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ORIGINAL ARTICLE

Effects of Plant Growth Regulator on the Okra Growth, Yield, Chlorophyll Content and Aborted Seed Production In vivo

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ABSTRACT - The study was conducted to evaluate the effect of different concentrations of indole acetic acid (IAA) as plant growth regulator on okra growth and development. The stem injection innovative method of application was used in this experiment rather than spray as a common and traditional method. The stem injection method was applied on the stem of the okra plant using IAA at different concentrations. The higher concentrations (100 mg/l) of IAA greatly increased the plant height compared to the control. IAA application at 100 mg/l induced the highest value of stem girth over the control. The chlorophyll content in leaves was affected significantly by different concentrations of IAA. It was found that all concentrations of IAA (25, 50, 100, and 200 mg/l) increased chlorophyll content per leaf by 37, 45, 60, and 55% compared to the control. The pod per plant, pod length, pod diameter, pod size, per pod weight and healthy seeds percentage per pod were significantly affected by different concentrations of IAA. The 100 and 200 mg/l concentrations of IAA had increased the production of healthy seeds compared with control. These findings suggest that the application of IAA, particularly at higher concentrations, could potentially enhance okra growth, yield, chlorophyll content, and healthy seed production, thereby benefiting the agricultural industry.

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INTRODUCTION

Okra (*Abelmoschus esculentus*) is one of the critical and popular vegetable crops in tropical and subtropical areas in Asia [1] and Africa [2]. Okra is also known as lady's finger, gumbo, bhindi in Malaysia, and bamya in Arabic countries. It belongs to the family Malvaceae, genus Abelmoschus, and species *esculentus*. Cultivated okra is suitable for agriculture as garden crops and on commercial farms. It is one of the vegetables grown commercially in many countries such as India, Western Africa, Iraq, the United States, and other countries around the world. The global importance of okra is underscored by the fact that total okra production was 18 -25 m tons in the world [3]. The production was 6.0, 2.5, 2.6, 2.8, 8.7 and 40.5 m tons in the USA, Ivory Coast, Iraq, Sudan, Nigeria and India respectively [3].

It was reported that mentioned that okra pods are considered nutritious, providing some human supplementary vitamins such as vitamin C, A, B-complex, calcium, potassium, iron, and other minerals [4]. Okra pods contain many nutritional contents that are important for human health. One hundred gram of fresh pod has around; moisture (89.6 percent). K (103 mg), Ca (90 mg), Mg (43 mg), P (56 mg), vitamin C (18 mg) and some important metals such as iron and aluminum [2; 5].

The application of plant growth regulators is known as one of the most important treatments used nowadays in agriculture. Some horticulture crop production was increased by the application of different growth regulators [6]. Growth regulators mainly regulate the plant physiological and biochemical

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processes. For example, they play a major role in dormancy, organ size, crop improvement, flowering, fruit set, and regulation of the chemical composition of plants The phytohormone auxin affects approximately all developmental processes in plants, including fruit improvement. However, auxin is produced in meristems and young leaves and moved to other parts of the plant in a polar fashion [7].
There are more than 100 distinct gibberellins produced primarily in roots and young leaves as growth promoters [8]. GA3 and auxin have many effects on plant growth, such as enhancing stem and internode elongation, producing seed germination, enzyme production during germination and fruit setting and growth [9] and breaking of dormancy [10]. It was indicated that plant growth regulators may be used to regulate the vegetative growth of plants [11]. The application of growth regulators increased the plant height, number of internodes, leaf area, dry weight of shoot, and dry weight of Gram plant, respectively [12]. However, work has been done on the use of GA3 to improve vegetative growth and pod size and delay pod maturity in vegetables using the spray method. However, a few studies have been conducted to evaluate the complete profile of vegetative growth, pod quality, and seed yield in response to IAA application to okra using stem injection.

This study investigates the effect of different concentrations of applied IAA on plant height, stem girth, leaves, chlorophyll content, maximum quantum yield (Fv/Fm), pod size, and yield. It also evaluates the efficacy of this injection method (treated stem) of application on seeds for inducing parthenocarpy or stenospermocarpy (aborted seeds) in okra pod.

MATERIALS AND METHODOLOGY

Study Site

The present investigation was carried out in the University of Malaya Experimental Farm, Institute of Biological Sciences, Kuala Lumpur, Malaysia. The soil in this field was clay loam with a mean pH of 6.6

Plant materials, cultural operation and experimental design

The seeds of the local *Abelmoschus esculentus* variety were sown in the experimental field. These seeds were soaked in distilled water for 24 hours, after which they were spread on moist filter paper in a Petri dish. Okra seeds were sown directly into the soil in soil fertilized with NPK 19 g/hill 14-14-14 as basal fertilization. Thirty days after emergence, side-dress with 10g/hill 46-0-0 [13] and plots were irrigated when necessary. The experiment was laid out in randomized block design having four replications (5 plants were used for each replicate). The size of the unit plot was 1×1 m^2. The seeds were shown in rows made by hand plough. The plant-to-plant distance was 30 cm. The depth of planting was 1cm from the surface of the soil. Hoeing, weeding and other cultural practices were done uniformly.

Preparation of plant growth regulators

The growth regulators employed in the experiment were indole acetic acid (IAA). The concentrations of the growth regulator treatments were 25, 50, 100, and 200 mg/L. The IAA was dissolved in 2 ml of 1% ethanol to make the desired concentration. Each rate of chemical IAA was added with distilled water to make 100 ml of solutions. The control plants were injected with 100 ml of water mixed with 2 ml of 1% ethanol.

Application

One and a half ml (1.5ml) of the various concentrations of IAA (0, 25, 50, 100 and 200 mg/l) were applied to the stem by injecting the plant stems with a needle for a surgical purpose of 1 dose at a height of 3 cm above the ground level. The control was distilled water mixed with 2 ml of 1% ethanol (Figure 1).

Figure 1. Photo shows stem injection technique.

Measurement of parameters

Data were recorded considering the following parameters:

Plant height and stem girth (cm)

Plant height was measured from above ground level up to the uppermost tip of the leaves at the end of harvesting. Both plant height and stem girth were measured using a meter rule with the aid of thread.

Leaves numbers

Number of leaves on each treated and control plants was counted.

Leaf chlorophyll content

The chlorophyll content in the leaves was measured by SPAD meter (Minolta 502, Japan).

Leaf chlorophyll fluorescence measurement

Fast chlorophyll fluorescence was evaluated on the upper surface of latest fully expanded leaf by using a Plant Efficiency Analyzer (PEA, Hansatech Instruments Ltd., England). A leaf clip was appended to the leaf and kept in the dark for 15 minutes for dark adaptation. After that the shutter plate was opened and light was applied on the leaf. The initial fluorescence intensity (Fo) when all reaction centers (RCs) were open, the maximal fluorescence intensity when all reactions were closed (Fm), the variable fluorescence (Fv = Fm-Fo), and the time to reach the maximal fluorescence intensity (tmax), were calculated. The quantum yield was determined according to the equation Fv/Fm.

Pod parameters

Five pods were randomly chosen from each treatment to determine the following characters green pod length (cm), green pod diameter (cm), pod size (cm^2), pod size was determined by measuring the length and diameter of pod per treatments with a varnier caliper.

Single pod weight

Green pod weight (g) was determined with help of a digital UWE-ESP Digital Electric Balance and the average weight calculated.

Seed production

For the determination of healthy seeds from treated flowers, the number of health seeds and aborted seeds was counted after dry stage. Healthy seeds/pod (%) and seedless or aborted seeds/pod (%) were recorded.

Statistical analysis

The obtained data were statistically analysed using SPSS Computer Programme, Version16. The data were analyzed following Analysis of Variance (ANOVA) technique and mean differences were tested by using Duncan's Multiple Test (DMRT) at 5% level of significance.

RESULTS

Plant height, number of branches, number of leaves and chlorophyll content

Plant height was influenced by the application of IAA (Table 1). IAA applied at different concentrations influenced the plant height significantly ($P<0.05$). The higher concentrations (50 and 100 mg/l) of IAA increased the plant height compared to the control and other concentrations. The lower concentrations had lesser plant height but higher than the control.

A significant variation was evident in the number of branches per plant, stem girth, number of leaves and leave area due to the application of IAA at different concentrations (Table 1). The treated plants generated higher number of branches over control. Among the IAA application, 100 mg/l of IAA induced the maximum number of branches (4.5) followed by 200 mg/l (4.15), 50 mg/l (3.5), 25 ml/l (3.0) and control (1.5). In the contrary, IAA application at 200 and 100 mg/l induced the highest value of stem girth over the control. The analysis of variance showed that IAA application exerted highly varied influence on leaves number per plant. The highest number of leaves per plant was obtained by 100 mg/l followed by 200 mg/l and the lowest leaves number/plant was observed with control treatment. The data indicated that the higher concentration of IAA increased number of leaves more efficiently than the lower concentrations. Results in Table 2 indicated that leaves content of chlorophyll was affected significantly by different concentrations of IAA. The results showed that all concentrations of IAA (25, 50, 100 and 200mg/l) increased chlorophyll content per leaf by 37, 45, 60 and 37% of the control.

Pod production, yield contributing characters and seeds yield percentage per pod

Results shown in Table 2, indicated that total pod per plant, pod length, pod diameter, pod size, individual pod weight and healthy seeds percentage per pod were significantly affected by different concentrations of IAA. Among the concentrations, 100 mg/l had the maximum number of pods per plant followed by 200 mg/l and 50 mg/l in comparison with control. The photosynthetic yield (Fv/Fm) was found highest in the concentration of 100mg/l. The data revealed that 100 mg/l produced the longest pod (4.25cm) followed by 200 mg/l (4.24cm) (Table 3). Pod diameter was found maximum with 100 mg/l and 200 mg/l and followed by 50 mg/l and 25 mg/l. Significantly highest pod size was obtained in 100 mg/l followed by 200 mg/l . In this respect, pod weight recorded significantly highest in 100 mg/l. Second heaviest pods were obtained in 200 mg/l, 50 mg/l and 25 mg/l. Pod harvested from 50, 100 and 200 mg/l treated plants had significant highest aborted seeds percentage (4.66%) and it was followed by 25 mg/l (4.65%), control (4.64%). The healthy seed was found in the control followed by 25 ml/l.

Table 1. Effect of stem injection treatment at different concentrations of IAA on some vegetative parameters of okra. Values are means ± standard deviation. Means followed by same letter or no letter do not differ significantly at 5% level by Duncan's Multiple Range Test (DMRT)

Concentrations (mg/l)	Plant height (cm)	No. of branches	Stem girth (cm)	No. of leaves/plant
0	78.83±0.01ab	1.50±0.50c	2.20±0.02e	22.00±1.41b
25	78.84±0.01ab	3.00±0.00b	2.74±0.02d	23.25 ±1.71b
50	78.85±0.02a	3.50±0.57b	4.22±0.03c	23.25±1.26b
100	02±0. 78.85 a	4.50±0.57a	4.73±0.02b	25.75±1.29a
200	78.82±0.02b	4.15±0.50a	5.21±0.02a	23.50±1.25b
LSD (0.05)	0.023	0.75	0.02	2.03
	*	*	*	*

Table 2. Effect Of IAA Injection Treatment at Various Concentrations Stem on Leave Area, Chlorophyll Contents, Fv/Fm Yield and Number of Fruits of Okra. Values are Means ± Standard Deviation. Means Followed by Same Letter or No Letter Do Not Differ Significantly at 5% level by Duncan's Multiple Range Test (DMRT).

Concentrations (mg/l)	Leave area/plant (cm^2)	Chlorophyll content (Spad value)	Fv/Fm Photosynthetic yield	No. of pod/plant
0	325.73±0.01d	40.43±0.50	0.691±0.002	9.50±1.29c
25	325.76±0.03c	40.43±0.01	0.691 ±0.001	10.00 ±1.41bc
50	326.76±0.02a	40.44±0.02	0.692±0.002	10.00±1.41bc
100	326.12±0.24b	40.45±0.01	0.693±0.002	11.75±0.95b
200	325.74±0.01cd	40.43±0.02	0.692±1.41	10.50±1.29a
LSD (0.05)	0.025	0.032	0.02	1.93
	*	NS	NS	*

Table 3. Yield and Yield Contributing Characters of Okra as Influenced by with IAA at Different Concentrations Applied by Stem Injection Treatment. N.S. : No Significant Differences.

Concentrations (mg/l)	Pod length (cm)	Pod diameter (cm)	Pod size (cm^2)	Pod weight (g)	Healthy seeds/fruit (%)	Aborted seeds/fruit (%)
0	4.23±0.02	1.23±0.01	5.20±0.08	2.72±0.02	95.36±0.02	4.64±0.01
25	4.23±0.01	1.23 ±0.02	5.21±0.06	2.73±0.02	95.35±0.01	4.65 ±0.01
50	4.24±0.01	1.23±0.01	5.21±0.05	2.73±0.01	95.34±0.01	4.66±0.02
100	4.25±0.01	1.24±0.02	07 ±0. 5.27	2.74±0.01	95.34±0.01	4.66±0.02
200	4.24±0.01	1.23±0.03	5.25±0.05	2.73±0.01	95.34±0.02	4.66±0.02
LSD (0.05)	0.020	0.021	0.10	0.022	0.02	0.03
	NS	NS	NS	NS	NS	NS

Values are means ± standard deviation
*: Means followed by same letter or no letter do not differ significantly at 5% level by Duncan's Multiple Range Test (DMRT).
N .S. : no significant difference.

DISCUSSION

This study compared the bioavailability of different concentrations of IAA for improving growth, yield and fruit quality when applied to okra crop by stem injection technique. The use of the plant growth regulators (PGRs) is becoming an increasingly important aspect in agricultural and horticulture practices for many cultivated plants [2]. Several reports which indicate that application of the plant growth regulators can provide germination, growth, fruit set, fresh vegetables weight and seed yields quality [14-15]. It was observed that natural plant growth regulators or synthetic were controlled the plant activities and their productions by controlling one or more of one or more specific physiological processes within a plant [16].

Plant growth regulators play a central role in morphology and physiology of the plants. The effect of growth regulator depends on plant species, variety, their growth stage, concentration of chemicals that used, application technique and frequency of application [17-18]. It was stated that increased stem elongation might be due to stimulating action of GA3, which alleviate the cell wall by increasing its plasticity [19-21]. The results confirmed with those who found that GA3 and IAA applications increased the plant height of soybean and Red sorrel, respectively [22].

Also, earlier studies reported that GA3 increased plant height in various crops; soybean, sesame [23], rice [24] and some cowpea cultivars [25]. With GA3 at 100 and 200 mg/l concentrations, there was a significant difference in pod in comparison with control. GA3 increased leaves number per plant in Bell pepper [26]. It was found that GA3 and IAA treatment at 100 ppm increased leaves number and leaves area and chlorophyll content in Hibiscus sabdariffa L [22]. Also, it was mentioned a significant increase in the leaf length in onion by application of GA3 [27]. This may be attributed that GA3 and IAA increase the division and elongation of the cells led to better vegetative growth of plants. Also, it was observed that GA3 application increased branches number by breaking apical dominance and had better effects in higher than lower concentrations (25 and 50 mg/l) and control [29].

GA3 and IAA developed yield and physiochemical characteristics of leafy vegetables [29]. IAA and GA3 application at 100 ppm increased the yield of rice and soybean [30-32] respectively. A significant decrease of seed abortion percentage was observed after GA3 treatment at 200 mg/l compared with control. The increase in seed yield due to GA3 application and other treatments may be related to improved vegetative growth (leaf area and leaf number plant). The present observations were in confirmation with those who observed that GA3 application at 100 ppm to soybean produced the highest yield of seeds per plant [33-34].

CONCLUSION

From the above discussion, it can be concluded that 100 and 200 mg/l of IAA concentrations were the best for okra growth and development. So it can be recommended that stem injection technique can be used commercially in the vegetable industry. The internal application stem injection can reduce the chemical and production cost without hazardous any environmental pollution.

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