International Journal on Science and Technology

One Day National Seminar on

"Advances in Life Sciences for Diversity, Applications, and Human Welfare"

(ALSDAHW – 2025)

Organized by Department of Microbiology & Department of Biotechnology

M.V.S. Government Arts & Science College (Autonomous), Mahabubnagar-509001

E-ISSN: 2229-7677 • Website: www.ijsat.org • Email: editor@ijsat.org

Impact of Growth Regulators on Floral Sex Determination and Yield Attributes in Castor (*Ricinus communis* L.)

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Abstract

Castor is a non-edible, economically important oilseed crop with many industrial uses (pharmaceuticals, cosmetics, biofuels, lubricants). It is a monoecious plant with male and female flowers in variable proportions. Female flowers in more number directly affects fruit/seed set. Sex determination in castor is highly influenced by environmental factors, viz, high temperature, age of the plant, nutrition and growth regulators. A field experiment was conducted during *Kharif,* 2024, at the Students farm at Loyola Academy Degree and P.G. College, Alwal, Secunderabad, to know the effect of NAA and Ethephon on sex expression of Pistillate or Staminate flowers in 3 monoecious lines of castor. viz., (DCS 107, DCH 177, GCH 4). Growth regulators NAA and Ethephon were foliar sprayed at 100 ppm, 150 ppm and 200 ppm concentrations successively at 30, 45 and 60 DAS. Data were recorded on floral characters and yield attributes. The results indicated that application of NAA and Ethephon at all concentrations significantly increased the expression of pistillate flowers by suppression of male flowers in monoecious lines compared to control. NAA applied @ 150 ppm significantly increased number of pistilate flowers, and reduced number of staminate (male) flowers, increased spike length and enhanced number of capsules/spikes,100-seed weight (g), and seed yield. Similar results were also observed with the application of Ethephon @ 200 ppm for all the floral characters and yield attributes. The study revealed that the NAA @150 ppm or Ethephon @ 200 ppm has a great potential as growth regulators in promoting female flowers in hybrid seed production of castor for increasing the overall yield attributing parameters, which can be successfully used in crop improvement work for enhancing genetic purity.

Keywords: Castor, Floral sex Determination, NAA, Ethephon, Seed yield.

1. Introduction:

Castor *(Ricinus communis L.)* plays a vital role, especially in the industrial area and is utilised as a non-edible oilseed crop which is grown mainly under the varied agro-climatic conditions, especially including tropical, sub-tropical and temperate regions. Castor seed oil has a very uniqueness and importance in relation for its dominance for its single fatty acid- ricinoleic acid (85-95%), Castor oil and its derivatives are being utilized for the textiles industries, soaps making, wetting agents, synthetic resins, cosmetics, nylon fibers, and used as antifreeze for fuels and lubricants utilized in the aircrafts and in the space rockets (***Ogunniyi*, 2006**).

Castor, which is polymorphic in nature, which has different forms of sex flowers, *viz.,* monoecious, pistillate, sex revertants and pistillate with the interspersed staminate flowers (ISFs). Castor is the most natural occurrence of annual and perennial castor, which is in the form of a monoecious in nature. The spike in castor which has a basal 1/3rd to ½ male flowers, while the top portion has female flowers. The pistillate spike occurs as a rare recessive mutant, characterised by female flowers throughout the spike. A variant of the pistillate form with male flowers is mainly interspersed throughout the entire female flowers on the spike, which is termed as Interspersed Staminate Flowers (ISF). The sex expression in the castor is highly dominated and expressed by the environmental factors *viz.,* high day temperature, photoperiod regulations, fertility, age of the plant, nutrition, etc. (**Shifriss, 1960; Zimmerman and Smith, 1966**).

The castor plant, which is perennial in nature, by which it produces the indeterminate branches ending with the raceme kind of inflorescence known as the spike. The inflorescence development along any one of the axis is sequential in nature; thus, it is possible to have the inflorescence in various stages of development at a given particular point of the time. The proportion of the male and female flower ratios differs from the orders of the racemes in different forms of sex expression, or the genotypes depends on the nature of the genetic variation and temperature (***Parvathy et al.*, 2021**).The basic nature of the sex expression found in natural diverse ecosystem which is monoecious (M), where unisexual flowers are found to be at the different positions on the same spike. The typical monoecious form of the female flowers and male flowers is at the apex and at the base of the spike, respectively. Pistillate (P) genotypes would have female flowers on the spike, with or without Interspersed Staminate flowers (ISFs) or reversion.

By the various several mechanisms, it has been postulated that mainly for governing the sex lability in the castor, mainly for the reproductive biology, morphology and evolutionary aspects of monoecy, is not explained in the context for the complex traits and intriguing phenomenon for the sex expression.(**Cronquist.A,1988, Charles worth.D,2002**) Sexual determination systems in plants have evolved from hermaphroditic ancestors. Bisexual flowers are ancestral, and unisexual flowers have originated form many times independently. Understanding the molecular mechanisms of unisexuality has been a long-standing quest in plant biology systems, though various developmental and genetic mechanisms underlying the unisexual flower development are predicted. (**Diggle, P. K. *et al*,2011; Sobral, R.,2016; Saquet, H. *et al*.,2017**). With this background, a field experiment was conducted to determine the effect of growth regulators (NAA & Ethephon) on flower sex determination and yield attributes in castor.

2. Materials and Methods:

The research trial was conducted at the School of Agriculture, Students farm, Loyola Academy Degree & P.G. College, Alwal, Secunderabad, during the Kharif season 2024, by using 3 genotypes, with 2 growth regulators for observing the sex expression of Pistillate and Staminate flower behaviour, respectively. Each genotype sowing has been done with four rows with a spacing of 60 cm X 30 cm, with a plot size of 6 X 8 sq.mts. For the present investigation in our study, we have followed Randomized Block Design (RBD) with 3 replications, with 12 treatments (T_1, T_2, T_3 & T_0), respectively, with the three monoecious lines of castor, represented in Figure 1. The layout is mentioned in Figure 2. A list of genotypes and growth regulators used in this experiment were shown in Table 1, and the layout of the experiment in Figure 2. Floral parameters and yield attributes were recorded for the number of male and female flowers /spike, spike length (cm), Number of capsules,100 seed wt (g), and seed yield /plant (g). Growth regulators NAA and Ethephon were foliar sprayed at 100 ppm, 150 ppm and 200 ppm concentrations successively at 30, 45 and 60 DAS.

Table 1: List of Genotypes and Growth Regulators used in the Experiment

S. No	Genotypes	Conc (ppm)	Growth Regulators Utilized	Source of Genotypes
1	DCS-107	100,150, 200	NAA & Ethephon	Indian Institute of Oil Seed Research (**IIOR**) Rajendranagar. Hyderabad
2	DCH-177	100,150, 200		
3	GCH-4	100,150, 200		

Figure :1 Castor Plant with Inflorescence

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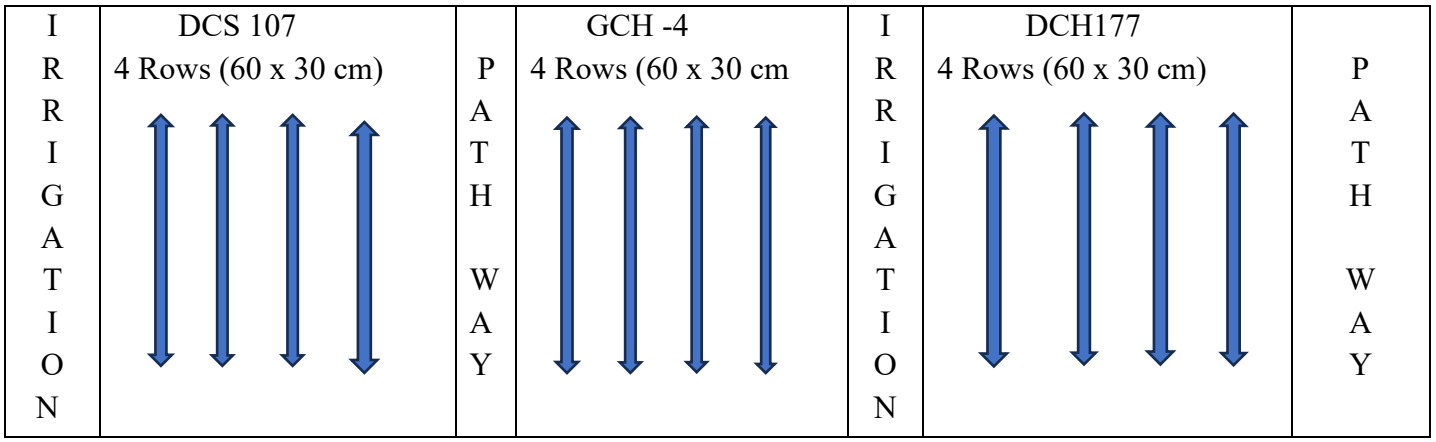

Plot size (6 x 8 sq.m) **Plot size (6 x 8 sq.m)** **Plot size (6 x 8 sq.m)**

Fig 2 : Layout of the field

3. Results & Discussions:

From the present investigation, floral parameters and yield attributes were recorded for the number of male and female flowers /spike, spike length (cm), Number of capsules,100 seed wt (g), and seed yield /plant (g)., at 100 ppm, 150 ppm, and 200 ppm concentrations, by using growth regulators of NAA and Ethephon are mentioned in Tables from 2A to 2N, respectively. The present study focused on a trend in decreasing the number of male flowers and increasing the number of female flowers, which were observed at the concentrations by using 2 growth regulators, NAA @ 150 ppm and Ethephon 200 ppm, respectively, and in the control plot, water was sprayed.

3.1. Number of Male Flowers in Primary Spike & Secondary Spike

The treatment effects of male flower reduction in primary and secondary spikes are greatly enhanced by the use of growth regulators. The least number of male flowers was observed (5.25) @ 150 ppm NAA concentration in DCS-107, whereas (4.25) in secondary spike DCS-107, with NAA @ 150 ppm, followed by the least number of male flowers observed in DCS-107, DCH-177, GCH-4 @ 200 ppm of Ethephon concentration, i.e., (5) in primary spike and in secondary spike (4.44) in DCS-107, when compared to the control $T_{0.}$ i.e water spray (10 & 10) at primary and secondary spike & (11,8) at primary and secondary spike.

3.2. Number of Female Flowers in Primary Spike

The effective usage of the growth regulators has increased the number of female flowers with the utilisation of NAA @ 150 ppm and Ethephon @ 200 ppm, respectively. A larger number of female flowers (55) were observed in GCH-4, @ 150 ppm of NAA, followed by (50) in GCH-4, @ 200 ppm of Ethephon, at the primary spikes when compared to the control $T_{0.}$ i.e water spray (35, both at primary and secondary spikes).

3.3. Primary Spike Length of Castor (cm)

The treatments have a significant effect in terms of spike length, which was found to be statistically sig-

nificant. The highest spike length (60 cm) was observed in the genotype GCH-4 @ NAA 150 ppm, followed by (66cm) in DCH-177 @ 200 ppm of Ethephon concentration. when compared to the control T_0. i.e water spray (45 and 35 at primary spike).

3.4. Number of Capsules in the primary spike

The treatments have a significant and effective impact on the increase in the number of capsules in the primary spike. Ethephon @ 200 ppm and NAA @ 150 ppm has shown a drastic increase in the number of capsules in the primary spike, maximum number of capsules (53) was reported in the genotype GCH-4 @ 150 ppm concentration, whereas in Ethephon @ 200 ppm maximum number of capsules (54) was observed in GCH-4, when compared to the control T_0. i.e water spray (45 and 39 at primary spike)

3.5. 100-Seed Weight (g)

The 100-seed weight has shown and revealed statistically significant for the present study. Among the genotypes, DCH-177 recorded the highest seed weight (30) in NAA @ 150 ppm, followed by DCS-107, which recorded the highest seed weight (30) in Ethephon @ 200 ppm concentration, respectively, when compared to the control T_0 i.e water spray (26 and 24)

3.6. Seed yield (g)/plant.

The data was found to be statistically significant in terms of seed yield/ plant. Among the genotypes, maximum seed yield (g)/plant (89) was observed in the genotype DCH-177 for the concentrations of NAA @ 150 ppm and (92) in DCH-177 for Ethephon @ 200 ppm, when compared to the control T_0 i.e water spray (79 and 80).

Table 2A. Effect of NAA on the Number of Male Flowers in primary spike of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 NAA @ 100 ppm	6.44	17	23	15.48
T_2 NAA @ 150 ppm	5.25	14	20	13.08
T_3 NAA @ 200 ppm	6.33	16	25	15.77
T_0 Control (Water spray)	10	20	36	22
Mean	7.00	16.75	26	
S.E m+	0.27	0.17	0.04	
C.D (0.05)	0.62	0.53	0.32	

Table 2B. Effect of NAA on the Number of Male Flowers in the Secondary Spike of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 NAA@ 100 ppm	7	6.33	16	9.77
T_2 NAA @ 150 ppm	4.25	5.54	13	7.59
T_3 NAA @ 200 ppm	4.33	6.09	14	8.14

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T_0 Control (Water spray)	10	13	20	13.01
Mean	6.39	7.74	15.75	
S.E m+	0.24	0.15	0.05	
C.D (0.05)	0.61	0.52	0.33	

Table 2C. Effect of Ethephon on the Number of Male Flowers in primary spike of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 Ethephon @ 100 ppm	7	7	12	8.67
T_2 Ethephon @ 150 ppm	6	6	11	7.67
T_3 Ethephon @ 200 ppm	5	5	10	6.67
T_0 Control (Water spray)	11	12	13	12
Mean	7.25	7.5	11.5	
S.E m+	0.23	0.13	0.06	
C.D (0.05)	0.57	0.54	0.37	

Table 2D. Effect of Ethephon on the Number of Male Flowers in secondary spike of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 Ethephon @ 100 ppm	5.44	6	6	5.81
T_2 Ethephon @ 150 ppm	4.44	5.56	5	21.66
T_3 Ethephon @ 200 ppm	4.33	5.55	6	4.96
T_0 Control (Water spray)	8	9	8	8.33
Mean	5.55	6.52	6.25	
S.E m+	0.22	0.11	0.04	
C.D (0.05)	0.51	0.58	0.39	

Table 2E. Effect of NAA on the Number of Female Flowers in Primary Spike of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 NAA@ 100 ppm	40	40	46	42
T_2 NAA @ 150 ppm	45	47	55	49
T_3 NAA @ 200 ppm	45	47	48	46.67
T_0 Control (Water spray)	35	30	40	35
Mean	41.25	41	47.25	
S.E m+	0.20	0.09	0.018	

C.D (0.05)	0.50	0.54	0.27	

Table 2 F. Effect of Ethephon on the Number of Female Flowers in the Primary Spike of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 Ethephon @ 100 ppm	38	43	38	39.67
T_2 Ethephon @ 150 ppm	45	48	44	45.67
T_3 Ethephon @ 200 ppm	46	49	50	48.33
T_0 Control (Water spray)	35	40	33	36
Mean	41	45	41.25	
S.E m+	0.21	0.10	0.02	
C.D (0.05)	0.52	0.57	0.29	

Table 2 G. Effect of NAA on the Primary Spike length (cm) of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 NAA@ 100 ppm	55	49	50	51.33
T_2 NAA @ 150 ppm	58	57	59	58
T_3 NAA @ 200 ppm	58	57.5	60	58.5
T_0 Control (Water spray)	45	47	45	45.67
Mean	54	52.62	53.5	
S.E m+	0.19	0.12	0.02	
C.D (0.05)	0.45	0.51	0.22	

Table 2 H. Effect of Ethephon on Primary spike length (cm) of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 Ethephon @ 100 ppm	40	52	54	48.67
T_2 Ethephon @ 150 ppm	46	60	59	55
T_3 Ethephon @ 200 ppm	47	66	62	58.33
T_0 Control (Water spray)	35	40	50	41.67
Mean	42	54.5	56.25	
S.E m+	0.14	0.16	0.22	
C.D (0.05)	0.55	0.47	0.25	

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Table 2.I . Effect of NAA on the Number of Capsules in the Primary Spike of the Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 NAA @ 100 ppm	49	**51**	**45**	48.33
T_2 NAA @ 150 ppm	50	54	53	52.33
T_3 NAA @ 200 ppm	51	55	57	54.33
T_0 Control (Water spray)	45	42	43	43.33
Mean	48.75	50.5	49.5	
S.E m+	0.18	0.19	0.34	
C.D (0.05)	0.53	0.51	0.27	

Table 2.J. Effect of Ethephon on the Number of Capsules in the Primary Spike of the Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 Ethephon @ 100 ppm	42	46	42	43.33
T_2 Ethephon @ 150 ppm	47	47	48	47.33
T_3 Ethephon @ 200 ppm	53	50	54	52.33
T_0 Control (Water spray)	39	44	40	41
Mean	45.25	46.75	46	
S.E m+	0.17	0.18	0.03	
C.D (0.05)	0.52	0.50	0.26	

Table 2 K. Effect of NAA on the 100 Seed Weight (g) in Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 NAA@ 100 ppm	27	28	28	27.67
T_2 NAA @ 150 ppm	30	30	29	29.67
T_3 NAA @ 200 ppm	29	29.5	30	20.5
T_0 Control (Water spray)	26	25	26	25.67
Mean	28	28.12	28.25	
S.E m+	0.20	0.09	0.018	
C.D (0.05)	0.50	0.54	0.27	

Table 2L. Effect of Ethephon on the 100 Seed Weight (g) in Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	

T_1 Ethephon @ 100 ppm	26	28	26	26.67
T_2 Ethephon @ 150 ppm	28	29	28	28.33
T_3 Ethephon @ 200 ppm	30	27	28.5	28.5
T_0 Control (Water spray)	24	26	24	24.67
Mean	27	27.5	26.62	
S.E m+	0.22	0.11	0.04	
C.D (0.05)	0.51	0.58	0.39	

Table 2M. Effect of NAA on the Seed yield (g)/plant of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 NAA@ 100 ppm	85	90	84	86.33
T_2 NAA @ 150 ppm	87	89	88	88
T_3 NAA @ 200 ppm	86	91	84	87
T_0 Control (Water spray)	79	78	79	78.67
Mean	84.25	87	83.75	
S.E m+	0.20	0.09	0.018	
C.D (0.05)	0.50	0.54	0.27	

Table 2N. Effect of Ethephon on seed yield (g)/plant of Castor

Treatments	Genotypes			Mean
	DCS-107	**DCH-177**	**GCH-4**	
T_1 Ethephon @ 100 ppm	85	85	84	84.67
T_2 Ethephon @ 150 ppm	88	90	87	88.33
T_3 Ethephon @ 200 ppm	89	92	91	90.67
T_0 Control (Water spray)	80	79	76	78.33
Mean	85.5	86.5	84.5	
S.E m+	0.15	0.12	0.01	
C.D (0.05)	0.55	0.58	0.31	

4. Conclusions

The results indicated that application of NAA and Ethephon at all concentrations significantly increased the expression of pistillate flowers by suppression of male flowers in monoecious lines compared to the control. NAA applied @ 150 ppm significantly increased the number of pistilate flowers, and reduced the number of staminate (male) flowers, increased spike length and enhanced the number of capsules/spikes,100-seed weight (g), and seed yield. Similar results were also observed with the application of Ethephon at 200 ppm for all floral characters and yield attributes. The effective utilization

in hybrid seed production increases the overall yield, by growth regulators. Key effects of NAA and Ethephon on castor flower production promote femaleness. NAA, as a synthetic auxin, encourages the development of pistillate flowers, increasing the proportion of female flowers within the raceme (flower spike). The study revealed that NAA at 150 ppm or Ethephon at 200 ppm has great potential as growth regulators in promoting female flowers in hybrid seed production of castor, thereby increasing overall yield attributing parameters. This can be successfully used in crop improvement work to enhance genetic purity.

The application of NAA and Ethephon leads to a decrease in the number of male flowers per plant compared to untreated control plants. Higher concentrations of NAA and Ethephon can further reduce the number of male flowers, increases female-to-male flower ratio. The net result is an increase in the female-to-male flower ratio, which is desirable for commercial seed production, as only female flowers produce the seed-bearing capsules, which enhances Seed Yield. By shifting the floral balance toward female flowers and increasing the number of capsules per spike, NAA and Ethephon application can ultimately improve the total seed yield and oil content. In other crops, foliar sprays of NAA are known to increase flower production, reduce flower drop, and increase fruit set and yield, suggesting similar benefits may apply to castor flower retention. Plant growth regulators such as NAA and Ethephon play a key role as a management tool for manipulating the sex expression flower ratio and ensuring efficient pollination and high yields.

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