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Study Of The Effects Of Indole-3-Butyric Acid (IBA) And Water Stress On Germination And Physiological Growth Of Basil Cultivars (Ocimum Basilicum And Ocimum Kilimandscharicum)

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Abstract *The present study evaluated the impact of indole-3-butyric acid (IBA) application and varying soil moisture levels on germination and early seedling growth of two basil species, Ocimum basilicum and Ocimum kilimandscharicum. Results showed that seed treatment and foliar application of IBA significantly enhanced germination percentage, root and shoot elongation, dry biomass accumulation, and vigor index. These effects are attributed to IBA's auxin-like activity, which promotes cell division, elongation, enzymatic activation, and improved water and nutrient uptake, particularly under drought stress conditions. Additionally, O. kilimandscharicum demonstrated superior physiological performance and adaptability compared to O. basilicum. Increased soil field capacity further improved all measured growth parameters by facilitating enzymatic activities and metabolic processes essential for seedling establishment. The findings suggest that IBA application combined with optimized soil moisture management can effectively improve basil propagation and growth, especially under water-limited environments.*
Keywords: *Basil, Drought, Germination, IBA.*

INTRODUCTION

Basil (Ocimum spp.) is an important aromatic and medicinal plant belonging to the Lamiaceae family, which includes approximately 150 economically valuable species (Güez et al., 2017). This genus is highly diverse, comprising more than 60 species of herbs and shrubs distributed across tropical and subtropical regions of Asia, Africa, and Central and South America (Padalia et al., 2017; Zare et al., 2021). Basil is characterized by quadrangular stems covered with fine hairs and simple, opposite leaves that vary in size and color, containing glandular trichomes that secrete volatile oils with distinctive aromas (Chenni, 2016; Paton et al., 1999). Its flowers are bilabiate and arranged in terminal clusters with colors ranging from white to purple (Khair-ul-Bariya et al., 2012). The chemical composition of basil's essential oils includes monoterpene derivatives such as camphor and linalool, as well as potent phenolic compounds like eugenol and methyl chavicol, in addition to polyphenols and flavonoids that enhance its antioxidant and anti-inflammatory properties (Hiltunen & Holm, 1999; Gurav et al., 2022).Plant growth regulators, such as indole-3-butyric acid (IBA), play a vital role in stimulating root formation, which is essential for the successful vegetative propagation of plants. IBA belongs to the auxin group and promotes cell division in the cambium and differentiation into root cells, facilitating the development of a strong and efficient root system that improves water and nutrient uptake, thereby supporting overall plant growth (Alaf, 2010; Rahman et al., 2020).On the other hand, water stress is one of the most significant environmental factors negatively affecting plant growth and productivity. This stress occurs due to the insufficient availability of water necessary for vital plant processes and results from multiple causes, including reduced rainfall, high temperatures, increased evaporation rates, and high soil salinity, which impairs the plant's ability to absorb water (Seleiman et al., 2021).

Materials and Methods

This study was conducted in the laboratories of the Department of Life Sciences, College of Science, University of Mosul. A laboratory experiment was designed to investigate the effects of different concentrations of indole-3-butyric acid (IBA) on the germination and seedling growth of two basil cultivars (*Ocimum basilicum* – sweet basil and *Ocimum kilimandscharicum* – camphor basil) under water stress conditions. The experiment was arranged as a factorial design using a completely randomized design (CRD) with a factorial arrangement (3 × 3 × 3 × 2) to evaluate the individual and interactive effects of IBA concentrations and water stress levels on seedling growth parameters.Seeds of each cultivar were soaked in three concentrations of IBA (0, 0.025, and 0.075 mg/L) for 12 hours, followed by drying at room temperature. Then, ten viable seeds from each treatment were sown in sterile Petri dishes (13.8 cm diameter) lined with two layers of Whatman No. 1 filter paper, with three replicates per treatment. The Petri dishes were subjected to three levels of water stress (0%, 5%, and 10%) induced by polyethylene glycol (PEG-6000) solution and incubated at 20 ± 2 °C for 14 days. To compensate for water loss due to evaporation, 2 ml of distilled water was added daily to each dish

.The following parameters were measured:

Germination Percentage (%): calculated based on the percentage of germinated seeds after 14 days according to(Saied 1984) using the formula:

Germination Percentage = Number of normal seedlings\Number of seeds sown * 100

Root Length (cm): measured from the point of attachment to the hypocotyl to the tip of the radicle.

Shoot Length (cm): measured from the point of attachment to the radicle to the tip of the hypocotyl.

Dry Weight of Root and Shoot (mg): determined after drying samples in an electric oven at 72 °C for 48 hours.

Vigor Index: calculated according to (Abdul-Baki and Anderson 1973) using the formula:

Vigor Index = Germination Percentage *Radicle Length

RESULTS AND DISCUSSION

Germination Percentage (%)

The results presented in Table (1) indicated that soaking basil seeds in different concentrations of the plant growth regulator Indole-3-butyric acid (IBA) at 0, 50, and 100 ppm resulted in a significant increase in germination percentage. Similarly, different concentrations of polyethylene glycol (PEG-6000) at 20, 50, and 80 g/L had a significant effect on germination percentage.

Furthermore, the camphor basil cultivar (*Ocimum kilimandscharicum*) exhibited a significantly higher germination percentage compared to the sweet basil cultivar (*Ocimum basilicum*).Regarding the interaction between cultivars and IBA concentrations, both *O. kilimandscharicum* and *O. basilicum* showed a significant increase in germination percentage with increasing IBA concentrations. Moreover, in the three-way interaction among cultivar, IBA concentration, and water stress level, *O. kilimandscharicum* treated with 100 ppm IBA under non-stress conditions (i.e., 80% field capacity) recorded the highest germination percentage compared to all other treatment combinations

Table (1): Effect of Different Concentrations of Indole-3-butyric Acid and PEG on Germination Percentage (%) of Two Basil Cultivars

Effect of PEG	Effect of cultivars	Interaction between cultivars and PEG	IBA ppm			PEG g/L	Cultivars
			100	50	0		
		96.67a	98.00a	97.00 ab	95.00ab	% 80	*O. kilimandscharicum*
		87.67b	90.00c	88.00 cd	85.00d	% 50	
		79.33d	85.00d	81.00 e	72.00g	% 20	
		95.67a	97.00ab	96.00 ab	94.00b	% 80	*O. basilicum*
		84.67c	88.00 cd	85.00 d	81.00e	% 50	
		75.67e	81.00e	76.00 f	70.00g	% 20	
	87.89a		91.00a	88.67 b	84.00c	*Ocimum kilimandscharicum*	The interaction between cultivars and growth regulator
	85.33b		88.67b	85.67 c	81.67d	*Ocimum basilicum*	
96.17a			97.50a	96.50 ab	94.50b	% 80	The interaction between field capacity and growth regulator
86.17b			89.00c	86.50 d	83.00e	% 50	

77.50c			83.00e	78.50 f	71.00g	% 20	
			89.83a	87.17 b	82.83c	Effect of growth regulator	

Means followed by the same letter are not significantly different from each other at the 0.05 probability level, according to Duncan's multiple range test."

Root Length (cm)

The results presented in the table demonstrated a statistically significant reduction in root length of basil plants not treated with the growth regulator Indole-3-butyric acid (IBA), showing a decrease of 26.7% compared to plants treated with 100 ppm IBA.

Additionally, water stress induced by polyethylene glycol (PEG) caused a marked decline in root length with increasing PEG concentrations. Specifically, reductions of 13.4% and 34.8% were observed at PEG concentrations of 50 g/L and 20 g/L, respectively, relative to plants grown under non-stress conditions (80% field capacity).

Regarding cultivar effects, *Ocimum kilimandscharicum* (camphor basil) exhibited significantly greater root length than *Ocimum basilicum* (sweet basil).

The interaction between cultivar and PEG concentration revealed that *O. kilimandscharicum* plants grown under non-stress conditions (80% field capacity) had superior root length compared to other treatments.

Furthermore, the three-way interaction among cultivar, IBA concentration, and PEG concentration showed that *O. kilimandscharicum* treated with 50 ppm IBA and subjected to 80% field capacity exhibited the greatest root length.

Table (2): Effect of different concentrations of Indole-3-butyric acid and polyethylene glycol on root length (cm) of two basil cultivars

Effect of PEG	Effect of cultivars	Interaction between cultivars and PEG	IBA ppm			PEG g\L	Cultivars
			100	50	0		
		5.23a	5.91 a	5.15 c	4.63h	% 80	*O. kilimandscharicum*
		4.57c	5.00 d	4.71 f	4.00k	% 50	
		3.68e	4.25 j	3.70 l	3.10n	% 20	
		5.06b	5.50 b	5.00 d	4.67g	% 80	*O. basilicum*
		4.32d	4.95 e	4.31 i	3.71l	% 50	
		3.02f	3.70 l	3.30 m	2.07o	% 20	
	4.49a		5.05 a	4.52 c	3.91e	*Ocimum kilimandscharicum*	The interaction between cultivars and growth regulator
	4.13b		4.72 b	4.20 d	3.48f	*Ocimum basilicum*	
5.14a			5.71 a	5.08 b	4.65d	% 80	The interaction between field capacity and growth regulator
4.45b			4.98 c	4.51 e	3.86g	% 50	

3.35c			3.98 f	3.50 h	2.59i	% 20	
			4.89 a	4.36 b	3.70c	Effect of growth regulator	

Shoot Length (cm)

The results presented in the table indicate that treating basil plants with different concentrations of Indole-3-butyric acid (IBA) led to a significant increase in shoot length. Treatments with 100 ppm and 50 ppm IBA showed notable superiority over the control, with increases of 8.5% and 8.2%, respectively.

Furthermore, the results demonstrated that increasing polyethylene glycol (PEG) concentration caused a significant decrease in shoot length. Specifically, the 20 g/L PEG treatment resulted in a 10.7% reduction compared to plants grown under non-stress conditions

The interaction between cultivar and growth regulator revealed a significant advantage for the camphor basil cultivar (*Ocimum kilimandscharicum*) over the sweet basil cultivar (*Ocimum basilicum*) in shoot length.Moreover, the interaction between field capacity and growth regulator showed that higher PEG concentrations led to a reduction in shoot length, while IBA treatments significantly improved this parameter.

Table (3): Effect of different concentrations of Indole-3-butyric acid and polyethylene glycol on shoot length (cm) of two basil cultivars

Effect of PEG	Effect of cultivars	Interaction between cultivars and PEG	IBA ppm			PEG g\L	Cultivars
			100	50	0		
		10.85a	11.73 a	10.82 c	10.00f	% 80	*O. kilimandscharicum*
		9.68c	10.12 e	9.67g	9.25j	% 50	
		8.51e	9.38i	8.53l	7.61n	% 20	
		10.29b	10.95 b	10.31 d	9.62h	% 80	*O. basilicum*
		9.40d	10.00 f	9.35i	8.86k	% 50	
		8.06f	8.89k	8.29 m	7.00o	% 20	
	9.68a		10.41 a	9.67c	8.95e	*Ocimum kilimandscharicum*	The interaction between cultivars and growth regulator
	9.25b		9.95b	9.32d	8.49f	*Ocimum basilicum*	
10.57a			11.34 a	10.57 b	9.81d	% 80	The interaction between field capacity and growth regulator
9.54b			10.06 c	9.51e	9.06g	% 50	
8.28c			9.14f	8.41h	7.31i	% 20	
			10.18 a	9.50b	8.72c	Effect of growth regulator	

Dry Root Weight (g)

The results presented in the table showed a significant decrease in the dry root weight of basil plants untreated with the growth regulator Indole-3-butyric acid (IBA), with a reduction of approximately 20.8% compared to plants treated with 100 ppm IBA.

Additionally, the results indicated that increasing the concentration of polyethylene glycol (PEG) caused a significant reduction in dry root weight, with decreases of 5.1% and 28.6% at PEG concentrations of 50 g/L and 20 g/L, respectively, compared to plants grown under non-water stress conditions (80% field capacity).

Table (4): Effect of different concentrations of Indole-3-butyric acid and polyethylene glycol on dry root weight (g) of two basil cultivars

Effect of PEG	Effect of cultivars	Interaction between cultivars and PEG	IBA ppm			PEG g\L	Cultivars
			100	50	0		
		0.0436a	0.0490 a	0.0431 a	0.0388a	% 80	*O. kilimandscharicum*
		0.0420a	0.0465 a	0.0415 a	0.0379a	% 50	
		0.0310a b	0.0350 a	0.0300 a	0.0281a	% 20	
		0.0397a b	0.0440 a	0.0401 a	0.0350a	% 80	*O. basilicum*
		0.0346a b	0.0397 a	0.0345 a	0.0297a	% 50	
		0.0249b	0.0281 a	0.0270 a	0.0195a	% 20	
	0.0389a		0.0435 a	0.0382 a	0.0349a	*Ocimum kilimandscharicum*	The interaction between cultivars and growth regulator
	0.0331a		0.0373 a	0.0339 a	0.0281a	*Ocimum basilicum*	
0.0417 a			0.0465 a	0.0416 a b	0.0369a b	% 80	The interaction between field capacity and growth regulator
0.0383 a			0.0431 a b	0.0380 a b	0.0338a b	% 50	
0.0280 b			0.0316 a b	0.0285 a b	0.0238b	% 20	
			0.0404 a	0.0360 a	0.0315a	Effect of growth regulator	

Regarding cultivar effects, the camphor basil cultivar (*Ocimum kilimandscharicum*) showed a significant superiority in dry root weight compared to the sweet basil cultivar (*Ocimum basilicum*). The interaction between cultivars and PEG levels revealed that camphor basil plants grown under non-water stress conditions outperformed other treatments. Moreover, the three-way interaction among cultivar, growth regulator, and PEG showed that camphor basil plants treated with 50 ppm IBA and grown at 80% field capacity recorded the highest dry root weight.

Dry Shoot Weight (g)

The results presented in the table indicate a significant effect of Indole-3-butyric acid (IBA) on dry shoot weight, with the highest dry weight recorded at 100 ppm IBA, showing an increase of approximately 12.8% compared to the control. Similarly, the treatment with 50 ppm IBA resulted in a higher dry weight than the control by about 2.6%.

Table (5): Effect of different concentrations of Indole-3-butyric acid and polyethylene glycol on dry shoot weight (g) of two basil cultivars

Effect of PEG	Effect of cultivars	Interaction between cultivars and PEG	IBA ppm	PEG g\L	Cultivars

			100	50	0		
		0.082a	0.088 a	0.080 a b	0.078a b	% 80	*O. kilimandscharicum*
		0.079a b	0.083 a b	0.079 a b	0.074a b	% 50	
		0.068a b	0.075 a b	0.069 a b	0.060a b	% 20	
		0.079a b	0.085 a b	0.079 a b	0.073a b	% 80	*O. basilicum*
		0.073a b	0.078 a b	0.073 a b	0.068a b	% 50	
		0.064b	0.072 a b	0.065 a b	0.056b	% 20	
	0.076a		0.082 a	0.076 a b	0.071a b	*Ocimum kilimandscharicum*	The interaction between cultivars and growth regulator
	0.072a		0.078 a b	0.072 a b	0.066b	*Ocimum basilicum*	
0.081 a			0.087 a	0.080 a	0.076a b	% 80	The interaction between field capacity and growth regulator
0.076 ab			0.081 a	0.076 a b	0.071a b	% 50	
0.066 b			0.074 a b	0.067 a b	0.058b	% 20	
			0.080 a	0.074 ab	0.068b	Effect of growth regulator	

The results also showed that increasing polyethylene glycol (PEG) concentration led to a significant decrease in dry shoot weight. Specifically, the dry weight at 20 g/L PEG was reduced by approximately 24.1% compared to plants grown under non-stress conditions (80% field capacity).Regarding cultivar effects, the camphor basil cultivar (*Ocimum kilimandscharicum*) exhibited superior dry shoot weight compared to the sweet basil cultivar (*Ocimum basilicum*).The interaction between cultivars and growth regulator showed that camphor basil plants grown under non-water stress conditions outperformed other treatments.Moreover, the three-way interaction among cultivars, growth regulator, and PEG revealed that camphor basil plants treated with 50 ppm IBA under 80% field capacity water stress recorded the highest dry shoot weight.

Vigor Index

The results presented in the table indicate that treatment with Indole-3-butyric acid (IBA) caused a significant increase in the vigor index, with the highest values recorded at the concentration of 100 ppm, showing an increase of approximately 15.0% compared to the control. Treatment with 50 ppm IBA also resulted in a slight increase in the vigor index, by about 13.4% compared to the control. The results further revealed that increasing the concentration of water stress induced by polyethylene glycol (PEG) caused a significant decrease in the vigor index, with a marked reduction of approximately 55.9% at 20 g/L PEG compared to non-stressed plants.

Regarding cultivar effects, *Ocimum kilimandscharicum* (camphor basil) significantly outperformed *Ocimum basilicum* (sweet basil) in vigor index across all treatments. The interaction between cultivar and growth regulator showed that *O. kilimandscharicum* had higher vigor index values than *O. basilicum* at 100 ppm IBA.

Furthermore, the three-way interaction among cultivar, IBA concentration, and PEG treatment revealed that the highest vigor index was observed in *O. kilimandscharicum* plants treated with 50 ppm IBA under non-stress conditions.

Table (6): Effect of different concentrations of Indole-3-butyric acid and PEG on vigor index of two basil cultivars

Effect of PEG	Effect of cultivars	Interaction between cultivars and PEG	IBA ppm			PEG g\L	Cultivars
			100	50	0		
		5.0619a	5.7918a	4.9955c	4.3985f	% 80	*O. kilimandscharicum*
		4.0149c	4.5000e	4.1448h	3.4000k	% 50	
		2.9472e	3.6125j	2.9970l	2.2320n	% 20	
		4.8416b	5.3350b	4.8000d	4.3898f	% 80	*O. basilicum*
		3.6749d	4.3560g	3.6635i	3.00511	% 50	
		2.3180f	2.9970l	2.5080m	1.4490o	% 20	
	4.0080a		4.6348a	4.0458c	3.3435e	*Ocimum kilimandscharicum*	The interaction between cultivars and growth regulator
	3.6115b		4.2293b	3.6572d	2.9480f	*Ocimum basilicum*	
4.9518a			5.5634a	4.8978b	4.3942d	% 80	The interaction between field capacity and growth regulator
3.8449b			4.4280c	3.9042e	3.2026g	% 50	
2.6326c			3.3048f	2.7525h	1.8405i	% 20	
			4.4321a	3.8515b	3.1457c	Effect of growth regulator	

CONCLUSIONS

The results of this study support previous research showing that the application of indole-3-butyric acid (IBA) enhances plant growth by stimulating root formation, which increases the plant's ability to absorb water and nutrients from the soil, thereby improving yield and crop quality. This effect is attributed to IBA's role as a plant growth regulator belonging to the auxin group, which plays a central role in regulating cell division and elongation, supporting increased root and shoot length as well as plant biomass (Strader & Bartel, 2011; Elhindi et al., 2016).The study demonstrated that IBA application significantly increased the germination percentage of basil seeds, reflecting stimulation of vital metabolic processes related to germination such as the activity of hydrolytic enzymes that mobilize stored compounds within the seed and increased permeability of the seed coat to water. These factors collectively accelerate water uptake and initiate the physiological processes necessary for embryo growth. The positive effect of IBA was more evident under non-stress conditions, emphasizing the importance of a suitable environment to maximize the efficacy of this growth regulator (Elhindi et al., 2016).Results related to physiological growth indicators, including increased root and shoot length, dry weight, and vigor index, indicate overall improved plant performance. This improvement contributes to enhanced photosynthesis, nutrient use efficiency, and enzyme activity associated with stress tolerance, supporting the plant's ability to adapt to drought conditions (Abdel-Rahman et al., 2023). The increase in vigor index reflects improved growth efficiency and environmental adaptation, especially under reduced soil moisture conditions.The *Ocimum kilimandscharicum* cultivar showed clear superiority over *Ocimum basilicum* in most germination and growth traits, indicating higher physiological efficiency and adaptability under the experimental conditions. This may be attributed to genetic and physiological differences between the cultivars that affect their response to growth regulators and water stress (Khan et al., 2018).The results also demonstrated the importance of soil moisture (field capacity) in promoting plant growth, with a positive effect of increased soil moisture on germination percentage, root and shoot lengths, dry biomass, and vigor index. This reflects the critical role of water availability in supporting metabolic activities such as photosynthesis and organic matter synthesis essential for plant development (Ahmed & Hassan, 2019; Singh et al., 2020).Moreover, plants adapt to drought stress through morphological changes such as increasing the root-to-shoot ratio and modifying leaf structure to reduce water loss by decreasing leaf size, thickening the epidermis, or forming trichomes, which act as defense mechanisms to minimize transpiration and improve survival (Seleiman et al., 2021).

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