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Inter relationship and path analysis for seed yield in Indian mustard [*Brassica juncea* (L.) Czern and Coss]

Suman Yadav and Anil Pandey

Abstract
Twenty genotypes of Indian mustard were evaluated for seed yield and its seventeen yield components for correlation and path coefficient analysis. The seed yield per plant had significant and positive correlation with plant height, number of primary branches, number of secondary branches, silique on primary branches, silique on secondary branches, silique on primary mother axis, biological yield per plant and physiological maturity at both genotypic and phenotypic levels. Among the component traits, biological yield per plant had significant and positive association with number of primary branches as well as number of secondary branches, silique on primary branches, siliqueon secondary branches and silique on primary mother axis at genotypic level. Further, path coefficient analysis of seventeen yield contributing characters clearly indicated that number of primary branches as well as biological yield per plant showed the highest positive direct effect on seed yield followed by harvest index, test weight, length of siliqua, silique on primary mother axis, which indicated positive direct effects in descending order and other characters contributed indirectly towards seed yield in Indian mustard.

Keywords: Correlation, path analysis, yield components, mustard

Introduction
Mustard is the third most important source of edible oil of the world after soya bean and palm. In India it ranks second in acreage superseded by groundnut only. Mustard crop is grown both in tropical and subtropical countries. Out of seven edible oilseed crops cultivated in India, rapeseed mustard occupies second position in area and production next to groundnut sharing 27.80% in the Indias oilseed economy and countries 28.60 % in the total oilseeds production (Shekhawat *et al.* 2012) [10]. Indian mustard [*Brasicajuncea* (L.) Czern & Coss] is an important *rabi* season crop extensively gown as rain- fed as well as under irrigated conditions. Yield is complex character which dependent on the various yield contributing characters and these components of seed yield very often exhibit varying degree of associations with seed yield as well as among themselves. Thus, the study of correlation between yield and its component is of primary importance in formulating the selection criteria under crop improvement. Selection of any desirable trait is generally performed based on the phenotypic value of the plants, which is partly determined by geno types, which is heri table, and partly by environment which is non- heritable. Therefore, it is necessary to know the various component soft he yield and its mutual correlation with other independent traits. This is because, selection would be more efficient if it is based on some components which less sensitive to environment. It is well known that correlation mainly does not fulfill the purpose of there searchers because it does not detect the characters having indirect effects on seed yield. In such situation path-coefficient analysis developed by Wright (1921) [23] would gives there al importance of such characters of partitioning the correlation coefficient into direct as well as indirect effects. The correlation between two characters can be partitioned into a portion that is due to genetic cause and the other due to environmental factors.

Materials and Methods
Twenty genotypes of Indian mustard (*Brassica juncea* L.) were taken from the various All India Co-ordinated Research Project- Rapeseed and Mustard centres: DRMR, Bharatpur, Rajasthan, CCSHAU, Hisar, Haryana, BARC, Trombay, Maharashtra, GBPUAT, Pantnagar, Uttarakhand, CSAUAT, Kanpur, U. P, IARI, New Delhi, Sriganganagar, Rajasthan, DR. RPCAU, Dholi, Bihar, were evaluated with one national check namely Varuna as well as two zonal checks namely Pusa mustard and Pusamahak released for commercial cultivation. The test material was laid out in randomized block design (RBD) with three replications.

Each entry was planted in plot size of 2.5 x 0.45m with plant to plant space of 0.15m at the research farm TCA Dholi, DrRPCAU, Pusa, Bihar (India) on 13 october2017 during rabi season 2017-2018. The recommended package and practices were followed to raise good crop. The data was recorded on eighteen quantitative traits *viz:* plant height (cm), days to first flower open, days to 50 % flowering, number of primary branches, number of secondary branches, length of primary mother axis, days to physiological maturity, number of siliqua on primary branches, silique on secondary branches, silique on primary mother axis, number of seeds per siliquae, siliquae length (cm), 1000 seeds weight (g), total biological yield (g) per plant, harvest index (%) and seed yield per plant (g), vegetative phase duration and post-anthesis phase duration. All the mathematical calculation was based on the mean values for different characters for each line. The statistical analyses (ANOVA) were performed using OPSTATE software to determine the trial authentication. The correlations at genotypic and phenotypic levels were estimated from the analysis of variance and covariance as suggested by Searle (1961). The genotypic and phenotypic correlation obtained from 20 genotypes were estimated according to the formula given by Al-Jibouri*et al.* (1958) [12] was subjected to path analysis of Wright (1921) [23] as elaborated by. In the present investigation, path coefficient analysis was carried out by taking seed yield per plant as dependent variable and other observed traits as independent variables.

Result and Discussion

The analysis of variance revealed that mean squares due to genotypes were highly significant for all the eighteen characters indicating the presence of sufficient amount of variability among the geno types. The estimates of all possible genotypic and phenotypic correlation coefficient (Table 1) showed that estimates of genotypic correlation coefficient were higher than their corresponding phenotypic correlation coefficient indicating that there was an inherent association among the various characters and less influence of environment on phenotypic expression of correlation in Indian mustard. The association analysis revealed that, in general, the values of genotypic correlations were higher than their phenotypic correlations indicating the inherent association among the traits. Similar findings were also reported by Shah *et al*. (2002) [15], Singh *et al*. (2003) [17]and Joshi *et al*. (2009) [7] Correlation coefficient analysis revealed that seed yield had significant and positive association with physiological maturity (1.12G & 0.43P), number of secondary branches (1.00G & 0.78P), silique on secondary branches (0.96G & 0.57P), number of primary branches (0.95G & 0.67) and biological yield per plant (0.90G & 0.81P), plant height (0.74G & 0.46P), silique on primary mother axis (0.73G & 0.49P), silique on primary branches (0.72G & 0.53P), length of primary mother axis (0.52G & 0.29P) at genotypic and phenotypic levels. Thus, these above said attributes can serve as marker characters for seed yield improvement in mustard. Such positive interrelationships between seed yield and these attributes have also been reported in mustard by Illmulwar *et al*. (2003) [6], Sirohi *et al*. (2004) [20], Kardam and Singh (2005) [5], Acharya (2006) [1], Singh and Singh (2010) [18] and Sekhar *et al*. (2012) [16]. The estimates of minimum positive non-significant correlation with yield for two characters only days to 50 %flowering (0.21G & 015P) and harvest index (0.21G & 0.31P) and six characters were found negative and non-significance genotypic correlation with seed yield/plant viz. silique length (-0.18), number of seeds per silique (-0.11), post- an thesis phase duration (-0.11), days to first flower open (-.09), vegetative phase duration (-0.07) and test weight (-0.06).Similar findings have been given by the following authors, Singh and, Shweta and, and. Seed yield is positively correlated with days to 50 % flowering and days to physiological maturity which promotes early flowering and early maturing genotypes confirming the necessity of photosynthetic accumulation period for plant and seeds development. Positive significant correlation was observed between biological yield per plant and days to physiological maturity at both levels, suggested that selection of short duration genotypes would be rewarding for increasing seed yield since seed yield is associated with biological yield/plant positively. These results are in favour of findings of Rawat and and Satyavathi *et al.,* (2000) [11]. The significant and positive correlation coefficients were observed in primary branches per plant with secondary branches per plant (0.98G and 0.74P), plant height with days to physiological maturity (1.20G) and days to 50 % flowering with days to physiological maturity (0.51G and 0.22P) thereby establishing strong inherent relationship among themselves. These findings are in accordance with Shalini *et al.,* (2000) [13], Choudhary *et al.,* (2003) [3] and Singh and The positive and significant association of harvest index and total biological yield with seed yield per plant made it possible to select genotypes having more biological yield with higher harvest index, a desirable combination must have resulted due to simultaneous selection of these characters. The results of path coefficient analysis of direct and indirect effects of different characters on seed yield are presented inTable2. The genotypic path coefficient analysis revealed that number of primary branches (0.77G), biological yield per plant (0.72G), harvest index (0.53G),test weight (0.31G), silique on primary mother axis (0.28G) and silique length (0.28G) exhibited highand positive direct effects on seed yield per plant. Biological yield/plant (0.77P) and harvest index (0.47P) had positive phenotypic association with seed yield. These characters turned out to be the major components of seed yield. The maximum and positive direct effects of biological yield per plant and harvest index were also reported by Dastidar and Patra (2004) [4], Sirohi *et al*. (2004) [20] and Sirohi *et al*. (2008) [19]. The negative direct effect of low magnitude of days to physiological maturity was nullified by high and positive indirect effects of days to 50 per cent flowering. Similarly, the negative direct effect of low magnitude of number of seeds per silique was nullified by high and positive indirect effects of biological yield per plant. The residual effect was of low magnitude suggesting that the majority of the yield attributes have been included in the path analysis. Considering the correlation and path coefficient analysis for seed yield per plant and its component traits, an ideal plant type in mustard would be one with high biological yield per plant, number of primary branches, high harvest index and more length of siliquaas well as silique on primary mother axis accompanied with early flowering and maturity. Therefore, more emphasis should be given to these components while making selection for higher seed yield in mustard.

Table 1: Genotypic (r_g) and phenotypic (r_p) correlations coefficients among 18 characters of mustard

Character		Pant height	Number of primary branches	Number of secondary branches	Length of primary mother axis	Silique on primary branches	Silique on secondary branches	Siliqua on primary mother axis	Siliqua length	Number of seeds/siliqua	Bioogical yield/plant	Harvest index	Days to first flower open	Vegetative phase duration	Physiological maturity	Post anthesis phase duration	Days to 50% flowering	Test weight	Seed yield per plant
Plant height	rg	1.00	0.56**	0.69**	0.45**	0.56*	0.49**	0.34**	-0.23	-0.62	0.61**	0.18	0.56**	0.21	1.20**	-0.69	0.60**	-0.36	0.74**
	rp	1.00	0.33**	0.47**	0.45**	0.34**	0.41**	0.41**	-0.04	-0.13	0.52**	-0.07	0.27*	0.21	0.18	-0.28*	0.20	-0.23	0.46**
No. of primary branches	rg		1.00	0.98**	0.62**	0.66**	0.86**	0.80**	-0.30*	-0.26	0.96**	-0.08	0.06	-0.26*	0.90**	-0.29*	0.46**	-0.02	0.95**
	rp		1.00	0.74**	0.33*	0.59**	0.57**	0.56**	-0.02	-0.08	0.75**	-0.11	-0.009	-0.09	0.34**	-0.11	0.28*	-0.01	0.67**
No. of secondary branches	rg			1.00	0.66**	0.62**	0.87**	0.86**	-0.45**	-0.26*	1.01**	-0.04	0.02	-0.14	1.27	-0.29*	0.48**	0.00	1.00**
	rp			1.00	0.32*	0.62**	0.73**	0.66**	-0.06	-0.21*	0.79**	-0.03	0.02	0.05	0.35**	-0.11	0.23*	0.002	0.78**
Length of primary mother axis	rg				1.00	0.53**	0.48**	0.66**	-0.31*	-0.43**	0.53**	-0.07	0.36**	0.12	0.52**	-0.50**	0.32*	0.19	0.52**
	rp				1.00	0.25*	0.26*	0.39**	-0.20*	-0.005	0.47**	-0.25*	0.15	0.13	0.11	-0.20*	0.17	0.15	0.29*
Siliqua on primary	rg					1.00	1.00**	0.78**	-0.35**	-0.39**	0.82**	-0.12	0.44**	0.34**	0.85**	-0.60**	0.63**	0.05	0.72**
	rp					1.00	0.70**	0.58**	-0.04	-0.23*	0.65**	-0.12	0.28*	0.34**	0.45**	-0.34**	0.38**	0.03	0.53**
Siliqua on secondary branches	rg						1.00	0.90**	-0.43**	-0.28*	1.07**	-0.06	0.28*	0.18	1.36**	-0.53**	0.74**	0.18	0.96**
	rp						1.00	0.66**	-0.18	-0.18	0.76**	-0.23*	0.24*	0.29*	0.31*	-0.30*	0.26*	0.08	0.57**
Silique on primary mother axis	rg							1.00	-0.42**	-0.30*	0.77**	-0.23*	0.37**	0.24*	0.92**	-0.60**	0.70**	0.29*	0.73**
	rp							1.00	-0.14	-0.13	0.65**	-0.31*	0.31*	0.33*	0.29*	-0.39**	0.29*	0.23*	0.49**
Silique length	rg								1.00	0.71**	-0.28*	0.42**	-0.45**	-0.45**	-0.34**	0.48**	-0.46**	0.45**	-0.18*
	rp								1.00	0.33*	-0.12	0.36**	-0.14	-0.03	-0.03	0.20	-0.003	-0.25*	0.02
No. of seeds/siliqua	rg									1.00	-0.32*	0.63***	-0.33**	-0.47**	0.01	0.41**	-0.34**	0.32*	-0.11
	rp									1.00	-0.16	0.22*	-0.22*	-0.21*	-0.16	0.19	-0.27*	0.17	-0.09
Biological yield/plant	rg										1.00	-0.13	0.11	-0.05	1.02**	-0.32*	0.58**	-0.04	0.90**
	rp										1.00	-0.19	0.14	0.01	0.41**	-0.28*	0.34**	-0.03	0.81**
Harvest index	rg											1.00	-0.50**	-0.10	0.44**	0.51**	-0.96**	-0.12	0.21*
	rp											1.00	-0.41**	-0.16	0.07	0.43**	-0.30*	-0.11	0.31*
Days to first flower open	rg												1.00	0.77**	0.32*	-1.00**	1.06**	0.16	-0.09
	rp												1.00	0.65**	0.21*	-0.95**	0.53**	0.12	-0.08
Vegetative phase duration	rg													1.00	0.41**	-0.77**	0.59**	0.21	-0.07
	rp													1.00	0.19	-0.57**	0.43**	0.14	-0.03
Physiological maturity	rg														1.00	-0.53**	0.51**	-0.28	1.12**
	rp														1.00	-0.25*	0.22*	-0.09	0.43**
Post anthesis phase duration	rg															1.00	-1.16**	-0.18	-0.11
	rp															1.00	-0.53**	-0.15	-0.05
Days to 50% flowering	rg																1.00	0.02	0.21*
	rp																1.00	-0.02	0.15
Test weight	rg																	1.00	-0.06
	rp																	1.00	-0.07

Table2: Genotypic (G) and phenotypic (P) Path coefficients among 18 characters of mustard

Character		Plant height	Number of primary branches	Number of secondary branches	Length of primary mother axis	Silique on primary branches	Silique on secondary branches	Siliqua on primary mother axis	Siliqua length	Number of seeds/siliqua	Bioogical yield/plant	Harvest Index	Days to first flower open	Vegetative phase duration	Physiological maturity	Post anthesis phase duration	Days to 50% flowering	Test weight	Seed yield per plant
Plant height	rg	0.17	0.09	0.12	0.08	0.09	0.08	0.06	-0.04	-0.11	0.10	0.03	0.09	0.03	0.21	-0.12	0.10	-0.06	0.74
	rp	0.04	0.01	0.02	0.02	0.01	0.01	0.01	-0.002	-0.006	0.02	-0.003	0.01	0.009	0.008	-0.01	0.009	-0.01	0.46
No. of primary branches	rg	0.43	0.77	0.75	0.48	0.51	0.66	0.62	-0.23	-0.20	0.74	-0.06	0.05	-0.20	0.70	-0.22	0.35	-0.02	0.95
	rp	0.01	0.05	0.04	0.01	0.03	0.03	0.03	-0.001	-0.005	0.04	-0.006	-0.005	-0.005	0.02	-0.006	0.016	-0.001	0.67
No. of secondary branches	rg	-0.23	-0.33	-0.34	-0.22	-0.21	-0.30	-0.29	0.15	0.09	-0.34	0.01	-0.008	0.04	-0.43	0.10	-0.16	-0.002	1.00
	rp	0.09	0.14	0.19	0.06	0.11	0.14	0.12	-0.01	-0.04	0.15	-0.007	0.005	0.01	0.06	-0.02	0.04	0.005	0.78
Length of primary mother axis	rg	-0.17	-0.23	-0.25	-0.37	-0.20	-0.18	-0.25	0.11	0.16	-0.20	0.02	-0.13	-0.04	-0.19	0.19	-0.12	-0.07	0.52
	rp	-0.01	-0.01	-0.01	-0.03	-0.01	-0.01	-0.01	0.008	0.002	-0.018	0.01	-0.006	-0.005	-0.004	0.008	-0.006	-0.006	0.29
Siliqua on primary	rg	-0.24	-0.29	-0.27	-0.23	-0.44	-0.44	-0.34	0.16	0.17	-0.36	0.05	-0.19	-0.15	-0.38	0.27	-0.28	-0.02	0.72
	rp	-0.02	-0.04	-0.04	-0.01	-0.07	-0.05	-0.04	0.003	0.01	-0.04	0.008	-0.02	-0.02	-0.03	0.02	-0.02	-0.002	0.53
Siliqua on secondary branches	rg	0.03	0.05	0.06	0.03	0.06	0.06	0.06	-0.03	-0.01	0.07	-0.004	0.02	0.01	0.09	-0.03	0.05	0.01	0.96
	rp	-0.04	-0.06	-0.08	-0.02	-0.07	-0.11	-0.07	0.02	0.02	-0.08	0.02	-0.02	-0.03	-0.03	0.03	-0.02	-0.009	0.57
Silique on primary mother axis	rg	0.09	0.22	0.24	0.18	0.22	0.25	0.28	-0.12	-0.08	0.21	-0.06	0.10	0.06	0.26	-0.17	0.19	0.08	0.73
	rp	0.01	0.01	0.02	0.01	0.01	0.02	0.03	-0.005	-0.004	0.02	-0.01	0.01	0.01	0.01	-0.01	0.009	0.008	0.49
Silique length	rg	-0.06	-0.08	-0.12	-0.08	-0.10	-0.12	-0.12	0.28	0.20	-0.08	0.11	-0.12	-0.12	-0.09	0.13	-0.13	-0.12	-0.18
	rp	0.001	0.006	0.002	0.006	0.001	0.005	0.004	-0.03	-0.01	0.004	-0.01	0.0004	0.001	0.001	-0.006	0.001	0.007	0.02
No. of seeds/siliqua	rg	0.25	0.11	0.11	0.17	0.16	0.11	0.12	-0.29	-0.41	0.13	-0.26	0.14	0.19	0.006	-0.17	0.14	-0.13	-0.11
	rp	0.005	0.003	0.008	0.002	0.009	0.007	0.005	-0.01	-0.03	0.006	-0.008	0.008	0.008	0.006	-0.007	0.01	-0.006	-0.09
Biological yield/plant	rg	0.44	0.69	0.73	0.39	0.59	0.77	0.55	-0.20	-0.23	0.72	-0.09	0.08	-0.04	0.73	-0.23	0.42	-0.03	0.90
	rp	0.40	0.58	0.61	0.36	0.51	0.59	0.50	-0.100	-0.12	0.77	-0.15	0.11	0.01	0.32	-0.22	0.26	-0.02	0.81
Harvest index	rg	0.10	-0.04	-0.02	-0.04	-0.06	-0.03	-0.12	0.22	0.34	-0.07	0.53	-0.27	-0.05	0.23	0.27	-0.51	-0.06	0.21
	rp	-0.03	-0.05	-0.01	-0.12	-0.05	-0.11	-0.15	0.17	0.10	-0.09	0.47	-0.19	-0.07	0.03	0.20	-0.14	-0.05	0.31
Days to first flower open	rg	-0.26	-0.03	-0.01	-0.17	-0.20	-0.13	-0.17	0.21	0.15	-0.05	0.23	-0.46	-0.36	-0.15	0.46	-0.49	-0.07	-0.09
	rp	-0.09	0.003	-0.009	-0.05	-0.09	-0.08	-0.16	0.04	0.07	-0.04	0.13	-0.33	-0.21	-0.07	0.31	-0.17	-0.04	-0.08
Vegetative phase duration	rg	0.02	-0.02	-0.01	0.01	0.03	0.01	0.02	-0.04	-0.04	-0.005	-0.01	0.07	0.10	0.04	-0.07	0.06	0.02	-0.07
	rp	0.02	-0.01	0.006	0.01	0.03	0.03	0.03	-0.004	-0.02	0.001	-0.01	0.07	0.11	0.02	-0.06	0.05	0.01	-0.03
Physiological maturity	rg	-0.09	-0.07	-0.10	-0.04	-0.07	-0.11	-0.07	0.02	-0.001	-0.08	-0.03	-0.02	-0.03	-0.08	0.04	-0.04	0.02	1.12
	rp	0.003	0.005	0.006	0.002	0.007	0.005	0.005	-0.006	-0.002	0.007	0.001	0.003	0.003	0.017	-0.004	0.004	-0.001	0.43
Post anthesis phase duration	rg	0.43	0.18	0.18	0.31	0.38	0.34	0.38	-0.30	-0.26	0.20	-0.32	0.63	0.48	0.33	-0.63	0.73	0.11	-0.11
	rp	0.08	0.03	0.03	0.05	0.10	0.08	0.11	-0.05	-0.05	0.08	-0.12	0.28	0.16	0.07	-0.29	0.15	0.04	-0.05
Days to 50% flowering	rg	-0.06	-0.04	-0.05	-0.03	-0.06	-0.07	-0.07	0.04	0.03	-0.06	0.10	-0.11	-0.06	-0.05	0.12	-0.10	-0.003	0.21
	rp	-0.006	-0.009	-0.007	-0.005	-0.01	-0.008	-0.009	0.001	0.008	-0.01	0.009	-0.017	-0.013	-0.007	0.017	-0.03	0.007	0.15
Test weight	rg	-0.11	-0.008	0.002	0.06	0.01	0.05	0.09	-0.14	0.09	-0.01	-0.03	0.05	0.06	-0.08	-0.05	0.009	0.31	-0.06
	rp	-0.001	-0.001	0.001	0.008	0.002	0.004	0.013	-0.013	0.009	-0.002	-0.006	0.007	0.008	-0.0005	-0.008	-0.001	0.005	-0.07

Conclusion

From the present investigation, it can be concluded that seed yield/plant had significant and positive association with physiological maturity, number of primary as well as secondary branches per plant, silique on primary branches as well as secondary and primary mother axis and biological yield per plant at genotypic and phenotypic levels. Thus, these above said attributes can serve as marker characters for seed yield improvement in mustard. Further, path coefficient analysis clearly indicated that biological yield per plant, harvest index and number of primary branches exhibited high and positive direct effects on seed yield per plant. Therefore, more emphasis should be given to these components while making selection for higher seed yield in mustard.

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