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ORIGINAL ARTICLE

Association, Regression and Cause-Effect relationship for yield and its attributes in Indian mustard under Rainfed condition

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ABSTRACT
An experiment on Indian mustard (BrassicajunceaL. Czern&Coss) was conducted in Randomized Complete Block Design (RCBD) in three replications,randomly accommodating 50 genotypes, from various Rapeseed & Mustard centres located across countryfor association, regression and cause-effect studies,during Rabi 2015-16 at the research farm of Tirhut College of Agriculture, Dholi, Muzaffarpur under rainfed(residual moisture) condition. GYP^{-1} showed significant positive inter-relationship with root, siliqua, branching traits and other attributes like SG, IL, HP, TSW, BY, HI and DME whereas, negative significant association with flowering- maturity, HFPB, HFS, AB & AS and also showed uncorrelated response with OC. The path analysis revealed importance of traits like earliness in DFF, DFFO & DPM (negative high direct effect) and RV, SS^{-1}, IL (positive high direct effect) which can influence yield of the plant under studied moisture stress rainfed environment. Thus based on correlation, path and regression analyses, early fifty percent flowering with early physiological maturity genotypes possessing high RV, more RG, less IL bearing more number of seeds per siliqua inside longer siliqua were favourable for developing high yielding Brassica genotypes under residual moisture rainfed stressed environment. This can also be suggested that selections based on early stage scanning by using non-destructive methodologies, including magnetic resonance imaging, and X-rays for root characteristics like RV along with various morpho-physiological characters which are phenotypically identified at different phenological growth stages may be utilized for mustard genetic enhancement under rainfed moisture stressed environment.
Key words: *Brassicajuncea L., Association, Cause-Effect, Regression, Residual moisture*

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INTRODUCTION

Indian mustard [*Brassica juncea*(L.)Czern&Coss.] is amphidiploid (AABB; 2n=36) predominantly cultivated *Brassica* species occupying an important position along with Toria (diploid AA;2n=20) in the rainfed agriculture of our country. Rapeseed-mustard group of crops require less water (80-240 mm) and thus fits well in the rainfed cropping system, which accounts for 30% of the total cropped area in the country under these crops.

Generally, *Brassica* species has been developed in the areas with high rainfall and performs poorly in the areas with low rainfall [18, 20]. Growth and seed yield production of *Brassica* species have greatly decreased owing to drought conditions. Also, plant responses to water deficit stress are confounded by several factors such as time, intensity, duration and frequency of stress as well as by plant, soil and climate interactions [9,19]. In addition, the difficulty to establish well-defined and repeatable water stress conditions makes screening of drought tolerant genotypes more complex [17]. However plants respond and adapt to drought stress by the induction of various morphological and physiological responses [32]. Many physiological factors could be involved in the drought stress injury [10,11] which may promise for characterizing drought resistance in screening studies.

Yield is a complex, dependent character as it is associated with other morphological/agronomical traits that are transmitted quantitatively and more prone to environmental fluctuations than ancillary, independent morpho-physiological qualitatively inherited traits which cumulatively affect the yield expression. Any change in component traits likely to affect the whole network of cause and effect. The intern might affect the true association of traits, both in magnitude and direction and tend to vitiate association of yield and yield components [4]. To improve yield, it is necessary to evaluate the involvement of each character that contributes to it [30]. Understanding the association between yield and its components is of paramount importance for making the best use of these relationships in selection [22, 14]. Correlation coefficient measures only the degree and direction of relationship among the variables, while regression analysis quantifies the rate of change in dependent variable for unit change in independent variables. The degree and direction of relationship among attributes on the genetic linkage or pleiotropic effect of gene. The path coefficient analysis helps breeders to explain direct and indirect effects, in identifying component traits directly contributing towards yield in positive (eg. branching, root & siliqua traits or negative (DFFO, DFF, DPM, HFPB, HFS etc) direction and hence been extensively used in breeding experiments in different crop species [1, 2]. The present investigation was undertaken to assess the trait association, path coefficient and regression analyses in Indian mustard.

MATERIAL AND METHODS

The experiment consisting of 50 Indian mustard genotypes was planted on 10th October 2015 under rainfed condition, laid out in Randomized Complete Block Design (RCBD) with three replications during *Rabi* season (2015-16) , including four checks namely, Pusa Mahak (Zonal Check),Varuna (National Check), Pusa Bold (National Check) and Rajendra Suphlam (Local Check) for association, regression and cause-effect study, received from different All India Co-ordinated Research Project- Rapeseed & Mustard centres: DRMR, Bharatpur, Rajasthan, CCSHAU, Hisar, Haryana ,BARC, Trombay, Maharastra, GBPUAT, Pantnagar, Uttarkhand, CSAUAT, Kanpur, U.P, IARI, NewDelhi, ARS, RAU, Sriganganagar, Rajasthan, DR.RPCAU, Dholi, Bihar, NDUAT, Faizabad, U.P and BAU, Kanke, Ranchi, Jharkhand, providing only basal dose of fertilizers i.e. $N:P_2O_5:K_2O:S$:: 40:40:40:40 kg/ha under residual moisture conditions after the harvest of preceeding medium - early (110-115 days) paddy variety, Rajendra Bhagwati at the research farm in Loam soil (8.4 pH) of Tirhut College of Agriculture, Dholi, Muzaffarpur (25.5^0 N, 85.4^0E and 52.12 m MSL) (Dr. Rajendra Prasad Central Agricultural University, Pusa),Bihar. Each plot was consisted four rows of 5.0 m length keeping row to row and plant to plant distance 30cm and 10cm, respectively. The spacing between plants was maintained at 10 cm by thinning at 14 DAS.

Meteorological data (*Kharif* & *Rabi*2015-16) reflected that the experiment was sown, under residual moisture condition, as the preceeding *Kharif* crop rice has received 697.20 mm rainfall distributed in 25 rainy days between June to September (23rd to 38th meteorological weeks 2015). After that experiment faced climatic uncertainty by not receiving any rainfall at all its phenological stages.

The observations were recorded for days to first flower open (DFFO), days to 50%flowering (DFF), days to physiological maturity (DPM), primary branches plant^{-1}(PBP^{-1}), secondary branches plant^{-1}(SBP^{-1}), number of siliqua plant^{-1}(NS), length of siliqua (LS), stem girth (SG), internode length (IL), height of the plant (HP), number of siliqua on primary mother axis (SPMA), height of first primary branch (HFPB), height of first siliqua (HFS), angle of branch (AB), angle of siliqua (AS), number of seeds siliqua^{-1}(SS^{-1}), root volume (RV), root length (RL), root girth (RG), 1000 seed weight (TSW), biological yield (BY), harvest index (HI), oil content (OC), dry matter efficiency (DME) and grain yield plant^{-1} (GYP^{-1}). The data were recorded on five randomly selected plants from each genotype in each replication leaving the border rows to avoid the sampling error. The observations were recorded using standard methodology. Readings from five plants were averaged replication-wise and the mean data subjected for analysis by using statistical package WINDOSTAT version 9.2 (INDOSTAT Service, Hyderabad)for yield and its morpho-physio-quality traits. The Correlation, Regression and Path analysis were calculated following standard statistical methods [34, 35].

RESULTS AND DISCUSSION

From the study of 50 Indian mustard genotypes for association, it was clear that genotypic correlation for all the 25 characters were more than that of phenotypic correlation in different proportions between character to character which indicated that the traits are more or less influenced by environmental effects.

On perusal of Table 1 and 2 & Fig 1, DFFO, DFF, DPM exhibited positive significant association between them and also with HFPB, HFS, AB and AS; whereas reflected negative significant association with GYP^{-1}, DME, HI and root, siliqua, shoot related attributes except oil content for which uncorrelated response was noticed, indicating adverse effect of lateness in DFFO, DFF and DPM on yield and its attributes under rainfed- residual moisture stressed condition whereas with oil content was not affected by traits under rainfed residual moisture condition.

Root parameters, namely RL, RV and RG were positively significantly associated with yield revealing their importance for rainfed *Brassica* genotypes development and also positively associated between themselves. These characters showed negative significant association with HFPB, HFS, AB and AS.Except for oil content, root parameters reflected positive significant association with other morpho physiological traits.

Siliqua parameters, namely NS, LS, AS, SS^{-1} and SPMA reflected positive significant association between NS and LS; NS and SS^{-1}; NS and SPMA; LS and SPMA; LS and SS^{-1}, HFS and AS, whereas negative significant with NS and AS; LS and AS; SPMA and AS; HFS and SS^{-1} under rainfed - residual moisture condition. Similarly NS, LS and SS^{-1} exhibited positive whereas AS reflected negative significant association with GYP^{-1}.These results were in accordance with Ejaz-Ul-Hasan *et al.* [8] for association of NS and LS with SS^{-1}.

Table 1: Genotypic Correlation coefficient for characters in Indian mustard genotypes under rainfed (residual moisture) condition

No	1	2	3	4	5	6	7	8	9	10
Character	DFFO	DFF	DPM	PBP-1	SBP-1	NS	LS	SG	IL	HP
DFFO	1.000									
DFF	0.914	1.000								
DPM	0.391	0.223	1.000							
PBP-1	-0.953	-0.909	-0.222	1.000						
SBP-1	-0.972	-0.906	-0.236	0.995	1.000					
NS	-0.919	-0.962	-0.196	0.985	0.995	1.000				
LS	-0.856	-0.963	-0.299	0.973	0.948	0.915	1.000			
SG	-0.763	-0.931	-0.686	0.979	0.995	0.976	0.852	1.000		
IL	-0.995	-0.934	-0.706	0.886	0.907	0.970	0.997	0.905	1.000	
HP	-0.667	-0.831	-0.750	0.910	0.684	0.953	0.892	0.980	0.960	1.000
SPMA	-0.990	-0.912	-0.701	0.973	0.984	0.967	0.865	0.917	0.932	0.997
HFPB	0.375	0.334	0.460	-0.342	-0.379	-0.336	-0.433	-0.314	-0.442	-0.486
HFS	0.708	0.902	0.677	-0.978	-0.944	-0.908	-0.859	-0.933	-0.799	-0.905
AB	0.949	0.990	0.708	-0.993	-0.966	-0.948	-0.993	-0.973	-0.871	-0.869
AS	0.754	0.974	0.638	-0.893	-0.980	-0.969	-0.812	-0.894	-0.839	-0.851
SS-1	-0.632	-0.632	-0.809	0.621	0.604	0.592	0.762	0.593	0.700	0.721
RV	-0.931	-0.871	-0.928	0.889	0.906	0.917	0.964	0.936	0.925	0.879
RL	-0.743	-0.993	-0.709	0.967	0.973	0.965	0.657	0.993	0.993	0.985
RG	-0.725	-0.993	-0.691	0.964	0.981	0.967	0.806	0.930	0.993	0.983
TSW	-0.600	-0.652	-0.663	0.662	0.684	0.692	0.642	0.683	0.682	0.631
BY	-0.474	-0.550	-0.472	0.590	0.582	0.813	0.555	0.674	0.589	0.564
HI	-0.630	-0.806	-0.652	0.733	0.981	0.921	0.659	0.971	0.748	0.741
OC	0.062	-0.178	-0.174	-0.036	-0.037	-0.028	0.160	0.063	0.101	0.166
DME	-0.653	-0.914	-0.719	0.814	0.995	0.940	0.751	0.993	0.931	0.772
GYP-1	-0.759	-0.855	-0.742	0.991	0.979	0.926	0.968	0.980	0.817	0.853

0.981	-0.455	-0.836	-0.830	-0.873	0.745	0.802	0.951	0.943	0.778	0.786	0.846	0.052	0.760	1.000
0.972	-0.422	-0.821	-0.780	-0.727	0.679	0.832	0.945	0.945	0.664	0.583	0.994	0.091	1.000	
0.103	0.235	-0.036	-0.122	-0.157	0.264	0.091	0.142	0.127	0.048	-0.082	0.094	1.000		
0.954	-0.430	-0.618	-0.781	-0.780	0.706	0.803	0.923	0.922	0.723	0.483	1.000			
0.553	-0.644	-0.595	-0.587	-0.645	0.574	0.884	0.580	0.567	0.493	1.000				
0.664	-0.507	-0.659	-0.676	-0.651	0.953	0.654	0.670	0.703	1.000					
0.923	-0.305	-0.928	-0.975	-0.849	0.583	0.974	0.950	1.000						
0.714	-0.336	-0.935	-0.982	-0.998	0.617	0.964	1.000							
0.972	-0.297	-0.810	-0.877	-0.899	0.539	1.000								
0.599	-0.768	-0.690	-0.702	-0.735	1.000									
-0.921	0.447	0.868	0.893	1.000										
-0.977	0.457	0.944	1.000											
-0.944	0.474	1.000												
-0.373	1.000													
1.000														
SPMA	HFPB	HFS	AB	AS	SS-1	RV	RL	RG	TSW	BY	HI	OC	DME	GYP-1
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Branching traits PBP^{-1} and SBP^{-1} were negatively significantly associated and showed positive significant association with GYP^{-1} , DME, HI ; negative with HFS, HFPB, AB & AS whereas positive with most of other morpho- physiological traits except OC.
Oil content under rainfed (residual moisture) condition, reflected uncorrelated response with all the studied characters, including GYP^{-1}.

Table 2: Phenotypic Correlation coefficient for characters in Indian mustard genotypes under rainfed(residual moisture) condition

No	1	2	3	4	5	6	7	8	9	10	11
Character	DFFO	DFF	DPM	PBP-1	SBP-1	NS	LS	SG	IL	HP	SPMA
DFFO	1.000										
DFF	0.749**	1.000									
DPM	0.391**	0.323*	1.000								
PBP-1	-0.746**	-0.820**	-0.315*	1.000							
SBP-1	-0.766**	-0.847**	-0.326*	0.960**	1.000						
NS	-0.723**	-0.820**	-0.396**	0.938**	0.958**	1.000					
LS	-0.696**	-0.761**	-0.299*	0.816**	0.825**	0.824**	1.000				
SG	-0.363**	-0.837**	-0.291*	0.898**	0.935**	0.927**	0.821**	1.000			
IL	-0.745**	-0.828**	-0.265*	0.822**	0.900**	0.882**	0.837**	0.883**	1.000		
HP	-0.257*	-0.812**	-0.731**	0.844**	0.841**	0.819**	0.804**	0.830**	0.841**	1.000	
SPMA	-0.721**	-0.820**	-0.254*	0.890**	0.916**	0.889**	0.833**	0.712**	0.878**	0.832**	1.000
HFPB	0.267*	0.280*	0.288*	-0.334*	-0.373**	-0.322*	-0.348**	-0.304*	-0.387**	-0.438**	-0.354**
HFS	0.626**	0.793**	0.299*	-0.853**	-0.853**	-0.827**	-0.784**	-0.824**	-0.864**	-0.855**	-0.807**
AB	0.711**	0.848**	0.269*	-0.876**	-0.884**	-0.858**	-0.797**	-0.851**	-0.729**	-0.858**	-0.861**
AS	0.354**	0.806**	0.348**	-0.806**	-0.905**	-0.868**	-0.797**	-0.609**	-0.651**	-0.753**	-0.881**
SS-1	-0.560**	-0.592**	-0.491**	0.616**	0.591**	0.538**	0.572**	0.582**	0.601**	0.602**	0.596**
RV	-0.658**	-0.754**	-0.654**	0.842**	0.882**	0.897**	0.796**	0.903**	0.841**	0.779**	0.910**
RL	-0.433**	-0.843**	-0.232	0.901**	0.926**	0.924**	0.539**	0.941**	0.906**	0.855**	0.935**
RG	-0.465**	-0.827**	-0.245*	0.865**	0.902**	0.911**	0.639**	0.810**	0.868**	0.814**	0.711**
TSW	-0.412**	-0.357**	-0.559**	0.350**	0.342**	0.293*	0.408**	0.362**	0.364**	0.376**	0.373**
BY	-0.257*	-0.295*	-0.399**	0.220	0.236*	0.559**	0.289*	0.583**	0.254*	0.251*	0.222
HI	-0.230	-0.760**	-0.396**	0.406**	0.736**	0.715**	0.640**	0.713**	0.318**	0.641**	0.694**
OC	-0.034	-0.027	-0.019	-0.033	-0.016	-0.024	0.027	0.031	0.054	0.005	0.031
DME	-0.329**	-0.791**	-0.419**	0.764**	0.769**	0.749**	0.716**	0.743**	0.773**	0.639**	0.732**
GYP-1	-0.668**	-0.795**	-0.684**	0.837**	0.833**	0.801**	0.777**	0.816**	0.851**	0.790**	0.802**

-0.387**	-0.830**	-0.822**	-0.863**	0.556**	0.698**	0.812**	0.782**	0.608**	0.621**	0.738**	0.052	0.759**	1.000
-0.334**	-0.798**	-0.525**	-0.673**	0.540**	0.657**	0.768**	0.755**	0.588**	0.496**	0.802**	0.064	1.000	
0.093	-0.035	-0.010	-0.092	0.022	0.050	0.018	0.024	0.012	-0.027	0.025	1.000		
-0.330**	-0.321*	-0.618**	-0.672**	0.524**	0.617**	0.737**	0.352**	0.560**	0.278*	1.000			
-0.365**	-0.346**	-0.439**	-0.315*	0.317*	0.509**	0.380**	0.502**	0.422**	1.000				
-0.255*	-0.315*	-0.339**	-0.401**	0.556**	0.233*	0.359**	0.323*	1.000					
-0.288*	-0.811**	-0.849**	-0.603**	0.565**	0.920**	0.410**	1.000						
-0.320*	-0.847**	-0.884**	-0.892**	0.575**	0.937**	1.000							
-0.286*	-0.738**	-0.806**	-0.827**	0.415**	1.000								
-0.292*	-0.626**	-0.632**	-0.597**	1.000									
0.405**	0.515**	0.425**	1.000										
0.425**	0.896**	1.000											
0.435**	1.000												
1.000													
HFPB	HFS	AB	AS	SS-1	RV	RL	RG	TSW	BY	HI	OC	DME	GYP-1
12	13	14	15	16	17	18	19	20	21	22	23	24	25

GYP^{-1}, uncorrelated with oil content in rainfed – residual moisture condition, expressed positive, significant inter-relationship with root (RL, RV, RG), siliqua (NS, LS, SPMA and SS^{-1}) , branching traits (PBP^{-1} and SBP^{-1}) and other attributes like SG, IL, HP, TSW, BY, HI and DME. While negative significant association observed with flowering- maturity (DFFO, DFF, DPM), HFPB, HFS, AB & AS. HFPB & HFS were positively associated traits and were also positive with DFFO, DFF and DPM; AB & AS. These characters showed negative association with yield and other attributes except oil content. Similar results were found by Ramanjaneyulu and Giri [16], Verma *et al.* [31], Singh and Singh [25] for SBP^{-1}; Zhau and Liu [33] for HFPB; Malik *et al.* [14] for siliqua length; Thurling and Das [27] for DFF; Singh *et al*. [24] for TSW;

Thurling [28, 29], Campbell and Kondra [5] and Kumar *et al.* [12] for HI; Kardam & Singh [11] for HP, PBP^{-1}, NS, $SS^{-1}$and TSW; Gangapur *et al.* [9] for BY; Singh *et al.* [24] for RL ; Bind *et al.* [3] for DFF and DPM .Selection would be helpful in simultaneous improvement in some of these traits for yield improvement of Indian mustard genotypes under residual moisture condition depending upon their direct effect towards GYP^{-1}.Oil content can be improved independently without affecting others in this particular environmental condition. It is clear from the association that decrease in maturity durationwas correlated with lower placement of branch and siliqua; least branch and siliqua angle.

Perusal of genotypic and phenotypic path coefficient analyses (Table 3, 4 &Fig 3) RV & SS^{-1} showed high positive whereas, IL, RG, PBP^{-1} and LS exhibited moderate positive direct effects; Contrastingly, DFF, DFFO & DPM showed high negative direct effect on GYP^{-1}. Thus, reflecting role of more root volume and seeds per siliqua towards GYP $^{-1}$ and moderate role of more SL, RG, PBP^{-1} & IL along with importance of early, medium – early DFFO, DFF & DPM. This may be due to the fact that as early genotypes enter into reproductive phase and reach physiological maturity will be less affected by moisture stress in rainfed residual moisture crop conditions. These results were in accordance with Verma *et al.* [31] for PBP^{-1}. Singh and Sharma [23] observed flowering period is considerably reduced which increases synchrony both within and between racemes of a plant. It is known that earliness is associated with increased photoperiod insensitivity. Chatterjee and Sengupta [6] reported that allowing more vegetative growth only reduced the harvest index without any significant increase in yield. Sadaqat *et al*. [21]) and Naeemi *et al*. [15] observed condition of reduced number of branches during the shortage of soil moisture. Chauhan *et al.* [7] found that primary branches per plant and secondary branches per plants greatly reduced under drought conditions.

Flowering – maturity traits had high negative direct effect and established negative correlation with GYP^{-1} via indirect contribution of other traits like IL, RG, PBP^{-1}. Even though RV showed high positive indirect effect but it was nullified by the positive cumulative direct and indirect effects towards GYP^{-1}.

The root parameter RV showed high positive direct effect on GYP^{-1}, also contributed via PBP^{-1}, IL and RG and constituted positive phenotypic association with GYP^{-1}. Whereas, RG reflected moderate positive direct effect towards GYP^{-1} and with the help of positive indirect effects PBP^{-1}& IL established positive significant association. RL had low positive direct effect on GYP^{-1} but due to cumulative high (AS) and moderate (IL and PBP^{-1}) along with other traits contributed positive significant association with GYP^{-1}.Conclusively, exhibited maximum role of RV followed by RG as yield determinants.

The siliqua characteristics like SS^{-1} showed high positive direct effect on GYP^{-1} also contributed via IL, RG for establishing positive correlation with GYP^{-1}. LS showed moderate positive direct effect on GYP^{-1} also contributed via RL, RG, AS, PBP^{-1}; Whereas SPMA had low positive direct effect on GYP^{-1} and established positive association with GYP^{-1} utilizing indirect contributed via IL, AS & RG. AS reflected low negative direct effect on GYP^{-1}also contributed via PBP^{-1}, IL and RG.These results were in accordance with Lodhi *et al.* [13] for SS^{-1} indicated that under water stress condition total number of siliqua decreases.

Character like NS, HP, TSW and DME exhibited positive significant phenotypic correlation with yield but reflected negative low direct effect whereas AB expressed negative significant phenotypic correlation but its direct effect was low positive. Such characters, reflecting contracting direct effect and remaining those characters which have either expressed positive (PBP^{-1}, SBP^{-1}, SG, SPMA, RL, BY, HI) or negative (HFPB, HFS, AS) phenotypic association along with low direct effect in the same direction could not be utilized for improvement under rainfed residual moisture stress environment.

On the basis of the results of path analysis, it can be inferred traits like RV, SS^{-1}, IL(high); RG and LS (moderate) positive direct effect on yield of the plant whereas DFF, DFFO, DPM (high) negative direct effect reflected importance of early *Brassica* genotypes in rainfed residual moisture stress environment.

The multiple regression of GYP^{-1} on various agro-morphological traits studied to confirm the result of correlation analysis is presented in Table 5and 6. The adjusted coefficient of determination (R^2) for variance of grain yield per plant was recorded as 81.33 percent of variation explained by only the independent variables that actually affect the dependent variable i.e. GYP^{-1} RV and AS recorded maximum value of R^2. Among the agro-morphological traits studied, four traits viz., DFF, PH, SS^{-1} and RL showed significant values, DFF, PH and SS^{-1} showed negative while RL reflected positive correlation with GYP^{-1}. The stepwise regression coefficient of GYP^{-1} showed 82.18% adjusted R^2. It was also observed the maximum contribution was made by RV, RG, DFFO, AS, PBP^{-1}, DPM, IL and LS.These traits can be considered as selection criteria for yield improvement as early-flowering - maturing genotypes with more root volume and root girth , which is established before start of reproductive phase and early phonological growth stages ; less IL & less AS which minimize the transpiration loss by creating shadow effect over the green pod wall withhigh voluminous and maximum girth of root for establishment of plant during early phonological growth stages in Indian mustard genotypes under rainfed condition will improvised the yield.

Conclusively, the characters like DFF, DPM, RV, RG, SS-1, LS and IL based on correlation, path and regression analysis exhibited their importance towards grain yield and could be utilized for moisture stress-tolerant Indian mustard genotype development.

Table 3: Genotypic Path coefficient analysis of characters on grain yield in Indian mustard genotypes under rainfed (residual moisture) condition

No.	1	2	3	4	5	6	7	8	9	10
Character	DFFO	DFF	DPM	PBP-1	SBP-1	NS	LS	SG	IL	HP
DFFO	-0.388	-0.075	0.521	0.029	-0.069	-0.037	0.034	0.408	-0.014	-0.191
DFF	-0.081	-1.009	0.644	0.028	-0.065	-0.035	0.032	0.565	-0.012	-0.186
DPM	-0.099	-0.24	-0.463	0.034	-0.081	-0.043	0.037	0.7	-0.017	-0.225
PBP-1	0.081	0.998	-0.864	0.187	0.061	0.035	-0.031	-0.543	0.012	0.182
SBP-1	0.08	1.003	-0.873	-0.027	0.176	0.034	-0.03	-0.549	0.014	0.062
NS	0.08	0.698	-0.877	-0.027	0.061	-0.029	0.033	-0.52	0.012	0.169
LS	0.087	0.956	-0.79	-0.026	0.064	-0.034	0.037	-0.594	0.056	0.147
SG	0.079	0.797	-0.756	-0.027	0.063	0.034	-0.03	0.174	0.011	-0.565
IL	0.083	1.010	-0.651	-0.029	0.063	0.034	-0.033	-0.366	0.363	0.169
HP	0.082	0.987	-0.835	-0.029	0.061	0.036	-0.031	0.193	0.017	-0.556
SPMA	0.079	0.831	-0.848	-0.028	0.064	0.035	-0.031	-0.558	-0.021	0.175
HFPB	-0.028	-0.28	0.194	0.011	-0.02	-0.015	0.015	0.108	-0.036	-0.088
HFS	-0.079	-0.946	0.797	0.53	-0.059	-0.034	0.032	0.526	-0.017	-0.176
AB	-0.08	-0.769	0.432	0.329	-0.061	-0.035	0.033	0.645	-0.016	-0.194
AS	-0.081	-1.003	0.85	0.029	-0.063	-0.036	0.032	0.369	-0.016	-0.189
SS-1	0.131	0.485	-0.349	-0.046	0.099	0.058	-0.053	-0.892	0.028	0.314
RV	0.072	0.909	-0.804	-0.025	0.059	0.031	-0.027	-0.542	0.011	0.151
RL	0.078	0.975	-0.846	-0.027	0.062	0.034	-0.03	-0.566	0.012	0.174
RG	0.078	0.833	-0.848	-0.027	0.063	0.034	-0.03	-0.564	0.011	0.173
TSW	0.109	0.845	-1.134	-0.037	0.085	0.046	0.002	-0.268	0.018	0.244
BY	0.09	0.313	-0.888	-0.031	0.067	0.039	-0.037	-0.125	0.023	0.213
HI	0.081	0.984	-0.808	-0.027	0.061	0.035	-0.032	-0.532	0.015	0.19
OC	-0.002	-0.037	0.016	-0.004	0.004	0.003	-0.005	-0.058	-0.008	0.007
DME	0.082	0.998	-0.824	-0.027	0.062	0.035	-0.032	-0.542	0.015	0.19

-0.022	0.103	-0.003	-0.409	0.315	0.419	-0.053	0.209	-0.394	-0.001	0.483	0.082	0.898	-0.824	0.760
-0.003	0.005	0.003	-0.045	0.053	0.101	-0.002	-0.015	-0.037	-0.009	-0.037	-0.002	0.053	0.071	0.052
-0.022	0.102	-0.003	-0.395	0.347	0.247	-0.052	0.209	-0.393	-0.001	0.583	0.081	0.984	-0.808	0.846
-0.025	0.107	-0.004	-0.435	0.728	0.386	-0.055	0.178	-0.463	0.001	0.689	0.09	0.813	-0.888	0.786
-0.029	0.135	-0.004	-0.606	0.511	0.571	-0.039	0.388	-0.532	-0.042	0.995	0.309	0.345	-1.134	0.778
-0.021	0.096	-0.003	-0.479	0.377	0.190	-0.051	-0.362	0.810	-0.001	0.551	0.078	0.883	-0.848	0.943
-0.021	0.096	-0.003	-0.474	0.376	0.678	-0.052	0.190	-0.363	-0.001	0.552	0.078	0.875	-0.846	0.951
-0.019	0.086	-0.003	-0.492	-0.048	0.789	0.362	0.157	-0.316	-0.001	0.375	0.072	0.809	-0.804	0.802
-0.037	0.167	-0.002	-0.696	0.492	0.267	-0.075	0.259	-0.658	-0.002	0.978	0.131	0.495	-0.349	0.745
0.022	-0.096	0.003	0.842	-0.375	-0.802	0.054	-0.192	0.617	0.001	-0.605	-0.081	-1.003	0.85	-0.873
0.022	-0.099	0.203	0.431	-0.369	-0.79	0.361	-0.102	0.401	0.001	-0.556	-0.08	-0.969	0.432	-0.830
0.022	0.023	-0.088	0.398	-0.351	-0.752	0.051	-0.245	0.354	0.001	-0.595	-0.079	-0.946	0.797	-0.836
0.01	-0.043	0.001	0.146	-0.126	-0.147	0.032	-0.114	0.293	-0.008	-0.246	-0.028	-0.28	0.194	-0.455
0.013	0.098	-0.003	-0.478	0.381	0.819	-0.053	0.199	-0.375	-0.001	0.567	0.079	0.885	-0.848	0.981
-0.023	0.101	-0.402	-0.432	0.37	0.796	-0.053	0.215	-0.41	-0.002	0.574	0.082	0.947	-0.835	0.853
-0.022	0.101	-0.013	-0.455	0.016	0.804	-0.053	0.164	-0.4	-0.699	0.432	0.083	0.867	-0.651	0.817
-0.021	0.097	-0.003	-0.46	0.415	0.818	-0.053	0.191	-0.382	-0.001	0.579	0.079	0.697	-0.756	0.98
-0.024	0.105	-0.013	-0.474	0.39	0.642	-0.054	0.201	-0.409	-0.011	0.464	0.087	0.951	-0.79	0.968
-0.02	0.093	-0.023	-0.451	0.24	0.407	-0.05	0.18	-0.288	0.064	0.447	0.08	0.698	-0.977	0.926
-0.021	0.096	-0.023	-0.426	0.357	0.674	-0.052	0.187	-0.386	0.022	0.58	0.08	0.874	-0.873	0.979
-0.021	0.097	-0.003	-0.437	0.315	0.681	-0.052	-0.028	-0.396	0.011	0.591	0.081	0.898	-0.864	0.991
0.026	-0.13	0.004	0.455	-1.009	1.049	0.06	-0.239	0.47	0.016	-0.757	-0.099	-0.24	0.049	-0.742
0.021	-0.103	0.201	0.428	-0.363	-0.504	0.052	-0.212	0.296	0.012	-0.591	-0.081	-0.536	0.644	-0.855
0.023	-0.107	0.003	0.328	-0.085	-0.86	0.054	-0.523	0.428	-0.013	-0.658	-0.085	-0.075	0.593	-0.759
SPMA	HFPB	HFS	AB	AS	SS-1	RV	RL	RG	TSW	BY	HI	OC	DME	GYP-1
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Residual effect = 0.244

Table 4: Phenotypic Path coefficient analysis of characters on grain in Indian mustard genotypes under rainfed(residual moisture) condition

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Character	DFFO	DFF	DPM	PBP-1	SBP-1	NS	LS	SG	IL	HP	SPMA	HFPB	HFS	AB	AS	SS-1	RV
DFFO	-0.324	-0.072	-0.079	-0.108	-0.037	0.016	-0.077	-0.080	-0.182	0.080	-0.053	-0.009	-0.037	0.045	0.169	0.003	0.348
DFF	0.127	-0.346	-0.100	-0.119	-0.041	0.018	-0.084	-0.088	-0.202	0.098	-0.061	-0.009	-0.041	0.054	-0.096	0.003	0.399
DPM	0.104	-0.129	-0.274	-0.103	-0.035	0.016	-0.072	-0.072	-0.172	0.090	-0.052	-0.010	-0.035	0.045	-0.074	0.002	0.346
PBP-1	-0.126	0.079	0.093	0.145	0.047	-0.021	0.090	0.095	0.216	-0.102	0.066	0.011	0.044	-0.056	0.384	-0.003	-0.445
SBP-1	-0.130	0.082	0.094	0.139	0.049	-0.022	0.091	0.099	0.219	-0.103	0.068	0.013	0.044	-0.056	0.389	-0.003	-0.466
NS	-0.122	0.079	0.091	0.136	0.047	-0.023	0.091	0.098	0.215	-0.099	0.066	0.011	0.043	-0.054	0.373	-0.003	-0.474
LS	-0.118	0.073	0.084	0.118	0.040	-0.019	0.110	0.090	0.204	-0.097	0.062	0.012	0.041	-0.051	0.349	-0.003	-0.421
SG	-0.129	0.081	0.089	0.130	0.045	-0.021	0.094	0.105	0.215	-0.100	0.068	0.010	0.043	-0.054	0.384	-0.003	-0.478
IL	-0.126	0.080	0.091	0.128	0.044	-0.020	0.092	0.093	0.244	-0.101	0.065	0.013	0.045	-0.055	0.382	-0.003	-0.445
HP	-0.113	0.078	0.097	0.122	0.041	-0.018	0.088	0.087	0.205	-0.121	0.062	0.015	0.044	-0.055	0.366	-0.003	-0.412
SPMA	-0.122	0.079	0.091	0.129	0.045	-0.020	0.092	0.097	0.214	-0.100	0.074	0.012	0.042	-0.055	0.379	-0.006	-0.481
HFPB	0.045	-0.027	-0.037	-0.048	-0.018	0.007	-0.038	-0.032	-0.094	0.053	-0.026	-0.034	-0.023	0.027	-0.174	0.001	0.151
HFS	0.120	-0.076	-0.088	-0.123	-0.042	0.019	-0.086	-0.087	-0.211	0.103	-0.060	-0.015	-0.052	0.057	-0.373	0.003	0.390
AB	0.120	-0.082	-0.092	-0.127	-0.043	0.019	-0.088	-0.090	-0.212	0.105	-0.064	-0.014	-0.046	0.063	-0.384	0.003	0.426
AS	0.128	-0.088	-0.093	-0.129	-0.044	0.02	-0.093	-0.084	-0.213	0.103	-0.065	-0.014	-0.046	0.067	-0.43	0.003	0.438
SS-1	-0.095	0.057	0.064	0.089	0.029	-0.013	0.063	0.062	0.146	-0.073	0.044	0.010	0.032	-0.040	-0.005	0.256	-0.285
RV	-0.111	0.073	0.085	0.122	0.043	-0.020	0.088	0.095	0.205	-0.094	0.067	0.010	0.038	-0.051	-0.529	-0.003	0.356
RL	-0.126	0.081	0.092	0.130	0.045	-0.021	0.094	0.099	0.221	-0.103	0.069	0.011	0.044	-0.056	0.383	-0.003	-0.496
RG	-0.123	0.080	0.089	0.125	0.044	-0.021	0.089	0.098	0.212	-0.098	0.068	0.010	0.042	-0.054	0.365	-0.003	-0.486
TSW	-0.102	0.063	0.072	0.096	0.033	-0.016	0.071	0.072	0.166	-0.076	0.049	0.009	0.034	-0.043	0.280	-0.003	-0.346
BY	-0.080	0.053	0.061	0.085	0.028	-0.013	0.061	0.061	0.144	-0.068	0.041	0.012	0.031	-0.037	0.277	-0.002	-0.269
HI	-0.107	0.073	0.084	0.106	0.036	-0.016	0.076	0.075	0.182	-0.089	0.051	0.011	0.040	-0.048	0.303	-0.003	-0.326
OC	-0.023	-0.003	-0.002	0.005	0.001	0.001	0.003	0.003	0.013	-0.001	0.002	-0.003	0.002	-0.001	0.040	0.000	-0.027
DME	-0.111	0.076	0.093	0.110	0.037	-0.017	0.079	0.078	0.188	-0.093	0.054	0.011	0.041	-0.049	0.312	-0.003	-0.347

18	RL	-0.073	-0.083	-0.070	0.088	0.091	0.091	0.084	0.092	0.089	0.084	0.092	-0.031	-0.083	-0.084	-0.084	0.061	0.092	0.098	0.093	0.066	0.057	0.072	0.002	0.075
19	RG	-0.137	-0.156	-0.133	0.164	0.170	0.172	0.152	0.176	0.164	0.154	0.174	-0.055	-0.153	-0.161	-0.161	0.110	0.174	0.180	0.189	0.133	0.095	0.137	0.001	0.143
20	TSW	0.008	0.008	0.007	-0.010	-0.009	-0.009	-0.008	-0.009	-0.009	-0.008	-0.008	0.003	0.008	0.008	0.007	-0.007	-0.008	-0.008	-0.009	-0.013	-0.006	-0.007	0.000	-0.007
21	BY	-0.029	-0.034	-0.029	0.036	0.036	0.035	0.035	0.037	0.036	0.035	0.034	-0.023	-0.035	-0.036	-0.04	0.020	0.030	0.036	0.031	0.031	0.062	0.030	0.000	0.031
22	HI	-0.047	-0.057	-0.049	0.055	0.051	0.053	0.051	0.053	0.056	0.055	0.052	-0.025	-0.058	-0.057	-0.053	0.039	0.046	0.055	0.054	0.042	0.036	0.074	0.000	0.074
23	OC	-0.005	0.001	0.002	0.001	0.001	-0.001	0.002	0.001	0.002	0.001	0.001	0.004	-0.002	0.000	-0.005	0.002	0.002	0.001	0.001	0.001	0.001	0.002	0.039	0.002
24	DME	0.012	0.014	0.013	-0.014	-0.014	-0.015	-0.013	-0.013	-0.014	-0.014	-0.013	0.007	0.014	0.014	0.013	-0.010	-0.012	-0.014	-0.014	-0.011	-0.009	-0.018	0.000	-0.018
25	GYP-1	-0.668**	-0.795**	-0.684**	0.837**	0.833**	0.801**	0.777**	0.816**	0.851**	0.790**	0.802**	-0.387**	-0.830**	-0.822**	-0.863**	0.556**	0.698**	0.812**	0.782**	0.608**	0.621**	0.738**	0.052	0.759**

Residual effect=**0.396**

Table 5: Multiple regression analysis for independent association of twenty-five agro-morphological traits under rainfed(residual moisture) condition

Traits	a	b ± SE	% contribution of the parameters to R^2 values
Days to First Flower Open	0.164	0.194±0.074	0.052
Days to 50%flowering	-0.095	-0.109*±0.103	0.009
Days to Physiological Maturity	-0.114	-0.104±0.092	0.010
Primary Branches/ Plant	0.150	0.243±0.234	0.009
Secondary Branches/ Plant	0.043	0.023±0.098	0.000
Total No. of Siliqua	-0.026	0.000±0.002	0.000
Siliqua Length	0.111	0.645±0.453	0.016
Stem Girth	0.109	0.199±0.256	0.005
Internode Length	0.246	0.341±0.144	0.043
Plant Height	-0.111	-0.012*±0.010	0.012
Siliqua In Primary Mother Axis	0.079	0.034±0.054	0.003
First Primary Branch Height	-0.032	-0.005±0.007	0.004
Height of First Siliqua	-0.055	-0.007±0.013	0.002
Angle of Branch	0.070	0.029±0.047	0.003
Angle of Siliqua	-0.427	-0.195±0.053	0.096
Seeds/ Siliqua	-0.003	-0.009**±0.155	0.000
Root Volume	-0.526	-0.238±0.059	0.114
Root Length	0.096	0.075**±0.144	0.002
Root Girth	0.179	0.529±0.426	0.012
1000 Seed Weight	-0.013	-0.028±0.119	0.000
Biological Yield	0.061	0.001±0.000	0.011
Harvest Index	-0.010	-0.008±0.553	0.000
Oil Content	0.037	0.256±0.267	0.007
Dry Matter Efficiency	0.075	0.077±0.708	0.000
Intercept constant	25.398		
R^2 value	0.8434		
Adjusted R^2 value	0.8133		

*= P<0.05, **= P<0.01 level of significance, a= slop of regression, b= regression coefficient, SE= standard error

Table 6: Multiple regression analysis for independent association of twenty-five agro-morphological traits using step down method under rainfed(residual moisture) condition

Regression coefficients	Traits	b ± SE	% contribution of the parameters to R^2 values
b1	Days to First Flower Open	0.147**±0.067	0.095
b2	Days to Physiological Maturity	-0.130*±0.047	0.033
b3	Primary Branches/ Plant	0.302**±0.152	0.051
b4	Siliqua Length	0.813*±0.399	0.027
b5	Internode Length	0.413*±0.131	0.029
b6	Angle of Siliqua	-0.230**±0.042	0.066
b7	Root Volume	-0.226**±0.042	0.176
b8	Root Girth	0.815**±0.303	0.169
Intercept constant	30.571		
R^2 value	0.8313		
Adjusted R^2 value	0.8218		

*= P<0.05, **= P<0.01 level of significance, a= slop of regression, b= regression coefficient, SE= standard error

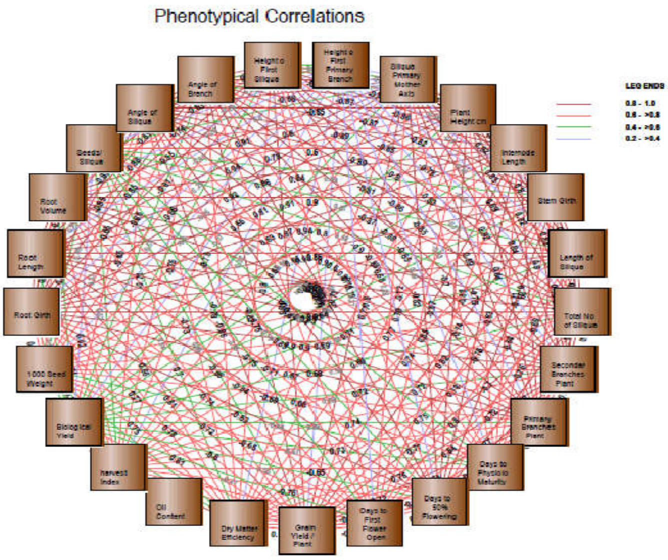

Fig1.Phenotypic correlation coefficient for various agro-morphological traits

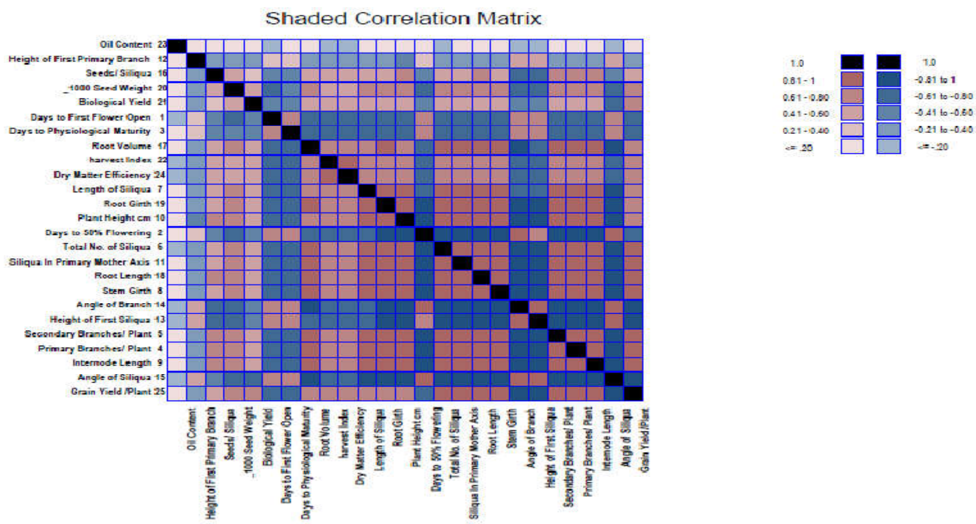

Fig2.Shaded correlation matrix of correlation coefficient for various agro-morphological traits

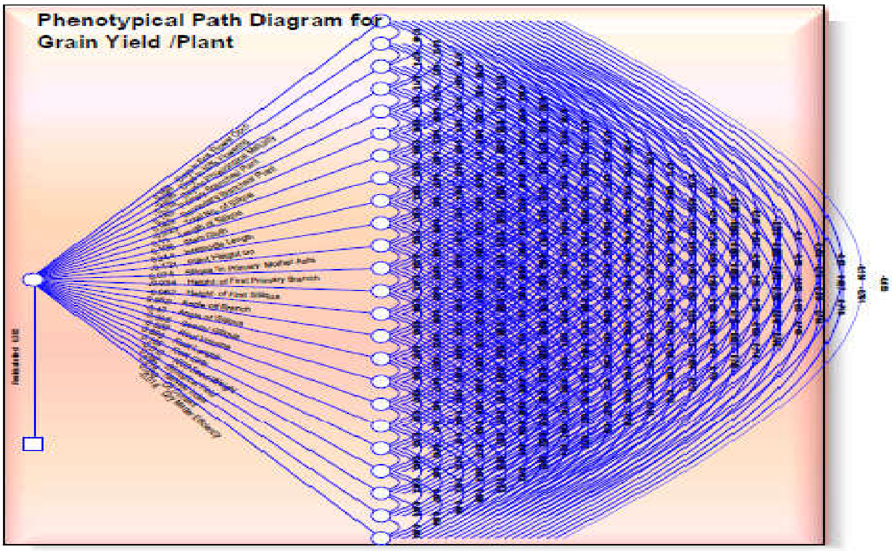

Fig 3. Phenotypic path diagram for various agro-morphological traits

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