Influence of environment on quality hybrid seed production in castor : A case study of participatory seed production

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ABSTRACT

This paper highlights the observations made regarding the influence of environmental factors on genetic purity of hybrid seed produced during the participatory seed production of two castor hybrids *viz.,* DCH 177 (DPC 9 x DCS 9) and DCH-519 (M 574 x DCS 78) in two villages of Mahabubnagar district, Telangana. Preliminary observations indicated that development of environmentally sensitive interspersed staminate flowers (ISF) on pistillate lines was influenced by their genetic nature, soil and agronomic management of crop as well as weather parameters. Higher incidence of ISF was observed in shallow and red soils irrigated by furrow method compared to medium/deep, clay loamy and black soils irrigated and fertigated by drip method, leading to higher number of selfed female plants, low genetic purity of certified hybrid seed (<85%) and rejection of seed lots during certification. Abiotic stress factors like maximum temperature (>32°C temperature) increased the number of ISF in primary spike order itself and later decreased in subsequent spike orders owing to decreased temperatures. Incidence of whiteflies and *Spodoptera* was particularly high in intensively cultivated agro-ecosystems. Small and marginal farmers depending on family labour were better suited for hybrid seed production of castor. Selection of suitable agro-ecosystem, farmers and their training, and genetic nature of parents proved to be critical requirements for hybrid seed production in castor.

Keywords: Castor, Genetic purity, Hybrid seed quality, Interspersed staminate flowers (ISF), Temperature

Castor (*Rcinus communis* L.) is an important commercial, industrial and non-edible oilseed crop suitable for both rainfed and irrigated cultivation in tropical and sub-tropical climatic conditions. Castor, a monotypic genus, with the chromosome number of 2n=20 and belongs to family Euphorbiaceae (Moshkin, 1986; Weiss, 2000). World's first castor hybrid, GCH-3, based on exotic line TSP 10 R crossed with JI 15 inbred as male, was released in 1968 at Oilseeds Research Station, Junagadh, Gujarat, India (Lavanya *et al*., 2019). Among the 22 hybrids released through active collaboration between ICAR-IIOR and State Agricultural Universities (SAUs), GCH-7, GCH-4, GAUCH-1, GCH-2, DCH-177, DCH-519, PCH-111 and YRCH-1 are prominent for their seed yield and wilt resistance (Lavanya *et al*., 2019).

Castor was cultivated in an area of 9.7 lakh hectare with a production of 16.6 lakh tonnes and 1720 kg/ha productivity (Ministry of Agriculture and Farmers Welfare, 2017-18). Major area was in Gujarat (5.9 lakh ha/72%) followed by Rajasthan (1.3 lakh ha/15.9%) and in Andhra Pradesh and Telangana together (0.58 lakh ha/7%) during the year 2017-18.

Castor is a sexually polymorphic species having multiple sex forms *viz.,* monoecious form- the plant type with female flowers at the top and staminate or male flowers at the bottom of the inflorescence; the pistillate from - plant having pistillate flowers all along the main axis of raceme with or without staminate flowers (ISF), though, with varying intensity depending on the genetic nature, order of spike, age of the plant and other environmental conditions; and revertants (Shifriss,1960; Lavanya and Solanki, 2010). The proportion of female flowers is usually high in winter months (with monthly mean temperature 29-32°C) in plants having pistillate genetic nature, when the other abiotic factors like temperature, nutrition, etc., are optimum, while the same pistillate plants tend to produce racemes with higher ISF or rarely, monoecious in summer months at >32°C and due to increased abiotic stresses (Hegde *et al.,* 2003; Lavanya, 2002). This temperature influenced nature of ISF production is utilized in hybrid seed production of castor (Lavanya *et al.,* 2006). Under this scheme, the hybrid seed production is taken up in winter months (as no ISF are produced in pistillate lines) while the maintenance of pistillate lines (ISF produced during this season can effect self-pollination of the plant) is taken up during summer. Hybrid seed production in castor is complicated due to the influence of weather parameters like temperature, humidity, soil moisture, nutrition, etc., on sex expression (Prabakaran *et al.,* 2009; Lavanya *et al.,* 2006). Any aberration in weather parameters leads to development of environmentally sensitive ISF which need to be manually removed before pollen dehiscence. Any laxity in removal of off-types or manual removal of ISF lead to selfing of female plants and ultimately rejection of seed lots due to low genetic purity (<85%). In participatory hybrid castor seed production, despite imparting skills, several other abiotic factors like soil type, soil depth, method of irrigation, etc. play a key role in quality seed production. Observations made during the participatory hybrid seed production of DCH-177 and DCH-519 in two villages of Mahabubnagar district, Telangana during 2015-16 *rabi* season, are summarized in this communication with an aim that these

remarks could be considered while taking up similar programmes in future to improve the quality of seeds produced. However, the preliminary observations made in the present study require further studies for confirmation.

Participatory hybrid seed production of DCH 177 (DPC 9 x DCS 9) and DCH-519 (M 574 x DCS 78) was taken up in 42 acres in two villages; Doddigadda Tanda, Krishna Nagar, a tribal village near Shadnagar and Konkal near Shantinagar, Mahabubnagar district of Telangana state during September to February, 2015-16. Optimum dates of sowing (September 14 to October 14, 2015) were followed by all the farmers in both the villages in different soil types (Table 1 and Table 2). Most of the soils had loamy or clay texture with good fertility, drainage and nutrient availability. There were eight spells (3 to 25 mm) of rainfall from September 14 to October 14, 2015. All the seed production plots were visited regularly at 10-12 days interval from the time of farmer and land selection (August 15, 2015) to final harvesting (February 15, 2016). Data on number of ISF in different orders of the female parents was recorded by observing at least 10 random plants for each order of spikes in all the seed production plots. Weather data during September, 2015 to January, 2016 were collected from online sources (www.worldweatheronline.com). Temperatures recorded at Kurnool city were considered as it was nearly 20 km (aerial distance) away from the seed production plots in Konkal village (Table 3).

Pick-wise hybrid seed was harvested separately at maturity from the female lines, DPC-9 and M-574 in all the plots, threshed and weighed separately. Pick wise grow out test (GoT) was conducted to estimate the genetic purity as per the standards of seed technology (Ramachandram and Ranga Rao, 1988; DOR, 2009). Details of size of farmer holding, soil type, irrigation method, pick-wise yield and purity of seed in DCH-177 and DCH-519 hybrids is provided in the Table 1 and Table 2, respectively.

Best management practices indicate that deep loamy, fertile, neutral and well drained soils were best suited for hybrid seed production in castor (Ramachandram and Ranga Rao, 1988; DOR, 2009; Raghavaiah and Suresh, 2010). Castor crop cannot tolerate alkalinity but can withstand slight to moderate acidity of soil (Raghavaiah and Suresh, 2010). Our observations indicated that pistillate lines were more sensitive to problematic soils than male parents. Plant vigour and growth of both the parents was affected in shallow soils leading to higher number of ISF under nutrient and soil moisture stress (farmer 7 in Table 1).

In hybrid seed production plots, DPC-9, the female parent of DCH-177, was earlier in flowering (45-57 DAS) compared to M-574 (69 DAS), the female parent of DCH-519. Flowering in seed production plots of DCH-177 sown on September 14, 2015 in black soil near Konkal village and on September 22, 2015 in red sandy loam soil near Shadnagar, Mahabubnagar district indicated that flowering was earlier in red sandy loam (45 DAS) soils compared to that in black soils (57 DAS) though both the places received almost the same rainfall during the season.

Preliminary observations on the source of irrigation supply indicated that development of environmentally sensitive ISF was lower (<5 / spike) in female parents in drip irrigated and fertigated crop due to supply of optimum moisture and frequent supply of nitrogen, especially, just before emergence of each spike order. In case of 3rd farmer (Table 1), excess application of nitrogen (300 kg N/ha), through flood irrigation, resulted in lanky growth and lodging of particularly male parents, affecting pollen availability leading to more selfed female plants. Saran and Giri (1987) have reported that nitrogen plays an important role in expressing pistillate character in female parent as deficiency of nitrogen leads to more ISF. Ramachandram and Rangarao (1988) recommended NPK @ 60:40:0 kg/ha for varietal seed production and 80:60:0 kg/ha for female parent and hybrid seed production. In case of farmer 5 (Table 1), generation of ISF was lower (<5/spike), may be due to application of 10 tonnes/ha of farm yard manure for seed production plot.

Castor requires a moderately high temperature of 20-27°C with low humidity throughout the growing season. High temperature above 41°C at the time of flowering even for a short duration will result in bursting of flowers causing non-availability of pollen and poor seed set (Singh, 2001). Though the genetic nature of a parent is crucial in sex expression, many environmental factors such as availability of soil nutrients, day temperature (>32°C), photoperiod, age of the plant, soil moisture etc., also play an important role in it (Shifriss, 1960; Lavanya, 2002; Lavanya *et al.,* 2019). Pistillate tendency was relatively strong in primary raceme and young plants, provided other abiotic conditions were optimum (Shifriss, 1956). Ankineedu and Rao (1973) opined that pistillate character of castor is governed by homozygous recessive and environmentally sensitive gene and therefore, interspersed staminate flowers may not be confined to any particular order and are temperature dependent. Ramachandram and Ranga Rao (1980) reported that polygenes influence the pistillate character and is highly unstable and varies with crop management levels. Hegde *et al*. (2003) opined that moderate temperature of 32°C promoted female tendency while high temperature promoted male tendency and the percentage of pistillate flowers were the highest on the main raceme and it decreased gradually with subsequent raceme orders.

In the present study, the temperatures recorded high and were up to 1 to 2°C more than normal (average) maximum or minimum temperatures. The actual maximum temperatures (33-30°C), minimum temperatures (24-20°C) and actual average temperatures (28-25°C) from the month of October (2015) to January (2016) were following a decreasing trend

during this period (Table 3). ISF was recorded in the primary racemes itself and were in the range of 30-40 ISF per primary raceme in DPC-9 and 15-20 in M-574 (Table 3). The secondary racemes, which emerged in the 1st and 2nd week of December on the female parent DPC-9, also had high number of ISF in the range of 25-30. The number of ISF drastically reduced to a level of zero to 5 in the third and 4th order racemes of DPC-9 and 2nd and 3rd order racemes of M-574 female parents in the month of January, 2016. The decreasing temperatures have resulted in less number of ISFs in the 2nd to 4th order spikes. The observed differences in the number of ISF could be ascribed to the differences in temperatures recorded during primordial initiation (10-15 days prior to flowering) of different orders of spikes. This indicated the influence of temperature on production of ISF. Similar observations have been reported by Ankineedu and Rao (1973) and Ramachandram and Rangarao (1980).

The proportion of male flowers in the male parents DCS-9 and DCS-78 also reduced during the months of December-January (2015-16) as the low temperatures promoted female flowers. This also contributed for female selfed seed in the third pick of the DCH-177 hybrid seed lot. Thus the selection and development of male parent having stable male expression even in cool temperatures is an important requirement in castor breeding programme. The number of ISF in M-574 was relatively less primarily due to its genetic nature and also, to some extent, due to its late sowing and late flowering (10-12 days later than DPC-9), coinciding with decreasing temperatures. The high incidence of ISF in female parents, particularly in DPC-9 female parent, even after their manual removal, had significant impact on the genetic purity of hybrid seed (Table 4). A comparative study of the pick-wise genetic purity of hybrids also indicated overall mean and range of genetic purity of hybrid seed lots from DCH-519 (98%, 92-100%) was higher than that of DCH-177 (76%, 58-92%). Cost of seed production also increased due to more labour engaged for removing the ISF in its bud stage itself. Seed lots of DCH-177 from farmers 1 to 3 (Table 1) had low genetic purity (more selfed seeds) due to dependence on hired labour and could not remove ISF in their bud stage.

Table 1 Land holding size of farmer, soil type, type of labour, yield and purity of DCH-177 hybrid seed

Farmer	Land holding size and type of labour	Soil type and irrigation method	Area (acre)	Date of sowing	Pick	Purity of seed (%)	Production (kg)	Yield/acre (kg)
1*	Medium farmer, hired labour	Black cotton soil	4.45	14.09.2015	1	48	1647	370
					2	71		
					3	74		
2*	Medium farmer, hired labour	Black cotton soil	2.03	14.09.2015	1	27	1080	532
					2	70		
					3	82		
3*	Medium farmer, hired labour	Clay-loamy soil, medium depth	3.27	14.09.2015	1	50	1451	444
					2	65		
					3	59		
4**	Medium farmer, hired labour	Clay-loamy soil, drip irrigated	2.43	22.09.2015	1	87	1940	798
					2	80		
					3	83		
5*	Small farmer, family labour	Red soil, Medium depth	0.81	22.09.2015	1	83	662	817
					2	82		
					3	72		
6*	Marginal farmer, family labour	Red soil, Medium depth	0.73	10.10.2015	1	94	240	329
					2	94		
					3	87		
7*	Marginal farmer, family labour	Red soil and shallow (<30 cm)	1.24	22.09.2015	1	79	231	186
					2	85		
8*	Medium farmer, hired labour	Clay loamy soil, Medium depth	1.96	22.09.2015	1	87	940	480
					2	84		
					3	88		
9**	Medium farmer, hired labour	Red soil, Medium depth, drip irrigated	3.58	23.09.2015	1	84	1311	366
					2	80		
					3	76		

Marginal farmer: <1 ha, Small farmer: 1-2 ha, Medium farmer: 4-10 ha, Medium depth: 45-60 cm; *Furrow/flood irrigation; **Drip irrigation and fertigation

Table 2 Land holding size of farmer, soil type, type of labour, whitefly incidence, yield and purity of DCH-519 hybrid seed

Farmer	Land holding size, type of labour and whitefly incidence	Soil type	Area (Acres)	Date of sowing	Pick	Purity of seed (%)	Production (Kg)	Yield (kg/acre)
1**	Marginal farmer, No whitefly incidence, family labour	Clay-loamy, medium depth	1	28.09.2015	1	98	488	488
					2	97		
2**	Marginal farmer, No whitefly incidence, family labour	Clay-loamy, medium depth	1	28.09.2015	1	99	390	390
					2	100		
3*	Medium farmer, depending on hired labour, severe whitefly incidence	Clay-loamy, saline and shallow to medium depth	6	30.09.2015 & 05.10.2015	1	98	882	147
					2	99		
					3	98		
4*	Marginal farmer, moderate whitefly incidence, family labour	Black cotton soil, Medium depth	1.5	30.09.2015	1	97	356	237
					2	99		
					3			
5*	Marginal farmer, severe whitefly incidence, family labour	Red soil, medium depth	2.5	30.09.2015	1	99	436	174
					2	99		
6*	Medium farmer, Severe whitefly incidence, family labour	Red coarse soil with gravels, medium depth	2	30.09.2015	1	99	462	231
					2	99		
7*	Medium farmer, low whitefly incidence, hired labour	Clay-loamy soil, Medium depth	4	01.10.2015	1	99	1632	408
					2	99		
8*	Medium farmer, hired labour, severe whitefly incidence	Black soil, Saline, Medium depth	1	06.10.2015	1&2	99	104	104
9*	Marginal farmer, moderate whitefly incidence, family labour	Red soil, coarse shallow soil	1.5	14.10.2015	1&2	97	340	227

*Farmers at Konkal village, Shantinagar with intensive cropping pattern including Bt-cotton, chillies and other vegetables, ** Farmers near Narkhoda (Non-intensive agro ecosystem), Shamshabad. All farmers followed flood irrigation method

Table 3 Temperatures, order of racemes and number of ISF

Month	Temperature (°C)				Actual Average	Departure from Avg. Max. & Min.	Raceme (spike) order and Number of ISF			
	Average (2010-2012)		Actual (2015-16)				DPC-9		M-574	
	Max.	Min.	Max.	Min.			Order	ISF	Order	ISF
September,2015	33	24	32	25	28.0	-1 to +1	-	-	-	-
October	32	23	33	24	28.0	+1 to +1	-	-	-	-
November	31	20	29	22	25.5	-2 to +2	1st	30-40	1st	15-20
December	30	18	30	20	25.0	0 to +2	2nd	25-30	2nd	0-5
January,2016	32	18	30	20	25.0	-2 to +2	3rd and 4th	0-5	3rd	0-5

Source of temperatures: average and actual temperatures from world weather online.com at Kurnool city, Andhra Pradesh

Table 4 Pick wise genetic purity of DCH-177 and DCH-519 hybrid seed

Farmers	DCH-177				DCH-519				
	1	2	3	Average	Farmer	1	2	3	Average
1	48	71	74	64	1	98	97	-	98
2	27	70	82	60	2	99	100	-	100
3	50	65	59	58	3	98	99	98	98
4	87	80	83	83	4	97	99	-	98
5	83	82	72	79	5	99	99	-	99
6	94	94	87	92	6	99	99	-	99
7	79	85	-	82	7	99	99	-	99
8	87	84	88	86	8	99	99	-	99
9	84	80	76	80	9	97	97	-	97
Average	71	79	77.6	76	Average	98.3	98.60	98.0	98.60

Selection of an agro-ecosystem for castor hybrid seed production plays an important role for its success. There was severe whitefly infestation in *rabi* season, particularly in double and triple bloom parents, in the farms (farmer 3 to 9 of Table 2) of Konkal village, near Shantinagar (Mahabubnagar Dist.). This could be due to favourable agro-ecosystem for whiteflies infestation and multiplication, resulting from intensive cropping system involving cotton, chillies and other vegetables. Further studies are required to uncover the reasons for severe whitefly infestation in this context. Date of sowing of seed production varies with region and state depending on onset and duration of winter (DOR, 2009). Sowing time needs to be adjusted so as to coincide the primordial initiation of primary spike emergence with peak winter period in December-January. In conclusion, our preliminary observations during the participatory hybrid seed production indicated that, apart from the genetic nature of parents, their maintenance and selection of favourable agro-ecosystem, farmers with their own family labour, particularly women, were better suited for hybrid castor seed production as it was difficult for timely completion of various activities depending totally on hired labour. Small and marginal farmers played very pro-active role in most of the activities of crop management and were best suited for seed production of castor. Feedback from the farmers indicated that timely removal of ISF and also management of whitefly infestation was difficult and costly involving an expenditure of up to ₹ 6000-10000 per acre. However, with an average hybrid castor seed yield of 104-798 kg and an expenditure of ₹ 15,000-25,000 per acre, most of the farmers were benefited with minimum net return of ₹.25000/acre.

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