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IDEAL PLANT CHARACTERS FOR MAXIMIZING YIELD UNDER RAINFED CONDITIONS IN CASTOR (*RICINUS COMMUNIS* L.)

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SUMMARY

A study was conducted with an objective of identifying the growth characters which influence yield potential under rainfed situations thereby defining an ideal plant type for rainfed situations. Seventy genotypes with distinct morphological characters were studied during rainy season from 1995-96 to 1998-99. Observations on different growth characters viz., plant height, number of branches, number of leaves, petiole length, node number, length of different order branches, leaf area, days to flowering, dry matter production, yield and yield components were recorded. The genotypes were categorized into different groups for each of these characters. Depending on nature of curve, suitable regression equations were worked out. Based on that, the ideal characters of castor for rainfed situations are proposed. These include dwarf to medium height (50-60) cm), short to medium durtion (120-150 days), 2-3 secondary and tertiary order branches with better orientation of leaves and branches for efficient light utilization, medium sized leaves of 35-40 with LAI of 3-3.5, long productive spikes with bold capsules and seeds, better harvest index (30-40%) with pest and disease resistance.

Key words: **Castor, ideotype, traits, yield.**

INTRODUCTION

Castor is grown in an area of 7.5 lakh ha with production of 7.7 lakh tonnes and productivity of 1210 kg/ha. India ranks first in castor production in the world. Gujarat and Rajasthan contribute 88% of the total castor production in our country and share 60% of the total castor growing area. However, castor productivity in rainfed area is very low (350 kg/ha). Since the area under cultivation is fixed, production per unit area i.e. genetic yield potential has to be increased to meet the demand. The empirical approach for the genetic improvement of a crop consists of 'defect elimination' and 'selection for enhanced yield (Hamblin 1993). But in the analytical approach, a model (or ideotype) should be established for each specified environment, aiming to increase the productivity in that specific situation. Ideotypes often have been determined with inputs from plant and crop physiology and morphology. The goal of ideotype breeding is to define theoretically the most efficient plant type for that crop and then breed towards this goal (Donald 1968). So, selection on growth characters of yield rather than selection on yield *per se* is pathway for maximizing yield potential per unit area and per unit time. Therefore, the relationships between growth characters and yield potential need to be established. Until recently, castor improvement is concentrated on varietal or hybrid development or agronomic management. Though, there is wide variation in productivity of this crop, the physiological basis for these variations were not studied. Therefore, the present study was proposed to define the ideal plant type for rainfed conditions by identifying the growth characters that influence yield potential in castor.

MATERIALS AND METHODS

Seventy genotypes including cultivated varieties, hybrids and germplasm lines with distinct morphological

Table 1a. Morphological characters of castor germplasm lines.

	Germplasm	Leaf Type			Duration				Node Number			Internodal length		Branching		Plant height			
		L*	S	P	EE	E	M	L	VL	L	H	E	C	C	D	D	M	T	TA
1	RG 17					E			VL			E		C		D			
2	RG 19					E			VL			E		C		D			
3	RG 22					E			VL			E		C			M		
4	RG 26					E			VL			E			D	D			
5	RG 28					E			VL			E		C		D			
6	RG 65					E				L		E		C		D			
7	RG 81									L			C	C		D			
8	RG 86		S						VL			E			D	D			
9	RG 91					E				L		E			D	D			
10	RG 170	L			EE					L		E		C			M		
11	RG 183					E			VL			E			D		M		
12	RG285					E				L		E			D		M	T	
13	RG 295		S							L		E		C			M		
14	RG 313		S							L		E		C					
15	RG 328										H	E			D			T	
16	RG 352				EE					L		E		C				T	
17	RG 388	L									H	E		C				T	
18	RG 389										H	E		C					
19	RG 391										H	E		C			M		
20	RG 398									L		E		C			M		
21	RG 428									L		E			D		M		
22	RG 429		S							L		E			D		M		
23	RG 640		S						VL			E	C		D	D			
24	RG 662										H	E	C				M		
25	RG 713										H	E		C			M		
26	RG 714		S							L		E		C			M		
27	RG 757						M			L		E		C			M		
28	RG 759		S				M			L		E			D		M		
29	RG 760						M			L		E			D		M		
30	RG 1594							L		L		E			D				VT
31	RG 1605	L						L			H	E			D				VT
32	RG 1607	L						L			H	E			D			T	
33	RG 1611	L									H	E		C					VT
34	RG 1615							L			H	E						T	
35	RG 1618									L		E			D			T	
36	RG 1633	L									H	E			D				VT
37	RG 1641							L		L		E					M		
38	RG 1646	L						L			H	E							VT
39	RG 1739			P							H	E		C					

(Continue....)

	Germplasm	Leaf Type			Duration				Node Number			Internodal length		Branching		Plant height			
		L*	S	P	EE	E	M	L	VL	L	H	E	C	C	D	D	M	T	TA
40	RG 1740			P							H	E		C					
41	RG 1756			P						L		E		C			M		
42	RG 1759			P							H	E			D		M		
43	RG 1771			P						L		E		C			M		
44	RG 2047		S							L		E			D		M		
45	RG 2049										H	E			D		M		
46	RG 2107	L									H	E		C				T	
47	RG 2152	L									H	E		C				T	

*Leaf type; L-large, S-small, P-papaya
Duration: EE-extra early, E-early, M-medium, L-late
Node number: VL-very low, L-low, H-high
Internodal length: E-elongated, C-condensed
Branching: C-convergent, D-divergent
Plant height: D-dwarf, M-medium, T-tall, VT-very tall

Table 1 b. Yield components of castor germplasm lines.

	Germplasm	Spike characters					Seed characters			Capsule characters			
		*B	C	L	LP	HP	S	B	HS	S	NS	B	SM
1	RG 268			L						S			SM
2	RG 286			L			S			S			SM
3	RG 328			L			S			S			SM
4	RG 339			L	LP					S			
5	RG 347	B			LP					S			
6	RG 388			L							N		
7	RG 389	B									N		SM
8	RG 417			L			S			S			
9	RG 639			L			S				N		
10	RG 655		C								N		
11	RG 1594			L			S			S		B	
12	RG 1597	B	S				S			S		B	
13	RG 1597		C										
14	RG 1605	B				HP	S			S		B	
15	RG 1607			L			S	B		S			
16	RG 1611		C							S			
17	RG 1615	B						B				B	
18	RG 1618		C					B		S		B	
19	RG 1627		C						HS	S		B	
20	RG 1633			L					HS	S		B	
21	RG 1641		C			HP				S			
22	RG 1646		C										
23	RG1690							B					
24	RG 2047			L			S			S			SM
25	RG 2049			L			S			S			SM

*Spike characters: B-broad, C- compact, L-loose, LP-long effective primary spike, HP-high no. of productive spikes
Seed characters: S-small, B-bold, HS-high seed weight
Capsule characters : S-spiny, NS-non spiny, B-bold, SM-small

characters were studied during rainy season from 1995-96 to 1998-99. The genotypes along with distinct characters are given in Table 1a and 1b.

The experiments were laid out in RBD with three replications at Narkhoda farm of DOR. After thorough ploughing of the land, plots of 9 x 3.6 m were made for each treatment. Sowing was done after seed treatment with thiram @ 3g/kg seed at spacing of 90 x 30 cm. Irrigation, weeding and plant protection measures were taken depedning on the requirement. Observations on different growth characters viz., plant height, number of branches, number of leaves, petiole length, node number, length of different order branches, leaf area, dry matter partitioning into different plant parts viz., leaf, stem, reproductive structures etc., yield components and yield were recorded at different stages of plant growth. Non destructive data were recorded on five plants in each treatment. Destructive sampling was done with two plants per treatment per replication. Yield was recorded in five plants.

The genotypes studied were categorized into different groups for each character. Correlation coefficients for important characters with yield were calculated. Regression analysis was carried out for all the characters. Step wise regression was run to identify important characters related to yield. The individual regression equations for all characters were derived taking into consideration the type of relationship (linear, quadratic etc.) between that particular character and yield. The regression equation fitted for these characters is $Y = a - \beta x - \gamma x^2$ where Y = yield, a = intercept, βx = coefficient for x, γx^2 = coefficient of X^2.

Depending on the nature of curve, suitable regression equations were worked out. Based on these relationships, the ranges for ideal characters were defined.

RESULTS AND DISCUSSION

Data on different growth characters viz., plant height, number of branches, number of leaves, petiole length, node number, length of different order branches, leaf area, dry matter partitioning into different plant parts viz., leaf, stem, reproductive structures etc., yield components and yield were recorded at different stages of plant growth. Correlation coefficients for improtant characters with yield were calculated and presented in Table 2. Yield showed significant positive correaltion with most of the spike characters upto tertiary order, crop duration, TDM and internodal length. Muthaiah *et al.* (1982) also reported that spike length, number of effective spikes, number of capsules on main spike and plant height has maximum direct and positive correlation with seed yield.

Important characters that showed significant correlation with yield (Y) based on step wise regression analysis are Y = 1105 + (-47.1 (Node No.) + {-62.4 (S+T branches)} + 10.73 (LAI) + {80.88 (leaf wt)} + (-25.7 (P+S+T capsule No.)} + (-10.6 (P+S capsule) weight)} + 11.2 (P+S+T capsule weight) + (16.3) (mean test weight).

Table 2. Correlation coefficients of important characters with yield

Character	Correlation coefficient with yield (Significant at 5%)		
Internodal length	0.30		
Stem girth	0.30		
Stem weight	0.30		
TDM	0.45		
Duration	0.37		
Spike characters	Primary	Primary + Secondary	Primary + Secondary + Tertiary
Effective spike length	0.38	0.44	0.33
Capsule no/plant	0.25	0.28	0.35
Capsule weight g /spike	0.41	0.46	0.59
Test weight (g)	0.25	0.38	0.49

The individual regression equations for important characters are given in Table 3. Based on these relationships in association with visual observation and imagination, the ideal characters for castor under rainfed conditions are listed in Table 4.

Desirable morpho-physiological characters

Castor plant with dwarf to medium height is desirable. Very tall plants (germplasm lines) are usually without any branches or with one or two branches. In these plants,

Table 3. Regression analysis of improrant characters

Character	Regression equation	R value
Plant height	$Y = 2529 + 0.94x - 0.004 X^2$	0.47
Node No.	$Y = 1973 + 25.57 - 0.17 X^2$	0.15
Internodal length	$Y = 1129 + 319.9x - 9.98 X^2$	0.79
Leaf No.	$Y = 1490 + 28.37x - 0.137 X^2$	0.66
Leaf weight	$Y = 1591 + 24.31x - 9.106 X^2$	0.71
LAI	$Y = 2584 + 18.99 - 0.0778 X^2$	0.64
Capsule No. (P+S+T)	$Y = 1771 + 14.99x - 0.0207 X^2$	0.60
Capsule weight (P+S+T)	$Y = 2002 + 11.76x - 0.0154 X^2$	0.65

Table 4. Ideal range for different characters

Character	Ideal range		
1. Plant height (cm)	50-60		
2. Node number	8-10		
3. Internodal length (cm)	6-7		
4. Stem girth (cm)	10-13		
5. Leaf number	35-40		
6. LAI	3-3.5		
7. Leaf weight (gpl^{-1})	40-50		
8. Steam weight (gpl^{-1})	100-150		
9. Total dry weight (g pl^{-1})	300-400		
10. Duration (days)	120-150		
11. Harvest index (%)	30-40		
	Primary	*Secondary*	*Tertiary*
12. Branches			
a) number	-	2-3	2-3
b) length (cm)	-	50-60	40-50
c) node number	-	5-6	5-6
d) angle	-	65°	50°
13. Petiole length (cm)	35	25	20
14. Leaf angle	55-60°	50-55°	45-50°
15. Spike characters			
a) effective spike length (cm)	40-50	20-30	15-20
b) capsule number $spike^{-1}$	40-50	30-40	20-30
c) capsule weight (g $spike^{-1}$)	30-40	50-60	15-20
16. Test weight (g)	20	25	20

though the vegetative growth i.e. photosynthetic accmulation in stem is very high, translocation to the sink is poor. Node number represent duration in castor. Tall plants with more nodes and inter nodal length and without branches is not a desirable trait.

More branches (> 3) with indeterminate growth increases crop duration and hinders taking up sowing of second crop. Capsules of late formed spikes would not be filled properly and lead to less yield advantage. So a plant with 2-3 secondary and 2-3 tertiary order branches with crop duration of 120-150 days is ideal (Table 4). Vergera Chang and Lilis (1969) also opined that variation in crop duration largely reflects differences in the vegetative growth period. Branching habit (upto 2-3 secondary and tertiary branches) is essential for rainfed situations to compensate yield losses due to biotic and abiotic stresses. Branches with wide branch and leaf angle with long petioles with somewhat horizontally oriented leaves at bottom, leaves with plagiofil orientation (less branch, leaf angle and petiole length) in the middle and erect leaves at the top increases interception of light by the crop and photosynthate production. More number of medium sized leaves (35-40) with an LAI of 3-3.5 is ideal for efficient solar energy utilization. Crop uses light more efficiently at high LAI in an erect leafed canopy (Yoshida, 1976). Tanaka (1976) also revealed that a plant community with vertically oriented leaves gives better light penetration and higher carbon assimilation per unit leaf area.

Yield and yield components

Long effective spikes with more number of capsules associated with bold seeds are desirable. Different ideal

Table 5. Ideal plant characters present in different germplasm lines

	Trait	Range	Germplasm line
1.	Plant	50-60cm	RG 86, RG 388, RG 417, RG 2047
2.	Node No.	8-10	Aruna, RG 28, RG 65, RG 285
3.	Internodal length	6-7cm	RG 17, RG 170, RG 352, RG 388, RG 1544, RG 1646, RG 2047, RG 2049
4.	Stem girth	10-13cm	RG 17, RG 22, RG 170, RG 352, RG 1646, RG 2047
5.	Sec. + Tert. branches	2-3 + 2-3	RG 22, RG 285, RG 428, RG 1740
6.	Leaf number	35-40	DCS-9, GCH-4, VP-1, RG 352, RG 2047
7.	Leaf weight	40-50g	RG 17, RG 170, RG 1611, RG 2047
8.	LAI	3-3.5	RG 81, RG 389, RG 1615, RG 2107
9.	Stem weight	100-150 g	48-1, VP-1, RG 81, RG 170, RG 328
10.	Total drymatter	300-400 g	VP-1, RG 17, RG 22, RG 1756, RG 2047
11.	Duration	120-150 days	Aruna, DCS-9, RG 1, RG 26, RG 352
12.	Effective spike length		
	a) primary	40-50cm	VP-1, RG 1646, RG 1739
	b) secondary	20-30cm	RG 170, RG 352, RG 388, RG 1611, RG 1615, RG 1646, RG 1739
	c) Tertiary	15-20 cm	GCH-4, RG 389, RG 1594, RG 1615, RG 1646, RG 1740, RG 1778, RG 2049
13.	Capsule no./ spike		
	a) primary	40-50	VP-1, RG 170, RG 1611, RG 1615, RG 2049, RG 1646
	b) Pri. + Sec.	70-90	RG 1611, RG 1615, RG 1646, RG 2049
	c) Pri. + Sec + Tert.	90-120	RG 91, RG 285, RG 1615, RG 1646, RG 2049
14.	Capsule weight / spike		
	a) Primary	30-40g	GCH-4, RG 170, RG 1611, RG 1615, RG 2049
	b) Pri. + Sec.	80-100g	VP-1, GCH-4, RG 170, RG 388, RG 1615, RG 2049
	c) Pri. + Sec. + Tert.	95-120g	RG 170, RG 389, RG 1607, RG 1615, RG 1740, RG 2049

spike characters are listed in Table 4. Harvest index is low (0.1 to 0.2) in castor as translocation of assimilates from source to sink, especially from stem reserves is less even though biomass production is more. There is a scope for improvement of HI to 0.4-0.5 by increasing translocation efficiency and sink size. Sink size can be increased by increasing effective spike length, capsule number and test weight. Resistance to pests and diseases like wilt, botrytis grey rot and semilooper is essential to get maximum yield potential in castor.

There is a possibility to develop the proposed ideotype as the required genetic deversity for the desired traits exist in the germplasm. Different germplasm lines with desired plant characters are presented in Table 5. With incorporation of all these characters into one genotype through breeding programme 5-6 tons/ha of seed yield can be realized even under rainfed situation. The castor plant of dwarf to medium height, short to medium duration, 2-3 secondary and tertiary order branches, better orientation of leaves and branches for efficient light utilization, medium sized leaves, long productive spikes with bold capsules and seeds, better harvest index and resistance of pests and diseases is ideal for rainfed situations.

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