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Increase the yield and fruit quality of white flesh dragon fruit (*Hylocereus undatus*) using the combination of gibberellic acid and naphthalene acetic acid

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Abstract
Dragon fruit (*Hylocereus undatus*) has played an important role in horticulture of Vietnam for many years. White flesh dragon fruit variety was cultivated commercially in the Southern of Vietnam. The yield and quality of the fruits can be affected by using plant growth regulators. The present study aimed to evaluate the influence of GA_3 and NAA on yield and fruit quality of five year old white flesh dragon fruit in Cho Gao district, Tien Giang province. The field experiment was carried out on randomized complete block design (RCBD) with four replications and five treatments. The treatments included GA_3 30 ppm, GA_3 40 ppm, the combination of GA_3 + NAA (30 ppm + 20 ppm), GA_3 + NAA (40 ppm + 20 ppm) and the control. The treatments were applied at 7, 14, and 21 days after fruit set. The use of GA_3 + NAA (40 ppm + 20 ppm) increased flesh firmness (1.08 kg/cm2), fruit length (12.01 cm), fruit weight (562.08 g/fruit), fruit yield (35.05 kg/tree), and improved fruit peel luminosity. According to the findings, combining GA_3 and NAA at appropriate concentrations can improve yield and fruit quality in white flesh dragon fruit.

Keywords: *Hylocereus undatus*, GA_3, NAA, white flesh dragon fruit, Vietnam

Introduction
Dragon fruit (*Hylocereus undatus*) is a popular tropical fruit in the Cactaceae family. It is also known as "pitaya," and it has long played an important role in small farmer horticulture in Vietnam. It has brought economic efficiency to growers. Vietnam currently is the potential dragon fruit producer in the world and the planting area has reached to 54,000 ha. Binh Thuan (29,000 ha), Long An (11,000 ha) and Tien Giang (8,000 ha) provinces are the main dragon fruit production areas which produce 93.6% area and 95.5% production of dragon fruit in Vietnam [21]. White flesh dragon fruit variety with pink peel and white flesh was first introduced to Binh Thuan province centuries ago which subsequently reached to the Mekong River Delta and grown in 2 provinces Long An and Tien Giang. Gibberellic acid and Naphthalene acetic acid have ability to increase fruit set percentage, yield and quality in fruit crops. The size and quality of the fruits can be affected by the application of plant growth hormones [9, 22]. GA_3 increased soluble solids, fruit firmness and fruit weight in cherry fruit [4, 5, 8]. GA_3 increased the fruit yield of Balady mandarin [7]. The gibberellin is involved in cell elongation, which results in larger and heavier fruits. Another effect is an increase in fruit set, so all of these effects combined provided more yield and higher fruit quality [14]. NAA increased fruit number, fruit weight and yield of sapota [1]. Using GA_3 was beneficial to the pitaya's agronomic characteristics as increased fruit set, fruit number, average fruit mass and productivity [20]. Due to their importance in agriculture, the biological effects of the application of growth regulators to fruit trees have been of great interest to many growers.

Materials and Methods
Experimental site and treatments
The experiment was performed at 5 years old white flesh dragon fruit orchard in Cho Gao district, Tien Giang province. Planting distance was 2.5 m x 3.0 m and all trees received similar cultural practices as watering, fertilization and induce flowering. The experiment conducted in randomized complete block design (RBCD) with five treatments and four replications. The tested trees were applied GA_3 and NAA either individually or in combinations. The five treatments as follow GA_3 (30 ppm, 40 ppm), GA_3 + NAA (30 ppm +20 ppm), GA_3 + NAA (40 ppm + 20 ppm) and control.

Each treatment was consisted of 16 trees and randomly selected and tagged for data collection. Fruit on trees were sprayed three stages at 7, 14 and 21 days after anthesis.

Assessed parameters

Number of fruit (fruit/ tree) and yield (kg/tree): Fruits were harvested and recorded total number of fruits on tree from treatments. All fruits per tree were weighted to actual yield.

At harvest, the fruits at each sampling point were tags and sent immediately to Fruit Analysis Laboratory to measure their characteristics.

Fruit physical characteristics: Samples of ten fruits were devoted to determining the following fruit characteristics as fruit length (cm) fruit diameter (cm), fruit peel thickness (mm), fruit weight (g), fruit firmness (kg/cm^2) using digital ruler, penetrometer. The color of the peel was determined by a Minolta colorimeter, the CIELAB, L*a*b* system. L* (luminosity), a* (the green-red variation degree) and b* (the blue-yellow variations degree) values were obtained.

Fruit total acidity (g/100 ml) was followed method from AOAC [2]. Total soluble solids (%) content was measured by hand refractometer (ATAGO, Japan).

Data analysis

Data collected and analyzed using analysis of variance (ANOVA), and Duncan's Multiple Range Test (DMRT) used for means comparison when treatments were significant by using SPSS program.

Results and Discussions

Number of fruits, fruit weight and fruit physical characteristics of white flesh dragon fruit

Table 1 recorded that the number of fruits per tree was not significantly different among treatments when GA_3 and NAA were used individually or in combination. There were significant difference in fruit weight between treatments. The combination GA_3 + NAA (40 ppm + 20 ppm) performed fruit weight (562.08 g) higher than individually GA_3 30 ppm (465.42 g) and control (397.58 g).

Table 1: Effect of GA_3 and NAA on number of fruits per tree and fruit weight of white flesh dragon fruit

Treatment	Number of fruit (fruit)	Fruit weight (g)
GA_3 30 ppm	33.52	465.42^{bc}
GA_3 40 ppm	34.30	477.42^{abc}
GA_3 30 ppm + NAA 20 ppm	35.05	556.00^{ab}
GA_3 40 ppm + NAA 20 ppm	35.55	562.08^{a}
Control	32.03	397.58^{c}
Level of significance	ns	*

In a column, means followed by same letters are not significantly different at 5% probability level by Duncan's Multiple Range Test (DMRT), ns = not significant.

Table 2 showed that using GA_3 and NAA increased fruit size and firmness in comparison to the control. In terms of fruit length, GA_3 and NAA, either individually or in combination, were significantly different from control. The treatments GA_3 + NAA (40 ppm + 20 ppm; 30 ppm + 20 ppm), GA_3 (30 ppm; 40 ppm) and control were recorded fruit length 12.01 cm, 11.87 cm, 11.19 cm, 11.14 cm and 10,19 cm, respectively. In fruit diameter, the treatments GA_3 + NAA (40 ppm + 20 ppm; 30 ppm + 20 ppm) were 8.38 cm and 8.18 cm, respectively. However, their combinations were significantly different when compared to treatment individually GA_3 and control. Control was shortest (7.20 cm). In relation to fruit firmness, a high pulp tissue were recorded in GA_3 + NAA (30 ppm + 20 ppm; 40 ppm + 20 ppm) were 1.00 kg/cm^2; 1.08 kg/cm^2, respectively. Control had the lowest (0.68 kg/cm^2) value (Table 2). Applying GA_3 during stage I of fruit growth increased aril weight and fruit size in Yu Her Pau' litchi [19]. Spraying GA_3 on Valencia oranges increased fruit weight, peel thickness, and fruit diameter [18]. GA_3 25 ppm treated trees produced fruit with 13.4% and 14.1% greater weight and 38% and 25% greater firmness in '0900 Ziraat' sweet cherry [8]. Wax apple (*Syzygium samarangense*) var. Jambu air madu applied GA_3 50 mg/L increased fruit length, fruit diameter and fruit weight [15]. Using GA_3 25 ppm and NAA 25 ppm increased number of fruits per bunch, fruit weight, and improved fruit quality of Keitt Mangoes [16]. The foliar spraying Washington navel orange trees with 20 ppm GA_3 and 25 ppm of NAA gave the highest of fruit physical as fruit weight, fruit size, fruit diameter [12].

Table 2: Effect of GA_3 and NAA on fruit length, fruit diameter and fruit firmness of white flesh dragon fruit

Treatment	Fruit length (cm)	Fruit diameter (cm)	Fruit firmness (kg/cm^2)
GA_3 30 ppm	11.19^{ab}	7.99^{b}	0.87^{bc}
GA_3 40 ppm	11.14^{ab}	8.00^{b}	0.99^{b}
GA_3 30 ppm + NAA 20 ppm	11.87^{a}	8.18^{ab}	1.00^{ab}
GA_3 40 ppm + NAA 20 ppm	12.01^{a}	8.38^{a}	1.08^{a}
Control	10.19^{c}	7.20^{c}	0.68^{c}
Level of significance	*	*	*

In a column, means followed by same letters are not significantly different at 5% probability level by Duncan's Multiple Range Test (DMRT).

Table 3 showed that GA_3 and NAA treatments, either alone or in combination, increased the peel thickness of white flesh dragon fruit. According to the results, the treatment GA_3 40 ppm + NAA 20 ppm had the highest firm thickness (4.49 mm), while the control had the lowest firm thickness (3.1 mm). The color of the fruit indicates maturity indices. Colors are represented three-dimensionally in the L*a*b* system. The L* coordinate represents luminosity, which ranges from zero (completely black) to 100 (completely white). The green-red variation degree is expressed by a* coordinate, and the blue-yellow variation degree is expressed by the b* coordinate. Fruits were harvested, and the red color predominated, indicating that green fruits had matured. In terms of dragon fruit peel color, the L* luminosity index revealed statistical differences between GA_3 + NAA (30 ppm + 20 ppm; 40 ppm + 20 ppm) and GA_3 30 ppm, 40 ppm, and control (Fig. 1). Values a* b* did not differ significantly between treatments. Peel thickness was not significantly different between treatments when GA_3 and NAA were used individually or in combination. Regarding dragon fruit peel color, using GA_3 + NAA (30 ppm + 20 ppm; 40 ppm + 20 ppm) shown that luminosity index of fruit peel were better than GA_3 individually. Using of 30 ppm NAA + 40 ppm GA_3 and 40 ppm NAA + 40 ppm GA_3 also improved the bright color on fruit peel of LD5 pinkish flesh dragon fruit variety [10].

Table 3: Effect of GA_3 and NAA on fruit peel color and peel thickness of white flesh dragon fruit

Treatment	L*	a*	b*	Peel thickness (mm)
GA_3 30 ppm	43.83[b]	28.45	9.35	3.52
GA_3 40 ppm	44.36[b]	28.57	9.22	3.79
GA_3 30 ppm + NAA 20 ppm	47.19[a]	31.97	9.20	3.96
GA_3 40 ppm + NAA 20 ppm	47.29[a]	32.36	9.35	4.49
Control	43.32[b]	28.60	9.08	3.10
Level of significance	*	ns	ns	ns

L* =lightness, a* = the red/green coordinate, and b* = the yellow/blue coordinate.
In a column, means followed by same letters are not significantly different at 5% probability level by Duncan's Multiple Range Test (DMRT), ns = not significant

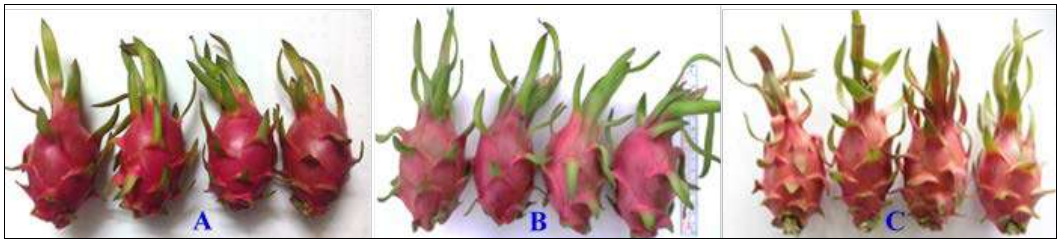

Fig 1: Dragon fruit peel color A: GA_3 40 ppm + NAA 20 ppm; B: GA_3 30 ppm + NAA 20 ppm; C: Control

Fruit chemical characteristics of white flesh dragon fruit

The TSS and total acidity of treatments ranged from 17.03% - 17.77% and 0.25 g/100 ml - 0.39 g/100 ml, respectively (Table 4). NAA and GA_3 applying on sweet cherries, citrus species, wax apple and mango increased TSS (Brix°) [6, 13, 15, 17]. Described a similar trend in Java rambutan spraying 30 ppm GA_3; 20 ppm NAA + 30 ppm GA_3; 500 ppm (2% α - NAA, 0.5% β – NAA and 0.1% GA_3) increased firm thickness, total soluble solid (TSS) [10].

Table 4: Effect of GA_3 and NAA on total acidity, total soluble solid of white flesh dragon fruit

Treatment	TSS (%)	Total acidity (g/100ml)
GA_3 30 ppm	17.07	0.37
GA_3 40 ppm	17.00	0.26
GA_3 30 ppm + NAA 20 ppm	17.63	0.26
GA_3 40 ppm + NAA 20 ppm	17.77	0,25
Control	17.03	0.39
Level of significance	ns	ns

Fruit yield of white flesh dragon fruit

The results shown that the yield among treatments GA_3 40 ppm, GA_3 + NAA (30 ppm + 20 ppm; 40 ppm + 20 ppm) were 31.47 kg/tree, 32.25 kg/tree, 34.05 kg/tree, respectively. However, these were significantly different in yield compared to GA_3 30 ppm (28.42 kg/tree) and control (24.35 kg/tree) (Fig. 2). Study on LD5 pinkish flesh dragon fruit variety showed that the applications of GA_3 + NAA (40 ppm + 30 ppm; 40 ppm + 20 ppm) at stages 10 day flower bud and 5, 10, 15, 20 days after blooming increased fruit yield as compared to control variety [11]. Gibberellic acid and Naphthalene acetic acid have ability to increase fruit yield and fruit quality of 'Chau Nghe' mango, 'Java' rambutan, 'LD5' dragon fruit [3, 10, 11].

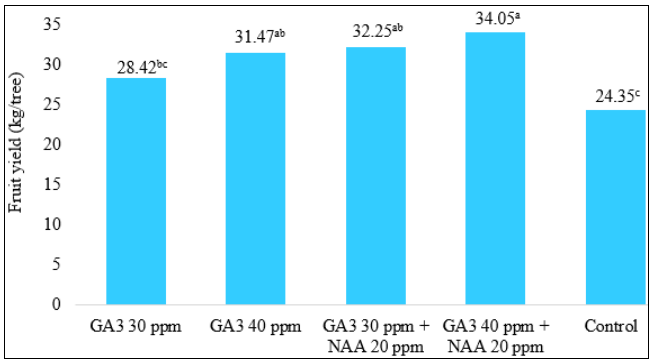

Fig 2: Effect of GA_3, NAA on the yield of white flesh dragon fruit

Conclusion

Foliar spraying GA_3 + NAA (40 ppm + 20 ppm) on white flesh dragon fruit at stages 7, 14, 21 days after blooming increased in flesh firmness (1.08 kg/cm^2), fruit length (12.01 cm), fruit weight (562.08 g/fruit) and yield (34.05 kg/tree), also improved the luminosity of fruit peel. Therefore, it can be indicated that the combined application of GA_3 and NAA with suitable concentrations can be improved yield and some fruit quality in white flesh dragon fruit.

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