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PCA of various component traits on yield in elite linseed (*Linum usitatissimum* L.) genotypes

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Abstract
The current study was conducted with the objective to determine the direct and indirect effects of different component traits on seed yield using PCA (path coefficient analysis) to select the most promising genotypes for their subsequent future use in fifty two elite linseed genotypes. The present experiment was conducted with the materials (48 genotypes and 4 checks) which were evaluated in randomized block design with two replications at EB-II section of the Department of Plant Breeding and Genetics, OUAT, Bhubaneswar during *rabi,* 2016-17.The total number of branches per plant is the trait that exhibited highest positive direct effect on seed yield both at genotypic and phenotypic level. Out of several characters under study, days to maturity exhibited highest indirect effect on yield via days to 50% flowering in normal sown condition.

Keywords: Linseed, PCA, elite, genotypes

Introduction

Flaxseed (*Linum usitatissimum* L.) is a functional food source due to its high dietary fiber and α-linolenic acid content (Prasad & Dhar, 2016) [7]. Studies reported that consuming flaxseed meal (Ndou et al., 2018) [6] or its gum (Luo et al., 2018) [5] helps prevent obesity (Boueri et al., 2015) [1] and improve lipid metabolism (Imran et al., 2015) [4]. Linseed or oil flax (*Linum usitatissimum* L., 2n= 30, X = 15) belongs to the order Malpighiales, the family Linaceae, and the tribe Lineae. It is popularly known as *atasi, pesi, phesi* or *tisi* in Odia. It is the second most important winter oilseed crop and stands next to rapeseed-mustard in area and production in India. Although linseed plants have several utilities, it is commercially cultivated for its seed, which is processed into oil and after extraction of oil, a high protein livestock feed is left. Linseed oil content varies from 33-45% and has been used for centuries as a drying oil. About 20% of the total linseed oil produced in India is used by the farmers and the rest about 80% goes to industries for the manufacture of paints, varnish, oilcloth, linoleum, printing ink etc.

Linseed has an important position in Indian economy due to its wide industrial utility. But, the national average productivity of linseed is quite low. As per FAOSTAT (2014) [3], India ranks 4th among world’s linseed producing countries. However, in terms of productivity, India (392 kg/ha) is far below than Switzerland (2647 kg/ha), Tunisia (2633 kg/ha), U.K. (2600 kg/ha), France (2121 kg/ha) and New Zealand (1853 kg/ha). In India, during 2013-14 linseed is grown in an area of 292.1 thousand hectares with annual production of 141.2 thousand tonnes and productivity of 484 kg/ha. Out of 15 linseed growing states, the major are Madhya Pradesh (110.4 thousand ha), Maharashtra (31.0 thousand ha), Chhattisgarh (26.2 thousand ha), Uttar Pradesh (26.0 thousand ha), Jharkhand (25.5 thousand ha), Odisha (22.9 thousand ha) and Bihar (18.7 thousand ha). In Odisha, the annual production is 11 thousand tonnes with productivity of 478 kg/ha (Anonymous, 2015a, b).

In Odisha, the annual production is 11 thousand tonnes with productivity of 478 kg/ha. The North Central Plateau Zone of Odisha comprising the districts of Mayurbhanj and Keonjhar contributes to about 50.6% of the total area of the state (Anonymous, 2015b).

The ultimate criterion of productivity in an oilseed crop is the oil yield, which depends on seed yield and oil content. Although improvement in oil content is possible, there appears to be much greater scope of increasing seed yield potential. Yield, however, is a polygenically controlled complex character and is determined by a number of multiplicative character components, which are also quantitatively inherited.

The primary objective of linseed breeder is to increase the seed yield. Generally, yield represents the final character resulting from many developmental and biochemical processes which occur between germination and maturity.

Before yield improvement can be realized, the linseed breeder needs to identify the cause of variability in seed yield and acquire information on the nature and magnitude of variation in the available materials in any given environment, since fluctuations in environment generally affects yield through its components.

The PCA developed by Wright (1921, 1960) and described by Dewey and Lu (1959) [2] is a standardized partial regression analysis that allows partitioning of correlation coefficient into direct and indirect effects of various traits (independent variables) towards dependent variable (seed yield), and thus helps in assessing the cause effect relationship as well as effective selection. If the correlation between the seed yield and a character is due to the direct effect of the character, it shows the true relationship between them. So, selection can be focused on this character to improve seed yield. If the correlation is due to indirect effect of the character through another component trait, the selection would be based on later trait through which indirect effect is exerted. Equipped with such information, a linseed breeder can devise more precise and effective breeding programme. Keeping in view the nutritional importance and future market requirement of flax, this work is directed towards the analysis of Indian flax varieties. Thus, fifty two linseed genotypes were evaluated for the PCA to assess the direct and indirect effects of different component traits present in them.

Materials and Methods

The present investigation was carried out at EB-II section of the Department of Plant Breeding and Genetics, OUAT, Bhubaneswar during *rabi,* 2016-17. Geographically, the place is located at about 24.00°N latitude and 90.25°E longitude with an elevation of 8.4 meters from the sea level and is characterized by subtropical climate. The soil of the experimental site was clay loam in texture. The objectives of the investigation were to estimate the extent of genetic variability, character association, genetic advance and to have a productive insight into the genetic diversity existing in a set of 52 linseed genotypes including 4 check varieties (Table 1).

Experimental Details

The field trial was laid out in a Randomized Block Design (RBD) with two replications. Each genotype was represented by three lines of 3 meters row length having 30 cm spacing between lines to lines and 10 cm spacing between plant to plant after thinning. The seeds were sown on 6th December, 2016. Fertilizers were applied @ 60 kg N, 40 kg P2 O5 and 40 kg K2O in the form of Urea, SSP and MOP besides 8 cartloads of farmyard manure per hectare. The fertilizers were applied and weeding was done at the right stage following normal package of practices. The crop was protected against insect-pests by spraying pesticide besides seed treatment.

Characters Studied

Ten competitive plants per replication for each variety were sampled at random at the time of harvest. Out of the eight quantitative traits, days to 50% flowering (50% of the plant coming to flower), and days to maturity (physiological maturity) were recorded on plot basis. Rest of the traits was recorded on the basis of ten randomly chosen plants at the time of harvest.

1. **Days to 50% flowering (DF**): Number of days taken from the date of sowing to the date when 50% of plants in the plot started blooming.
2. **Days to maturity (DM):** Number of days taken for all the plants (minimum 85%) in a plot to reach physiological maturity *i.e.* ready for harvest (the plants in the plot turned yellow to brownish in color) was recorded.
3. **Plant Height (PH):** The plant height was measured to the nearest centimeter (cm) from the base of the plant *i.e.* ground level to the tip of main shoot. Height measurements in centimeter were taken for ten random plants per plot in each replication.
4. **Number of branches / plant (B/P):** Total number of branches arising from main stem in ten randomly chosen plants per plot in each replication were recorded and expressed in number.
5. **Total number of capsules / plant (C/P):** It was recorded as the average number of seed bearing capsules from a plant, which was taken on ten-plant basis.
6. **Number of seeds / capsule (S/C):** It was recorded as the average number of seeds from each random capsule, which was calculated by dividing total number of seeds from the randomly ten selected capsules by total number of capsules of the plant.
7. **1000-seed weight (TSW):** After recording the yield of individual plant, the seeds of all the ten random plants were bulked and the weight of 500 randomly chosen seeds was measured in grams using electronic balance with about 14-15% grain moisture level from each plot. The values were doubled to get 1000-seed weight.
8. **Single plant yield (SPY):** It was recorded as the average weight (in gram) of the seeds of ten randomly sampled plants by electronic balance with about 15% moisture level.

Path coefficient analysis

The method of analysis by path coefficients requires a cause-and-effect relationship among correlated variables. Path coefficients are standardized partial regression coefficients which individually provide a measure of the direct effect of a causal factor on the effect variable. They permit partitioning of the correlations between a causal factor and the effect variable into components of direct and indirect effects and thus, give a better picture of the associations of the causal factors with the effect variable. In the present study, yield was taken as the “effect” with seven other characters related to yield as the causal factors. The path coefficients were obtained by solving the following simultaneous equations which give the basic relationship between correlations and path coefficients in a system of correlated causes (Wright, 1921; and Dewey and Lu, 1959) [2].

r1.8 = p1.8+ r1.2 p2.8 + r1.3 p3.8+……….. + r1.7 p7.8
r2.7 = r2.1 p1.8 + p2.8 +r2.3 p3.8 + ……….. + r2.7 p7.8
r3.6 = r3.1 p1.8 + r3.2 p2.8 + p3.8 + ………. + r3.7 p7.8
r7.8 = r7.1 p1.8 + r7.2 p2.8 + r7.3 p3.8 + ……… + p7.8

Where

rij = The coefficient of correlation between i^{th} and j^{th} characters

pqi =The path coefficient (direct effect of i^{th} character on yield

The solutions for path coefficients, direct and indirect effects of the causal factors were estimated as the values of the individual terms of the above equation in RHS.

The residual effect (PR) was calculated as follows:
$I = P^2_{RPY} + Pipy. rIPY$

The path analysis at the phenotypic level with the same cause and effect relationship was computed using the phenotypic correlation as stated earlier.

Results

Seed yield is based on the net effect produced by various yield components interacting with one another. The association of different component characters among themselves and with yield is quite important for devising an efficient selection criterion for yield. The total correlation between yield and its component characters may be some times misleading, as it might be an over-estimate or under-estimate because of its association with other characters. Hence, indirect selection by correlated response may not be sometimes fruitful. When many characters are affecting a given character, splitting total correlation into direct and indirect effects of cause as devised by Wright (1921) would provide more meaningful interpretation to the cause of association between the dependent variable like yield and independent variables like yield component characters. If the correlation coefficient between caused factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and direct selection of this trait will be effective. The correlation coefficient is positive and the direct effects are negative or negligible, the indirect effects seem to be the cause of correlation. In such situations the other factors influencing the trait have to be considered simultaneously. Correlation coefficients may be negative but the direct effect may be positive and high. Under these conditions a restricted simultaneous selection model is to be followed i.e., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effects. With this background, in present investigation the direct and indirect effects of different yield contributing traits and seed quality parameters on yield were estimated using genotypic and phenotypic correlation coefficients and are presented in Table 4.6. As discussed in character association here also the results of both phenotypic and genotypic path coefficient analysis of yield, its contributing characters and seed quality parameters are discussed here under. It was revealed from the table that high direct effect to yield was manifested by no of branches per plant (0.340) followed by 1000-seed weight (0.302), days to maturity (0.199), no. of seeds per capsule (0.164), no. of capsules per plant (0.130) as per Table 2. Days to maturity exhibited highest indirect effect on yield via days to 50% flowering (0.162) followed by Days to maturity via seeds per capsule (0.263), seeds per capsule via days to maturity (0.094). Plant height (-0.223) and days to 50% flowering (-0.142) showed negative direct effect on yield.

Discussion

The correlation coefficient of component traits with seed yield were partitioned in to direct and indirect effects following PCA, to ascertain further conclusive evidence on choice of characters required for selection of high yielding genotypes. The PCA not only specify the effective measure of direct and indirect causes of association, but also depicts the relative importance of each factor involved in contributing to the final product of yield. At phenotypic level, high direct effect on yield was manifested by total number of branches followed by 1000-seed weight, days to maturity, seeds per capsule, and capsules per plant as per Table 2. Plant height and days to 50% flowering showed negative direct effect on yield. The indirect effects were recorded small and nominal for many character pairs with few exceptions. Days to maturity exhibited highest indirect effect on yield via days to 50% flowering (0.162) followed by days to maturity via seeds per capsule (0.263), seeds per capsule via days to maturity (0.094). At genotypic level, the total number of branches (0.536) exhibited maximum direct effect on yield followed by capsules per plant. A trait with high positive and direct effect on seed yield reveals its effectiveness towards the direct selection. Characters with high direct effect along with positive and high indirect effect through other traits provides a better chance to be selected through breeding programmes. The characters like plant height and days to 50% flowering exhibited negative direct effect on single plant yield. Thus, from the above observations on direct and indirect effects on yield, it is concluded that traits like total number of branches, capsules per plant, seeds per capsule, thousand seed weight should be considered as important selection criteria for increasing yield. Similar findings were reported by Kant *et al*. (2008), Nagaraja *et al* (2009), Jain *et al.*, (2011), Gauraha and Rao *et al.*, (2011) and Rahman *et al.* (2011).

Table 1: List of genotypes included in the experiment

Serial number	Name of genotype	Serial number	Name of genotype
1	OL-98-6-2	27	NDL-204
2	OL-98-6-4	28	RLC-95
3	OL-98-7-1	29	RLC-93
4	OL-98-7-4	30	NL-97
5	OL-98-13-1A	31	NL-119
6	OL-98-13-2	32	NL-157
7	OL-98-14-2	33	SWETA
8	OL-98-14-3	34	GARIMA
9	OL-98-15-2	35	KIRAN
10	OLC-10A	36	T-397
11	OLC-11	37	JOWHAR
12	OLC-15	38	RLC-74
13	OLC-51	39	SUVRA
14	OML-3	40	LCK-9930
15	JLT-32	41	OL-98-7-3
16	JLT-62	42	LMS-17-2K
17	V1K1-99-40	43	PADMINI A
18	V1K1-99-44	44	V2K3-99-71-1
19	V1K2-99-48	45	NDL-205
20	V1K2-99-57	46	SLS-51
21	V1K2-99-90	47	PADMINI B
22	V2K3-99-54-1	48	OLC-10 B
23	V2K3-99-70-1	49	KARTIK
24	SLS-52	50	OL-98-15-3
25	LCK-2108	51	INDIRA ALSI
26	LMS-47-2K	52	OL-98-13-1 B

Table 2: Direct and indirect effects of component traits on yield at phenotypic and genotypic level for 52 linseed genotypes

Characters		Days to 50% flowering	Days to Maturity	Plant height (cm)	Total number of branches	Capsules/ plant	Seeds/ capsule	1000 grain weight (g)	Single plant yield (g)
Days to 50% flowering	Pp	-0.142	0.162	0.008	0.025	0.031	0.071	-0.161	-0.006
	Pg	-2.472	3.648	0.022	0.029	0.079	-0.442	-0.878	-0.014
Days to Maturity	Pp	-0.116	0.199	-0.002	0.001	0.039	0.094	-0.188	0.027

	Pg	-2.289	3.939	-0.012	0.012	0.097	-0.605	-1.145	-0.003
Plant height (cm)	Pp	0.005	0.002	-0.223	-0.035	0.021	-0.002	0.048	-0.184
	Pg	0.084	0.071	-0.661	-0.043	0.052	0.001	0.263	-0.233
Total number of branches	Pp	-0.011	0.001	0.023	0.340	0.022	-0.004	0.006	0.377
	Pg	-0.213	0.138	0.083	0.342	0.086	-0.042	0.046	0.440
Capsules/ plant	Pp	-0.034	0.059	-0.037	0.057	0.130	0.072	-0.052	0.196
	Pg	-0.680	1.324	-0.120	0.102	0.288	-0.424	-0.288	0.202
Seeds/ capsule	Pp	-0.062	0.114	0.002	-0.007	0.057	0.164	-0.136	0.132
	Pg	-1.320	2.879	0.001	0.017	0.147	-0.827	-0.791	0.106
1000 grain weight (g)	Pp	0.076	-0.124	-0.036	0.007	-0.022	-0.074	0.302	0.129
	Pg	1.468	-3.049	-0.118	0.011	-0.056	0.443	1.479	0.178

Phenotypic Path: P(R) = 0.859, R2(%)= 26.14 Genotypic Path: P(R) = 0.663, R2(%)= 56.07

Conclusion

The high estimates of correlation both at genotypic and phenotypic level was between yield and total number of branches per plant. The rest of the characters had non-significant correlation with yield. Days to 50% flowering had positive significant correlation with days to maturity, seeds per capsule but negative significant correlation with 1000 seed weight at both phenotypic and genotypic level. It had positive significant genotypic correlation with no. of capsules per plant. The highest direct effect to yield was manifested by total number of branches per plant followed by 1000 seed weight, days to maturity, no. of seeds per capsule, no. of capsules per plant. Phenotypically days to maturity exhibited highest indirect effect on yield via days to 50% flowering followed by days to maturity via seeds per capsule, seeds per capsule via days to maturity. Plant height and days to 50% flowering showed negative direct effect on yield.

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