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EFFECT OF THREE OKRA HYBRIDS TO SPRAY WITH BRASSINOLIDE AND THIDIAZURON ON SOME GROWTH AND YIELD TRAITS UNDER PROTECTED CULTIVATION CONDITIONS

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ABSTRACT

This experiment was conducted at one of the plastic houses at the research station of College of Agriculture - Anbar University at Ramadi city, Al-Bu'itha region, during Tow season 2021-2022 and 2022-2023, to determine the response of three okra hybrids (V1, V2 and V3) to application of growth regulators Brassinolide (BR) (T0, T1 and T2) and Thidiazuron (TDZ) (T3 and T4) to various growth and yield characteristics. The experiment was conducted using RCBD Within split plot design and three replicates, The hybrid Abeer exhibited a significant superiority over other hybrids in plant height (107.80 and 111.62 cm), number of lateral branches (8.37 and 9.71 branches plant-1), number of leaves (128.39 and 133.21 leaf plant-1), leaf area (206.2 and 211.6 cm2), pod weight (5.18 and 5.17 g), and plant yield (294.2 and 512.6 g plant-1). The results indicated that treatments T2 (application of Brassinolide at a concentration of 0.2 mg L-1) and T4 (application of Thidiazuron at a concentration of 2 mg L-1) exhibited superiority across all evaluated traits. Moreover, the interaction between experimental factors positively influenced traits in treatments V1T2 and V1T4, Which demonstrated a synergistic effect.

Key words: Foliar spraying ,Greenhouse conditions, Hybrid variation, Plant growth regulators

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INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is considered one of the important vegetable crops belonging to the Malvaceae family, desired in many countries worldwide, especially in Asia, Africa, Eastern Europe, and Latin America (Chanchal etal., 2018). It is a summer vegetable crop grown for its green pods, its nutritional value is impressive, offering a rich source of vitamins, minerals, and essential nutrients.. Every 100 g of the pods contain approximately 88.6 g of water, 36 calories, 8.20 g of carbohydrates, 2.10 g of protein, 1.70 g of fiber, 90.00 mg of phosphorus, 1.20 mg of iron 84.00 mg of calcium, 0.60 mg of nickel 0.08 mg of vitamin B2 0.04 mg of vitamin B3 and 47.00 mg of vitamin C. Additionally, its mature seeds contain unsaturated oils (Singh etal., 2012). Its nutritional value is impressive, offering a rich source of vitamins, minerals, and essential nutrients. Plant growth regulators (PGRs) are employed to augment the growth and yield of numerous agricultural crops, owing to their role in various physiological processes within the plant. Among these plant regulators is Brassinolide, which plays a significant role in plant growth and development. Even at low concentrations, it induces certain physiological responses within the plant, such as elongation

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of plant tissues and stimulation of growth in young green parts. It also helps activate various compounds within the plant, including carbohydrates, amino acids, and proteins. Brassinosteroids also participate in regulating the distribution of representative substances to plant organs, aid in pollen tube growth, lateral root formation, increased flowering, productivity, stress resistance, and other processes (A l-Khafaji 2014). Cytokinins, classified as plant hormones, exhibit potent physiological effects when applied to diverse plant species. Their key modes of action include stimulation of cell division, promotion of lateral bud development, and suppression of apical dominance. These collective responses induce the formation of additional lateral, vegetative, and floral branches, ultimately leading to enhanced plant productivity (Al-Kikhani and Al-Asady. 2019;Pai and Desai.2018). The rationale behind this research stems from the critical need to provide farmers with regionally-adapted, high-yielding okra cultivars. Furthermore, assessing the response of these cultivars to exogenous application of plant growth regulators, such as Cytokinins, could offer valuable insights into optimizing their performance in controlled environments.

MATERIALS AND METHODS

The experiment was conducted at one of the plastic houses at the research station of the College of Agriculture - Anbar University at Ramadi city, Al-Bu'itha region, during tow season 2021-2022 and 2022-2023. This study was conducted to investigated the growth and yield response of three okra hybrids (Abeer, Lotus, and Okra F1) to the application of plant growth regulators, Brassinolide (BR) and Thidiazuron (TDZ), under protected cultivation conditions. The objective is to assess the impact of these growth regulators on various growth and yield traits in these hybrids, thereby contributing to the optimization of okra production within controlled environments. Crop management practices including fertilization, weed control, and irrigation were conducted in the plastic house as recommended. Seeds were sown directly in the soil on 18/11/2021. The spacing between plants was 25 cm and between rows was 70 cm. All necessary maintenance operations were performed for the greenhouse. Seeds were sown directly in the soil on 18/11/2021. The spacing between plants was 25 cm and between rows was 70 cm. The study included two factors, the first factor being the hybrids (Abeer, Lotus, Okra F1), which were coded as V1, V2, and V3, respectively, and the second factor the application of the plant growth regulators Br (0, 0.1, and 0.2 mg L-1) and TDZ (1 and 2 mg L-1), were coded as T0, T1, T2, T3, T4 respectively. The experiment was conducted using a randomized complete block design (RCBD) with split-plot arrangements, where the main plots were the hybrids and the sub-plots were combinations of the plant growth regulators. The results were statistically analyzed using the GenStat program, and the means were compared using the L.S.D. least significant difference test at a probability level of 0.05 (8).

Characters studied

Plant Height (cm)
Number of lateral branches (branch plant-1)
Number of leaves (leaf Plant-1)
Leaf area (dm2) (17).
Pod weight (g) (10).
Plant yield (g plant-1)

RESULTS AND DISCUSSION

Plant height (cm)

The results in Table (1) indicate a significant effect of the hybrids, treatments and the interactions for both seasons. The hybrid V1 recorded the highest mean of 107.80 and

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111.62 cm, while hybrid V2 recorded the lowest mean of 97.54 and 97.68 cm for the two study seasons, respectively.The results of the growth regulator application treatments indicated that during the first season, treatment T2 demonstrated superiority with a mean height of 108.61 cm, whereas during the second season, treatment T4 exhibited superiority with a mean height of 111.37 cm. Conversely, Treatment T0 recorded the lowest rate at 98.36 and 93.45 cm for the two study seasons, respectively. The results of the interaction between hybrids and Br and TDZ growth regulator spraying treatments indicate significant differences in plant height. Treatment V1T4 recorded the highest rate of 112.75 and 119.90 cm, which did not differ significantly from treatment V1T2 at 112.26 cm and 118.83 cm. While, treatment V2T0 recorded the lowest rate, at 81.04 cm and 80.05 cm.

Table 1. Response of three okra hybrids to spraying with the growth regulators Brassinolide and Thidiazuron and the interaction between them on plant height (cm)

Treatment	Season 2021-2022				Season 2022-2023			
	Hybrid			Mean T	Hybrid			Mean T
	V_1	V_2	V_3		V_1	V_2	V_3	
T0	102.00	81.04	98.36	93.80	102.69	80.05	97.60	93.45
T1	105.78	93.11	102.61	100.50	109.69	94.27	104.19	102.69
T2	112.62	106.33	106.87	108.61	118.83	104.88	106.68	110.13
T3	105.84	101.36	106.74	104.65	107.04	102.49	109.18	106.23
T4	112.75	105.85	105.64	108.08	119.90	106.73	107.47	111.37
Mean V	107.80	97.54	104.04		111.62	97.68	105.02	
LSD 0.05	V	T		T×V	V	T		T×V
	2.60	3.06		5.08	2.13	3.29		5.30

Number of lateral branches (branches plant^{-1}): The results in Table (2) indicate that hybrids have a positive effect on the number of lateral branches. Hybrid V1 recorded the highest average with 8.37 and 9.71 branches plant-1, while hybrid V3 recorded the lowest average with 5.60 and 5.81 branches plant-1 for the two study seasons, respectively. The results revealed a significant effect between growth regulators treatments. Treatment T4 recorded the highest average with 7.99 and 8.81 branches plant-1, which did not differ significantly from treatment T2. In contrast, the control treatment T0 recorded the lowest average with 5.08 and 4.03 branches plant-1 for the two study seasons, respectively. The results of revealed a significant interaction between hybrids and Br and TDZ growth regulator spraying treatments. Treatment combination V1T2 recorded the highest average with 10.73 and 12.10 branches plant-1, for the two seasons respectively, while treatment combination V3T0 recorded the lowest average at3.87 and 4.03 branches plant-1 for the two study seasons, respectively.

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Table 2. Response of three okra hybrids to spraying with the growth regulators Brassinolide and Thidiazuron and the interaction between them on Number of lateral branches (branch plant-1)

Treatment	Season 2021-2022 Hybrid			Mean T	Season 2022-2023 Hybrid			Mean T
	V_1	V_2	V_3		V_1	V_2	V_3	
T0	5.80	5.57	3.87	5.08	7.00	4.90	4.03	5.31
T1	7.57	6.50	6.33	6.80	8.97	6.63	6.47	7.36
T2	10.73	6.73	6.37	7.94	12.10	6.90	6.57	8.52
T3	7.63	7.43	5.53	6.87	8.50	7.77	5.83	7.37
T4	10.10	7.97	5.90	7.99	12.00	8.30	6.13	8.81
Mean V	8.37	6.84	5.60		9.71	6.90	5.81	
LSD 0.05	V	T	T×V		V	T	T×V	
	0.73	0.98	1.61		0.59	0.94	1.51	

Number of leaves (leaf plant-1)

The results revealed a statistical significant of hybrids, treatments, and their interaction for the two seasons in number of leaves per plant (Table 3). The hybrid V1 recorded the highest average of 128.39 and 133.21 leaves plant-1, while hybrid V3 recorded the lowest average of 108.39 and 110.55 leaves plant-1 for the two seasons respectively. Regarding the spraying of growth regulators, treatment T2 recorded the highest average of 130.08 leaves plant-1 for the first season, whereas treatment T4 recorded the highest average of 131.79 leaves plant-1 for the second season. Conversely, the control treatment T0 recorded the lowest average of 98.03 and 100.41 leaves plant-1 for the two seasons respectively. This study revealed interaction between hybrids and growth regulator spraying. Treatment combination T2V1 recorded the highest average of 144.37 leaves plant-1 for the first season, while treatment combination T4V1 recorded the highest average of 152.88 leaves plant-1 in second season. In contrast, treatment combination T0V2 recorded the lowest average of 95.50 and 96.85 leaves plant-1 for the two seasons respectively.

Table 3. Response of three okra hybrids to spraying with the growth regulators Brassinolide and Thidiazuron and the interaction between them on Number of leaves (leaf plant-1)

Treatment	Season 2021-2022 Hybrid			Mean T	Season 2022-2023 Hybrid			Mean T
	V_1	V_2	V_3		V_1	V_2	V_3	
T0	102.11	95.50	96.47	98.03	105.17	96.85	99.20	100.41
T1	121.60	101.90	102.67	108.72	121.24	102.22	103.39	108.95
T2	144.37	127.73	118.13	130.08	151.92	121.57	120.17	131.22
T3	129.97	106.47	110.47	115.63	134.87	109.99	113.51	119.46
T4	143.90	128.47	114.23	128.87	152.88	126.00	116.49	131.79
Mean V	128.39	112.01	108.39		133.21	111.33	110.55	
LSD 0.05	V	T	T×V		V	T	T×V	
	1.59	3.45	5.45		3.82	5.88	5.88	

Leaf area (dm2)Top of Form

The results of Table (4) show significant differences among the hybrids. Hybrid V1 exhibited the highest average of 206.2 and 211.6 dm2, while hybrid V3 recorded the lowest average of 138.0 and 143.9 dm2 for the two seasons respectively. The results indicated significant differences between spraying treatments with the growth regulators Br and TDZ. Treatment T4 recorded the highest

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average of 198.0 and 204.5 dm2, which did not different significantly from treatment T2. Conversely, the control treatment T0 recorded the lowest average of 141.0 and 143.9 dm2 for the two seasons respectively. Significant interaction and hybrids and the spraying treatments with Br and TDZ, were also observed. All treatment combinations, V1T2 achieved the highest average area, at 281.1 and 289.4 dm2, outperforming all other treatments except V1T4, which did not significantly differ from it, with an average of 279.6 and 288.0 dm2. While, treatment combination V3T0 recorded the lowest average of 129.3 and 131.4 cm^2 for the two consecutive study seasons.

Table 4. Response of three okra hybrids to spraying with the growth regulators Brassinolide and Thidiazuron and the interaction between them on leaf area (dm2)

Treatment	Season 2021-2022 Hybrid			Mean T	Season 2022-2023 Hybrid			Mean T
	V_1	V_2	V_3		V_1	V_2	V_3	
T0	155.0	138.7	129.3	141.0	158.4	141.9	131.4	143.9
T1	160.1	146.5	140.4	145.7	161.9	149.5	146.8	152.7
T2	281.1	151.2	135.7	189.3	289.4	157.0	136.8	194.6
T3	155.4	147.6	141.1	148.0	160.6	155.7	147.7	154.7
T4	279.6	160.9	153.4	198.0	288.0	168.4	157.1	204.5
Mean V	206.2	149.0	138.0		211.6	154.6	143.9	
LSD 0.05	V	T	T×V		V	T	T×V	
	3.97	6.70	10.72		3.91	3.87	6.62	

Pod weight (g)

Data in Table (5) shows, significant impact of hybrids becomes evident. Hybrid V1 achieved the highest average pod weight (5.18 and 5.17 g) for the two consecutive study seasons, respectively. hybrid V3 recorded the lowest average pod weight, of 4.29 and 4.30g for the two seasons respectively. The results of the growth regulator spraying treatments revealed significant differences among the various treatments. Treatment T4 recorded the highest average pod weight at 5.33 and 5.32 g for the two consecutive study seasons, respectively, outperforming all other treatments except for treatment T2, which did not differ significantly from it. Treatment T0 recorded the lowest average pod weight, total of 4.26 and 4.27 g for the two seasons respectively. The analysis revealed a significant interaction among study factors. Treatment V1T2 recorded the highest average pod weight, totaling 6.12 and 6.10 g for the two consecutive study seasons, respectively, surpassing all other treatments except for treatment V1T4, which did not differ significantly from it. Conversely, treatment V3T0 recorded the lowest average pod weight, reaching 3.76 and 3.74 grams for the two seasons respectively.

Table 5. Response of three okra hybrids to spraying with the growth regulators Brassinolide and Thidiazuron and the interaction between them on Pod weight (g)

Treatment	Season 2021-2022 Hybrid			Mean T	Season 2022-2023 Hybrid			Mean T
	V_1	V_2	V_3		V_1	V_2	V_3	
T0	4.74	4.28	3.76	4.26	4.77	4.30	3.74	4.27
T1	4.64	4.47	4.32	4.48	4.64	4.48	4.35	4.49
T2	6.12	4.59	4.38	5.03	6.10	4.61	4.36	5.02
T3	4.41	4.12	4.25	4.29	4.36	4.23	4.28	4.29
T4	6.00	5.24	4.76	5.33	5.97	5.26	4.75	5.32
Mean V	5.18	4.56	4.29		5.17	4.58	4.30	
LSD 0.05	V	T	T×V		V	T	T×V	
	0.22	0.33	0.53		0.24	0.34	0.55	

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Yield per plant (g Plant-1)

The results of Table (6) reveal significant differences among the different hybrids. Hybrid V1 recorded the highest average plant Yield at 294.2 and 512.6 g plant-1 for the two consecutive study seasons, respectively, while hybrid V3 recorded the lowest average plant Yield, totaling 223.7 and 399.9 g plant-1 for the same seasons. Regarding the growth regulator spraying treatments, had a positive effects on the plant yield trait. Treatment T4 recorded the highest average plant Yield, reaching 332.3 and 562.5 g plant-1, which did not differ significantly from treatment T2, achieving an average of 328.3 and 548.4 g plant-1. Conversely, the control treatment T0 recorded the lowest average plant Yield, totaling 170.3 and 332.6 g plant-1 for the two consecutive study seasons.

The analysis of the interaction between the study factors showed a positive effect on the plant yield. Treatment combination V1T2 recorded the highest average plant yield weight at 426.4 and 699.2 g plant-1 for the two seasons, respectively. Conversely, treatment combination V3T0 recorded the lowest average plant yield, with 143.6 and 284.3 g plant-1 for both seasons respectively.

Table 6. Response of three okra hybrids to spraying with the growth regulators Brassinolide and Thidiazuron and the interaction between them on plant yield (g plant^{-1})

Treatment	Season 2021-2022				Season 2022-2023			
	Hybrid			Mean T	Hybrid			Mean T
	V_1	V_2	V_3		V_1	V_2	V_3	
T0	198.7	168.5	143.6	170.3	385.2	328.5	284.3	332.6
T1	224.2	201.9	195.2	207.1	412.4	380.3	367.8	386.8
T2	426.4	292.1	266.5	328.3	699.2	491.5	454.4	548.4
T3	206.5	208.5	231.0	215.4	384.0	384.3	408.1	392.1
T4	415.2	299.3	282.2	332.3	682.2	520.3	485.0	562.5
Mean V	294.2	234.1	223.7		512.6	421.0	399.9	
LSD 0.05	V	T	T×V		V	T	T×V	
	14.76	18.79	31.73		29.19	31.24	52.65	

The results from Tables (1, 2, 3, 4, 5, and 6) a significant increase in growth and yield characteristics for the two seasons among the different hybrids. The hybrid "Abeer" outperformed all other hybrids in plant height, number of lateral branches, number of leaves, leaf area, pod weight, and plant yield. This is attributed to genetic variation, the nature of gene expression, and the hybrid's response to surrounding environmental conditions, leading to differences in vegetative growth and yield rates (Almohammedi etal., 2019, Mohammed and Almohammedi. 2023). The increase could in growth and yield characteristics could be attributed to the role of plant growth regulators, which play a significant role in enhancing plant growth and improving yield. The positive effects of BR on vegetative growth and yield traits are attributed to its ability to increase the absorption of mineral elements from the soil and enhance the plant's utilization of them, as demonstrated in the study of (El-Khallal etal., 2009). The increase in leaf area, number of leaves, and plant height may also be attributed to the role of BR in stimulating the processes responsible for cell elongation and division. Cell elongation is controlled through various processes involving mechanical properties of the cell wall, biochemical processes, and gene expression. The primary cell wall in most dicotyledonous and monocotyledonous plants consists of cellulose microfibrils. It is believed that Brassinosteroids participate in cell wall relaxation. Therefore, the increase in vegetative growth resulting from the addition

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of BR may be attributed to cell elongation and division (A l-Khafaji 2014; Sekhi etal., 2023, Shraida and Almohammedi 2021). The observed growth enhancement could also be ascribed to the influence of the growth regulator TDZ in promoting cell division, suppressing senescence, and augmenting RNA synthesis. Additionally, cytokinins facilitate the transportation of nutrients and solutes to the sites of consumption. This aligns with previous studies (Al-Dulime and Al-Mohammedi. 2023; Al-Issawi and Al-Mohammedi 2023; Al-Issawi and Al-Mohammedi 2023; Çalişkan etal., 2021) which found that cytokinin application led to increased growth in okra plants (Talib, R.W. 2017).

CONCLUSION

The results of this study clearly demonstrated that foliar application of brassinolide and thidiazuron had a significant effect on the growth and yield traits of okra (*Abelmoschus esculentus L.*) grown under protected cultivation conditions. The three okra hybrids differed in their response to the applied plant growth regulators, indicating the presence of genetic variation among hybrids. Spraying with brassinolide enhanced vegetative growth traits by improving plant height, leaf number, and overall plant vigor, which consequently contributed to higher yield components. In addition, thidiazuron application significantly improved yield traits through its role in stimulating cell division and enhancing assimilate translocation toward reproductive organs. The interaction between okra hybrids and growth regulator treatments resulted in superior performance in most studied traits, suggesting that the combined use of suitable hybrids and appropriate concentrations of brassinolide and thidiazuron can be considered an effective strategy for improving okra productivity under protected cultivation conditions]

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

AUTHOR/S DECLARATION

We confirm that all Figures and Tables in the manuscript are original to us. Additionally, any Figures and images that do not belong to us have been incorporated with the required permissions for re-publication, which are included with the manuscript. Author/s signature on Ethical Approval Statement. Ethical Clearance and Animal welfare Funds:

AUTHOR'S CONTRIBUTION STATEMENT

All authors contributed to the conception and design of the experiment, data collection, statistical analysis, interpretation of results, and writing of the manuscript. All authors reviewed and approved the final version of the manuscript.

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العنوان تأثيررش ثلاثة هجن من الباميا بالبراسينولايد والثيديازورون في بعض صفات النمو والحاصل تحت ظروف الزراعة المحمية

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باحث استاذ

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المستخلص

نفذت التجربة في أحد البيوت البلاستيكية في المحطة البحثية التابعة لكلية الزراعة–جامعة الانبار في منطقة البوعيثة اثناء موسم النمو 2021–2022 و 2022–2023، لمعرفة استجابة ثلاثة هجن ورش منظمي النمو البراسينولايد والثيديازورون في بعض صفات النمو والحاصل. اظهر الهجين عبير تفوق معنوي على الهجن الاخرى في ارتفاع النبات 107.80 و111.62سم وعدد التفرعات الجانبية 8.37 و9.71فرع نبات$^{-1}$ وعدد الاوراق 128.39 و133.21ورقة نبات$^{-1}$ والمساحة الورقية للنبات 206.2 و211.6 دسم^{2} ووزن القرنة 5.18 و5.17غم وحاصل النبات 294.2 و512.6غم نبات$^{-1}$. كما اظهرت النتائج تفوق المعاملتين T_2(رش البراسينولايد بتركيز 0.2ملغم لتر$^{-1}$) وT_4(رش الثيديازورون بتركيز 2ملغم لتر$^{-1}$) في جميع الصفات المدروسة. كما كان للتداخل بين عوامل الدراسة تأثيراً ايجابياً عند المعاملتين V_1T_2 وV_1T_4 في أغلب الصفات المدروسة.

الكلمات المفتاحية: الرش، البيوت البلاستيكية، أداء هجين، منظمات النمو.