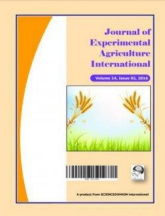

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Interrelationship and Cause - Effect of Morphological Traits with Grain Yield and Oil Content among Indian Mustard (*Brassica juncea* L. Czern & Coss) Genotypes under Non- irrigated and Irrigated Condition

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Water scarcity is a venomous upshot of climate change and is one of the sternest factors restraining global crop productivity. In order to study association and cause-effect of shortage in irrigation on some morphological and quality traits on yield, an experiment accommodating 20 genotypes of Indian mustard (*Brassica juncea* L. Czern & Coss), was conducted in Randomised Complete Block Design (RBCD) from various Rapeseed & Mustard centres located across country, randomly in three replications during *Rabi* 2016-17, one condition subjected to drought (devoid of irrigation) inside the Rainout shelter under residual moisture condition and another situation with normal irrigated field condition at research farm of Dr. Rajendra Prasad Central

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Agricultural University, Pusa, Samastipur. Genotypic correlations for grain yield and other characters were invariably higher than phenotypic correlations indicating indicated less influence of environment. Earliness in flowering (-0.010; -0.256) and maturity (-0.335; -0.185), Secondary branches per plant (0.267; 0.169), Siliqua on primary mother axis (0.162; 0.079), Length of primary axis (0.006; 0.275), Siliqua density (0.244; 0.189) and Biological yield (0.444*;0.411*) also had shown positive correlation with grain yield per plot at phenotypic level under both non- irrigated and irrigated condition indicated that improvement in these morphological parameters indicated genotypes with early flowering and maturity coupled with more secondary branches with more siliqua accommodated by longer primary mother axis with increasing density of siliqua along with high biological yield and will ultimately enhance the grain yield.

Keywords: Brassica juncea L.; association; drought; cause-effect; deficit irrigation.

ABBREVIATIONS

Days to first flower open (DFFO); Days to physiological maturity (DPM); Days to cessation of flowering (DCF); Height of first primary branch (HFPB); Primary branches per plant (PBP^{-1}); Secondary branches per plant (SBP^{-1}); Number of siliqua on Primary Mother Axis (SPMA); Length of Primary Mother Axis (LPMA); Siliqua density (SD); Length of siliqua (LS); Number of seeds $siliqua^{-1}$ (SS^{-1}); 1000 seed weight (TSW); Biological yield (BY); Oil content (OC) and Grain Yield/Plot (kg/ha) (GY/P).

1. INTRODUCTION

Presently agriculture is in front of manifold challenges like abiotic (water shortage and high temperature) stress including the inevitability for an extensive increase, in fabrication to meet the needs of an escalating human population. Drought pressure is the most vital factor limiting growth and yield of crops, affects about 40 to 60 percent of global agricultural lands [1]. Among the foremost food crops, *Brassica crops* are the mainly embellished by drought due to the fact that they are mainly grown in arid and semiarid areas. Hence, with the aim of research work is to screen varieties along with appropriate combinations of yield attributing traits which are suitable for moisture stress – a rainfed condition which give benefit to farmers of dryland areas. Yield is a multifaceted, dependent character as it is associated with other morphological and quality traits which are more prone to environmental fluctuations (here moisture stressed condition) than a subsidiary, independent morphological 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 [2]. Pleiotropic action of genes and/or linkage determines the inherent association between any two variables [3].

2. MATERIALS AND METHODS

The experiment consisting of 20 Indian mustard genotypes was planted on October 2016 under two conditions i.e. non-irrigated and irrigated , laid out in Randomised Complete Block Design (RCBD) with three replications during *Rabi* season (2015-16), including check for association 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, New Delhi, ARS, RAU, Sriganganagar, Rajasthan and DR. RPCAU, Dholi, Bihar, providing only basal dose of fertilizers i.e. $N:P_2O_5:K_2O:S$:: 40:20:20:40 kg/ha under residual moisture conditions inside rainout shelter and 40 Basal dose of fertilizer N:40 P_2O_5:40 K_2O:40 S kg/ha and other at pre flowering stage (E_4,45DAS) and green siliqua stage (E_4,65DAS) required 40 N for top dressing after pre flowering stage at Research Farm of Dr. Rajendra Prasad Central Agricultural University Farm (25.29^0 N, 85.40^0 E and 51.80 m MSL), Pusa, Samastipur, Bihar. Each plot consisted four rows of 5.0 m length keeping row to row and plant to plant distance 30 cm and 10 cm, respectively. The spacing between plants was maintained at 10cm by thinning at 14 DAE.

The observations were recorded for Days to first flower open (DFFO), Days to physiological

maturity (DPM), Days to cessation of flowering (DCF), Height of first primary branch (HFPB), Primary branches per plant (PBP^{-1}), Secondary branches per plant (SBP^{-1}), Number of siliqua on Primary Mother Axis (SPMA), Length of Primary Mother Axis (LPMA), Siliqua density (SD), Length of siliqua (LS), Number of seeds siliqua^{-1} (SS^{-1}), 1000 seed weight (TSW), Biological yield (BY), Oil content (OC) and Grain Yield/Plot (kg/ha) (GY/P).

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- quality traits**.** The Correlation and Path analysis were calculated following standard statistical methods [4,5].

Oil Content (%) – Oil content was estimated on dry seed basis by non-destructive method using Foss-tecator near- infrared reflectance spectroscopy (FT-NIRS) product analyzer at Directorate of Rapeseed Mustard Research (DRMR) Bharatpur, Rajasthan. Over 4 gram seeds of each intact sample were scanned in a 36 mm inner-diameter ring cup.

Siliqua density (cm^{-1}) - It is ratio of number of siliqua on main raceme and length of main raceme.

3. RESULTS AND DISCUSSION

Genotypic correlations for seed yield and other characters were invariably higher than phenotypic correlations (Tables 1, 2, 3 and 4). The high magnitude of genotypic correlation coefficients form sound base for their practical implications and also indicated for all the characters, less influence of environment. The results of the present study are in agreement with earlier studies [6].

Days to maturity and plant height had a positive association of with grain yield. Positive inter- the relationship of days to physiological maturity with grain yield is detrimental; therefore, efforts should be made to break this linkage by resorting to bi-parental mating to breed for varieties having earliness in *Brassica juncea*. Grain yield/plant was positively and significantly correlated at both phenotypic and genotypic levels under both conditions with siliqua on main shoot and biological yield/plant. Similar findings were in support by Meena et al. [7] and Shekhawat et al. [8]. Under both non- irrigated and irrigated condition DFFO showed negative association with DPM suggesting that under moisture stress condition if plant attains vegetative phase earlier would help plant to enter in reproductive phase soon allow them enlarge and better opportunity for seed filling insides pods as well for oil synthesis. Siliqua density showed positive association with SPMA and LPMA results in an increase of number of siliqua under non- irrigated and irrigated condition.

TSW and BY under non- irrigated condition whereas, SS^{-1} and BY under irrigated condition showed positive significant correlation with GY. SBP^{-1}, SPMA, LPMA, SD, LS also had showed a positive correlation with GY under both the condition at genotypic and phenotypic level. These results were in agreement with Verma et al. [9] for SBP^{-1} and SS^{-1}, Gangapur et al. [10] for BY, Singh et al. [11] for SPMA and LPMA; Ejaz-Ul-Hasan et al. [12] for LS and Roy et al. [13] for SS^{-1}.

Oil content was negatively correlated and had a negative moderate effect on seed yield/ plant at genotypic correlation under no irrigation condition it implies that consideration of this trait for increasing oil content is also valuable. The results were in full agreement with Lodhi et al. [14]; Singh and Chowdhury [15]; Singh et al. [16] and Roy et al. [17]. Oil content was positive significantly correlated and had a positive high effect on seed yield/ plant phenotypic correlation under no irrigation condition. This result is in accordance with Singh et al. [18] and Roy et al. [17].

PBP^{-1} and SBP^{-1}, showed negative and positive genotypic association under non- irrigated condition in respectively explained that under moisture stress condition development of more primary branches and secondary branches on primary branches means more time spent in completing vegetative phase (DFFO, DFF and DCF) which will expand time for maturity period drastically affect seed formation inside siliqua as well as synthesis of oil. These findings were in accordance with Singh et al. [19] and Priyamedha et al. [20] for SBP^{-1}. Rest of the characters with non-significant correlation could be improved independently without affecting others under both the conditions.

Table 1. Genotypic Correlation coefficient for characters in Indian mustard genotypes under non irrigated condition

No	Character	DFFO	DPM	DCF	HFPB	PBP^{-1}	SBP^{-}	SPMA	LPMA	SD	LS	SS^{-1}	TSW	BY	OC	GYP^{-1}
1	Days to first flower open	**1.000**	-0.067	0.168	0.249	-0.324	-0.034	0.217	-0.299	0.142	-0.081	-0.174	-0.250	-0.022	-1.103	**-0.201**
2	Days to physiological maturity		**1.000**	0.394	0.287	-0.341	-0.437	-0.351	-0.378	-0.495	0.180	-0.223	-0.338	0.017	-0.093	**-0.858**
3	Days to cessation of flowering			**1.000**	-0.191	0.044	0.110	0.068	-0.451	0.124	-0.226	-0.409	-0.270	0.120	0.885	**-0.399**
4	Height of first primary branch				**1.000**	-0.474	-0.524	-0.516	-0.422	-0.306	0.202	0.183	-0.045	0.062	-1.493	**-0.115**
5	Primary branches per plant					**1.000**	0.460	0.407	0.384	0.332	-0.387	-0.077	0.008	-0.033	0.650	**-0.207**
6	Secondary branches per plant						**1.000**	0.638	0.353	0.784	0.030	-0.251	0.635	0.466	0.566	**0.437**
7	Number of siliqua on Primary Mother Axis							**1.000**	0.220	0.585	-0.055	-0.306	0.128	0.472	0.648	**0.340**
8	Length of Primary Mother Axis								**1.000**	0.160	0.058	0.183	0.008	-0.401	0.717	**0.045**
9	Siliqua density									**1.000**	-0.069	-0.128	0.593	0.196	0.491	**0.501**
10	Length of siliqua										**1.000**	0.531	0.231	-0.076	0.094	**0.239**
11	Number of seeds siliqua^{-1}											**1.000**	0.292	-0.531	0.173	**0.280**
12	1000 seed weight												**1.000**	0.416	0.320	**0.844**
13	Biological yield													**1.000**	-0.359	**0.644**
14	Oil content														**1.000**	**0.092**
15	Grain yieldha^{-1}															**1.000**

Table 2. Genotypic Correlation coefficient for characters in Indian mustard genotypes under irrigated condition

No	Character	DFFO	DPM	DCF	HFPB	PBP^{-1}	SBP^{-}	SPMA	LPMA	SD	LS	SS^{-1}	TSW	BY	OC	GYP^{-1}
1	Days to first flower open	**1.000**	0.285	-0.139	-0.439	-0.394	-0.131	-0.064	-0.314	-0.094	0.112	-0.025	-0.131	-0.373	0.561	**-0.170**
2	Days to physiological maturity		**1.000**	0.130	-0.064	-0.434	-0.335	0.160	-0.392	-0.659	-0.384	-0.547	-0.180	-0.726	0.151	**-0.840**
3	Days to cessation of flowering			**1.000**	-0.141	0.482	0.631	0.257	0.055	-0.059	-0.301	-0.173	0.572	-0.400	-0.565	**-0.209**
4	Height of first primary branch				**1.000**	-0.292	-0.542	-0.244	0.078	-0.087	0.065	-0.167	-0.133	0.238	0.453	**-0.171**
5	Primary branches per plant					**1.000**	0.529	0.325	0.113	0.102	-0.369	0.318	0.512	-0.058	-1.030	**0.427**
6	Secondary branches per plant						**1.000**	0.580	0.474	0.307	0.141	0.373	0.315	0.201	-0.477	**0.384**
7	Number of siliqua on Primary Mother Axis							**1.000**	0.195	0.192	0.198	0.302	0.312	-0.097	-0.382	**0.170**
8	Length of Primary Mother Axis								**1.000**	0.412	0.444	0.432	0.012	0.368	-0.123	**0.412**
9	Siliqua density									**1.000**	0.772	0.164	0.268	0.606	-0.275	**0.307**
10	Length of siliqua										**1.000**	0.020	0.135	0.584	0.262	**0.122**
11	Number of seeds siliqua^{-1}											**1.000**	-0.049	0.047	0.036	**0.682**
12	1000 seed weight												**1.000**	0.025	-0.799	**-0.171**
13	Biological yield													**1.000**	0.143	**0.479**
14	Oil content														**1.000**	**-0.142**
15	Grain yieldha^{-1}															**1.000**

Table 3. Phenotypic Correlation coefficient for characters in Indian mustard genotypes under non irrigated condition

No	Character	DFFO	DPM	DCF	HFPB	PBP^{-1}	SBP^{-}	SPMA	LPMA	SD	LS	SS^{-1}	TSW	BY	OC	GYP^{-1}
1	Days to first flower open	**1.000**	-0.075	0.057	0.237	-0.262	-0.008	0.199	-0.269	0.140	-0.078	-0.169	-0.233	0.007	0.178	**-0.010**
2	Days to physiological maturity		**1.000**	0.180	0.216	-0.188	-0.263	-0.258	-0.214	-0.332	0.125	-0.141	-0.128	0.079	-0.090	**-0.335**
3	Days to cessation of flowering			**1.000**	-0.141	0.048	-0.002	0.052	-0.357	0.069	-0.163	-0.317	-0.093	-0.195	-0.013	**-0.319**
4	Height of first primary branch				**1.000**	-0.431	-0.426	-0.504	-0.400	-0.303	0.197	0.159	-0.026	0.038	0.279	**-0.032**
5	Primary branches per plant					**1.000**	0.347	0.368	0.343	0.293	-0.361	-0.051	-0.001	-0.006	-0.182	**-0.106**
6	Secondary branches per plant						**1.000**	0.534	0.274	0.645	0.037	-0.227	0.491	0.291	-0.124	**0.267**
7	Number of siliqua on Primary Mother Axis							**1.000**	0.215	0.572	-0.054	-0.288	0.122	0.292	-0.146	**0.162**
8	Length of Primary Mother Axis								**1.000**	0.163	0.056	0.154	-0.001	-0.223	-0.127	**0.006**
9	Siliqua density									**1.000**	-0.059	-0.134	0.539	0.138	-0.059	**0.244**
10	Length of siliqua										**1.000**	0.485	0.224	-0.032	-0.005	**0.106**
11	Number of seeds siliqua^{-1}											**1.000**	0.248	-0.318	0.050	**0.195**
12	1000 seed weight												**1.000**	0.262	-0.046	**0.414***
13	Biological yield													**1.000**	-0.034	**0.444***
14	Oil content														**1.000**	**-0.038**
15	Grain yieldha^{-1}															**1.000**

Table 4. Phenotypic Correlation coefficient for characters in Indian mustard genotypes under irrigated condition

No	Character	DFFO	DPM	DCF	HFPB	PBP^{-1}	SBP^{-}	SPMA	LPMA	SD	LS	SS^{-1}	TSW	BY	OC	GYP^{-1}
1	Days to first flower open	**1.000**	0.153	-0.067	-0.407	-0.356	-0.131	-0.070	-0.298	-0.086	0.101	-0.011	-0.096	-0.289	0.254	**-0.256**
2	Days to physiological maturity		**1.000**	0.072	-0.039	-0.200	-0.176	0.088	-0.256	-0.398	-0.264	-0.257	-0.164	-0.384	0.257	**-0.185**
3	Days to cessation of flowering			**1.000**	-0.082	0.254	0.336	0.121	-0.076	-0.041	-0.176	-0.041	0.280	-0.192	-0.124	**-0.285**
4	Height of first primary branch				**1.000**	-0.271	-0.515	-0.236	0.078	-0.084	0.060	-0.144	-0.097	0.184	0.210	**-0.002**
5	Primary branches per plant					**1.000**	0.465	0.310	0.101	0.096	-0.402	0.322	0.277	-0.047	-0.415	**0.308**
6	Secondary branches per plant						**1.000**	0.543	0.396	0.296	0.147	0.318	0.249	0.107	-0.236	**0.169**
7	Number of siliqua on Primary Mother Axis							**1.000**	0.200	0.191	0.192	0.281	0.191	-0.062	-0.149	**0.079**
8	Length of Primary Mother Axis								**1.000**	0.384	0.400	0.359	-0.016	0.349	-0.084	**0.275**
9	Siliqua density									**1.000**	0.754	0.148	0.188	0.466	-0.145	**0.189**
10	Length of siliqua										**1.000**	-0.020	0.145	0.448	0.102	**0.047**
11	Number of seeds siliqua^{-1}											**1.000**	-0.015	0.020	0.122	**0.453***
12	1000 seed weight												**1.000**	-0.137	-0.248	**-0.128**
13	Biological yield													**1.000**	0.120	**0.411***
14	Oil content														**1.000**	**0.277**
15	Grain yieldha^{-1}															**1.000**

Table 5. Genotypic Path coefficient analysis of characters on grain yield in Indian mustard genotypes under non irrigated condition

No.	Character	DFFO	DPM	DCF	HFPB	PBP^{-1}	SBP^{-}	SPMA	LPMA	SD	LS	SS^{-1}	TSW	BY	OC
1	Days to first flower open	**-0.779**	0.052	-0.131	-0.194	0.253	0.026	-0.169	0.233	-0.110	0.063	0.136	0.195	0.017	0.860
2	Days to physiological maturity	0.086	**-1.279**	-0.504	-0.367	0.436	0.558	0.448	0.483	0.633	-0.230	0.286	0.432	-0.021	0.119
3	Days to cessation of flowering	0.017	0.039	**0.099**	-0.019	0.004	0.011	0.007	-0.045	0.012	-0.022	-0.040	-0.027	0.012	0.087
4	Height of first primary branch	0.148	0.170	-0.113	**0.593**	-0.281	-0.311	-0.306	-0.250	-0.181	0.119	0.108	-0.026	0.037	-0.885
5	Primary branches per plant	0.304	0.320	-0.041	0.444	**-0.938**	-0.431	-0.382	-0.360	-0.312	0.363	0.072	-0.008	0.031	-0.610
6	Secondary branches per plant	-0.013	-0.173	0.044	-0.208	0.182	**0.396**	0.253	0.140	0.310	0.012	-0.100	0.251	0.184	0.224
7	Number of siliqua on Primary Mother Axis	0.184	-0.298	0.058	-0.438	0.346	0.542	**0.849**	0.187	0.497	-0.047	-0.260	0.109	0.401	0.550
8	Length of Primary Mother Axis	0.131	0.166	0.198	0.185	-0.168	-0.155	-0.097	**-0.438**	-0.070	-0.025	-0.080	-0.003	0.176	-0.314
9	Siliqua density	-0.076	0.267	-0.067	0.165	-0.179	-0.423	-0.316	-0.086	**-0.539**	0.037	0.069	-0.320	-0.106	-0.265
10	Length of siliqua	0.006	-0.012	0.015	-0.014	0.026	-0.002	0.004	-0.004	0.005	**-0.068**	-0.036	-0.016	0.005	-0.006
11	Number of seeds $siliqua^{-1}$	0.029	0.037	0.067	-0.030	0.013	0.041	0.050	-0.030	0.021	-0.087	**-0.164**	-0.048	0.087	-0.028
12	1000 seed weight	-0.096	-0.130	-0.104	-0.017	0.003	0.244	0.049	0.003	0.228	0.089	0.112	**0.384**	0.160	0.123
13	Biological yield	0.006	-0.005	-0.035	-0.018	0.010	-0.136	-0.137	0.117	-0.057	0.022	0.155	-0.121	**-0.291**	0.105
14	Oil content	-0.146	-0.012	0.117	-0.197	0.086	0.075	0.086	0.095	0.065	0.012	0.023	0.042	-0.047	**0.132**
15	Grain $yieldha^{-1}$	**-0.201**	**-0.858**	**-0.399**	**-0.115**	**-0.207**	**0.437**	**0.340**	**0.045**	**0.501**	**0.239**	**0.280**	**0.844**	**0.644**	**0.092**

Residual effect = 0.3616

Table 6. Genotypic Path coefficient analysis of characters on grain yield in Indian mustard genotypes under irrigated condition

No.	Character	DFFO	DPM	DCF	HFPB	PBP^{-1}	SBP^{-}	SPMA	LPMA	SD	LS	SS^{-1}	TSW	BY	OC
1	Days to first flower open	**0.1869**	0.0533	-0.0260	-0.0820	-0.0737	-0.0246	-0.0120	-0.0588	-0.0176	0.0209	-0.0046	-0.0245	-0.0697	0.1049
2	Days to physiological maturity	0.0636	**0.2229**	0.0289	-0.0142	-0.0967	-0.0748	0.0356	-0.0874	-0.1468	-0.0857	-0.1219	-0.0401	-0.1618	0.0337
3	Days to cessation of flowering	0.0716	-0.0666	**-0.5141**	0.0727	-0.2479	-0.3245	-0.1321	-0.0284	0.0302	0.1549	0.0892	-0.2939	0.2056	0.2905
4	Height of first primary branch	-0.1636	-0.0238	-0.0527	**0.3729**	-0.1090	-0.2022	-0.0911	0.0290	-0.0326	0.0241	-0.0622	-0.0495	0.0887	0.1689
5	Primary branches per plant	-0.4503	-0.4953	0.5506	-0.3340	**1.1421**	0.6042	0.3712	0.1295	0.1170	-0.4219	0.3632	0.5850	-0.0658	-1.1762
6	Secondary branches per plant	-0.0920	-0.2348	0.4418	-0.3796	0.3703	**0.7001**	0.4058	0.3321	0.2150	0.0987	0.2610	0.2202	0.1410	-0.3342
7	Number of siliqua on Primary Mother Axis	0.0244	-0.0606	-0.0973	0.0925	-0.1231	-0.2195	**-0.3786**	-0.0737	-0.0728	-0.0749	-0.1145	-0.1180	0.0366	0.1445
8	Length of Primary Mother Axis	0.0557	0.0695	-0.0098	-0.0138	-0.0201	-0.0840	-0.0345	**-0.1772**	-0.0730	-0.0786	-0.0765	-0.0021	-0.0652	0.0217
9	Siliqua density	0.0070	0.0490	0.0044	0.0065	-0.0076	-0.0228	-0.0143	-0.0306	**-0.0743**	-0.0574	-0.0122	-0.0199	-0.0450	0.0204
10	Length of siliqua	0.0554	-0.1909	-0.1496	0.0321	-0.1835	0.0700	0.0983	0.2204	0.3834	**0.4967**	0.0101	0.0669	0.2900	0.1299
11	Number of seeds $siliqua^{-1}$	-0.0079	-0.1764	-0.0560	-0.0539	0.1026	0.1203	0.0976	0.1392	0.0530	0.0065	**0.3226**	-0.0157	0.0152	0.0115
12	1000 seed weight	0.0506	0.0695	-0.2209	0.0513	-0.1980	-0.1216	-0.1205	-0.0046	-0.1037	-0.0521	0.0188	**-0.3865**	-0.0096	0.3090
13	Biological yield	-0.0381	-0.0741	-0.0408	0.0243	-0.0059	0.0206	-0.0099	0.0376	0.0618	0.0596	0.0048	0.0025	**0.1021**	0.0146
14	Oil content	0.0668	0.0180	-0.0672	0.0539	-0.1226	-0.0568	-0.0454	-0.0146	-0.0327	0.0311	0.0043	-0.0952	0.0170	**0.1190**
15	Grain $yieldha^{-1}$	**-0.1699**	**-0.8403**	**-0.2089**	**-0.1713**	**0.4270**	**0.3844**	**0.1701**	**0.4125**	**0.3071**	**0.1219**	**0.6821**	**-0.1708**	**0.4793**	**-0.1417**

Residual effect = 0.8248

Table 7. Phenotypic Path coefficient analysis of characters on grain in Indian mustard genotypes under non- irrigated condition

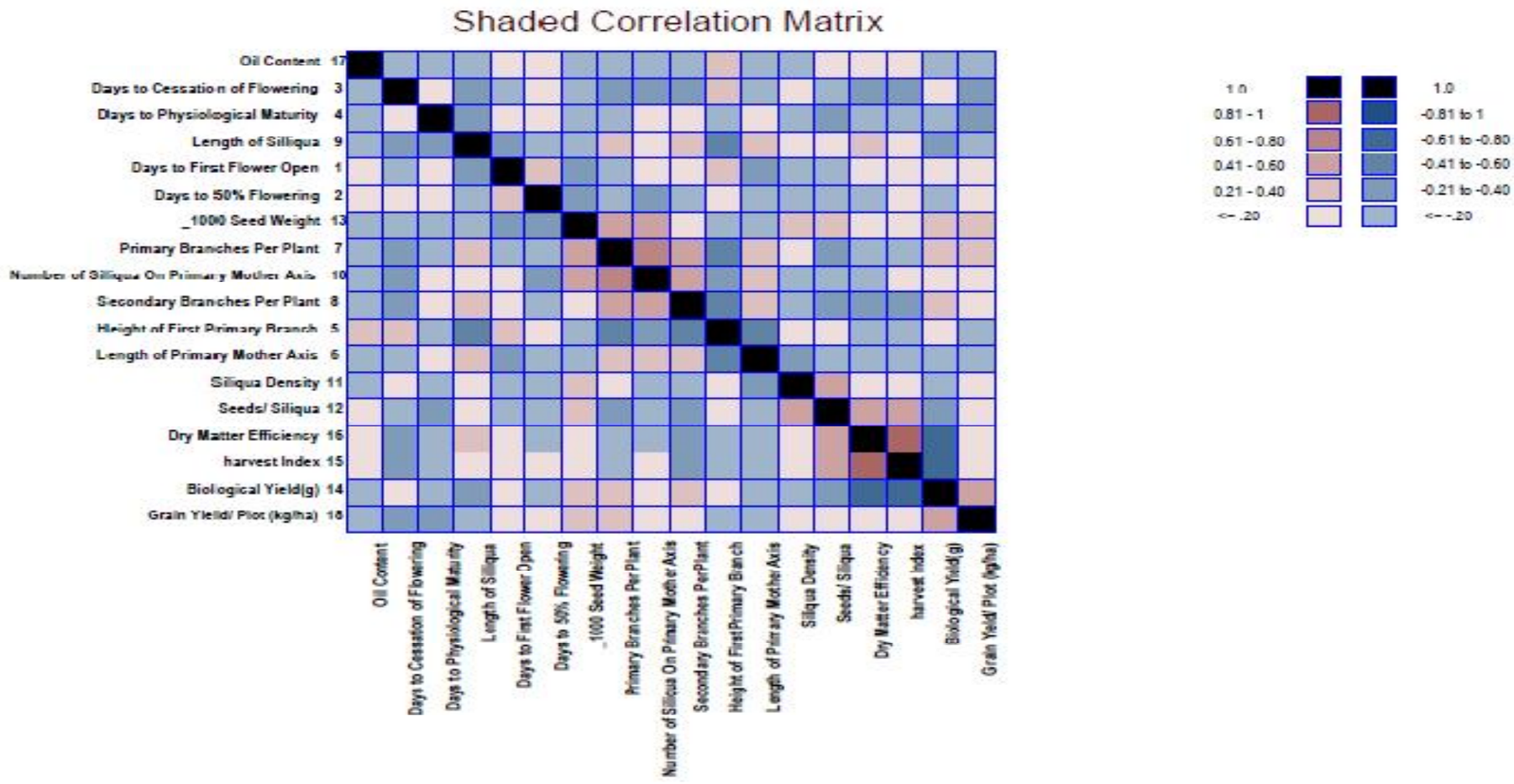
No.	Character	DFFO	DPM	DCF	HFPB	PBP^{-1}	SBP^{-}	SPMA	LPMA	SD	LS	SS^{-1}	TSW	BY	OC
1	Days to first flower open	**-0.0336**	0.0025	-0.0019	-0.0080	0.0088	0.0003	-0.0067	0.0090	-0.0047	0.0026	0.0057	0.0078	-0.0002	-0.0060
2	Days to physiological maturity	0.0200	**-0.2682**	-0.0483	-0.0580	0.0505	0.0706	0.0692	0.0575	0.0891	-0.0335	0.0379	0.0345	-0.0211	0.0241
3	Days to cessation of flowering	-0.0037	-0.0116	**-0.0644**	0.0091	-0.0031	0.0001	-0.0034	0.0230	-0.0045	0.0105	0.0204	0.0060	0.0125	0.0009
4	Height of first primary branch	-0.0104	-0.0095	0.0062	**-0.0438**	0.0189	0.0187	0.0221	0.0175	0.0133	-0.0086	-0.0069	0.0011	-0.0017	-0.0122
5	Primary branches per plant	0.0811	0.0584	-0.0150	0.1338	**-0.3102**	-0.1077	-0.1141	-0.1063	-0.0908	0.1119	0.0157	0.0003	0.0018	0.0565
6	Secondary branches per plant	-0.0011	-0.0366	-0.0003	-0.0592	0.0482	**0.1388**	0.0741	0.0380	0.0895	0.0051	-0.0315	0.0682	0.0404	-0.0173
7	Number of siliqua on Primary Mother Axis	0.0024	-0.0031	0.0006	-0.0061	0.0045	0.0065	**0.0121**	0.0026	0.0069	-0.0007	-0.0035	0.0015	0.0035	-0.0018
8	Length of Primary Mother Axis	-0.0002	-0.0001	-0.0002	-0.0003	0.0002	0.0002	0.0001	**0.0007**	0.0001	0.0000	0.0001	0.0000	-0.0002	-0.0001
9	Siliqua density	0.0124	-0.0294	0.0061	-0.0268	0.0259	0.0571	0.0506	0.0144	**0.0886**	-0.0053	-0.0119	0.0477	0.0122	-0.0052
10	Length of siliqua	0.0129	-0.0207	0.0271	-0.0327	0.0598	-0.0061	0.0089	-0.0093	0.0098	**-0.1657**	-0.0804	-0.0371	0.0054	0.0008
11	Number of seeds $siliqua^{-1}$	-0.0681	-0.0567	-0.1275	0.0637	-0.0203	-0.0912	-0.1155	0.0617	-0.0538	0.1948	**0.4016**	0.0997	-0.1278	0.0200
12	1000 seed weight	-0.0113	-0.0062	-0.0045	-0.0013	0.0000	0.0239	0.0060	0.0000	0.0262	0.0109	0.0121	**0.0487**	0.0127	-0.0023
13	Biological yield	0.0037	0.0396	-0.0980	0.0193	-0.0030	0.1463	0.1468	-0.1123	0.0694	-0.0163	-0.1601	0.1317	**0.5032**	-0.0173
14	Oil content	-0.0139	0.0070	0.0010	-0.0218	0.0142	0.0097	0.0114	0.0099	0.0046	0.0004	-0.0039	0.0036	0.0027	**-0.0781**
15	Grain $yieldha^{-1}$	**-0.0097**	**-0.3347**	**-0.3192**	**-0.0320**	**-0.1057**	**0.2672**	**0.1616**	**0.0065**	**0.2437**	**0.1060**	**0.1953**	**0.4138**	**0.4435**	**-0.0379**

Residual effect = 0.4816

Table 8. Phenotypic Path coefficient analysis of characters on grain in Indian mustard genotypes under irrigated condition

No.	Character	DFFO	DPM	DCF	HFPB	PBP^{-1}	SBP^{-}	SPMA	LPMA	SD	LS	SS^{-1}	TSW	BY	OC
1	Days to first flower open	**-0.2190**	-0.0334	0.0147	0.0892	0.0781	0.0286	0.0154	0.0653	0.0188	-0.0221	0.0025	0.0210	0.0634	-0.0555
2	Days to physiological maturity	0.0050	**0.0327**	0.0024	-0.0013	-0.0066	-0.0058	0.0029	-0.0084	-0.0130	-0.0086	-0.0084	-0.0054	-0.0125	0.0084
3	Days to cessation of flowering	0.0181	-0.0194	**-0.2701**	0.0220	-0.0686	-0.0908	-0.0327	0.0206	0.0110	0.0476	0.0111	-0.0756	0.0520	0.0335
4	Height of first primary branch	0.0443	0.0043	0.0089	**-0.1088**	0.0295	0.0560	0.0257	-0.0084	0.0091	-0.0065	0.0157	0.0105	-0.0200	-0.0228
5	Primary branches per plant	-0.1838	-0.1033	0.1310	-0.1397	**0.5158**	0.2400	0.1598	0.0522	0.0496	-0.2075	0.1660	0.1429	-0.0243	-0.2143
6	Secondary branches per plant	-0.0007	-0.0010	0.0018	-0.0028	0.0025	**0.0054**	0.0029	0.0021	0.0016	0.0008	0.0017	0.0013	0.0006	-0.0013
7	Number of siliqua on Primary Mother Axis	0.0069	-0.0086	-0.0118	0.0230	-0.0301	-0.0529	**-0.0973**	-0.0194	-0.0186	-0.0186	-0.0274	-0.0186	0.0061	0.0145
8	Length of Primary Mother Axis	0.0072	0.0062	0.0018	-0.0019	-0.0024	-0.0096	-0.0048	**-0.0241**	-0.0093	-0.0097	-0.0087	0.0004	-0.0084	0.0020
9	Siliqua density	0.0089	0.0415	0.0042	0.0087	-0.0100	-0.0308	-0.0199	-0.0400	**-0.1042**	-0.0786	-0.0154	-0.0196	-0.0485	0.0151
10	Length of siliqua	0.0222	-0.0581	-0.0387	0.0131	-0.0884	0.0324	0.0421	0.0880	0.1657	**0.2197**	-0.0043	0.0319	0.0985	0.0224
11	Number of seeds $siliqua^{-1}$	-0.0030	-0.0683	-0.0109	-0.0383	0.0855	0.0846	0.0747	0.0953	0.0393	-0.0052	**0.2658**	-0.0039	0.0053	0.0325
12	1000 seed weight	0.0080	0.0136	-0.0233	0.0080	-0.0230	-0.0207	-0.0159	0.0014	-0.0156	-0.0121	0.0012	**-0.0832**	0.0114	0.0206
13	Biological yield	-0.0695	-0.0921	-0.0462	0.0442	-0.0113	0.0257	-0.0150	0.0838	0.1119	0.1077	0.0048	-0.0329	**0.2402**	0.0289
14	Oil content	0.0997	0.1008	-0.0487	0.0823	-0.1633	-0.0929	-0.0584	-0.0331	-0.0570	0.0401	0.0480	-0.0974	0.0473	**0.3930**
15	Grain $yieldha^{-1}$	**-0.2559**	**-0.1851**	**-0.2849**	**-0.0022**	**0.3076**	**0.1691**	**0.0794**	**0.2752**	**0.1893**	**0.0470**	**0.4526**	**-0.1283**	**0.4110**	**0.2771**

Residual effect = 0.6124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Oil Content 17
Days to Cessation of Flowering 3
Days to Physiological Maturity 4
Length of Silliqua 9
Days to First Flower Open 1
Days to 50% Flowering 2
_1000 Seed Weight 13
Primary Branches Per Plant 7
Number of Silliqua On Primary Mother Axis 10
Secondary Branches Per Plant 8
Height of First Primary Branch 5
Length of Primary Mother Axis 6
Siliqua Density 11
Seeds/ Siliqua 12
Dry Matter Efficiency 16
harvest Index 15
Biological Yield(g) 14
Grain Yield/ Plot (kg/ha) 16
Oil Content
Days to Cessation of Flowering
Days to Physiological Maturity
Length of Silliqua
Days to First Flower Open
Days to 50% Flowering
_1000 Seed Weight
Primary Branches Per Plant
Number of Silliqua On Primary Mother Axis
Secondary Branches Per Plant
Height of First Primary Branch
Length of Primary Mother Axis
Siliqua Density
Seeds/ Siliqua
Dry Matter Efficiency
harvest Index
Biological Yield(g)
Grain Yield/ Plot (kg/ha)
1.0
0.81 - 1
0.61 - 0.80
0.41 - 0.60
0.21 - 0.40
<= .20
1.0
-0.81 to 1
-0.61 to -0.80
-0.41 to -0.60
-0.21 to -0.40
<= -.20

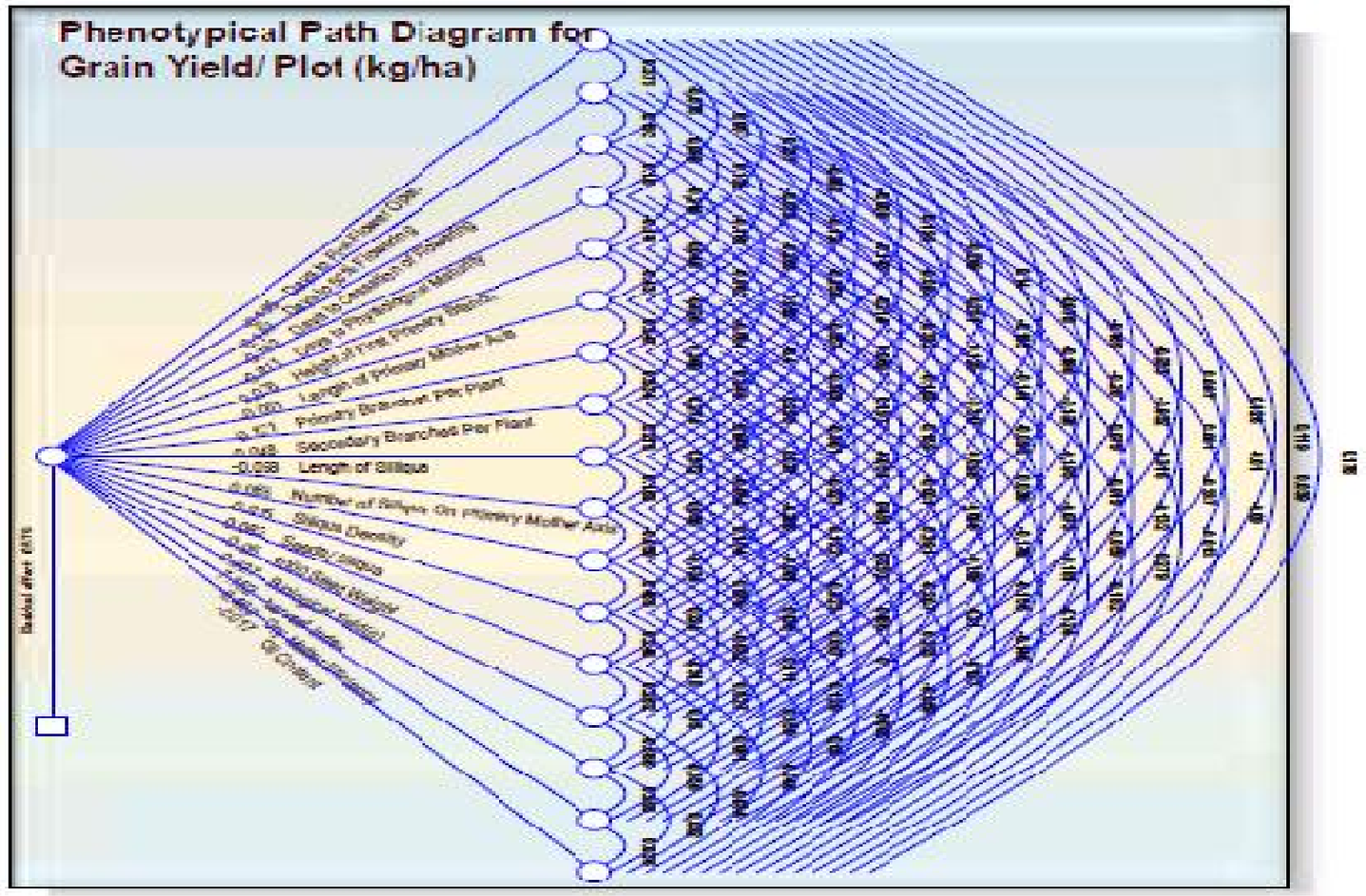
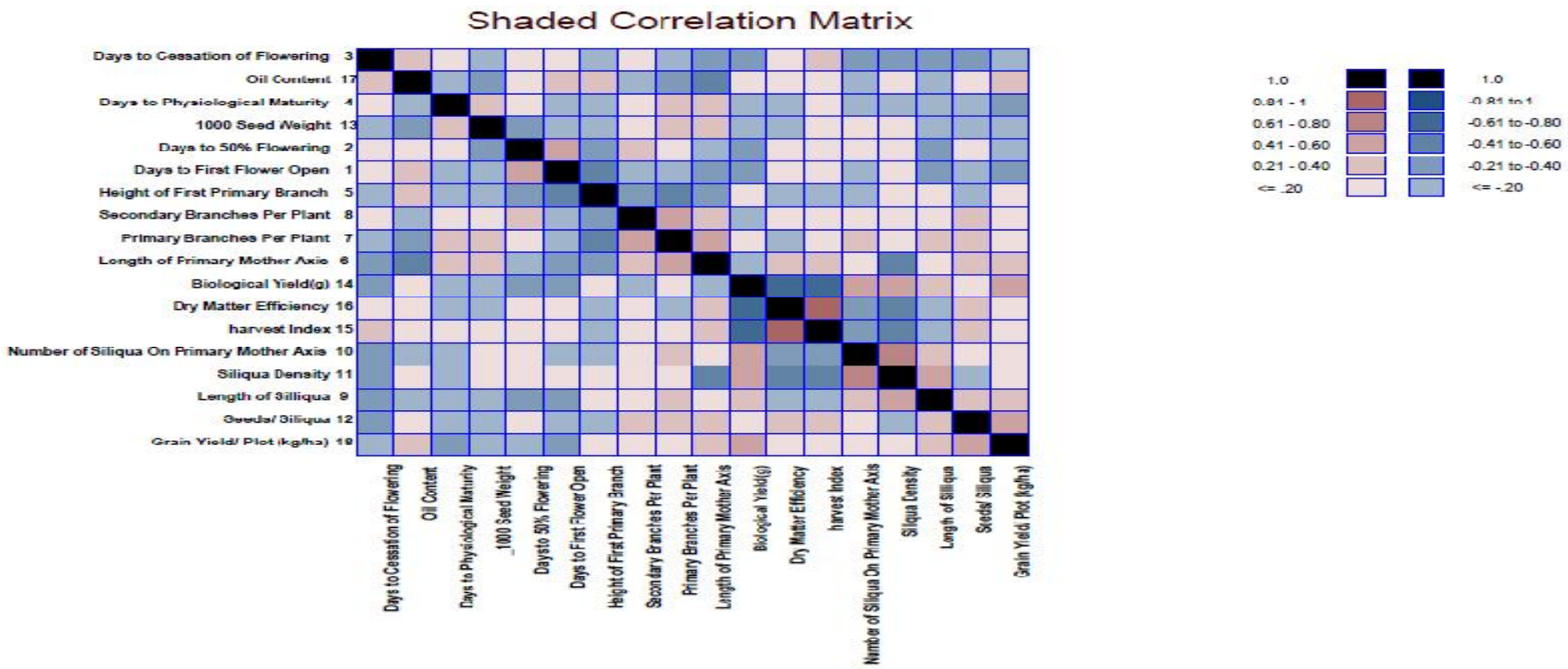


Fig. 1. Diagram for phenotypic correlation and path under non- irrigated condition


Shaded Correlation Matrix
Days to Cessation of Flowering 3
Oil Content 17
Days to Physiological Maturity 4
1000 Seed Weight 13
Days to 50% Flowering 2
Days to First Flower Open 1
Height of First Primary Branch 5
Secondary Branches Per Plant 8
Primary Branches Per Plant 7
Length of Primary Mother Axis 6
Biological Yield(g) 14
Dry Matter Efficiency 16
harvest Index 15
Number of Siliqua On Primary Mother Axis 10
Siliqua Density 11
Length of Silliqua 9
Seeds/ Siliqua 12
Grain Yield/ Plot (kg/ha) 19
Days to Cessation of Flowering
Oil Content
Days to Physiological Maturity
_1000 Seed Weight
Days to 50% Flowering
Days to First Flower Open
Height of First Primary Branch
Secondary Branches Per Plant
Primary Branches Per Plant
Length of Primary Mother Axis
Biological Yield(g)
Dry Matter Efficiency
harvest Index
Number of Siliqua On Primary Mother Axis
Siliqua Density
Length of Silliqua
Seeds/ Siliqua
Grain Yield/ Plot (kg/ha)
1.0
0.81 - 1
0.61 - 0.80
0.41 - 0.60
0.21 - 0.40
<= .20
1.0
-0.81 to -1
-0.61 to -0.80
-0.41 to -0.60
-0.21 to -0.40
<= -.20

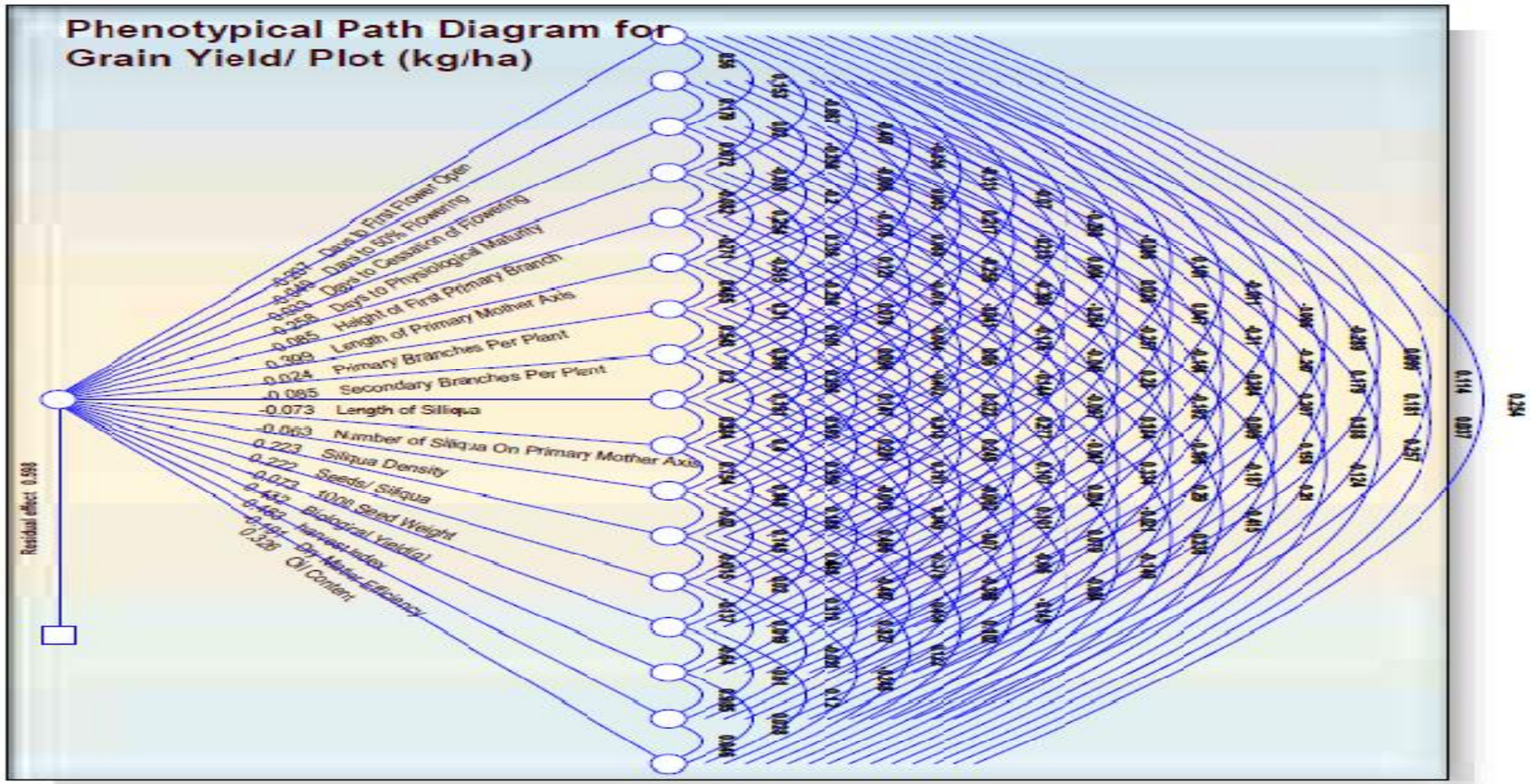


Fig. 2. Diagram for phenotypic correlation and path under irrigated condition

DPM, PBP^{-1}, SBP^{-1}, SPMA, LPMA and biological yield showed (Tables 5, 6, 7 and 8) high direct effect on grain yield per plot in negative (for flowering – maturity) and positive (for morphological traits). Similar findings were reported by Doddabhimappa et al. [21]; Singh and Singh [11] and Shweta and Om Prakash [22] had an agreement for primary and secondary branches per plant.

SBP^{-1} showed a high direct effect in the negative (non- irrigation condition) and positive direction (irrigation condition) suggested that under moisture stress condition time span for vegetative growth ceased off earlier resulting in few secondary branches but if the irrigated condition is available fully fledged vegetative growth permits more primary and secondary branches.

Thus, the material studied along with the usefully associated traits is of assorted nature and information emanated would help in architecting the selection methodology which can further be used in the breeding programme for improvement of seed yield.

4. CONCLUSION

The results of association and cause-effect suggesting that if plant selected for early flowering and maturity with more number of primary and secondary branches, length of primary mother axis, siliqua on primary mother axis and the total dry matter accumulation of a plant system which improved harvest index represents increased physiological capacity to mobilize photosynthates and translocate them into organs having economic yield. These will ultimately improvised grain yield per plot along with the associated traits which can be indirectly affecting yield of the plant.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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