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Effects of 1-Naphthyl Acetic Acid (NAA) and Gibberellic Acid (GA_3) on Sex Expression and Growth of Papaya (*Caric papaya* L.)

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ABSTRACT

A study was made on sex expression of papaya plants treated with NAA and GA_3. The results showed that NAA treatment reduced the proportion of male plants compared with those treated with the control treatment, but this chemical did not change the relative proportion of female and hermaphroditic plants. The GA_3 treatment did not alter the proportion of male, female and hermaphroditic plants. However, the maleness character appeared before the other two sex categories.

Other effects of the growth regulators were on the vegetative and reproductive growth. The NAA treatment resulted in the expression of epinasty in the sprayed plants, resulting in the plants being smaller than those in the control treatment. On the other hand, the GA_3 treated seedlings grew more vigorously than the control plants. Over the 90 days growing period, maximum growth rate in all treatments was recorded at the 60^{th} - 70^{th} days after sowing. Flowers in the NAA treated plants were seen at about six days later than those in the control treatment. In the GA_3 treated plants, the flowers were seen at about 20 days earlier than those in the control treatment.

Key Words : *Carica papaya* L., papaya, NAA, GA_3, sex expression, growth.

INTRODUCTION

The papaya (*Carica papaya* L.) is an important fruit of the tropics and subtropics. In Thailand, the cultivation of papaya is becoming more popular due to its fast growing and early bearing habit, low input requirement and multipurpose uses. The fruits of papaya are good sources of vitamin A and C and also are rich in enzyme papain which is an essential ingredient in pharmaceutical, textile and tanning industries (Ranganna, 1977).

Papaya is a polygamous species. In nature, it is dioecious plant with both male and female plants in the population, but possibly due to Man's interference and deliberate selection against non-productive male plants, gynodioecious populations with female and hermaphroditic plants also exist (Storey, 1969). In Thailand, although gynodioecious plants are mostly cultivated in papaya planting areas such as Damnern Saduak District in Rachaburi Province, Khon Kaen and Nakhon Rachasima Provinces, but occasionally some male plants are found. For dioecious populations, several workers

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(Prest, 1955; Storey, 1969) agreed that wind is the main agent of pollen dispersal. The long pendulous male inflorescence which readily shed pollen in the breeze, lend support to this belief. However, Allan (1963) reported that very little papaya pollen was airborne and suggested that honeybees were responsible, although papaya flowers were not the priority sites for visits. Free (1975) reported that papaya flowers were often visited by many Skipper butterflies *Perichars philetes philetes* during dusk in Jamaica and suggested their use as pollinators if the need arose. Dioecious papaya varieties are, therefore, enforced cross-pollinators because of separation of the androecium and gynoecium. With this aspect, male progeny can be found if pollens from male plants are in the vicinity of papaya planting areas.

The basic sex types in papaya are genetically determined (Storey, 1958). The pistillate or female plant is phenotypically very stable. However, certain male and hermaphroditic plants have been known to undergo sex reversal under the influence of various environmental changes such as temperature, soil moisture, nitrogen and plant growth regulators (Chan, 1995). Several experiments have been carried out to increase femaleness in papaya (Ghosh and Sen, 1975; Biswas *et al.*, 1988). Growth regulating chemicals were found to play a significant role in controlling growth, increasing fruit yield, and improving quality of papaya fruits (Biswas *et al.*, 1988; Hore *et al.*, 1989). Jutamanee *et al.*, (1993) reported the influence of growth regulators in modifying sex expression of cucumber plants. Our earlier experiment showed that at the vegetative stage, the male, female and hermaphroditic papaya plants differed in the average contents of auxin like substances, but at this stage, the average contents of gibberellin like substances were not significantly different among these three sexes (Hasdiseve *et al.*, 1989). Therefore, the present experiment was carried out to study the effects of exogenously applied auxin (representing by NAA) and gibberellin (representing by GA_3) on growth and sex expression of papaya.

MATERIALS AND METHODS

The experiment was carried out at the Experimental Unit, Department of Horticulture, Kamphaengsaen Campus during 1987-88. Papaya seeds from three uniform fruits derived from hand crossing hermaphroditic and male flowers of the same trees were germinated in plastics boxes with germinating medium of sand, husk coir and soil at the ratio of 1:1:1. When the seedlings were about 14 days after sowing seeds, or at two leaves stage (Figure 1), they were transplanted into 22.9×50.8 cm. black plastic bags. The survival seedlings from each fruit were regarded as one group, so there were three groups, one group from each fruit. In each group, the plants were sprayed until runoff with 100 ppm NAA, 500 ppm GA_3 and distilled water (control). The sprayings were conducted two times firstly at 30 days and then repeated at 60 days after sowing.

The following parameters were recorded in this experiment.

1) Seed germination ability, percent of dead seedlings after transplanting to plastic bags.

2) Number of plants in each sex, i.e. male, female and hermaphroditic plants. These sexes were compared with the total plants in each group for the determination of sex ratio after receiving growth regulators.

3) The growth of papaya plants were determined as follows.

3.1) Vegetative growth. This parameter was conducted by measuring plant height and trunk diameter. The measurement was done every ten days when the plants were 30 days old until they were 90 days old or at the time when they started flowering.

3.2) Reproductive growth. The measurement in this parameter included average heights of the plant, average trunk diameter at 5 cm. above soil level, plant age at first flowering and position of the first flower.

Completely randomized design was employed in 3.1 and 3.2, having 5 replicates with 12 plants in each replication. Repeated measurement analysis proposed by Keuntham (1986) was used to analyse data in 3.1.

RESULTS AND DISCUSSION

As the papaya seeds from the three controlled pollination fruits were not tested for germination, thus it is difficult to know the number of seedlings in each group. When seeds from these three fruits were germinated those from fruit number 1, or group 1, had 364 seedlings from 710 seeds, or 51.27 percent germination. Those from group 2 had 369 seedlings from 675 seeds, or 54.67 percent germination. Also 361 seedlings were obtained from 606 seeds, or 59.57 percent germination in group 3. After transplanting into black plastic bags, the seedlings from group 1, 2 and 3 died at the rate of 3.02, 8.67 and 8.31 percent respectively, and this left the population of papaya in group, 1, 2 and 3 as 353, 337 and 331 plants, respectively (Table 1). The rather low percent germination was due to the storing of the seeds, as the seeds were kept for many months before sowing. The dead seedlings after transplant may be due to the dry weather during the experiment even though watering was applied regularly.

Papaya plants from group 1, 2 and 3 after receiving NAA 100 ppm, distilled water and GA_3 500 ppm respectively, were grown until flowering. However, before flowering some plants were infected with root rot disease and died. Thus the population of plants receiving NAA 100 ppm, was 334 plants of which there were 86 male, 113 female and 135 hermaphroditic plants. The plants in group 2, receiving distilled water (control) totalled 320 plants of which there were 105 male, 106 female and 109 hermaphroditic plants. The plants in group 3, receiving GA_3 500 ppm totalled 314 plants, of which there were 116 male, 114 female and 84 hermaphroditic plants (Table 2). The male plant contained only staminate flowers, female plant had only pistillate flowers and hermaphroditic plants had reduced elongata flowers (Figure 2A, 2B and 2C).

When considering the number of plants expressing various sexes in the population receiving NAA 100 ppm, we found the ratio of male plant as 86/334 = 0.26, ratio of female plant as 113/334 = 0.34 and ratio of hermaphroditic plant as 135/334 = 0.40. Those plants that received GA_3 500 ppm showed the ratio of male plant as 116/314 = 0.37, ratio of female plant as 114/314 = 0.36 and ratio of hermaphroditic plant as 84/314 = 0.27. The control plants receiving only distilled water showed the ratio of male plant as 105/320 = 0.33, ratio of female plant as 106/320 = 0.33 and ratio of hermaphroditic plant as 109/320 = 0.34 (Table 3).

The data from Table 3 showed that NAA 100 ppm had a tendency to decrease the ratio of male plants which was in agreement to the experiments in cucumber which showed that NAA 100-200 ppm can reduce the number of male flower (Santos and Lopes, 1981). However, the ratios of female and hermaphroditic plants from the population receiving NAA 100 ppm did not show any significant difference from those control population. Also GA_3 at 500 ppm did not give the ratios of male, female and hermaphroditic plants significantly different from those control population. This may be due to either small number of the population studied or the concentrations of the growth regulators used are not suitable. Future experiments should be aware of these points.

Besides sex expression, this study was also

looked at the effects of NAA 100 ppm and GA_3 500 ppm on some physiological characters such as growth during the juvenile phase and growth during the adult phase of papaya plants.

Vegetative growth of the plants was measured at the age from 30 to 90 days after germination. The measurements were on plant height and trunk diameter at 5 cm. above soil level. It was found that the growth of these two characters followed the sigmoidal pattern (Figure 3 and Figure 4). It was found that the average height increased in 10 days of those plants receiving NAA 100 ppm was 21.7 cm. this was less than those control plants which was 28.2 cm. whereas those plants receiving GA_3 500 ppm had the greatest height of 29 cm. (Table 4). As for trunk diameter, the plants that received NAA 100 ppm had the average increase in trunk diameter of 0.34 cm, this was less than those control plants which had the figure of 0.42 cm., plants that received GA_3 500 ppm showed an average increase in trunk diameter of 0.39 cm. which was not significantly different from those control plants. (Table 5).

In this experiment, it was noticed that when the papaya plants were sprayed twice with 100 ppm NAA, the epinasty was found (Figure 5 and Figure 6). This symptom retards vegetative growth until

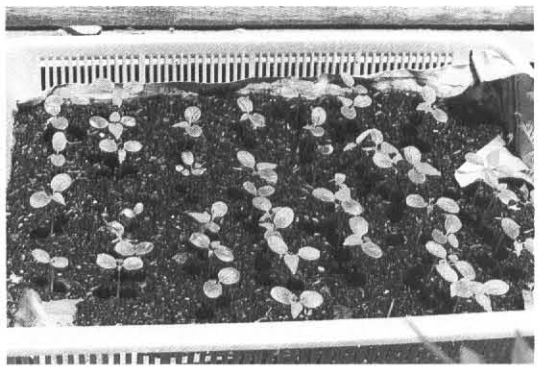


Figure 1 Papaya seedlings at 14 days after sowing and ready for transplant into plastic bags.

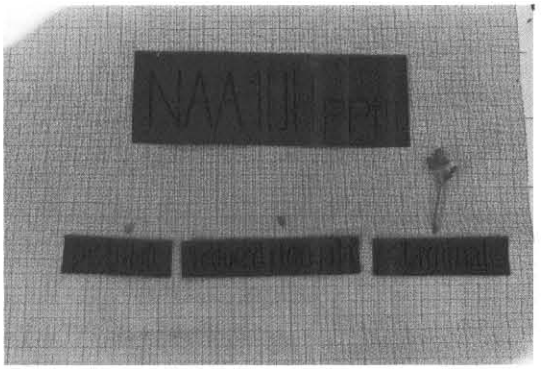


Figure 2A

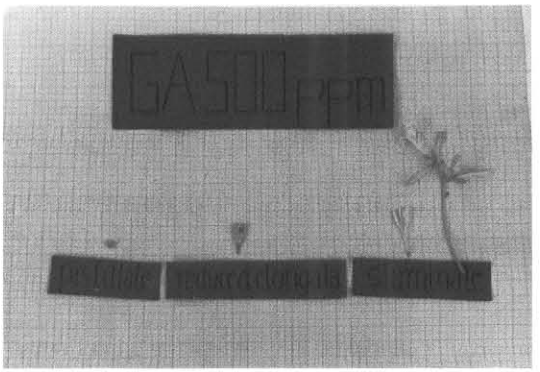


Figure 2B

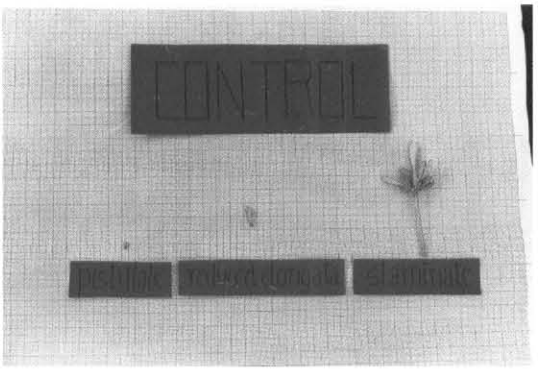


Figure 2C

Figure 2 Female (pistillate), hermaphrodite (reduced elongata) and male (staminate) flowers of papaya A) treated with NAA 100 ppm, B) treated with GA_3 500 ppm. and C) control plants.

the residual effect of NAA ceased, and normal growth was resumed. GA_3 at 500 ppm caused the elongation of stem and the plants grew at more height than width. In all plants vegetative growth was found at the maximal rate when the plants were 60-70 days old which can be seen in Figure 3 and Figure 4.

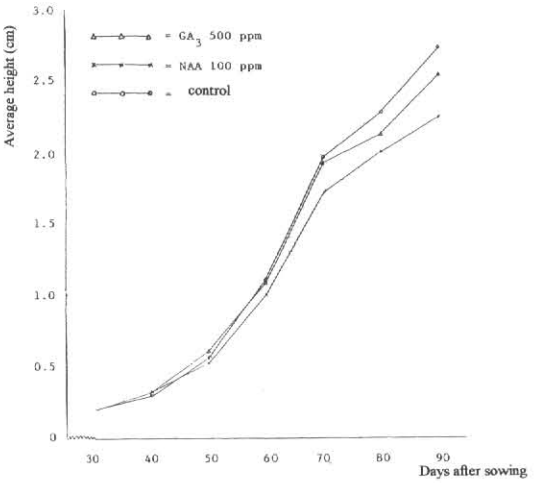


Figure 3 Average height of papaya plants at various ages from 30-90 days after sowing seeds, of those receiving NAA 100 ppm, GA_3 500 ppm and control plants.

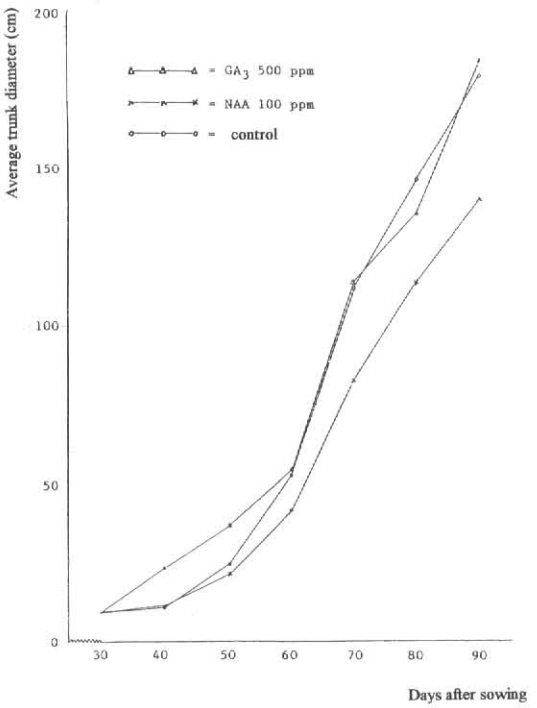


Figure 4 Average trunk diameter (at 5 cm. above soil level) of papaya plants at various ages from 30-90 days after sowing seeds, of those receiving NAA 100 ppm, GA_3 500 ppm and control plants.

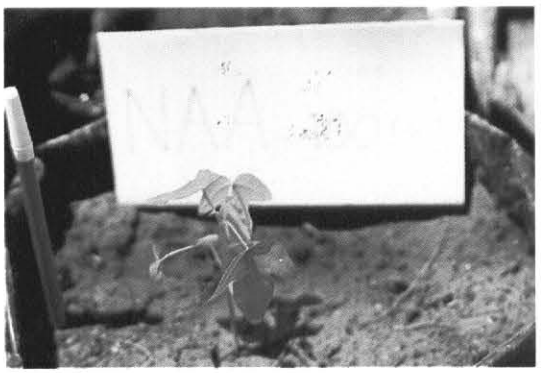


Figure 5 Thirty days old papaya seedling, receiving NAA 100 ppm at first spray, showed epinasty within 24 hours.



Figure 6 Sixty days old papaya plant receiving NAA 100 ppm at the second spray, showed epinasty within 6 hours.

Study on the reproductive growth revealed that the papaya plants that received NAA 100 ppm started to flower when the plants were 196 cm. tall, whereas the control plants flowered at 175 cm. in height. The GA_3 500 ppm treated plants were the shortest to flower at 138 cm. (Table 6). At flowering, the plants treated with NAA 100 ppm did not have the trunk diameter differed from that of the controlled plants, but those plants receiving GA_3 500 ppm had the trunk diameter of 2.18 cm. which was less than those in the other two treatments.

Plant receiving NAA 100 ppm were the last group to flower, they took the time of 110 days after germination, while the control and the GA_3 treated plants took 96 and 76 days from germination to flowering respectively (Table 6). This corresponded to the position of node at first flower in which the NAA treated plants flowered at the highest node of 24. The reason may be explained as the epinasty effect of NAA at 100 ppm which delay the flowering as the plants had to recover from epinasty symptom before they can flower. Those plants receiving GA_3 500 ppm had more vegetative growth which helped them to accumulate food reserve quicker, so they can flower earlier than the other treated plants.

However, the results from this study can only indicate the effect of NAA at 100 ppm and GA_3 at 500 ppm. As in this experiment, the papaya plants were grown in 22.9 × 50.8 cm. black plastic bags which may restrict root growth. Thus the results obtained here may be different from the experiment on plants growing in the field. Also the concentration of NAA used in this experiment seemed to be too high as it can cause epinasty to plants. Further experiments should be conducted using various concentrations of these two plant growth regulators for obtaining the proper concentrations in influencing sex expression and growth of papaya plants.

CONCLUSION

The study on the influence of NAA 100 ppm and GA_3 500 ppm on sex expression, vegetative and reproductive growth of papaya plants can be concluded as follows.

1. NAA at 100 ppm caused the reduction of the male plants in the population, whereas the ratio of female and hermaphroditic plants was not differed among the treatments. Applied GA_3 plants did not show an effect on sex ratio as compared to the control population.

2. GA_3 caused the elongation in the inflorescence of male flowers whereas NAA did not have this effect.

3. NAA 100 ppm caused less vegetative growth, while GA_3 500 ppm produced more vegetative growth than the control plants. Plants

Table 1 Germination of papaya seeds from three fruits (group) and the number of seedlings left after transplanting.

Seeds from fruit number	Total seeds	Total seedlings	Percent germination	Percent dead seedlings after transplant	Number of papaya plants left for experiment
1	710	364	51.3	3.01	353
2	675	369	54.7	8.7	337
3	606	361	59.6	8.3	331

Table 2 Number of papaya plants at various sexes after receiving NAA 100 ppm, GA3 500 ppm and distilled water.

Treatment	Number of plants			Total
	Male	Female	Hermaphrodite	
NAA 100 ppm	86	113	135	334
GA_3 500 ppm	116	114	84	314
Distilled water	105	106	109	320

Table 3 Ratio of male, female and hermaphrodite of population receiving NAA 100 ppm GA3 500 ppm and distilled water, with calculated z values.

Treatment	Male ratio	z value	Female ratio	z value	Hermaphrodite ratio	z value
NAA 100 ppm	0.26	-1.97*	0.34	0.27	0.40	1.59
GA_3 500 ppm	0.37	1.06	0.36	0.79	0.27	-1.92
Distilled water	0.33	-	0.33	-	0.34	-

* Significant difference at $\alpha = .05$

Table 4 The average increase in plant height during the growth period from 30 to 90 days after germination of papaya plants receiving NAA 100 ppm, GA_3 500 ppm and distilled water (control).

Treatment	Average height (cm) increased during						Mean
	31-40 days	41-50 days	51-60 days	61-70 days	71-80 days	81-90 days	
NAA 100 ppm	2.1	10.1	19.8	41.6	30.3	26.5	21.7
GA_3 500 ppm	13.7	13.6	17.8	59.2	21.5	48.8	29.1
Distilled water (control)	1.9	13.3	28.2	59.3	34.4	32.3	28.2
Mean	5.9	12.3	21.9	53.4	28.7	35.8	-

For chemical treatment
$LSD_{.05}$ = 3.51 cm
$LSD_{.01}$ = 4.92 cm

For plant age
$LSD_{.05}$ = 2.25 cm
$LSD_{.01}$ = 2.99 cm

Table 5 The average increase in trunk diameter during the growth period from 30 to 90 days after germination of papaya plants receiving NAA 100 ppm, GA_3 500 ppm and distilled water (control).

Treatment	Average diameter (cm) increased during						Mean
	31-40 days	41-50 days	51-60 days	61-70 days	71-80 days	81-90 days	
NAA 100 ppm	0.12	0.20	0.48	0.72	0.28	0.24	0.34
GA_3 500 ppm	0.12	0.28	0.48	0.84	0.20	0.42	0.39
Distilled water (control)	0.10	0.26	0.54	0.86	0.32	0.46	0.42
Mean	0.11	0.24	0.50	0.80	0.26	0.37	-

For chemical treatment
$LSD_{.05}$ = 0.056 cm
$LSD_{.01}$ = 0.078 cm

For plant age
$LSD_{.05}$ = 0.046 cm
$LSD_{.01}$ = 0.061 cm

Table 6 Average plant height, trunk diameter, age at first flowering and position of the first flower of papaya plants receiving NAA 100 ppm, GA_3 500 ppm and distilled water (control).

Treatment	Plant height (cm.)	Trunk diameter (cm.)	Age at flowering (day)	Position of first flower (node)
NAA 100 ppm	196	3.18	110	24
GA_3 500 ppm	138	2.18	79	17
Distilled water (control)	175	3.18	96	21
$LSD_{.05}$	11.30	0.19	10.00	1.47
$LSD_{.01}$	15.90	0.27	14.00	2.07

from all treatments had the maximal growth rate at the age of 60-70 days after germination.

4. NAA treated plants were the last group to flower, whereas GA_3 treated plants were the first group to flowers.

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