DEVELOPMENT OF PISTILLATE CASTOR

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A CRITICAL analysis of genetic and non-genetic factors influencing sexual polymorphism in castor (*Ricinus communis* L.) has enabled identification of three systems of femaleness, the N, S and the NES (Classen and Hoffman, 1950; Shifriss, 1960 and Zimmerman and Smith, 1966). The N-pistillate is a simply inherited gynodioecious system in which monoecious and female plants occur in a 1 : 1 ratio; the S-system behaves like a polygenic complex and the NES-system is homozygous for the N-pistillate gene (**f**) and also contains environmentally sensitive genes (**s**) for interspersed staminate flowers. The NES mechanism is obviously advantageous to the breeder since transference of a single recessive gene for femaleness is easily accomplished and the environmentally sensitive genes confer advantages for its maintenance. The present paper is a report on the independent development of a stable line of pistillate castor similar to the NES mechanism.

MATERIALS AND METHODS

Several crosses were undertaken for further improvement of *Aruna* castor, an induced mutant developed earlier (Ankineedu and Kulkarni, 1968). In the early segregating generations of the cross (High oil mutant from H.C. 6 × Mauthner's dwarf) × (*Aruna* × Mauthner's dwarf), one of the single plants designated 240, looked very desirable since it was early and bearing mostly female racemes of all orders. Since selfed racemes did not bear seeds, its open pollinated progeny was studied during summer 1970. Selection under selfing was continued through 1970 (summer), 1970 (*kharif*), 1971 (summer) and 1971 and 1972 (*kharif*) seasons. The *kharif* plantings were normally taken up during July-August and the summer (offseason) plantings during December-January. The different years and more particularly seasons, furnished a wide range of temperatures during flowering period (Table 1).

Selection under selfing was confined to plants bearing female racemes of all orders but with 1–2 interspersed staminate flowers in a few racemes, non-spiny capsules and low node number (6–12). Since the staminate flowers were few and getting dropped, the rapidly developing female flowers were removed so as to enable normal development of staminate flowers. The pollen from such flowers was used to dust the stigmas of female flowers of the same plant.

RESULTS

The breeding behaviour of the progeny of plant 240 in successive years under continued selfing and selection for female racemes of different orders with only 1–2 interspersed staminate flowers in few racemes was followed up.

1. *Summer and kharif seasons of* 1970*:* During 1970 summer only two plants were observed to be completely female with one or two staminate flowers out

TABLE 1

Monthly average of mean maximum and mean minimum temperatures (°C) Rajendranagar, Hyderabad (A.P.), India

	Jan	Feb	Mar	July	Aug	Sept	Oct	Nov	Dec
				(1962–72)					
Mean max.	28·6	32·1	35·3	31·3	30·5	30·7	30·6	29·2	28·0
Mean min.	14·3	16·1	20·0	23·0	22·7	22·0	19·4	16·1	13·4
				(1971–72)					
Mean max.	28·7	31·9	34·6	32·5	31·5	31·6	29·5	28·5	27·1
	*					*			
Mean max.	28·4	31·1	36·2	31·8	31·8	32·6	33·1	28·9	29·2
				*					

*Crop growth period.

of which only one plant, 240–9 was selected for further studies since it had a low node number.

The 240-9 progeny segregated for monoecism as well as complete femaleness with few interspersed staminate flowers. Out of the 17 plants that could be studied during *kharif* 1970 only one plant 240-9-17 was selected for further studies. It had only one staminate flower each on the primary raceme (P) as well as in secondary racemes one and two (S_1 and S_2). This plant was characterized by red stem, double bloom, eleven nodes to flower, non-spiny capsules and yielded 44 selfed seeds.

2. *Behaviour of* 240-9-17 *progeny during summer* 1971. Selfed seeds of 240-9-17 were sown on December 15, 1970 and 26 plants were available for an analysis of the sex variation. All the 26 plants bred true to the pistillate character and could be put into the following four phenotypic classes (Table 2).

TABLE 2

Phenotypic behaviour of the progeny 240-9-17

Phenotypic class	Primary raceme	Sequential racemes
(1)	♀	♀
(2)	♀♀*	♀♀
(3)	♀♀♀	♀♀, ♀*
(4)	♀♀♀	♀, ♀*

♀ Female raceme; ♀*Female raceme having one or two late developing interspersed staminate flowers.

The developmental behaviour of these four phenotypic classes is summarized in Table 3.

TABLE 3

Data showing the behaviour of different phenotypic classes of the progeny of 240-9-17 *during summer* 1971

Particulars	Phenotypic class			
	(1)	(2)	(3)	(4)
Plants in each group	7	3	9	7
Average number of racemes per plant	6·71	6·00	7·55	5·43
Average number of racemes bearing one or two interspersed staminate flowers per plant	0·00	1·00	2·22	2·86
Average number of male flowers per plant	0·00	1·00	3·80	4·75
Average percentage of racemes bearing one or two interspersed staminate flowers per plant	0·00	16·66	29·87	52·60
Average percentage of female racemes per plant	100·00	83·34	70·13	47·40

The genotype attained stability for the pistillate character and the observed variation for the development of the interspersed staminate flowers between classes, between plants of the same class and within racemes of a plant did not exhibit sequential reversion as seen from Table 4. The individual plant behaviour of each class in Table 4 further confirms this.

3. *Behaviour of progenies during* kharif 1971*:* Female plants of class (1) were sibmated to other groups but no seed was obtained possibly due to sudden rise in temperature on April 2, 1971. Studies on the breeding behaviour of selfed progeny from other classes were continued during *kharif* 1971.

A total of 14 progenies, one from class (2), seven from class (3), and six from class (4) were planted on August 28, 1971.

The breeding behaviour of the selfed progenies again revealed that all the progenies were stable for the pistillate character, with occasional occurrence of one or two staminate flowers which were confined to primary and secondary recemes. The mean maximum temperature at Hyderabad in September, 1971 was 31·6° C and it decreased to 29·5° C in October and to 27·1° C in December. As the winter progressed, the mean maximum temperature became low and the latter order racemes became female. The population also became uniform for almost all observable traits.

4. *Kharif 1972:* Since the population attained uniformity for all traits by 1971, a representative bulk sample of the pistillate line was drawn for further studies during *kharif* 1972. Plantings were done on July 10, 1972 with a wide

TABLE 4

Developmental variation for interspersed male flowers within each of the four classes (Summer 1971)

Class	Plant No.	P	S_1	S_1T_1	S_2	S_2T_1	S_2T_2	S_3	S_5T_1
(2)	1	♀*	♀	♀	♀	♀	♀	♀	♀
(3)	1	♀	♀*	♀					
	2	♀	♀*	♀					
	3	♀	♀*	♀					
	4	♀	♀*	♀*	♀*	♀			
	5	♀	♀*	♀	♀*	♀			
	6	♀	♀*	♀	♀*	♀		♀*	♀
	7	♀	♀*	♀					
	8	♀	♀*	♀	♀*	♀		♀***	♀
	9	♀	♀	♀	♀*	♀		♀	
(4)	1	♀*	♀		♀*				
	2	♀*	♀***	♀	♀**	♀		♀*	♀*
	3	♀*	♀**	♀	♀				
	4	♀*	♀*		♀				
	5	♀*	♀**	♀*	♀*	♀*	♀	♀	
	6	♀*	♀*	♀		♀			
	7	♀*	♀*	♀	♀	♀			

P, Primary raceme; S_1, Secondary (1) raceme; S_1T_1, Tertiary (1) on secondary (1); S_2, Secondary (2) raceme; S_2T_1, Tertiary (1) on secondary (2); S_2T_2, Tertiary (2) on secondary (2); S_3, Secondary (3); S_3T_1, Tertiary (1) on secondary (3).

♀, Female racemes; ♀*, Female raceme with one male flower; ♀**, Female raceme with two male flowers; ♀***, Female raceme with three male flowers.

spacing (100 cm between rows and 50 cm between plants) so as to enable development of maximum number of racemes per plant. Detailed observations were recorded on 75 individual plants. Racemes of all orders were bagged and described (Table 5).

It will be seen that an average number of 47·65 racemes per plant were produced out of which 9·67 racemes (approximately 1/5) bore one or two interspersed staminate flowers, the remaining being completely female. A total of 18·6 staminate flowers were produced per plant. The mean maximum temperature during the crop period was highest in October with 33.1°C and 31·5°C for the five months crop period.

5. *Production of interspersed staminate flowers:* The temperature sensitivity of genes for production of interspersed staminate flowers is indicated. As could be seen from Table 5, the average maximum number of 18·56 interspersed staminate flowers per plant were produced with a mean maximum temperature of 31·5° C for the whole crop period while in *kharif* 1971 with a mean maximum

TABLE 5

Data showing the behaviour of 240 *pistillate line (based on observations on* 75 *individual plants during* kharif (1972)

*Order of flowering	*Av. No. of nodes to flower	*Ht. upto raceme cm	*Av. length of raceme cm	**Av. No. of racemes / plant	**Av. racemes / plant having 1·2 male flowers	**Av. male flowers / plant on racemes bearing male flowers	**Av. % female racemes / plant
P	11·7	40·8	29·1	1·00	0·92	1·92	10·34
S_1	3·8	33·3	23·9	17·29	3·54	6·71	36·15
S_2	4·2	33·9	24·1	15·23	3·02	5·51	29·68
S_3	4·8	38·0	21·5	9·23	1·65	3·38	18·21
S_4	5·3	30·9	17·8	3·28	0·45	0·94	5·06
S_5	6·5	31·0	18·0	1·03	0·05	0·05	0·28
S_6	6·0	0·0	0·0	0·59	0·05	0·05	0·28
Total	—	—	—	47·65	9·67	18·56	78·56

*represent raceme; P, Primary raceme; S_1, Secondary (1) raceme; S_2, Secondary (2) raceme; S_3, Secondary (3) raceme; S_4, Secondary (4) raceme; S_5, Secondary (5) raceme; S_6, Secondary (6) raceme;

**Includes all orders (S_1T_1, S_1T_2, $S_1T_1Q_1$....) of racemes on S_1, S_2, S_3, S_4, S_5 and S_6 respectively.

temperature of 28·76° C during crop period only one or two male flowers were expressed.

DISCUSSION

From an extensive analysis of sex variation in castor, Shifriss (1956, 1960) described two genetic systems: 'conventional' and 'unconventional' which influence sex tendency and sex pattern. The 'conventional' system included monoecious variants and a rare recessive female mutant whereas the 'unconventional' forms evolved from dominant female mutants which occur commonly in all the inbreds of the 'conventional' system. Inbreeding of the dominant female mutants occurring in the normal populations gave various proportions of females and monoecists. Shifriss (1960) reported that the phenotypic reversion to monoecism in the dominant female mutants is ontogenetically irreversible. True breeding, non-reverted female lines were developed (Shifriss, 1960) from dominant female mutants. These lines called S-pistillate types, were considered more advantageous for developing commercial castor hybrids over N-pistillate

(N 145-4) which required rogueing of 50% monoecious plants in crossing blocks. Since the genetic behaviour of S-pistillateness simulates a polygenic system, the NES-pistillate mechanism described by Zimmerman and Smith (1966) was considered more advantageous to the plant breeder since it involves transference of a single recessive gene (**f**) along with manipulation of environmentally sensitive genes (**s**) for interspersed staminate flowers influencing penetrance and expressivity.

The breeding and developmental behaviour of pistillate 240 line in early segregating generations indicates that it is a recessive female rendered homozygous for the female trait as well as interspersed staminate flowers through continuous selection under selfing. Inbreeding of the '240' female plants gives all female plants in the offspring with the expression of interspersed staminate flowers resembling the NES mechanism. The expression of interspersed staminate flowers without confining to a specific order of racemes further confirms that it is a recessive female combined with environmentally sensitive genes for the expression of interspersed staminate flowers. The 240 pistillate, therefore, is of the NES type.

The $CNES_1$ pistillate line developed by Zimmerman and Smith (1966) was propagated at a location having high summer temperature (July average of 32·78°C) when the penetrance and expressivity of interspersed staminate flowers was marked. The F_1 hybrid seed was produced at locations having lower summer temperatures (July averages 23·89°C to 28·33°C) with non-penetrance of interspersed staminate flowers. Compared with this, the pistillate line 240 produced only one or two staminate flowers per plant during *kharif* 1971 when the mean maximum temperature was 28·76°C. During *kharif* 1972 when the mean maximum temperature was 31·5°C, 18·56 interspersed staminate flowers were produced per plant. Further, it is also of interest to note that in *kharif* 1971 one or two interspersed staminate flowers developed at a particular developmental phase on primary and secondary racemes when the mean maximum temperatures was 31·6°C in September, 1971. Thus, the temperature of about 31–32°C appears desirable for maximum expression of interspersed staminate flowers. The maintenance of 240 pistillate line and hybrid seed production could, therefore, be accomplished at the same location. By advancing planting dates during *kharif* season, more number of male flowers are encouraged for the maintenance and multiplication of the pistillate line. For purposes of multiplication of the pistillate line in an isolation, dusting of the stigmas with pollen from the interspersed staminate flowers could be accomplished by a few unskilled workers. 930 kg of selfed seed per hectare was obtained by following this procedure and could be improved with experience.

If *kharif* plantings are delayed flowering coincides with low temperatures resulting in only pistillate racemes and such plantings could be used to establish crossing blocks. The few late developing staminate flowers, if any, may automatically drop off and not cause any serious inbreeding problems. If desired,

they could be removed manually. Pistillate 240 has, therefore, advantages for maintenance as well as establishing crossing blocks at the same location.

In the context of emphasis being laid on development of male steriles of maize and sorghum based on diverse cytoplasmic sources to minimize the possible genetic vulnerability attributable to a common source of cytoplasm, the development of diverse pistillate lines of castor is worth the efforts. Pistillate 240 is characterized by a low node number (12), normal plant type, medium tall (165 cm), red stem, double bloom, non-spiny and non-shattering capsules and has an oil content of 54·5%. It is, therefore, a desirable genotype from plant breeding considerations. Studies are in progress to study its combining ability and identify suitable male parents to develop commercial hybrids.

Summary

The development of a stable pistillate castor 240 is reported. The breeding and developmental behaviour of 240 pistillate indicates it to be of the NES type. The expression of a few interspersed male flowers is not confined to any particular order of racemes but is temperature dependent. Temperatures of 31–32° C promote interspersed male flowers while lower order temperatures result in fully female racemes. By manipulating planting dates multiplication of the pistillate line and establishment of crossing blocks could be achieved at the same location. Pistillate 240 has desirable attributes such as low node number (12), normal plant type, medium tall, red stem, double bloom, non-spiny and non-shattering capsules and an oil content of 54·5%.

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