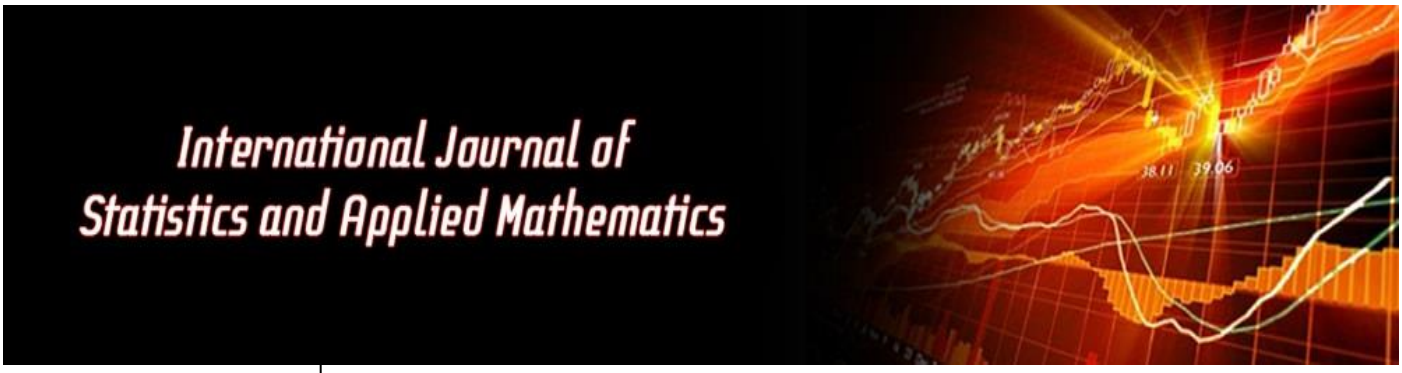

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Study on correlation and path coefficient analysis for yield and some quality traits in Indian mustard (*Brassica juncea* L.)

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Abstract
The present investigation was carried out at Oilseed Research Farm, Kanpur during *Rabi* 2020-22 with 28 treatments [7 parents (PR-20, PR-21, Azad Mahak, KMR17-5, KMR17-4, NDR-8501 and KMR(L)17-6] and their possible combination excluding reciprocals)] following diallel cross analysis excluding reciprocals in 3 replications laid out in randomized block design. Genotypic correlation coefficient was higher in magnitude than their corresponding phenotypic correlation coefficient for all the characters. Significant positive correlations were found in seed yield per plant with number siliquae per plant, number of secondary branches per plant, number of primary branches per plant and main raceme length (cm),1000 seed weight (g), oil content (%), protein content (%), methionine content (%) and tryptophan content (%).
Phenotypic path analysis values revealed that positive and direct effect on seed yield per plant was exerted by number of siliquae per plant followed by number of secondary branches per plant, protein content, number of primary branches, 1000 seed weight days to maturity and methionine content. Whereas, tryptophan content, days to 50% flowering, main raceme length, plant height and oil content showed negative direct effects. Thus, in this experimental material, these traits are recognized as the effective and probable choices for indirect selection towards increasing productivity. The challenge of the study is to find out the character associations to the yield and to estimate the direct and indirect effects of each character on yield. Ultimate aim is to enhance the yield and also enhance the quality of grain.

Keywords: Correlation, genotypic, oilseed, path-coefficient, seed yield

Introduction
Indian mustard (*Brassica juncea* L.) is an important *Rabi* season crop extensively grown as under irrigated condition. The genus *Brassica*, belongs to *Cruciferae or Brassicaceae* family and includes six cultivated species. Among those, *Brassica nigra* (n=8), *B. oleraceae* (n=9), *B. rapa* (n=10) are diploids. Rest of the three, namely *B. carinata* (n=17), *B. napus* (n=19) and *B. juncea* (n=18) are amphidiploids (Nagaheru U, 1935) [12]. Indian mustard is a natural amphidiploid (2n=36) of *Brassica campestris* (2n=20) and *Brassica nigra* (2n=16). It is largely self-pollinated crop (85-90%). Mustard crops need a temperature between 10°C to 25 °C and are grown in areas where 625 mm-1000 mm annual rainfall is received (Reddy, 2015) [14]. In water logging conditions, mustard crops do not grow in heavy soils and require soil pH 6.0-7.5 (Madhusoodanan *et al*., 2016) [11]. The mustard seed contains carbohydrates of nutritious quality 4.51 g, 1.41 g sugar fibre 2 g, 0.47 g of fat and 2.56 g of protein/100 g. The volume of oil ranges from 37% to 49% (Bhownik *et al*. 2014, Barfa, 2016) [22, 3]. However, owing to insects, especially the honeybees, the extent of cross-pollination varies from 4.0 to 16.6%. *Brassica juncea* L. has numerous common names used, e.g., brown mustard, Chinese mustard, or oriental mustard.

In India, rapeseed-mustard is cultivated over an area of 5.98 million hectares and total production is 8.4 million tones with a productivity of 1410 kg/hectare (Anonymous, 2018). Rapeseed-mustard stands at second position just after soybean in terms of area and production (About one fourth in both area and production of total oilseeds) and stands first in terms of total edible oil produced (Jat *et al.*, 2019) [6]. Among different rapeseed-mustard species, Indian mustard [*Brassica juncea* (L.) Czern &Coss.] is a predominantly cultivated crop of India with approximately 90 per cent of the total area under rapeseed-mustard cultivation in the country is occupied by Indian mustard. Its oil is having high omega-3 fatty acids, free from cholesterol. Its defatted cake is highly enriched in protein with well-balanced essential amino acids which serve as a very good source of nutrients for livestock and poultry (Sahni *et al.*, 2007) [16]. Though, India inhabiting one of the world's largest areas and production of Indian mustard, its productivity is low in our country as compared to other mustard growing countries *viz.*, China, Canada and European union's as well as to the world average productivity (Yadav *et al.*, 2019; Kumar *et al.*, 2016) [21, 8]. Major mustard producing states in the country are Rajasthan, accounting more than 47% of its production followed by Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat. In 2018-19, the average area was 36.59 million ha, production 72.37 million tonne with the productivity of 1980 kg/ha in the world (ICAR-DRMR). In India area under mustard is 6.02 mha, with production of 7.98 million tones and productivity is 1324 kg per hectare. (Directorate of Economics and Statistics, MoA, 2016-17).

Materials and Methods

The field experiment was conducted at Oilseed Research Farm, Chandra Shekhar Azad University of Agriculture and Technology, situated at Kalyanpur, Kanpur, 208024 (U.P.) during, Rabi 2020-22. Seven diverse parents were sown in five rows each during Rabi 2020-21 at Oilseed Research Farm, Kalyanpur, Kanpur for crossing programme. All possible cross combination excluding reciprocals were attempted in diallel fashion to produce F0 seeds. The final experiment was conducted at Oilseed Research Farm, Kalyanpur, Kanpur during *Rabi* 2021-22. Each Parent and F1s were evaluated in a Randomized Compact Block design with three replications. Each genotype was sown in single row of 5.0m long spaced at 45cm. The plant-to-plant distance was maintained at 20 cm by thinning at 15 DAS. All the recommended package of practices were adopted to raise good crop. The observations were recorded by five randomly selected plant for days to 50% flowering, days to maturity, plant height (cm), Length of main raceme (cm), Number of primary branches, Number of secondary branches, Number of siliquae per plant, Seed yield per plant (g),1000 seed weight (g), Oil content (%), Protein content (%), Methionine content (%), Tryptophan content (%).

The recommended set of steps was carried out along with the necessary preventative plant protection measures in order to raise a satisfactory harvest. It was done to record observations and statistically analyze the data. 'r' stands for the correlation coefficient, which indicates the strength and direction of relationship between two or more variables. A positive value of 'r' implies that changes in two variables are moving in the same direction, or positively correlated, whereas a negative value of 'r' shows that changes are moving in the opposite way. There are three different types of correlation, including phenotypic correlation, environmental correlation, and genotypic correlation.

The form of analysis taken up for obtaining co-variance components among different pairs of observations was the same as that for analysis of variance except that sum of squares were replaced by sum of products and mean squares were replaced by mean products. The phenotypic and genotypic correlation coefficients for all the characters under present investigation were calculated as per the method advocated by Singh and Chaudhary (1985) [17] and Al-Jibouri *et al*. (1958) [17, 2].

The estimates of co-variance and variance were utilized for computation of genotypic and phenotypic correlation coefficients.

Test of significance: The 't' values were approximated to test the significance of the correlation coefficients with (n-2) degrees of freedom by utilizing the formula advocated by Panse and Sukhatme (1985) [13].

Path Coefficient Analysis

Wright (1921) [20] suggested the procedure for path coefficient analysis and further elaborated by Dewey and Lu (1959) [5] for plant breeding. It was carried out on the basis of genotypic correlation. In order to devise path analysis three steps were followed calculation of direct effect, indirect effect and residual effect.

Direct effects: In path analysis, the straightway effect of an independent character on dependent character. The estimates of direct effect are worked out by putting the values of simple correlation coefficients on equations.

Indirect effects: It is effect of an independent character on dependent character via other independent characters. It is estimated by putting correlation coefficient values and those of direct effect values in equation.

Residual effects: The residual effects are those variations which occurred due to other possible independent variables and which cannot be explained under the present investigation. It is evaluated by deducting the value of coefficient of determination from unity. Residual effect was estimated by using the values of direct effects and correlation coefficients.

Results and Discussion

Correlation Coefficient Analysis

The correlation coefficient is carried out primarily to know the association between various attributes for indirect selection. Therefore, the knowledge of genetic association existing between yield and its components is essential for improving the efficiency of selection programme. Genotypic and phenotypic associations were worked out in all possible combinations involving 13 characters related to yield and its components.

In the present investigation, it was observed that the genotypic correlation coefficient was higher in magnitude than their corresponding phenotypic correlation coefficient for all the characters. The genotypic correlation coefficient of seed yield per plant (g) exhibited significant and positive correlation with main raceme length, number of primary branches per plant, number of secondary branches per plant, protein content (%), 1000 seed weight (g), oil content (%), tryptophan content (%), methionine content (%) and number of siliquae per plant while negative non-significant correlation with days to 50% flowering, days to maturity and plant height (cm).

Oil content showed significant and positive correlation with number of primary branches per plant, number of secondary branches per plant, main raceme length, number of siliquae per plant,1000 seed weight, protein content, seed yield per plant, methionine content and tryptophan content while negative non-significant correlation with days to 50% flowering, days to maturity andplant height.

Seed yield per plant exhibited positive significant phenotypic correlation with main raceme length, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, 1000 seed weight, oil content, protein content, methionine content and tryptophan content whereas days to 50% flowering, days to maturity and plant height showed negative non-significant correlation.

Oil content exhibited positive significant correlation with main raceme length, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, 1000 seed weight, protein content, seed yield per plant, methionine content and tryptophan content. While days to maturity, days to 50% flowering, plant height showed negatively non-significant correlation. These results were in parity of the findings of Vaghela *et al.* (2011) [19], Ali *et al.* (2002) [1] and Kumar *et al.* (2019) [7].

Path coefficient analysis

As simple correlation does not give a true contribution of the characters towards the yield, so these correlation values need to partitioned into their direct and indirect effects with the help of path coefficient analysis. Path coefficient analysis is simply a standardized partial regression coefficient which splits the genotypic correlation into the measures of direct and indirect effects. Thus, the correlation and path coefficient in combination can give a better insight into cause-and-effect relationship between different pairs of characters.

If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and a direct selection through this trait will be effective. If the correlation coefficient is negative and direct effect is also negative, then we drop the selection based on that character. Phenotypic path analysis values revealed that positive and direct effect on seed yield per plant was exerted by number of siliquae per plant followed by days to maturity, number of secondary branches per plant, protein content, methionine content, number of primary branches and 1000 seed weight. Whereas, oil content, tryptophan content, days to 50% flowering, plant height and main raceme length showed negative direct effect. The high values of direct effects show the true correlation of the characters with the yield. It was also reported that most of the characters showed high values of indirect effects *via* number of siliquae per plant, 1000 grain weight and oil content which shows that correlation of these characters with yield is not due to their direct effect but due to effect of other characters which can affect the effectivity during selection of these characters. The residual effect of path analysis was positive which indicates that some important yield contributing characters either genotypically or phenotypically have been left out. It is advised that they should be incorporated for study along with the attributes contributing for high yield potential. The present findings reflected the positive association between seed yield and all traits contributing to combined traits Lodhi *et al.* (2014) [10], Tripati *et al.* (2020) [18], Roy *et al.* (2018) [15] and Lavanya *et al.* (2022) [9].

Table 1: Details of genotype used as parents in the experiment:

S. No.	Genotypes	Pedigree	Characters
1	PR-20	Pureline selection from KRANTI	Days to maturity: 130-135 days, Oil content: 40-42 %
2	PR-21	(Varuna × Pusa Bold) × BSISP-23	Days to maturity: 130-135 days, Oil content: 38-40%
3	Azad Mahak	Mathura Rai × JD-6	Days to maturity: 120-125 days, Oil content: 41.6-42.1%
4	KMR17-5	Vardan × Maya	Days to maturity: 128-132 days, Oil content: 35-38%
5	KMR17-4	Rohini × B-85	Days to maturity:132-137 days, Oil content: 39-40%
6	NDR-8501	Selection from Atwa local (Fatehpur)	Days to maturity:130-155 days, Oil content: 38-42%
7	KMR(L)17-6	Vardan × Kranti	Days to maturity:125-128 days, Oil content: 35-38%

Table 2: Genotypic correlations

Characters	Days to 50% flowering	Days to maturity	Main raceme length (cm)	Plant height (cm)	Primary branches/plant	No of sec branches / plant	No. of siliqua/plant	1000 grain weight (g)	Oil content (%)	Protein content (%)	Methionine content (%)	Tryptophan content (%)	Seed yield per plant (g)
Days to 50% flowering	1.000	0.308**	-0.070	0.289**	-0.062	-0.265*	-0.278*	0.110	-0.013	-0.100	0.188	-0.256*	-0.135
Days to maturity			-0.362**	0.278*	-0.230*	-0.207	-0.153	0.079	-0.115	-0.158	-0.267*	-0.194	-0.065
Main raceme length (cm)				-0.071	0.599**	0.803**	0.760**	0.568**	0.607**	0.639**	0.589**	0.661**	0.669**
Plant height (cm)					0.128	-0.211	-0.213	-0.106	-0.183	-0.040	0.026	-0.189	-0.092
primary branches /plant						0.718**	0.528**	0.704**	0.733**	0.880**	0.628**	0.273*	0.711**
No of sec branches / plant							0.853**	0.799**	0.882**	0.822**	0.547**	0.590**	0.827**
No. of siliqua / plant								0.582**	0.767**	0.619**	0.364**	0.618**	0.754**
1000 grain weight (g)									0.857**	0.752**	0.647**	0.329**	0.785**
Oil content (%)										0.822**	0.660**	0.429**	0.752**
Protein content (%)											0.574**	0.394**	0.776**
Methionine content (%)												0.306**	0.568**
Tryptophan content (%)													0.485**
Seed yield per plant (g)													1.000

*, ** significant at 5% and 1% level, respectively

Table 3: Phenotypic correlations

Characters	Days to 50% flowering	Days to maturity	Main raceme length (cm)	Plant height (cm)	primary branches/plant	No of sec branches/plant	No. of siliqua / plant	1000 grain weight (g)	Oil content (%)	Protein content (%)	Methionine content (%)	Tryptophan content (%)	Seed yield per plant (g)
Days to 50% flowering	1.000	0.224*	-0.050	0.234*	-0.077	-0.177	-0.256*	0.083	-0.012	-0.068	0.162	-0.199	-0.128
Days to maturity			-0.282**	0.197	-0.175	-0.152	-0.135	0.080	-0.096	-0.116	-0.239*	-0.160	-0.052
Main raceme length (cm)				-0.078	0.502**	0.665**	0.691**	0.532**	0.574**	0.555**	0.548**	0.574**	0.625**
Plant height (cm)					0.107	-0.171	-0.193	-0.100	-0.158	-0.015	0.039	-0.175	-0.104
primary branches/plant						0.587**	0.475**	0.651**	0.647**	0.797**	0.576**	0.245*	0.640**
No of sec branches/plant							0.737**	0.690**	0.747**	0.700**	0.483**	0.541**	0.731**
No. of siliqua / plant								0.558**	0.720**	0.593**	0.349**	0.576**	0.735**
1000 grain weight (g)									0.820**	0.696**	0.628**	0.309**	0.759**
Oil content (%)										0.747**	0.625**	0.375**	0.704**
Protein content (%)											0.550**	0.342**	0.731**
Methionine content (%)												0.270*	0.552**
Tryptophan content (%)													0.438**
Seed yield per plant (g)													1.000

*, ** significant at 5% and 1% level, respectively

Table 4: Genotypic path with seed yield per plant (g)

Characters	Days to 50% flowering	Days to maturity	Main raceme length (cm)	Plant height (cm)	primary branches/plant	No of sec branches / plant	No. of siliqua / plant	1000 grain weight (g)	Oil content (%)	Protein content (%)	Methionine content (%)	Tryptophan content (%)	Seed yield per plant (g)
Days to 50% flowering	0.4275	-0.0671	0.0960	0.0027	-0.0002	-0.3307	-0.3881	0.0677	0.0291	-0.0651	0.1246	-0.0320	-0.135
Days to maturity	0.1318	-0.2176	0.4952	0.0026	-0.0007	-0.2581	-0.2127	0.0487	0.2498	-0.1030	-0.1768	-0.0241	-0.065
Main raceme length (cm)	-0.0300	0.0787	-1.3696	-0.0007	0.0018	1.0033	1.0594	0.3507	-1.3131	0.4156	0.3905	0.0823	0.669**
Plant height (cm)	0.1237	-0.0606	0.0977	0.0094	0.0004	-0.2641	-0.2963	-0.0654	0.3960	-0.0262	0.0169	-0.0236	-0.092
primary branches /plant	-0.0264	0.0501	-0.8207	0.0012	0.0030	0.8977	0.7359	0.4344	-1.5867	0.5725	0.4162	0.0340	0.711**
No of sec branches / plant	-0.1131	0.0449	-1.0994	-0.0020	0.0022	1.2499	1.1894	0.4930	-1.9088	0.5349	0.3624	0.0736	0.827**
No. of siliqua / plant	-0.1190	0.0332	-1.0408	-0.0020	0.0016	1.0664	1.3941	0.3593	-1.6600	0.4031	0.2410	0.0770	0.754**
1000 grain weight (g)	0.0469	-0.0172	-0.7786	-0.0010	0.0021	0.9987	0.8117	0.6170	-1.8537	0.4895	0.4286	0.0409	0.785**
Oil content (%)	-0.0058	0.0251	-0.8313	-0.0017	0.0022	1.1028	1.0697	0.5287	-2.1634	0.5348	0.4376	0.0535	0.752**
Protein content (%)	-0.0428	0.0344	-0.8745	-0.0004	0.0026	1.0271	0.8633	0.4640	-1.7775	0.6509	0.3801	0.0491	0.776**
Methionine content (%)	0.0804	0.0581	-0.8071	0.0002	0.0019	0.6836	0.5069	0.3990	-1.4287	0.3733	0.6627	0.0382	0.568**
Tryptophan content (%)	-0.1096	0.0422	-0.9047	-0.0018	0.0008	0.7379	0.8619	0.2027	-0.9281	0.2565	0.2029	0.1246	0.485**

Resi- 0.0746

*, ** significant at 5% and 1% level, respectively

Table 5: Phenotypic path with seed yield per plant (g)

Characters	Days to 50% flowering	Days to maturity	Main raceme length (cm)	Plant height (cm)	primary branches/plant	No of sec branches/plant	No. of siliqua/plant	1000 grain weight (g)	Oil content (%)	Protein content (%)	Methionine content (%)	Tryptophan content (%)	Seed yield per plant (g)
Days to 50% flowering	-0.0505	0.0078	0.0011	-0.0038	-0.0023	-0.0148	-0.1217	0.0377	0.0045	-0.0169	0.0273	0.0035	-0.128
Days to maturity	-0.0113	0.0347	0.0059	-0.0032	-0.0052	-0.0126	-0.0643	0.0361	0.0347	-0.0290	-0.0402	0.0028	-0.052
Main raceme length (cm)	0.0026	-0.0098	-0.0210	0.0013	0.0149	0.0553	0.3286	0.2403	-0.2078	0.1382	0.0922	-0.0102	0.625**
Plant height (cm)	-0.0118	0.0068	0.0016	-0.0164	0.0032	-0.0142	-0.0917	-0.0450	0.0573	-0.0037	0.0066	0.0031	-0.104
primary branches/plant	0.0039	-0.0061	-0.0106	-0.0018	0.0296	0.0488	0.2258	0.2938	-0.2346	0.1987	0.0969	-0.0043	0.640**
No of sec branches/plant	0.0090	-0.0053	-0.0140	0.0028	0.0174	0.0832	0.3505	0.3117	-0.2709	0.1746	0.0813	-0.0096	0.731**
No. of siliqua/plant	0.0129	-0.0047	-0.0145	0.0032	0.0141	0.0613	0.4755	0.2519	-0.2609	0.1478	0.0588	-0.0102	0.735**
1000 grain weight (g)	-0.0042	0.0028	-0.0112	0.0016	0.0193	0.0574	0.2653	0.4515	-0.2972	0.1734	0.1057	-0.0055	0.759**
Oil content (%)	0.0006	-0.0033	-0.0121	0.0026	0.0192	0.0622	0.3424	0.3702	-0.3624	0.1862	0.1052	-0.0067	0.704**
Protein content (%)	0.0034	-0.0040	-0.0117	0.0002	0.0236	0.0583	0.2819	0.3140	-0.2707	0.2492	0.0925	-0.0061	0.731**
Methionine content (%)	-0.0082	-0.0083	-0.0115	-0.0007	0.0170	0.0402	0.1662	0.2834	-0.2264	0.1370	0.1684	-0.0048	0.552**
Tryptophan content (%)	0.0100	-0.0056	-0.0121	0.0029	0.0073	0.0450	0.2737	0.1396	-0.1360	0.0851	0.0455	-0.0177	0.438**

Resi-0.02228

*, ** significant at 5% and 1% level, respectively

Conclusion

Genotypic and phenotypic correlation coefficients & path coefficient analysis for 13 characters in all possible combinations were computed. Significant positive correlation coefficient values were found in seed yield per plant with number siliquae per plant, number of secondary branches per plant, number of primary branches per plant, main raceme length, oil content, protein content, 1000 seed weight, tryptophan content and methionine content.

On portioning the phenotypic path coefficient, it was observed that the highest positive and direct effect on seed yield per plant was exerted by number of siliquae per plant followed by days to maturity, number of secondary branches per plant, protein content, methionine content, number of primary branches and 1000 seed weight. Whereas, tryptophan content, days to 50% flowering, main raceme length, oil content and plant height showed negative direct effects.

Thus, the selection pressure on these traits may lead to overall increase in the yield.

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