectiveness on growth of two peanut (*Arachis hypogaea* L.) varieties. Paper presented at the *Improving food, energy and environment with better crops. 7th Asian Crop Science Association Conference, IPB International Convention Center, Bogor, Indonesia*, 225-229.

Million, J. B., Barrett, J. E., Nell, T. A., & Clark, D. G. (1999). Paclobutrazol distribution following application to two media as determined by bioassay. *American Society for Horticultural Science*, 34(6), 1099-1102.

Painawadee, M., Jogloy, S., Kesmala, T., Akkasaeng, C., &Patanothai, A. (2009). Identification of traits related to drought resistance in peanut (*Arachis hypogaea*L.). *Asian Journal of Plant Sciences*, 8(2), 120-128.

Pal, S., Zhao, J., Khan, A., Yadav, N. S., Batushansky, A., Barak, S., &Rachmilevitch, S. (2016). Paclobutrazol induces tolerance in tomato to deficit irrigation through diversified effects on plant morphology, physiology and metabolism. *Scientific reports*, 6(1), 39321.

Pervin, S., Islam, M. S., Akanda, A. R., Rahman, M. S., & Mila, A. J. (2014). Effect of irrigation levels on the yield of groundnut. *International Journal of Experimental Agriculture*, 4(1), 17-21.

Singh, A. L., Nakar, R. N., Goswami, N., Kalariya, K. A., Chakraborty, K., & Singh, M. (2013). Water deficit stress and its management in groundnut. *Physiology of Nutrition and Environmental Stresses on Crop Productivity*, 14, 371-465.

Soumya, P. R., & Kumar, P. (2017). Optimization of paclobutrazol dose for foliar and drenching applications under water deficit stress in chickpea *(Cicer arietinum L.)*. *International Journal of Bio-resource and Stress Management*, 8(4), 566-573.

Vaghasia, P. M., Jadav, K. V., &Nadiyadhara, M. V. (2010). Effect of soil moisture stress at various growth stages on growth and productivity of summer groundnut (*Arachis hypogaea* L.) genotypes. *International Journal of Agricultural Sciences*, 6(1), 141-143.

Wallace, J. S. (2000). Increasing agricultural water use efficiency to meet future food production. *Agriculture, ecosystems and environment*, 82(1-3), 105-119.

Win, A., Htwe, N. M., Myint, N. O., Toe, K., & Hom, N. H. (2017). Effects of paclobutrazol on growth of groundnut (*Arachis hypogaea* L.). *Journal of Agricultural Research*, 4(1), 15-22.

Yooyongwech, S., Samphumphuang, T., Tisarum, R., Theerawitaya, C., & Cha-Um, S. (2017). Water-deficit tolerance in sweet potato [*Ipomoea batatas* (L.) Lam.] by foliar application of paclobutrazol: role of soluble sugar and free proline. *Frontiers in Plant Science*, 8, 1400.