International Journal of Agricultural Sciences
Volume 12 | Issue 1 | December, 2016 | 22-27 ■ e ISSN-0976-5670
DOI:10.15740/HAS/IJAS/12.1/22-27
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RESEARCH PAPER

Character association and path analysis in castor (*Ricinus communis* L.)

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Abstract : Total seed yield g per plant exhibited significant positive correlation with seed yield at 120, 150, 180 days after sowing, total and effective length of primary spike, 100 capsule and seed weight, shelling per cent and oil content. Yield was significantly negatively correlated with number of nodes upto primary spike and seed specific gravity. Path analysis revealed that yield at 120 and 180 days after sowing, effective length of primary spike, and seed specific gravity exhibited significantly high direct effects in positive desirable direction. The number of nodes up to primary spike and total length of primary spike exhibited highly significant direct effects in negative direction for total seed yield. Their association with total seed yield was significant and positive indicating the factor that there exists a true and perfect association between these traits.

Key Words : Correlation, Direct, Indirect effects, Castor, *Ricinus communis*

View Point Article : Patel, J.K. and Nakarani, D.B. (2016). Character association and path analysis in castor (*Ricinus communis* L.). *Internat. J. agric. Sci.*, **12** (1) : 22-27.

Article History : Received : 18.05.2015**; Revised :** 07.11.2015**; Accepted :** 22.11.2015

INTRODUCTION

Castor (*Ricinus communis* L.) with 2n=20, an important industrial non-edible oil seed crop belongs to the family Euphorbiaceae, indigenous to Eastern Africa. It is grown in arid and semi-arid regions. Yield is a complex character which depends upon many determining characters hence, the information on correlation between yield and its component character is prerequisite for crop improvement. The phenotypic correlation indicate the extent of observed relationship between the two characters while genotypic correlation provides information about linkage for the gene controlling the pair of characters. Therefore, the correlation co-efficient at genotypic and phenotypic levels were considered, however, they do not provide the exact picture of direct and indirect cause of such association, which can be cleared through path analysis. Thus, path analysis is very useful to pin point the important yield components which can be utilized for recommending selection indices. In the present studies attempts was, therefore, made to obtain such information in castor.

MATERIAL AND METHODS

The experimental material for present study comprised of 43 indigeneous genotypes of castor (*Ricinus communis* L.) collected from Regional

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Research Station, Sanand, Main Castor and Mustard research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Research Scientist (Groundnut) Junagadh Agricultural University, Junagadh. The field experiment was carried out in a Randomized Block Design with three replications at Agricultural Research Station, Sansoli. Each plot consisted of single row of 6 m length with a spacing of 60 cm length between two plants and 120 cm between two rows. Two border rows were planted at both the side to reduce the border effect. The recommended package of practices of crop production and protection were followed for successful crop growth.

The observations regarding the seed yield per plant and yield determing attributes were recorded on randomly selected five competitive plants from each genotype in each replication for eighteen characters. The correlation co-efficient were worked out to understand the association among characters by adopting method described by Singh and Chaudhary (1977) and path analysis was done according to the procedure suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The summary of the genotypic and phenotypic correlations for seed yield and eighteen agronomic traits is presented in Table 1. Generally, the genotypic and phenotypic both types of correlation were of comparable magnitude, the genotypic correlation were in most cases higher than the phenotypic correlation indicating that the characters were more related genotypically. From the correlation studies (Table 1), it was evident that, the characters *viz.*, seed yield at 120, 150 and 180 days after sowing, total and effective length of primary spike, 100 capsule and seed weight, shelling percentage and oil content showed significant positive association with total seed yield at genotypic and phenotypic level, indicating possibility of improving these characters simultaneously. Generally, the nature of inter trait correlations may enhance or retard the selection progress. A positive relationship indicates that the selection for improvement in one of the yield components would result in concomitant increase in one or more components. Similar significant positive correlations were reported by Tewari and Mishra (2013) for seed yield and number of capsules in primary raceme, number of effective spikes per plant, 100 seed weight, and oil content. Seed yield per plant and capsule yield by Ahmed *et al*. (2012) in M_4 and M_5 generations and seed yield per plant and number of spikes per plant in M_5 generation. Adeyanju *et al*. (2010) for oil yield percentage and days to 50 per cent germination, days to 50 per cent flowering, fruit yield, 100 seed weight, days to maturity, pedicel length and plant height. Significant positive correlations were also reported by Sarwar *et al*. (2010) for seed yield and main spike length, capsules of main spike, capsules of secondary spike and spikes per plant in M_5 generation and seed yield per plant and capsule weight per plant in M_4 generation by Sarwar and Chaudhry (2008).

This relationship was recorded among the agronomic traits in this study. Positive and significant genotypic and phenotypic relationships among the traits seed yield per plant, 100 seed weight, days to 50 per cent flowering, seed yield, days to maturity, pedicel length and plant height suggests that seed yield can be improved through selection for this yield components. Aswani *et al*. (2003) reported that number of capsules in primary spike, number of spikes per plant, number of days to 50 per cent flowering and maturity, length of primary spike and 100 seed weight were the major yield contributing characters in castor.

This significant positive relationship among agronomic traits in this study at genotypic and phenotypic level is in accordance with the report of Yadav *et al*. (2004). Improvement of castor seed yield can, therefore, be achieved through selection of these highly correlated characters as increase in mean value of any one of the characters would significantly increase the mean of others.

The association between total seed yield and number of nodes up to primary spike (-0.568) and seed specific gravity (-0.556) were highly significant and negative at genetic as well as phenotypic level, suggesting the negative relation of those traits with total seed yield per plant. Significant negative correlations were also reported by Tewari and Mishra (2013) for seed yield and number of nodes to primary raceme, days to maturity of spike. The association between total number of branches and effective number of branches were positive but non-significant at phenotypic level, suggesting the absence of any relation of those traits with total seed yield per plant. Whereas, days to 50 per cent flowering (-0.064), days to maturity of primary spike (-0.105) and number of capsules on primary spike (-0.115) showed negative but non-significant association with total seed yield per plant suggesting the absence of any relation of those traits with total seed yield. Such non-significant negative

Table 1 : Genotypic (above diagonal) and phenotypic (below diagonal) correlation of 18 characters in castor

Characters	Seed yield (g/plant) 210 days after sowing	120 days after sowing	150 days after sowing	180 days after sowing	Days to 50 % flowering	Days to maturity	Number of nodes up to primary spike	Plant height upto primary spike (cm)	Total length of primary spike	Effective length of primary spike	Number of capsules on primary spike	Total number of branches	Effective number of branches per plant	100 capsule weight (g)	100 Seed weight (g)	Shelling percentage (%)	Seed specific gravity	Oil content (%)
1.	1.000	0.923**	0.989**	0.984**	-0.064	-0.105	-0.568**	0.188	0.363*	0.361*	-0.115	0.051	0.018	0.484**	0.327*	0.315*	-0.556**	0.547**
2.	0.767**	1.000	0.883**	0.873**	-0.247	-0.226	-0.580**	0.147	0.243	0.254	-0.124	-0.161	-0.129	0.374*	0.233	0.440**	-0.617**	0.500**
3.	0.850**	0.772**	1.000	0.995**	-0.172	-0.189	-0.401**	0.184	0.458**	0.459**	-0.021	0.133	0.145	0.402**	0.195	0.152	-0.507**	0.508**
4.	0.919**	0.776**	0.955**	1.000	-0.181	-0.174	-0.411**	0.167	0.417**	0.419**	-0.057	0.112	0.089	0.325*	0.154	0.250	-0.448**	0.474**
5.	-0.060	-0.177*	-0.123	-0.124	1.000	0.671**	-0.069	0.298	0.117	0.145	-0.048	0.378*	0.393**	0.348*	0.204	-0.018	-0.165	-0.119
6.	-0.098	-0.140	-0.140	-0.156	0.487**	1.000	-0.034	0.373*	-0.051	-0.021	0.012	0.395**	0.398**	0.100	0.003	-0.044	-0.021	-0.452**
7.	-0.376**	-0.442**	-0.236**	-0.226*	-0.059	-0.069	1.000	-0.045	-0.094	-0.087	0.088	0.295	0.192	-0.710**	-0.489**	-0.119	0.810	-0.434**
8.	0.120	0.112	0.107	0.085	0.168	0.235**	-0.045	1.000	0.084	0.098	-0.076	0.413**	0.413**	0.057	0.031	0.039	-0.152	0.063
9.	0.252**	0.168	0.267**	0.277**	0.131	-0.033	-0.069	-0.055	1.000	0.998**	0.662**	0.417**	0.497**	0.075	-0.044	-0.244	-0.303*	0.017
10.	0.273**	0.175*	0.266**	0.290**	0.140	-0.017	-0.070	-0.049	0.984**	1.000	0.628**	0.391**	0.469**	0.093	0.006	-0.201	-0.280	0.011
11.	-0.055	-0.099	-0.005	-0.021	-0.072	-0.042	0.118	-0.015	0.468**	0.437**	1.000	0.236	0.259	-0.193	-0.368*	-0.286	-0.063	-0.127
12.	0.052	-0.084	0.063	0.061	0.225*	0.266**	0.215*	0.317**	0.258**	0.264**	0.177*	1.000	0.962**	-0.066	-0.082	-0.383*	-0.054	-0.186
13.	0.073	-0.069	0.079	0.084	0.195*	0.279**	0.135	0.302**	0.285**	0.291**	0.180*	0.371**	1.000	-0.055	-0.035	-0.319*	-0.143	-0.070
14.	0.393**	0.298**	0.246**	0.241**	0.240**	0.076	-0.518**	0.035	0.092	0.105	-0.094	-0.028	0.025	1.000	0.951**	0.184	-0.645**	0.459**
15.	0.341	0.243	0.165	0.183	0.155	0.030	-0.333	-0.014	-0.062	-0.039	-0.269	-0.054	-0.018	0.695	1.000	0.307*	-0.376*	0.510**
16.	0.130	0.194*	0.091	0.118	-0.004	-0.044	-0.081	-0.030	-0.113	-0.085	-0.165	-0.121	-0.116	-0.091	0.146	1.000	0.066	0.105
17.	-0.411**	-0.456**	-0.342**	-0.304**	-0.092	-0.020	0.672**	-0.116	-0.231**	-0.212*	-0.072	-0.018	-0.087	-0.477**	-0.289**	0.022	1.000	-0.395**
18.	0.353**	0.348**	0.301**	0.299**	-0.117	-0.258**	-0.308**	0.021	0.020	0.040	-0.077	-0.122	0.000	0.355**	0.290**	0.054	-0.281**	1.000

* and ** indicate significance of values at P=0.05 and 0.01, respectively

correlation were reported for seed yield and days to 50 per cent flowering, height up to primary raceme by Tewari and Mishra (2013), for seed yield per plant and days to mature, plant height in M_4 and M_5 generations, for seed yield per plant and length of main spike, number of capsules of main spike in M_4 generation and 100 seed weight in M_5 generation by Ahmed *et al*. (2012). Seed yield and plant height, 100 seed weight were non-significant negatively correlated in M_5 generation reported by Sarwar *et al*. (2010). Negative non-significant correlation were also reported for seed yield per plant and days to mature, plant height, length of main spike, number of capsules of main spike in M_4 generation by Sarwar and Chaudhry (2008).

Table 2 and 3 shows the combine summary of the direct and indirect genotypic and phenotypic effects of eighteen agronomic traits on castor seed yield, respectively. The results show that effective length of primary spike, seed yield at 120 days after sowing, seed specific gravity and seed yield at 180 days after sowing had significant positive direct path co-efficient with total seed yield. The direct effect of total length of primary spike and number of nodes up to primary spike were found significant negatively associated. Path co-efficient analysis indicated that the effective length of primary spike (1.376), seed yield at 120 days after sowing (0.691), seed specific gravity (0.510) and seed yield at 180 days after sowing (0.437) had large positive direct effects on seed yield per plant.

Path analysis indicated the importance of seed yield per plant, effective length of primary spike, seed yield at 120 days after sowing, seed specific gravity and seed yield at 180 days after sowing suggesting that these traits should be given main emphasis for evolving high yielding genotypes of castor. Positive correlation of seed yield with number of capsules in primary raceme and 100 seed weight was observed by Raghuwanshi *et al*. (2003). High direct positive effect were observed for seed yield and days to 50 per cent flowering, number of effective spikes per plant, number of capsules in primary raceme and oil content by Tewari and Mishra (2013).

Babu *et al*. (2004) reported that oil yield per plant was positively associated with number of primaries per plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight, leaf area index, harvest index and seed yield per plant both at genotypic and phenotypic level. Seed yield per plant exerted the highest positive direct effect on oil yield per plant followed by number of primaries per plant, oil content, leaf area index

Table 2 : Direct (main diagonal) and indirect (above and below diagonal) genotypic path effects of different characters towards total seed yield in castor

Characters	Seed yield (g/plant)			Days to 50 % flowering	Days to maturity	Number of nodes up to primary spike	Plant height upto primary spike (cm)	Total length of primary spike	Effective length of primary spike	Number of capsules on primary spike	Total number of branches	Effective number of branches per plant	100 capsule weight (g)	100 Seed weight (g)	Shelling percentage (%)	Seed specific gravity	Oil content (%)	Correlation with seed yield (g/plant)
	120 days after sowing	150 days after sowing	180 days after sowing															
1.	0.691**	0.082	0.381*	-0.061	0.057	0.250	-0.006	-0.399**	0.350*	-0.020	-0.041	-0.008	0.094	-0.034	-0.069	-0.315**	-0.030	0.923**
2.	0.610**	0.093	0.435**	-0.043	0.048	0.173	-0.008	-0.752**	0.631**	-0.004	0.034	0.010	0.101	-0.028	-0.024	-0.258	-0.031	0.989**
3.	0.603**	0.092	0.437**	-0.045	0.044	0.177	-0.007	-0.684**	0.577**	-0.009	0.029	0.006	0.082	-0.022	-0.039	-0.228	-0.029	0.984**
4.	-0.171	-0.016	-0.079	0.248	-0.170	0.030	-0.013	-0.192	0.200	-0.008	0.097	0.026	0.088	-0.029	0.003	-0.084	0.007	-0.064
5.	-0.157	-0.018	-0.076	0.166	-0.254	0.015	-0.016	0.084	-0.028	0.002	0.101	0.026	0.025	0.000	0.007	-0.011	0.027	-0.105
6.	-0.401*	-0.037	-0.180	-0.017	0.009	-0.431**	0.002	0.155	-0.119	0.015	0.075	0.013	-0.179	0.071	0.019	0.413**	0.026	-0.568**
7.	0.102	0.017	0.073	0.074	-0.095	0.020	-0.042	-0.138	0.135	-0.013	0.106	0.027	0.014	-0.004	-0.006	-0.078	-0.004	0.188
8.	0.168	0.043	0.182	0.029	0.013	0.041	-0.004	-1.640**	1.373**	0.109	0.107	0.033	0.019	0.006	0.038	-0.154	-0.001	0.363*
9.	0.176	0.043	0.183	0.036	0.005	0.037	-0.004	-1.637**	1.376**	0.104	0.100	0.031	0.023	-0.001	0.032	-0.143	-0.001	0.361*
10.	-0.086	-0.002	-0.025	-0.012	-0.003	-0.038	0.003	-1.085**	0.864**	0.165	0.060	0.017	-0.049	0.053	0.045	-0.032	0.008	-0.115
11.	-0.111	0.012	0.049	0.094	-0.100	-0.127	-0.017	-0.684**	0.539**	0.039	0.256	0.063	-0.017	0.012	0.060	-0.028	0.011	0.051
12.	-0.089	0.013	0.039	0.097	-0.101	-0.083	-0.017	-0.815**	0.646**	0.043	0.246	0.066	-0.014	0.005	0.050	-0.073	0.004	0.018
13.	0.258	0.037	0.142	0.086	-0.025	0.306*	-0.002	-0.124	0.128	-0.032	-0.017	-0.004	0.252	-0.137	-0.029	-0.329*	-0.028	0.484**
14.	0.161	0.018	0.067	0.051	-0.001	0.211	-0.001	0.073	0.009	-0.061	-0.021	-0.002	0.240	-0.144	-0.048	-0.192	-0.031	0.327*
15.	0.304*	0.014	0.109	-0.005	0.011	0.051	-0.002	0.401**	-0.277	-0.047	-0.098	-0.021	0.046	-0.044	-0.157	0.037	-0.006	0.315*
16.	-0.427*	-0.047	-0.196	-0.041	0.005	-0.349*	0.006	0.496**	-0.385*	-0.010	-0.014	-0.009	-0.163	0.054	-0.010	0.510**	0.024	-0.556**
17.	0.345*	0.047	0.207	-0.030	0.115	0.187	-0.003	-0.028	0.015	-0.021	-0.048	-0.005	0.116	-0.073	-0.017	-0.201	-0.060	0.547

Residual = -0.0147 * and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 3 : Direct (main diagonal) and indirect (above and below diagonal) phenotypic path effects of different characters towards total seed yield in castor.

Characters	Seed yield (g/plant)			Days to 50 % flowering	Days to maturity	Number of nodes up to primary spike	Plant height up to primary spike (cm)	Total length of primary spike	Effective length of primary spike	Number of capsules on primary spike	Total number of branches	Effective number of branches per plant	100 capsule weight (g)	100 seed weight (g)	Shelling percentage (%)	Seed specific gravity	Oil content (%)	Correlation with seed yield (g/plant)
	120 days after sowing	150 days after sowing	180 days after sowing															
1.	0.025	-0.304**	0.932**	0.002	-0.004	0.041	0.005	-0.002	0.003	-0.001	-0.007	0.005	0.013	0.025	0.001	0.021	0.011	0.767**
2.	0.019	-0.394**	1.146**	0.002	-0.004	0.022	0.004	-0.002	0.004	0.000	0.005	-0.006	0.011	0.017	0.001	0.016	0.010	0.850**
3.	0.019	-0.376**	1.200**	0.002	-0.005	0.021	0.003	-0.003	0.005	0.000	0.005	-0.006	0.011	0.019	0.001	0.014	0.010	0.919**
4.	-0.004	0.048	-0.148	-0.013	0.015	0.006	0.007	-0.001	0.002	-0.001	0.018	-0.015	0.011	0.016	0.000	0.004	-0.004	-0.060
5.	-0.003	0.055	-0.187	-0.006	0.030	0.006	0.009	0.000	0.003	0.000	0.022	-0.022	0.003	0.003	0.000	0.001	-0.008	-0.098
6.	-0.011	0.093	-0.271	0.001	-0.002	-0.093	-0.002	0.001	-0.001	0.001	0.018	-0.010	-0.023	-0.034	0.000	-0.032	-0.010	-0.376**
7.	0.003	-0.042	0.132	-0.002	0.007	0.004	0.040	0.001	-0.001	0.000	0.026	-0.023	0.002	-0.001	0.000	0.005	0.001	0.120
8.	0.004	-0.105	0.332**	-0.002	-0.001	0.006	-0.002	-0.009	0.015	0.005	0.021	-0.022	0.004	-0.006	-0.001	0.011	0.001	0.252**
9.	0.004	-0.105	0.348**	-0.002	-0.001	0.007	-0.002	-0.009	0.015	0.005	0.022	-0.023	0.005	-0.004	0.000	0.010	0.001	0.273**
10.	-0.002	0.002	-0.025	0.001	-0.001	-0.011	-0.001	-0.004	0.007	0.012	0.014	-0.014	-0.004	-0.028	-0.001	0.003	-0.002	-0.055
11.	-0.002	-0.025	0.073	-0.003	0.008	-0.020	0.013	-0.002	0.004	0.002	0.082	-0.068	-0.001	-0.006	-0.001	0.001	-0.004	0.052
12.	-0.002	-0.031	0.100	-0.003	0.008	-0.013	0.012	-0.003	0.005	0.002	0.071	-0.078	0.001	-0.002	-0.001	0.004	0.000	0.073
13.	0.007	-0.097	0.289**	-0.003	0.002	0.048	0.001	-0.001	0.002	-0.001	-0.002	-0.002	0.044	0.072	-0.001	0.022	0.011	0.393**
14.	0.006	-0.065	0.219*	-0.002	0.001	0.031	-0.001	0.001	-0.001	-0.003	-0.004	0.001	0.030	0.103	0.001	0.014	0.009	0.341**
15.	0.005	-0.036	0.112	0.000	-0.001	0.008	-0.001	0.001	-0.001	-0.002	-0.010	0.009	-0.001	0.015	0.006	-0.001	0.002	0.130
16.	-0.011	0.135	-0.365**	0.001	-0.001	-0.063	-0.005	0.002	-0.003	-0.001	-0.001	0.007	-0.021	-0.030	0.000	-0.047	-0.009	-0.411**
17.	0.009	-0.119	0.359**	0.002	-0.008	0.029	0.001	0.000	0.001	-0.001	-0.010	0.000	0.016	0.030	0.000	0.013	0.032	0.353**

Residual = 0.0915 * and ** indicate significance of values at P=0.05 and 0.01, respectively

and harvest index.

Generally, 100 seed weight emerged as the best most important seed yield component. This is judged especially from the fact that apart from its highly significant genotypic and phenotypic correlation with seed yield, it also has direct effect on seed yield per plant and at the same time influenced seed yield per plant. Sarwar and Chaudhry (2008) by acting as a relay route through which other characters influenced seed yield positively. However, Yadav *et al*. (2004) reported that seed yield and 100 seed weight had a negative direct effect on seed yield. The residual effect was not high and most of the variability in seed yield per plant was well accounted for by the variables. From the results obtained, it would be reasonable to suggest that a breeder engaged in the improvements of castor seed yield should place emphasis on number of spikes per plant and number of capsules in primary raceme. Selection for these traits will therefore directly become helpful in increasing the seed yield. From the results obtained, it would be reasonable to suggest that a breeder engaged in the improvement of castor oil yield should place emphasis on 100-seed weight, fruit yield and days to maturity. Selection for these traits will, therefore, indirectly increase oil yield. In conclusion, the main emphasis in the selection of high yielding variants should be placed on the number of spikes and capsule weight. To a lesser extent, the spike length and 100 seed weight may also be considered.

High positive phenotypic correlations on seed yield per plant were shown by number of effective spikes per plant, 100 seed weight and number of capsules in primary raceme, whereas number of nodes upto primary raceme were negatively associated. Path co-efficient analysis indicated that the number of capsules in primary raceme, number of effective spikes per plant and days to 50 per cent flowering have large positive direct effects on seed yield per plant. Ramu *et al*. (2005) and Uzun and Carigan (2001) observed that number of capsules per plant was highly correlated with seed yield.

The highest positive direct effects were observed in case of days to mature followed by capsule of main spike and number of branches by Sarwar *et al*. (2010). Days to mature, number of branches and capsules of main spike showed positive direct effect alongwith high positive genotypic correlation. These characters may be selected directly for seed yield improvement. In some cases, the direct effect is positive and high alongwith negative correlation, under these circumstances, a restricted simultaneous selection model is to be followed *i.e*. restrictions are to be imposed to nullify undesirable indirect effects to make use of direct effect.

It is concluded that at the time of selection, main emphasis may be given to effective length of primary spike, seed specific gravity, total number of branches, 100 capsule weight, days to 50 per cent flowering and number of capsules on primary spikes for seed yield improvement rather than total length of main primary spike, number of nodes upto primary spike, 100 seed weight and selling per cent.

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