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Evaluation and Characterization of Brown Mustard Accessions for Yield Contributing Traits

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Abstract: *Indian mustard (Brassica juncea L.) is an important source of oil in Pakistan and is known for its pest resistance and short duration which may fit well in triple cropping system in the province of Punjab. Therefore, study aims to make comparisons among germplasm accessions and elite varieties available for cultivation in Pakistan. The present research was performed to evaluate 45 genotypes of Raya (Brassica juncea L.) for yield contributing and related traits. The study employs a split-plot design, with 2 sowing dates and varieties as main and subplots, using three replications in the field research area of Plant Breeding and Genetics, College of Agriculture, University of Sargodha (2022-2023). Experimental accessions such as 24037, 19511, 24087 and 24067 show early germination and flowering than all other genotypes. But not a single genotype of them showed good harvested yield and harvest index, G44 (Faisalabad Mustard) and G45 (FMC Raya) also displayed good biomass and seed yield at harvested stage. G11 (24042), G38 (24057), G18 (22854) and G3*

(24037) showed maximum 1000 seed weight and only G38 performed good and showed excellent harvested yield among other genotypes. G42 (Raya Anmol), G3 (24087) and G33 (Super Raya) showed maximum plant height. In this research we assume that those genotypes which showed maximum height do not display good yield. Genotypes G38, G33, G36, and G34 showed maximum pods per plant but only G38 of them show maximum yield because of its maximum seed weight. G3, G34 and G40 show maximum seeds per pod. From this, we can have concluded that G34 has both maximum seeds per pod and pods per plant but do not show maximum seed yield because of its small seed size and less weight. G2, G9, G28 and G26 showed maximum oil content among studied genotypes. G44, G45, G23 and G38 show maximum harvested yield and performed well overall, showing their potential for enhanced agricultural productivity.

Key words: *Indian Mustard, Diversity, Components and Variability.*

Introduction

Pakistan has a constant scarcity of edible oil which results in high import costs. An abundant amount of edible oil is needed to bridge the gap between local production and use. Furthermore, rising demand for edible oil, combined with static production, has accelerated the global edible oil production process. As a result, there is an urgent need to enhance edible oil output or production to meet national demand while reducing import bills [1]. According to current analysis and research by Polaris Market, the worldwide mustard seed market will be worth USD 1062.31 million in 2030. Canola varieties or hybrids are mustard varieties with less than 2% erucic acid in oil and less than 30 U mole/g glucosinolate in oil-free meals. Canola oil and meal are preferable for human consumption, while meal is a good feed for animals and birds. Additionally, canola meal has balanced and well-suited profile of amino acid, ideal for poultry and cattle consumption. It is grown in all provinces of Pakistan on an area of 26.02 thousand hectares, with an annual production of 215.0 thousand tones (2022-23). Mustard seeds were the 3317th most traded product in the world in 2021(out of 4,641). Rapeseed and Mustard are grown in Chakwal, Rahim Yar Khan, Sargodha, Attock, Rawalpindi, Jehlum, Faisalabad, Multan, Bahawalpur, and Muzaffargarh. Originating from the Indian subcontinent, Brown Mustard (Raya) is globally recognized for its adaptability and practical applications. Widely cultivated for edible leaves, oil-rich seeds, and flavorful profile, it plays a crucial role in regional cuisines, particularly in South Asia. The plant's mustard oil, known for its nutritional worth and potential health advantages, is used in food preparation, medicines, and traditional therapeutic practices [2]. The Brassicaceae family has 338 genera and 3709 species which include weeds, ornamental plants of aesthetic value, and economically valuable crops [3]. Though classified as a perennial herb, mustard (*Brassica juncea* L.) is primarily cultivated as an annual or biennial crop While Central Asia is considered the primary center of origin for this species, secondary centers of diversity are western and central China. [4]. The plant is also used as a forage crop, vegetable, and in countless medicines and the seeds are extracted for edible oil. The plant's oil is highly prized for its aroma, flavor, food preservation, skin tonics and hair oil. Raya counts for global food security and agricultural sustainability due to its tolerance to a broad range of climatic conditions and nutritional value [5]. Raya contributes significantly to the nation's cooking oil supply providing one-third of all edible oil needs. It also has a high-calorie level and the right amount of vitamins (A, D, E, and K) that are fat-soluble for human consumption [6]. Indian mustard, which is primarily grown in India & Pakistan for oil seed, is starting to take center stage in Canada and the USA as a replacement for Brassica napus or rapeseed [7].

Results and Discussion

Table 1 indicates that the days to flowering was maximum on G2 (73.33333) and minimum on G41 (52.83333 days). This result depicted that genotype G2 (line 19511) takes more time to reach flowering stage. However, the other Genotype G41 (Bagho Bahar) needs less time duration to initiate its flowering. So, we can also infer that G41 exhibits high yield because it shows early flowering. It also tells that sowing date greatly affects the days to flowering trait and flower bud development. Such results were also aligning with the findings of [8]. Leaf area was maximum on G27

(351.3958) and mean value of leaf area was minimum on G28 (156.0833). Larger leaf area generally correlates with an increased capacity for photosynthesis. Genotypes with a larger maximum leaf area often exhibit greater biomass production. Maximum leaf area of B. juncea can influence not only overall biomass but also the yield and quality of the harvested product. Such results were also aligning with the findings of [9]. The association tests revealed a strong and positive correlation between seed production and 1000 seed weight at both the genotypic and phenotypic levels. This finding of 1000 seed weight trait resemble with the research and statistical findings of [10]. The height and width of a plant are important geometric traits that can be used as indicators of plant growth, site-specific applications, and yield estimation [11]. Plant height, days to 50% flowering and days to maturity had negative direct effect on seed yield. If plants show more vertical growth or vegetative growth then reproductive stage may affect and number of pods per plant also affects yield [12]. The result also shows that the G38 has a high mean value of pods per plant and G5 shows the lowest mean value of pods per plant. It means that almost all plants of replication of G38 (ZBJ-17008) have a larger number of pods than other genotypes even at different sowing dates. So, we can infer that this genotype will show maximum yield production than others and may be further used in a breeding program to maximize yield potential. These results are further supported by the results of [13]. The result also shows that the G23 and G19 has a high mean value of stem diameter and G2 shows minimum mean value of stem diameter. These genotypes with good stem diameter also show good seed yield per plant at harvesting stage [14][15]. Oil content value of 51.7% was recorded in G2 while the minimum mean value of oil content is 32.8% which was recorded in G35. These results also show significantly negative relation because G2, G9 and G28 showed maximum oil content percentage but at the same time these genotypes do not show good, harvested yield. These findings were in accordance with the results of [16]. It was determined that seeds per plant and 1000-seed weight were traits with the greatest potential to select for high-yielding genotypes in mustard because they showed a positive association and the greatest positive direct effects on seed yield. Similar results were also observed and concluded by [17].

Table 2 indicates that seeds per plant and plant height had high values of heritability in the broad sense (0.99 and 0.95, respectively). [18] also calculated high heritability for these traits. Maximum genotypic and phenotypic variances were found for seeds per plant (7874.22 and 7919.26) and maximum genotypic and phenotypic coefficients of variance were found for pods per plant (21.60 and 23.32%) respectively. Similar results were reported by [19].

The genotypic and phenotypic correlations between traits on first sowing date are summarized in Table 3. Harvest index was significantly correlated with days to flowering (0.574) and total biomass, showing accessions with high harvest index took lower days to flowering and also had low biomass. Stem diameter positively correlated with seed weight (0.07), oil content (0.35), and total biomass (0.138). Plant height also had negative relationship with days to flowering (-0.24) showing tall accessions had early flowering. Seed per plant had positive relationships with pods per plants (0.32) and negative relationship with oil contents (-0.25).

On the second sowing date harvest index was significantly correlated with days to flowering (-0.371), leaf area (-0.205), 1000 seed weight (0.227) and total biomass (-0.42), showing accessions with high harvest index took lower days to flowering, small leaf area and also had low biomass but larger 1000 seed weight (Table 4.) A positive and highly significant genotypic correlation between branches per plant and yield per plant was also concluded by [20]. A highly positive correlation was determined between plant height and yield per plant by [21].

Path Analysis

In phenotypic path analysis, leaf area (0.208) had the highest direct effects on seed yield followed by seeds per pod (0.19) and stem diameter (0.08) which had small positive direct effect on seed yield (Table 5) Days to flowering (-0.18) had negative direct effect on seed yield but positive indirect effects on seed yield via pods per plant (0.06). Leaf area (0.208) had positive direct effect on seed yield but also displayed positive indirect effect through days to 50% floweing (0.02). Parameter like stem diameter (0.08) had positive direct effect on seed yield. Moreover, oil contents (-0.03) had negative direct effects on seed yield but actually positive indirect effects via plant height (0.008). Pods per plant (-0.23) had negative direct effects on harvested yield and positive indirect effect via days to flowering (0.08). Seed per pod (0.19) had positive direct effect on seed yield. Plant height (-0.19) had significant negative direct effects on seed yield and positive indirect effects via days to flowering and days to germination (0.04). Alike findings were specified by [22], but these results were a part from earlier findings of [23]. This extensive research improves our understanding of the complex interactions between phenotypic parameters in raya during the first planting date, providing useful insights for crop improvement techniques.

In genotypic path analysis, 1000-seed mass (0.048) had the highest direct effects on seed yield followed by stem diameter (0.009) which had small positive direct effect on seed yield (Table 6). Days to flowering (-0.168) had negative direct effect on seed yield but positive indirect effects on seed yield via plant height (0.04). Leaf area (0.26) had negligible direct effect on seed yield. Oil contents (-0.153) also had negative effects on seed yield but positive indirect effects via total biomass. [23] found positive direct effect of seeds per pod on yield. [24] reported that plant height had negative direct effect on yield per plant. It is observed that branches per plant, plant height, and pods per plant exerted negative direct effects on yield in that study. [25] also confirmed that the negative direct effects of plant height and branches plant on raya yield. Pods per plant (0.01) had positive indirect effects via days to flowering. Seed per pod had negative indirect via total biomass (-0.015). Plant height (-0.35) had significant negative direct effects on seed yield and positive indirect effects via days to flowering (0.11) and total biomass (0.08). Total biomass (-0.68) had the highest negative direct effects over seed yield. Residual effects of the genotypic coefficient path analysis are 0.21 which may be unexplained effects over seed yield under current environmental conditions.

Materials and Methods

Experimental Material

The germplasm was collected from the following institutions such as Plant Genetic Resource Institute at the National Agriculture Research Center (NARC), Research Council Pakistan, and Oil Seed Research Institute, Ayyub Agriculture Research Faisalabad. All 45 accessions namely

24037,19511,24087,24067,24107,24122,24142,24047,24052,24027,24042,19527,23680,24062,24133,24032,24117,22854,24127,24112,19493,24137,24007,24702,24162,24152,24157,24057,24102,24167, RBJ-15017, ZBJ-17019, Super Raya, RBJ-17003, ZBJ-19008, RBJ-16012, ZBJ-18008, ZBJ-17008, AARI Canola, RBJ-18007, Bagho Bahaar, Raya Anmol, Khanpur Raya, Faisalabad Mustard, FMC Raya were maintained in Department of Plant Breeding & Genetics College of Agriculture, University of Sargodha during 2022-2023.

Field Conditions

The experimental material was sown a loamy soil under optimum moisture condition. Field soil was prepared after single irrigation under water condition using two ploughs followed by single planking. The seed of all accessions was manually dibble with row to row (30 cm) distance carefully handled under optimal soil moisture conditions and germination data was meticulously recorded. During soil preparation, 50 kg of di-ammonium phosphate and 20 kg of sulfate of potash per acre were added. Seed materials of all accessions were manually sown at a depth of 1 inch. Additionally, sowing material off all genotypes was sown under two sowing dates (17th September and 7th October).

Experiment Design

The experimental design was Slit Plot Design in which the sowing dates were assigned to the mean plots and the accessions was sown in the sub-plot. There were three replications for each of the accession. The weeds were controlled manually and plants were also thinned when they reached at the height of 6 inch.

Data Collection

Research material was planted at two different sowing dates i.e. (17 September and 17 October). Ten randomly selected plants were marked to record data on Days to Germination, Days to Flowering, Leaf Area (cm), Stem Diameter (mm), 1000 Seed Weight (g), Pods per plant, Seeds per pods, Plant Height (cm), Total Biomass (g), Oil Content (%), Harvested yield (g) and Harvest index.

Statistical Analysis

Statistical Analysis was done using the split plot design on R Studio using the library Agricola and program functioning Split Plot Design. The significance of the mean value was also determined by using the multiple comparison test LSD on the R-Program using the Library Agricola and least significant design. Several biometrical parameters such as phenotypical coefficient of variation, genotypic coefficient of variation, genotypic correlation and phenotypic correlation were also determined by using the R-program.

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Table 1. Genetic parameters for yield related traits of Brassica juncea genotypes

Genotypes	DTG	DTF	LA	SW	PH	PPP	SD	SPP	OC	HY	TB	HI
Genotypic variance	13.34	8.28	0.31	0.21	236.28	4948	0.32	8	0.14	7974	0.46	13.46
Phenotypic variance	20.8	12.0	0.62	0.25	248	5768	0.61	9.93	1.00	7920	1.00	18
GCV	5.84	1.76	11.91	11.87	6.5	21.5	10.91	18.16	1.7	19.94	8.37	17.6
PCV	7.17	2.11	17.80	13.01	6.3	23.32	16.80	20.21	1	21	12.40	22
H^2	0.67	0.70	0.68	0.83	0.96	0.86	0.51	0.83	0.34	0.99	0.46	0.8

Table2. Mean values for different yield related traits of Brassica juncea genotypes

Genotypes	DTG	DTF	LA	SW	PH	PPP	SD	SPP	OC	HY	TB	HI
G1	18.50b	72.66b	246.00j-m	4.12gh	191.69rs	674.67op	15.45n-q	12.50j	40.78j-p	126.33g-j	302.50fg	41.81h-m
G2	19.66a	73.33a	257.00h-j	3.77ij	183.08st	750.33n	6.69u	15.66ef	51.63a	63.00n-s	145.33j-p	43.73e-j
G3	19.66a	72.16bc	329.83b	4.65cd	240.49ab	1141.50de	12.83t	17.33a	40.46k-q	35.80r-s	87.16n-p	41.09j-m
G4	18.83b	72.16bc	243.04j-m	4.45d-f	218.58k-o	1110.50ef	17.33k-m	16.16c-e	48.12bc	93.50j-o	228.16g-j	40.95j-m
G5	17.00c	72.33bc	167.20tu	3.54j-m	229.01c-j	400.00u	20.37hi	14.50hi	42.96f-k	38.66q-s	92.16m-p	41.92h-m
G6	16.50c	72.00c	314.00c	3.51j-m	199.01qr	637.00q	23.01a-c	15.00gh	38.46p-t	61.16n-s	151.00j-p	40.77j-m
G7	8.50k-m	67.33f-h	230.83mn	4.33e-g	226.28d-k	686.00o	19.06ij	16.66bc	41.19j-o	53.83o-s	115.33l-p	46.03b-f

G8	10.00hi	67.66f	204.18pq	4.29e-g	198.86qr	512.17t	21.45d-h	15.33fg	46.87cd	65.16n-s	136.00j-p	48.60ab
G9	10.00hi	67.33f-h	237.45k-n	4.48d-f	221.42i-n	577.00r	12.89t	11.33k	50.83a	35.33r-s	71.50p	48.34a-c
G10	10.00hi	67.16f-h	211.18op	3.63i-k	232.37b-e	546.66rs	20.76gh	11.33k	44.64d-h	32.16s	72.50op	44.46d-i
G11	9.50ij	66.83hi	251.02i-k	6.10a	217.29l-o	1109.33ef	20.45hi	14.83g-i	43.27f-j	35.33r-s	75.66n-p	46.83b-d
G12	10.66fg	67.33f-h	263.93g-i	4.64cd	199.15qr	1156.66d	16.31l-p	14.50hi	37.97q-t	79.83l-p	170.66j-n	46.96b-d
G13	12.83d	70.33d	248.92i-l	4.28e-g	228.51c-j	942.50j	23.75ab	15.00gh	39.02o-s	78.13m-q	188.66i-m	41.52i-m
G14	12.00e	70.00d	173.25st	2.58o	216.66m-o	657.67o-q	17.35kl	14.33i	40.09l-r	61.83n-s	150.83j-p	41.00j-m
G15	11.16f	58.16n	275.31fg	3.53j-m	216.26m-o	638.83q	15.64n-p	14.66hi	41.74i-n	84.43k-p	208.50h-l	40.54m
G16	12.50de	68.83e	200.91p-r	3.60i-k	197.53qr	568.17rs	16.61l-o	15.83d-f	40.41k-q	171.33c-f	424.16c-e	40.36m
G17	7.50o-q	66.00jk	171.91st	4.24e-g	210.57op	778.66n	17.44kl	16.00de	39.66m-r	74.50m-r	157.50j-p	47.34b-d
G18	8.33l-n	67.50fg	250.33i-l	4.78c	224.04e-m	779.00n	21.06f-h	15.66ef	39.97m-r	178.17c-e	440.00b-d	40.51m
G19	9.83hi	67.50fg	338.08ab	3.84hi	204.53pq	827.66m	23.80ab	15.66ef	38.51p-t	141.06e-h	339.33ef	41.85h-m
G20	10.16gh	67.33f-h	176.08st	3.27mn	225.63d-l	851.50lm	13.86r-t	15.66ef	40.35l-r	150.00d-g	367.66d-f	40.99j-m
G21	10.16gh	67.50fg	193.06qr	4.19fg	202.77pq	880.33kl	22.40b-f	15.66ef	44.66d-g	79.83l-p	158.50j-p	50.83a
G22	9.83hi	67.00g-i	174.83st	3.76ij	229.58c-i	950.83j	22.62a-e	15.66ef	39.89m-r	123.66g-k	301.33fg	41.09j-m
G23	9.50ij	66.83hi	161.27tu	3.57i-l	197.42qr	645.17pq	23.94a	15.66ef	44.22e-i	196.50bc	482.66b-c	40.72k-

												m
G24	9.00jk	66.50ij	238.91k-n	3.42k-n	220.70j-n	961.00ij	18.56jk	16.00de	37.87q-t	145.66e-h	358.66d-f	40.60lm
G25	9.50ij	66.83hi	338.54ab	3.45k-n	196.09qr	684.33o	21.20e-h	15.00gh	46.44c-e	139.50e-h	334.83ef	41.64h-m
G26	7.16p-r	65.66kl	168.25tu	3.63i-k	223.60f-m	776.00n	14.84p-s	14.50hi	49.66ab	91.50j-o	199.16h-l	45.55c-g
G27	7.16p-r	65.00m	351.39a	4.12gh	236.90a-c	536.17st	15.86m-p	15.66ef	39.81m-r	135.00f-i	333.33ef	40.63lm
G28	6.83r	65.33lm	156.08u	3.77ij	232.04b-f	1011.83h	16.57l-o	15.66ef	50.54ab	49.83p-s	115.67l-p	42.93g-m
G29	8.00m-o	65.33lm	307.64cd	3.17n	234.32b-d	986.33hi	14.07q-t	16.00de	40.61k-p	45.83p-s	100.66m-p	44.97d-g
G30	5.83s	65.00m	231.08mn	3.53j-m	230.96c-h	1102.16fg	15.31o-r	16.00de	37.06st	96.78i-n	208.66h-l	46.91b-d
G31	5.83s	57.66no	232.87mn	4.34e-g	222.36h-n	1077.00g	22.89a-d	15.83d-f	36.22t	106.50h-m	219.66g-k	48.66ab
G32	9.83hi	57.16o	331.33b	4.30e-g	226.07d-k	1202.83c	21.25e-h	15.66ef	40.65k-p	57.30n-s	127.17k-p	44.44d-i
G33	7.66op	55.83qr	287.18ef	3.83hi	239.81ab	1302.16b	13.53st	16.33cd	37.78r-t	67.33m-s	164.66j-p	41.54i-m
G34	7.83no	53.66s	332.02b	3.31l-n	221.55i-n	1274.83b	20.83gh	17.00ab	41.63i-n	77.50m-q	169.33j-o	45.72b-g
G35	7.50o-q	55.33r	163.35tu	3.61i-k	220.91i-n	1151.66d	13.36t	15.33fg	32.78u	64.38n-s	144.00j-p	44.61d-h
G36	6.83r	55.83qr	208.10pq	3.53j-m	214.22no	1289.16b	14.99p-s	14.33i	42.06h-m	119.50g-l	282.33f-i	43.30f-m
G37	7.00qr	53.33st	224.91no	3.71i-k	222.89h-n	962.16ij	20.16hi	15.33fg	38.21p-t	127.17g-j	272.50f-i	46.71b-e

G38	7.00qr	55.50qr	269.91gh	5.40b	223.28g-m	1397.00a	19.22ij	15.66ef	45.45d-f	188.67b-d	445.16b-d	43.55f-l
G39	7.00qr	53.66s	234.62l-n	3.51j-m	234.23b-d	857.50k-m	14.93p-s	16.00de	36.87st	120.83g-k	289.33f-h	41.80h-m
G40	7.00qr	55.66qr	187.58rs	4.49c-e	221.17i-n	750.66n	16.80l-n	16.66bc	42.60g-l	69.50m-s	159.66j-p	43.63f-k
G41	9.66hi	52.83t	201.77p-r	3.69i-k	226.79d-k	764.83n	15.98l-p	16.33cd	39.15n-s	97.83i-n	201.83h-l	48.54a-c
G42	8.00m-o	53.66s	204.16pq	4.64cd	243.74a	775.33n	13.68st	16.33cd	40.16l-r	95.00i-n	226.33g-j	41.88h-m
G43	9.83hi	56.50p	293.41de	4.50c-e	225.73d-l	887.66k	22.04c-g	16.66bc	38.65o-t	151.33d-g	349.66d-f	43.18f-m
G44	8.66kl	56.00pq	339.89ab	4.39d-g	231.92b-g	543.16st	16.05l-p	16.33cd	39.34n-s	299.50a	730.33a	41.07j-m
G45	8.83kl	55.66qr	344.06ab	3.42k-n	176.13t	957.83ij	18.41jk	16.66bc	42.12g-m	219.50b	533.50b	41.09j-m

Table 3. Genotypic and Phenotypic Correlation (1st sowing date)

		DTG	DTF	LA	SD	SW	OC	PPP	SPP	PH
DTF	G	0.574**								
	P	0.574**								
LA	G	0.1063 NS	-0.1628 NS							
	P	0.1032 NS	-0.1558 NS							
SD	G	-0.0797 NS	0.1863 NS	0.0416 NS						
	P	-0.0718 NS	0.1693 *	0.0375 NS						
SW	G	-0.104 NS	-0.047 NS	0.1182 NS	0.0775 NS					
	P	-0.097 NS	-0.0436 NS	0.1069 NS	0.0912NS					
OC	G	0.2636 NS	0.3901 **	-0.1317 NS	0.1297 NS	0.1075 NS				
	P	0.2397 **	0.3543 **	-0.1173 NS	-0.1105NS	0.0775NS				
PPP	G	-0.2514 NS	-0.3656 *	0.1543 NS	-0.1592 NS	0.2521 NS	-0.2044 NS			
	P	-0.2468 **	-0.363 **	0.1489 NS	-0.1442NS	0.233 **	-0.1861 *			
SPP	G	-0.1449 NS	-0.3535 *	0.2423 NS	-0.0194 NS	0.1239 NS	-0.2843 NS	0.3492 *		
	P	0.1347 NS	0.3301 **	0.2224 **	-0.0336NS	0.098NS	-0.2591 **	0.3233 **		
PH	G	-0.3304 *	-0.2677 NS	-0.059 NS	-0.2125 NS	0.1329 NS	-0.3193 *	0.1821 NS	0.1643 NS	
	P	-0.2989 **	-0.2457 **	-0.0655 NS	-0.1527NS	0.1092NS	-0.2572 **	0.1607 NS	0.1379 NS	
HI	G	-0.1983 NS	-0.2861 NS	0.3226 *	0.1593 NS	-0.0013 NS	-0.1983 NS	-0.0879 NS	0.2777 NS	-0.2354 NS
	P	-0.1684 NS	-0.236 **	0.2472 **	0.1296NS	-0.0132NS	-0.1263 **	-0.0725 NS	0.2223 **	-0.1323 NS

Table 4: Genotypic and Phenotypic Correlation of 2nd Sowing date

		DTF	LA	SD	SW	OC	PPP	SPP	PH	TB
LA	G	0.1011 NS								
	P	0.0926 NS								
SD	G	-0.087 NS	0.0989 NS							
	P	-0.0707 NS	0.0922 NS							
SW	G	-0.0436 NS	0.1537 NS	0.1328 NS						
	P	-0.0282 NS	0.1415 NS	0.1253 NS						
OC	G	0.0805 NS	-0.1663 NS	-0.1653 NS	0.147 NS					
	P	0.0505 NS	-0.1282 NS	-0.1649 NS	0.1053 NS					
PPP	G	-0.2151 NS	0.1821 NS	0.0471 NS	0.181 NS	-0.2484 NS				
	P	-0.2091 *	0.1818 *	0.0406 NS	0.1752 *	-0.1882 *				
SPP	G	-0.1255 NS	0.2127 NS	0.0565 NS	-0.007 NS	-0.3882 **	0.3452 *			
	P	-0.0941 NS	0.1836 *	0.0595 NS	-0.01 NS	-0.2667 **	0.3181 **			
PH	G	-0.3224 *	-0.0621 NS	-0.0518 NS	0.1336 NS	-0.212 NS	0.2155 NS	0.141 NS		
	P	-0.2465 **	-0.0521 NS	-0.0453 NS	0.0989 NS	-0.1608 NS	0.1776 *	0.1456 NS		
TB	G	-0.0282 NS	0.1958 NS	0.1386 NS	-0.0444 NS	-0.2239 NS	-0.1175 NS	0.281 NS	-0.253 NS	
	P	-0.0366 NS	0.1816 *	0.1014 NS	-0.0367 NS	-0.1263 NS	-0.0992 NS	0.2282 **	-0.1478 NS	
HI	G	-0.4885 **	-0.2333 NS	0.1362 NS	0.2674 NS	0.196 NS	0.0866 NS	-0.2404 NS	0.0417 NS	-0.5833 **
	P	-0.3719 **	-0.2053 *	0.1164 NS	0.2275 **	0.128 NS	0.0515 NS	-0.1644 NS	0.0068 NS	-0.4206 **

Table 5a: Genotypic path analysis of 1st sowing date

	DTG	DTF	LA	SD	SW	OC	PPP	SPP	PH
DTG	**-0.25306**	-0.09720	0.02792	-0.00076	-0.00505	-0.04040	0.07777	-0.03474	0.12722
DTF	-0.14593	**-0.16856**	-0.04276	0.00179	-0.00229	-0.05980	0.11311	-0.08472	0.10308
LA	-0.02690	0.02744	**0.26267**	0.00040	0.00575	0.02019	-0.04774	0.05807	0.02273
SD	0.02016	-0.03141	0.01092	**0.00959**	0.00377	0.01988	0.04925	-0.00465	0.08181
SW	0.02631	0.00792	0.03106	0.00074	**0.04862**	-0.01648	-0.07798	0.02968	-0.05119
OC	-0.06670	-0.06575	-0.03460	-0.00124	0.00523	**-0.15328**	0.06322	-0.06813	0.12293
PPP	0.06362	0.06163	0.04054	-0.00153	0.01226	0.03132	**-0.30934**	0.08369	-0.07010
SPP	0.03668	0.05958	0.06364	-0.00019	0.00602	0.04357	-0.10802	**0.23968**	-0.06327
PH	0.08361	0.04513	-0.01551	-0.00204	0.00646	0.04894	-0.05632	0.03938	**-0.38504**

Table 5b: Genotypic Path Analysis of 2nd Sowing date

	DTF	LA	SD	SW	OC	PPP	SPP	PH	TB
DTF	**-0.60743**	-0.00999	-0.01128	-0.01217	-0.00486	0.01804	0.00676	0.11314	0.01929
LA	-0.06140	**-0.09884**	0.01283	0.04291	0.01004	-0.01527	-0.01146	0.02180	-0.13390
SD	0.05282	-0.00978	**0.12973**	0.03705	0.00998	-0.00395	-0.00305	0.01817	-0.09476
SW	0.02650	-0.01520	0.01722	**0.27910**	-0.00888	-0.01518	0.00038	-0.04689	0.03032
OC	-0.04889	0.01644	-0.02145	0.04104	**-0.06038**	0.02083	0.02091	0.07438	0.15307

PPP	0.13068	-0.01800	0.00611	0.05053	0.01500	**-0.08386**	-0.01860	-0.07562	0.08032
SPP	0.07622	-0.02102	0.00733	-0.00195	0.02344	-0.02895	**-0.05388**	-0.04947	-0.19212
PH	0.19583	0.00614	-0.00672	0.03729	0.01280	-0.01807	-0.00760	**-0.35092**	0.17296
TB	0.01714	-0.01936	0.01798	-0.01238	0.01352	0.00985	-0.01514	0.08878	**-0.68369**

Table 6a: Phenotypic path analysis of 1st sowing date

	DTG	DTF	LA	SD	SW	OC	PPP	SPP	PH
DTG	**-0.16290**	-0.10443	0.02155	-0.00579	0.00067	-0.00797	0.05750	-0.02573	0.05870
DTF	-0.09351	**-0.18193**	-0.03254	0.01366	0.00030	-0.01178	0.08457	-0.06304	0.04825
LA	-0.01681	0.02834	**0.20883**	0.00303	-0.00074	0.00390	-0.03469	0.04248	0.01286
SD	0.01170	-0.03080	0.00783	**0.08067**	-0.00063	0.00367	0.03360	-0.00642	0.02999
SW	0.01577	0.00793	0.02232	0.00736	**-0.00690**	-0.00257	-0.05428	0.01862	-0.02145
OC	-0.03905	-0.06446	-0.02450	-0.00891	-0.00053	**-0.03324**	0.04336	-0.04949	0.05051
PPP	0.04020	0.06604	0.03109	-0.01163	-0.00161	0.00619	**-0.23298**	0.06176	-0.03156
SPP	0.02194	0.06004	0.04644	-0.00271	-0.00067	0.00861	-0.07532	**0.19105**	-0.02708
PH	0.04869	0.04470	-0.01368	-0.01232	-0.00075	0.00855	-0.03744	0.02634	**-0.19639**

Table 6b: Phenotypic Path Analysis of 2nd Sowing date

	DTF	LA	SD	SW	OC	PPP	SPP	PH	TB
DTF	**-0.41959**	-0.01089	-0.00816	-0.00639	0.00137	0.01159	0.00365	0.04048	0.01594
LA	-0.03885	**-0.11760**	0.01063	0.03174	-0.00349	-0.01008	-0.00711	0.00856	-0.07909
SD	0.02971	-0.01084	**0.11527**	0.02813	-0.00449	-0.00225	-0.00230	0.00744	-0.04416
SW	0.01196	-0.01664	0.01445	**0.22450**	0.00287	-0.00971	0.00040	-0.01622	0.01598
OC	-0.02115	0.01508	-0.01901	0.02365	**0.02725**	0.01043	0.01034	0.02640	0.05501
PPP	0.08774	-0.02138	0.00468	0.03931	-0.00513	**-0.05543**	-0.01232	-0.02916	0.04321
SPP	0.03953	-0.02159	0.00684	-0.00233	-0.00727	-0.01763	**-0.03873**	-0.02391	-0.09939
PH	0.10343	0.00613	-0.00522	0.02217	-0.00438	-0.00985	-0.00564	**-0.16420**	0.06437
TB	0.01536	-0.02136	0.01169	-0.00823	-0.00344	0.00550	-0.00884	0.02427	**-0.43554**