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Rooted cuttings by IBA (*Indole butyric acid*) and NAA (*Naphthalene acetic acid*) in black pepper (*piper nigrum*) - A case study in Vietnam

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Abstract
In order to investigate the effect of IBA (*Indole Butyric Acid*) and NAA (*Naphthalene Acetic Acid*) on rooted cuttings, there were two experiments were conducted. The first experiment was two factor experiment where IBA and NAA were applied as different concentrations to main stems (cuttings). There were 14 treatments and 4 replications, including 20 pots/treatment; 1,120 pots in total. Similarly, the second was also two factor experiment consisted of IBA and NAA in different concentrations. The total of 800 pots were divided into 10 treatments and 4 replications. The results showed that application of IBA at concentrations of 5,000 ppm on cuttings showed highest plant parameters in terms of plant and root growth. On the other hand, rooting hanging shoots could be found at lower concentrations of IBA 300 ppm and NAA 400 ppm. It is concluded that IBA and NAA can be used in vegetative propagation to improve success rare and obtain better cutting growth.

Keywords: IBA (*indole butyric acid*), NAA (*Naphthalene Acetic Acid*), *piper nigrum*, rooted cuttings

Introduction
Black pepper (*piper nigrum*) was first introduced to Vietnam in early nineteen century and has become popular since 1975 [1]. Nowadays, the plant has been cultivated mainly in Central Highlands and South-eastern areas with around 140,000 hectares and approximately 293,000 tons in production, represent around 40 % of global production [2]. This figure has made Vietnam become the biggest producer of black pepper over the world [3].
Black pepper can be propagated by seeds, however, it may take longer to reach bearing period. Therefore, vegetative propagation is more common and preferred. Main stems (cuttings with 5 nodes), runner shoots, hanging shoots are main propagation resources which are simply taken from mother gardens and directly planted to polyethylene bags in nurseries. It takes about 3 to 4 months from nurseries to field planting.
Currently, black pepper cutting quality remains quite low in terms of success rate and poor growth in root systems. As a result, the costs of cuttings are still very high and being unaffordable to customers.
These studies were designed to investigate the effects of IBA and NAA on rooted cuttings and hanging shoots to establish appropriate recommendations to farmers and nurseries.

Materials and Methods
Materials
Black pepper (*piper nigrum*) variety
Vinh Linh variety was used for these experiments, the cultivar is commonly cultivated in main pepper producing areas in Vietnam.

Cuttings preparation
There are two kinds of shoots were used for these experiments, main stems (cuttings) and hanging shoots. The main stems were taken from healthy mother plants which are 12 months old, then they were cut into two nodes. Similarly, hanging shoots were also harvested from Healthy mother plants which are around 60 months old. They were then cut into single node.

Finally, two node cuttings and single node hanging shoots were dipped into fungicide (*phosphorus acid*) mixture at concentration of 3 % during 10 minutes for sterilization.

IBA (*Indole butyric acid*) and NAA (*Naphthalene Acetic Acid*) preparation

Both IBA and NAA prepared in laboratory in different concentrations were used for experiments.

Potting preparation

Pots, 25 cm in height and 15 cm in diameter, were filled with 2 kg of potting mixtures including top soil (75 %), cow dung (15 %) and river sand (10 %). All pots were watered every two days and placed in green house.

Methods

Experiment 1: Effect of IBA and NAA concentrations on rooted two node cuttings

A two factor experiment was designed where factor A was IBA and NAA; factor B was 7 concentrations: 0 ppm, 1,000 ppm, 2,000 ppm, 3,000 ppm, 4,000 ppm, 5,000 ppm and 6,000 ppm. Thus, the experiments included 14 treatments: Treatment 1: IBA at 0 ppm; Treatment 2: IBA at 1,000 ppm; Treatment 3: IBA at 2,000 ppm; Treatment 4: IBA at 3,000 ppm; Treatment 5: IBA at 4,000 ppm; Treatment 6: IBA at 5,000 ppm; Treatment 7: IBA at 6,000 ppm; Treatment 8: NAA at 0 ppm; Treatment 9: NAA at 1,000 ppm; Treatment 10: NAA at 1,000 ppm; Treatment 11: NAA at 2,000 ppm; Treatment 12: NAA at 3,000 ppm; Treatment 13: NAA at 4,000 ppm; Treatment 14: NAA at 5,000 ppm.

The experiment consisted of four replications, 20 pots for one treatment. Total pots were 20 pots/treatment * 14 treatments * 4 replications = 1,120 pots.

Experiment protocol

After sterilization by fungicide, two node cuttings were washed by clean water. Then, they were dipped into different IBA and NAA concentrations for 10 seconds and quickly planted in the pots. During greenhouse conditions, the pots were watered every two days.

Data collection

Emerging new top shoot rate (%): recorded all pots after 30 days of application.

Plant height (cm), plant diameter (mm): measured all pots after 30 days, 60 days and 75 days of application.

Root parameters: measured one time after 75 days of application, all pots were harvested and carefully removed potting mixtures. Then, only root system was cut and washed by clean water. Finally they are recorded by following parameters:

Number of roots: counted all roots

Root length (cm): only five longest roots were chosen and measured.

Fresh root weight (g/plant): all roots were removed and measured

Dry root weight (g/plant): all roots were measured after being dried in drying oven at 105 ^{0}C during 10 hours until unchanged weight.

Experiment 2: Effect of IBA and NAA concentrations on rooted single hanging shoots

A two factor experiment was also conducted. Factor A was NAA and IBA. Factor B was 5 concentrations: 0 ppm, 100 ppm, 200 ppm, 300 ppm, 400 ppm. Totally, there were ten following treatments: Treatment 1: IBA at 0 ppm; Treatment 2: IBA at 100 ppm; Treatment 3: IBA at 200 ppm; Treatment 4: IBA at 300 ppm; Treatment 5: IBA at 400 ppm; Treatment 6: NAA at 0 ppm; Treatment 7: NAA at 100 ppm; Treatment 8: NAA at 200 ppm; Treatment 9: NAA at 300 ppm; Treatment 10: NAA at 400 ppm. There were four replications, each treatment was 20 pots, 800 pots in total.

The experiment protocol, data collection were the same as the experiment 1.

Data analysis: Two way Anova analysis was used for both experiment. Differences between the means of factor A, factor B and interaction between two factors (A & B) were analysed at 95% of significant difference.

Results and discussions

Experiment 1: Effect of IBA and NAA concentrations on rooted two node cuttings

Emerging top shoot rate was showed in Table 1. In general, there is no significant difference in appearing top shoots between treatments. Thus, IBA and NAA application did not give any effects on developing top shoots compared to control. After 30 days of application, around 77.14% to 78.93% cuttings are able to produce top shoots.

In term plant growth, IBA application gave better plant height in comparison to NAA. After 30 days, cuttings dipped by IBA grew to 3.95 cm while NAA was only 3.13 cm. The same figures could be found after 60 days and 75 days after application, where plants treated with IBA showed significantly higher plant height compared to NAA treatments.

Regarding to the concentrations, cuttings treated with IBA at concentration of 5,000 ppm showed highest plant growth. The figures were 4.26 cm, 27.28 cm and 36.73 cm after 30 days, 60 days and 75 days after application, respectively.

An increase in IBA concentrations from 1,000 ppm – 2,000 ppm – 3,000 ppm – 4,000 ppm – 5,000 ppm resulted in increasing plant height. However, at the concentration of 6,000 ppm, it seems to be inhibited plant growth.

Plant diameter: plant diameter was significantly different between treatments, the highest figure was IBA at 5,000 ppm after 60 days and 75 days application. In terms of IBA and NAA application, plants treated by IBA was higher than NAA. The significant difference could be found after 60 days where IBA was 4.48 mm while NAA was only 4.25 mm. However, at the stage of 30 days and 75 days there was no difference.

Root parameters:

Number of roots: IBA and NAA application increased significantly number of root compared to the control. In addition, plants treated by IBA (162.89 roots) gave more roots than NAA (127.11 roots). Between the treatments, the highest root number was 194.50 roots at IBA 5,000 ppm.

Root length: similarly, root length also was longer when applying IBA and NAA compared to control. IBA application facilitated root length much more better than NAA. The longest roots were found with the plants treated by IBA at 5,000 ppm.

Fresh root weight and dry root weight: the same patterns could be found for these root parameters when applying IBA and NAA has improved significant root weights. The best treatment was IBA at 5,000 ppm. An increase of IBA concentrations from 1,000 ppm to 5,000ppm could increase root weight, however, at IBA 6,000 ppm gave negative effects on root weight.

Table 1: Sprouting rate of cuttings after 30 days of application

Days after application	Factor B Concentrations	Factor A		Mean (B)
		NAA	IBA	
30 days	0 ppm	76.25^{a}	80.00^{a}	78.13^{a}
	1,000 ppm	77.50^{a}	80.00^{a}	78.75^{a}
	2,000 ppm	73.75^{a}	80.00^{a}	76.88^{a}
	3,000 ppm	78.75^{a}	78.75^{a}	78.75^{a}
	4,000 ppm	78.75^{a}	77.50^{a}	78.13^{a}
	5,000 ppm	78.75^{a}	78.75^{a}	78.75^{a}
	6,000 ppm	76.25^{a}	77.50^{a}	76.88^{a}
	Mean (A)	77.14^{a}	78.93^{a}	
	CV% = 4.8821; F_A^{ns}; F_B^{ns}; F_{A*B}^{ns}			

Different letters showed differences in means at $P_{0.05}$; ns = not significant differences
CV: Coefficient of Variation

Table 2: Plant parameters of cuttings after 30, 60 and 75 days after application

Days after application	Factor B Concentration	Plant height (cm)			Plant diameter (mm)		
		Factor A		Mean (B)	Factor A		Mean B
		NAA	IBA		NAA	IBA	
30 days	0 ppm	3.05^{e}	3.82^{c}	3.43^{c}	3.52^{ab}	3.39^{ab}	3.45^{ab}
	1,000 ppm	3.24^{de}	3.78^{c}	3.51^{bc}	3.22^{b}	3.28^{b}	3.25^{b}
	2,000 ppm	3.10^{e}	3.88^{bc}	3.49^{c}	3.57^{ab}	3.31^{ab}	3.44^{ab}
	3,000 ppm	3.30^{d}	3.94^{bc}	3.62^{ab}	3.69^{a}	3.33^{ab}	3.51^{a}
	4,000 ppm	3.06^{e}	4.05^{b}	3.55^{abc}	3.43^{ab}	3.29^{ab}	3.36^{ab}
	5,000 ppm	3.08^{e}	4.26^{a}	3.67^{a}	3.27^{b}	3.57^{ab}	3.42^{ab}
	6,000 ppm	3.07^{e}	3.96^{bc}	3.51^{bc}	3.48^{ab}	3.45^{ab}	3.46^{ab}
	Mean (A)	3.13^{b}	3.95^{a}		3.45^{a}	3.37^{a}	
	CV% = 3.7614; F_A^{*}; F_B^{*}; F_{A*B}^{*}				CV% = 6.9431; F_A^{ns}; F_B^{*}; F_{A*B}^{*}		
60 days	0 ppm	19.03^{d}	24.73^{c}	21.88^{b}	4.28^{bcd}	4.65^{ab}	4.46^{a}
	1,000 ppm	19.81^{d}	25.13^{bc}	22.47^{ab}	4.06^{d}	4.33^{abcd}	4.20^{b}
	2,000 ppm	20.21^{d}	25.88^{abc}	23.04^{a}	4.21^{cd}	4.41^{abcd}	4.31^{ab}
	3,000 ppm	20.69^{d}	26.20^{abc}	23.44^{a}	4.45^{abcd}	4.31^{bcd}	4.38^{ab}
	4,000 ppm	19.36^{d}	26.68^{ab}	23.02^{ab}	4.16^{d}	4.40^{abcd}	4.28^{ab}
	5,000 ppm	18.95^{d}	27.28^{a}	23.11^{a}	4.30^{bcd}	4.72^{a}	4.51^{a}
	6,000 ppm	19.38^{d}	25.58^{abc}	22.48^{ab}	4.27^{bcd}	4.58^{abc}	4.42^{ab}
	Mean (A)	19.63^{b}	25.92^{a}		4.25^{b}	4.48^{a}	
	CV% = 5.0713; F_A^{*}; F_B^{*}; F_{A*B}^{*}				CV% = 5.6174; F_A^{*}; F_B^{*}; F_{A*B}^{*}		
75 days	0 ppm	27.45^{cd}	33.45^{ab}	30.45^{a}	4.80^{abc}	4.89^{abc}	4.84^{ab}
	1,000 ppm	28.08^{cd}	34.10^{ab}	31.09^{a}	4.68^{c}	4.81^{abc}	4.75^{b}
	2,000 ppm	28.90^{cd}	34.73^{ab}	31.81^{a}	4.81^{abc}	4.81^{abc}	4.81^{ab}
	3,000 ppm	30.21^{bc}	35.20^{a}	32.70^{a}	5.02^{ab}	4.71^{bc}	4.87^{ab}
	4,000 ppm	27.15^{cd}	35.53^{a}	31.34^{a}	4.79^{abc}	4.88^{abc}	4.84^{ab}
	5,000 ppm	25.08^{d}	36.73^{a}	30.90^{a}	4.81^{abc}	5.12^{a}	4.96^{a}
	6,000 ppm	26.24^{cd}	34.29^{ab}	30.26^{a}	4.76^{bc}	4.93^{abc}	4.85^{ab}
	Mean (A)	27.59^{b}	34.86^{a}		4.81^{a}	4.88^{a}	
	CV% = 9.2739; F_A^{*}; F_B^{*}; F_{A*B}^{*}				CV% = 4.0780; F_A^{ns}; F_B^{*}; F_{A*B}^{*}		

Different letters showed differences in means at $P_{0.05}$; ns = not significant differences
CV: Coefficient of Variation

Table 3: Root parameters of cuttings after 30, 60 and 75 days after application

Root parameters	Factor B Concentrations	Factor A		Mean (B)
		NAA	IBA	
Number of roots	0 ppm	110.50^{e}	144.00^{bcd}	127.25^{d}
	1,000 ppm	12100de	146.75^{bcd}	133.88^{cd}
	2,000 ppm	121.00^{de}	155.50^{bc}	138.25^{cd}
	3,000 ppm	148.00^{bcd}	167.00^{b}	157.50^{ab}
	4,000 ppm	114.50^{e}	170.00^{b}	142.25^{bcd}
	5,000 ppm	143.25^{bcd}	194.50^{a}	168.88^{a}
	6,000 ppm	131.50^{cde}	162.50^{b}	147.00^{bc}
	Mean (A)	127.11^{b}	162.89^{a}	
	CV% = 11.7063; F_A^{*}; F_B^{*}; F_{A*B}^{*}			
Root length (cm)	0 ppm	12.63^{d}	18.85^{bc}	15.74^{c}
	1,000 ppm	18.20^{c}	20.40^{abc}	19.30^{b}
	2,000 ppm	18.85^{bc}	20.50^{abc}	19.68^{ab}
	3,000 ppm	21.90^{ab}	20.90^{abc}	21.40^{a}
	4,000 ppm	18.60^{c}	20.40^{abc}	19.50^{ab}
	5,000 ppm	19.25^{bc}	23.05^{a}	21.15^{ab}

	6,000 ppm	19.95^{abc}	19.55^{bc}	19.75^{ab}
	Mean (A)	18.48^{b}	20.52^{a}	
	CV% = 10.0054; F_A^*; F_B^*; F_{A*B}^*			
Fresh root weight (gram)	0 ppm	6.97^{c}	7.42^{bc}	7.19^{c}
	1,000 ppm	7.51^{bc}	7.18^{bc}	7.34^{c}
	2,000 ppm	7.69^{bc}	7.64^{bc}	7.66^{bc}
	3,000 ppm	8.19^{b}	8.06^{bc}	8.12^{b}
	4,000 ppm	7.16^{bc}	8.10^{b}	7.63^{bc}
	5,000 ppm	8.07^{bc}	9.61^{a}	8.84^{a}
	6,000 ppm	7.45^{bc}	7.85^{bc}	7.65^{bc}
	Mean (A)	7.58^{b}	7.98^{a}	
	CV% = 8.3712; F_A^*; F_B^*; F_{A*B}^*			
Dry root weight (gram)	0 ppm	1.10^{cd}	1.12^{bcd}	1.11^{c}
	1,000 ppm	1.19^{bcd}	1.09^{d}	1.14^{c}
	2,000 ppm	1.20^{bcd}	1.17^{bcd}	1.19^{bc}
	3,000 ppm	1.28^{b}	1.23^{bcd}	1.25^{b}
	4,000 ppm	1.12^{bcd}	1.24^{bcd}	1.18^{bc}
	5,000 ppm	1.26^{bc}	1.47^{a}	1.36^{a}
	6,000 ppm	1.19^{bcd}	1.19^{bcd}	1.19^{bc}
	Mean (A)	1.19^{a}	1.22^{a}	
	CV% = 8.1298; F_A^*; F_B^*; F_{A*B}^*			

Different letters showed differences in means at $P_{0.05}$; ns = not significant differences
CV: Coefficient of Variation

Experiment 2: Effect of IBA and NAA concentrations on rooted single hanging shoots

Table 4: Sprouting rate of hanging shoots after 30 days of application

Days after application	Factor B Concentrations	Factor A		Mean (B)
		NAA	IBA	
30 days	0 ppm	62.50^{b}	63.75^{ab}	63.13^{B}
	100 ppm	72.50^{ab}	70.00^{ab}	71.25^{A}
	200 ppm	70.00^{ab}	68.75^{ab}	69.38^{AB}
	300 ppm	71.25^{ab}	73.75^{a}	72.50^{A}
	400 ppm	68.75^{ab}	71.25^{ab}	70.00^{A}
	Mean (A)	69.00^{A}	69.50^{A}	
	CV% = 9.13; F_A^{ns}; F_B^*; F_{A*B}^*			

Different letters showed differences in means at $P_{0.05}$; ns = not significant differences
CV: Coefficient of Variation

Table 5: Plant parameters of hanging shoots after 30, 60, 90, 120 and 125 days after application

Days after application	Factor B Concentrations	Plant height (cm)			Plant diameter (mm)		
		Factor A		Mean (B)	Factor A		Mean (B)
		NAA	IBA		NAA	IBA	
30 days	0 ppm	5.80^{ab}	5.73^{b}	5.76^{B}	2.70^{b}	2.77^{ab}	2.73^{B}
	100 ppm	6.00^{ab}	5.93^{ab}	5.96^{AB}	2.84^{ab}	2.92^{a}	2.88^{A}
	200 ppm	6.05^{ab}	5.93^{ab}	5.99^{AB}	2.80^{ab}	2.86	2.83^{A}
	300 ppm	6.15^{ab}	6.70^{a}	6.43^{A}	2.83^{ab}	2.90^{a}	2.86^{A}
	400 ppm	6.33^{ab}	5.78^{b}	6.05^{AB}	2.86^{a}	2.91^{a}	2.89^{A}
	Mean (A)	6.07^{A}	6.01^{A}		2.81^{A}	2.87^{A}	
	CV% = 8.95; F_A^{ns}; F_B^*; F_{A*B}^*				CV% = 3,31; F_A^{ns}; F_B^*; F_{A*B}^*		
60 days	0 ppm	11.46^{b}	11.88^{ab}	11.67^{B}	2.87^{b}	2.98^{ab}	2.92^{B}
	100 ppm	11.83^{ab}	11.95^{ab}	11.89^{AB}	2.97^{ab}	3.03^{a}	3.00^{AB}
	200 ppm	11.95^{ab}	11.84^{ab}	11.89^{AB}	2.96^{ab}	2.99^{ab}	2.97^{AB}
	300 ppm	12.05^{ab}	12.68^{a}	12.36^{A}	2.99^{ab}	3.04^{a}	3.01^{A}
	400 ppm	12.14^{ab}	12.03^{ab}	12.08^{AB}	3.03^{a}	3.03^{a}	3.03^{A}
	Mean (A)	11.89^{A}	12.07^{A}		2.96^{A}	3.01^{A}	
	CV% = 4.94; F_A^{ns}; F_B^*; F_{A*B}^*				CV% = 2.90; F_A^{ns}; F_B^*; F_{A*B}^*		
90 days	0 ppm	17.44^{ab}	17.41^{ab}	17.43^{B}	3.04^{a}	3.07^{a}	3.05^{B}
	100 ppm	17.61^{ab}	17.54^{ab}	17.58^{AB}	3.10^{a}	3.13^{a}	3.12^{AB}
	200 ppm	17.80^{ab}	17.36^{b}	17.58^{AB}	3.09^{a}	3.09^{a}	3.09^{AB}
	300 ppm	17.91^{ab}	18.38^{a}	18.14^{A}	3.12^{a}	3.14^{a}	3.13^{A}
	400 ppm	18.05^{ab}	17.83^{ab}	17.94^{AB}	3.15^{a}	3.13^{a}	3.14^{A}
	Mean (A)	17.76^{A}	17.70^{A}		3.10^{A}	3.11^{A}	
	CV% = 3.30; F_A^{ns}; F_B^*; F_{A*B}^*				CV% = 2.32; F_A^{ns}; F_B^*; F_{A*B}^{ns}		
120 days	0 ppm	22.70^{c}	22.66^{c}	22.68^{C}	3.11^{a}	3.12^{a}	3.12^{B}
	100 ppm	23.53^{abc}	23.21^{bc}	23.37^{BC}	3.15^{a}	3.17^{a}	3.16^{AB}
	200 ppm	23.70^{abc}	23.29^{bc}	23.49^{AB}	3.15^{a}	3.15^{a}	3.15^{AB}
	300 ppm	23.75^{abc}	24.59^{a}	24.17^{A}	3.19^{a}	3.20^{a}	3.19^{A}

	400 ppm	24.09^{ab}	23.79^{abc}	23.94^{AB}	3.20^{a}	3.19^{a}	3.19^{A}
	Mean (A)	23.55^{A}	23.51^{A}		3.16^{A}	3.17^{A}	
	CV% = 2.99; F_A^{ns}; F_B^{*}; F_{A*B}^{*}				CV% = 1.93; F_A^{ns}; F_B^{*}; F_{A*B}^{ns}		
135 days	0 ppm	26.06^{c}	26.26^{c}	26.16^{B}	3.11^{b}	3.13^{ab}	3.12^{B}
	100 ppm	27.00^{bc}	27.03^{bc}	27.01^{A}	3.16^{ab}	3.18^{ab}	3.17^{AB}
	200 ppm	27.11^{bc}	27.08^{bc}	27.09^{A}	3.15^{ab}	3.17^{ab}	3.16^{AB}
	300 ppm	27.13^{bc}	28.28^{a}	27.70^{A}	3.19^{ab}	3.22^{a}	3.21^{A}
	400 ppm	27.46^{ab}	27.49^{ab}	27.48^{A}	3.20^{ab}	3.20^{ab}	3.20^{A}
	Mean (A)	26.95^{A}	27.23^{A}		3.16^{A}	3.18^{A}	
	CV% = 2.64; F_A^{ns}; F_B^{*}; F_{A*B}^{*}				CV% = 1.88; F_A^{ns}; F_B^{*}; F_{A*B}^{*}		

Different letters showed differences in means at $P_{0.05}$; ns = not significant differences
CV: Coefficient of Variation

Table 6: Root parameters of hanging shoots after 30, 60, 90, 120 and 125 days after application

Root parameters	Factor B Concentrations	Factor A		Mean (B)
		NAA	IBA	
Number of roots	0 ppm	10.50^{e}	10.75^{de}	10.63^{C}
	100 ppm	12.75^{bcd}	12.00^{cde}	12.38^{B}
	200 ppm	11.00^{de}	13.25^{abc}	12.13^{B}
	300 ppm	14.25^{ab}	15.25^{a}	14.75^{A}
	400 ppm	15.00^{a}	14.00^{abc}	14.50^{A}
	Mean (A)	12.70^{A}	13.05^{A}	
	CV% = 10.66; F_A^{ns}; F_B^{*}; F_{A*B}^{*}			
Root length (cm)	0 ppm	14.73^{d}	14.85^{d}	14.79^{C}
	100 ppm	17.20^{cd}	17.15^{cd}	17.18^{B}
	200 ppm	18.60^{abc}	17.90^{bc}	18.25^{AB}
	300 ppm	18.45^{abc}	20.65^{a}	19.55^{A}
	400 ppm	20.25^{ab}	18.15^{abc}	19.20^{A}
	Mean (A)	17.85^{A}	17.74^{A}	
	CV% = 8.86; F_A^{ns}; F_B^{*}; F_{A*B}^{*}			
Fresh root weight (g)	0 ppm	4.95^{de}	4.59^{e}	4.77^{C}
	100 ppm	5.28^{bcd}	5.11^{cde}	5.19^{B}
	200 ppm	5.11^{cde}	5.56^{bcd}	5.33^{B}
	300 ppm	5.65^{bc}	6.40^{a}	6.02^{A}
	400 ppm	5.81^{ab}	5.90^{ab}	5.86^{A}
	Mean (A)	5.36^{A}	5.51^{A}	
	CV% = 7.15; F_A^{ns}; F_B^{*}; F_{A*B}^{*}			
Dry root weight (g)	0 ppm	0.78^{de}	0.74^{e}	0.76^{C}
	100 ppm	0.84^{bcd}	0.80^{cde}	0.82^{BC}
	200 ppm	0.80^{cde}	0.86^{bcd}	0.83^{B}
	300 ppm	0.89^{abc}	0.97^{a}	0.93^{A}
	400 ppm	0.91^{ab}	0.92^{ab}	0.91^{A}
	Mean (A)	0.84^{A}	0.86^{A}	
	CV% = 7.12; F_A^{ns}; F_B^{*}; F_{A*B}^{*}			

Different letters showed differences in means at $P_{0.05}$; ns = not significant differences
CV: Coefficient of Variation

Table 7: Success rate of hanging shoots after 135 days of application

	Factor B Concentrations	Factor A		Mean (B)
		NAA	IBA	
Success rate	0 ppm	83.75^{c}	87.50^{abc}	85.63^{B}
	100 ppm	86.25^{bc}	90.00^{ab}	88.13^{AB}
	200 ppm	87.50^{abc}	90.00^{ab}	88.75^{AB}
	300 ppm	90.00^{ab}	92.50^{a}	91.25^{A}
	400 ppm	90.00^{ab}	88.75^{ab}	89.38^{A}
	Mean (A)	87.50^{B}	89.75^{A}	
	CV% = 3.46; F_A^{*}; F_B^{*}; F_{A*B}^{*}			

Different letters showed differences in means at $P_{0.05}$; ns = not significant differences
CV: Coefficient of Variation

Discussions

It is clear that different types of cuttings will require different appropriate concentrations of IBA and NAA. Therefore, the above results of these studies can be discussed in two categories, main stems (cuttings) and hanging shoots.

To begin with, the application of IBA and NAA on cuttings, the first experiment showed IBA at concentration of 4,000 ppm – 5,000 ppm gave highest plant growth and root development. These can be found to be similar to other studies, Secundino et al., 2014 concluded that cuttings of variety *Bragantina* (*piper nigrum*) treated by IBA at the concentrations of 4,000 ppm showed highest cutting growth as well as root growth [4]. IBA application to improve the plant and root growth also can be found to other studies where

the authors concluded that IBA, plant hormone belongs to auxin family can be used as many commercial horticultural plant rooting products, can be used at appropriate concentrations to obtain better plants in nurseries [5-7]

Other study also combined IBA and NAA in one treatment, Wulandari *et al.*, 2018 [8] indicated that IBA 1,500 ppm + NAA 1,000 ppm gave highest shoot length while IBA 2,500 ppm + NAA 0 ppm showed highest root volume [8].

In the second category where hanging shoots was used, on the other hand, the concentrations of IBA and NAA has been reduced significantly. The second experiment confirmed that IBA 300 ppm and NAA 400 ppm showed the best treatments giving significantly positive effects on plant and root growth.

Prajapati, 2015 also conculded that the combination between IBA 250 ppm and NAA 250 ppm was the best treatment, facilitating shoot and root growth of black pepper cv. Panniyur-1 under South Gujarat conditions, India. The author further concluded that IBA 500 ppm application to two node cutting also demonstrated the best treatment [9].

Conclusion

It is concluded that IBA application at concentration of 5,000 ppm to cuttings gave highest plant and root parameters. On the other hand, hanging shoots treated by lower concentrations of IBA 300 ppm and NAA 400 ppm showed significant improvements in plant and root characteristics. Thus, the studies have provided important recommendations to farmers and nurseries to improve success rate and plant quality.

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