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PATH COEFFICIENT AND CORRELATION ANALYSIS IN SECOND CROP SOYBEAN [*Glycine max* (L.) Merrill]

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ABSTRACT

Soybean is the most widely grown leguminous and nutritionally important crop in the world. The selection criteria in soybean breeding suitable for second crop (double cropping) are expected to vary according to the main product conditions. Fourteen soybean [*Glycine max* (L.) Merr.] genotypes were studied in 2014, 2015 and 2016 to determine selection criteria for plant breeders using correlation and path coefficient analyses in soybean under second crop conditions. Randomized complete block design with four replicates was used for laying out the field experiments at research fields of Ege University. Variance analysis was perform for each characters and it was concluded that the genotype x year interaction was statistically significant at the 1% probability level in terms of all the traits examined. According to results of the correlation analysis, it is seen that six traits are positively correlated with grain yield, while the other traits are negatively correlated with seed yield. The six characters are pod numbers per plant (r= 313.3*), days to 50% flowering (r= 0.270*), days to maturity (r=0.286*), plant height (r=0.027ns), first pod height (r=0.181ns) and crude protein ratio (r=0.112ns). Path coefficient analysis showed grain yield positively and directly effected by pods number per plant (0.5532) followed by day to maturity (0.2483), plant height (0.1920), crude protein ratio (0.0403), first pod height (0.0266) and days to 50% flowering (0.0104); Grain yield was negatively and directly effected by 100-seed weight (-0.1697) and crude oil ratio (-0.0097). In conclusion under the second crop conditions, pod number per plant could be used as a selection criterion due to its high direct and positively effect on grain yield.

Keywords: Coefficient, correlation, path analysis, soybean, yield.

INTRODUCTION

Soybean is the most produced plant among oilseed crops, it contains 20% oil. In addition to being an oilseed plant, soybean contains 40% protein and it is an important protein source for both animal and human nutrition (He and Chen, 2013; Malek et al., 2014; Ghosh et al., 2014). Rich in polyunsaturated fatty acids, soybean oil is among the healthiest and most preferred vegetable oil in the kitchen. Soybean, which contains phytochemicals with antioxidant properties such as isoflavones and lignans, has positive effects on human health. It is stated that protein, high amount of essential fatty acids and minerals in soy are effective especially in preventing cardiovascular diseases. (Palomo et al., 2011, Bakal et al., 2017). For vegan-vegetarians and people with lactose intolerance, alternative plant-based milk and dairy products, as well as plant-based meat and meat products, can be easily obtained from soybean. Soybean can be cultivated both as a main crop and as a secondary crop. Since it is a legume plant, soybean fixes nitrogen and is a good rotation plant as it reduces the use of chemical fertilizers and leaves organic matter in the soil (Arioglu, 2014; Kumar et al., 2014). All these features increased the importance of soybean and positively effected the production pattern and quantity. According to FAO reports, 609.21 million tons of oilseed plants were produced in the 2021/22 season, and soybean was the most produced plant with a production of 359.80 million metric tons and a share of 59% in the total production (Anonymous, 2023). In Turkey, soy is primarily used as an animal feed additive. Soybean production in Turkey, which has an ecological environment where soybean can be grown as both the main product and the second product, is not sufficient and the import of soybean grain and meal is increasing every year (Gulluoglu et al., 2016). Since this situation significantly effects meat prices, efforts to increase soybean production in such countries are very important. It is known that 94% of the soybeans produced in the world are produced from genetically modified seeds, and this situation poses a significant problem to find high yielding and valuable soybean seeds in countries where planting of genetically modified seeds is prohibited (Statista, 2022). In these countries, it is important to develop new non-GMO and high-yielding varieties for both production and export.

Grain yield that extremely complex character is very important trait for plant breeders. Grain yield is reportedly associated with a number of component traits and these traits are themselves inter-related (Pandey and Torrie, 1973; Balla and Ibrahim, 2017). The success of selection for grain yield can be achieved by finding the desired variation in the genetic stock. Selection for direct grain yield may fail because successful yield selection is dependent on genetic variation and the relationship between yield and yield traits. These associations could be evaluated by correlation analysis, that helps in the simultaneous selection for more than one character (Akhter et al., 1996; Salimi and Moradi, 2012; Akram et al., 2016). To maximize grain yield, it is necessary to determine the key characteristics of yield and other components related to yield (Aditya et al., 2011; Ilker, 2011; Malek et al., 2014; Akram et al., 2016;). Correlation analysis is not adaquate to understand cause and effect associations among traits between related with yield hence correlation studies along with path coefficient analysis provide accurate idea of the relation of traits with grain yield (Balla and Ibrahim, 2017; Machado et al., 2017). The goal of this study is to determine selection criteria for plant breeders using correlation and path coefficient analyses in soybean under second crop conditions.

MATERIALS AND METHODS

Location of the field experimental area

Field experiments were conducted throughout the 2014, 2015 and 2016 growing seasons at Ege University's Faculty of Agriculture in Izmir, Turkey (latitude 38˚27′ N, longitude 27˚13′ E and altitude 29 m a.s.l).

Plant Material

Ten advanced soybean lines (BATEM 317, BATEM 306, BATEM 223, BATEM 207, BDSA 05, KASM-02, KASM-03, KANA, KAMA, BDUS-04) and four soybean registered varieties (ARISOY, NOVA, ATAEM-7, BRAVO) were used as plant material.

Soil properties, weather conditions, experimental design, and field period treatments

Soil samples from the experimental field was collected and analyzed at Ege University. Table 1 shows properties of the soil in the area. The trial plots had clayey-loam soil (30.0% clay, 38.2% silt, and 32.8% sand 0–40 cm). The experimental soil is medium and slightly alkaline, has minimal organic matter, has a high total N concentration, and has a calcareous structure (Kacar, 2009).

Table 1. Physical and chemical characteristics of soil properties at the field.

Parameters	Unit	Depth of the soil (cm) 0–20	20–40
Texture		Clayey-loam	Clayey-loam
Sand	%	35.05	35.05
Silt	%	32.22	32.22
Clay	%	33.00	33.00
pH		8.11	7.22
Organic matter	%	1.43	1.96
$CaCO_3$	%	21.02	21.94
Total N	mg kg^{-1}	0.068	0.095

The climate data during the growing period in experimental area were presented in Table 2. The Bornova-Izmir region, where the research was done, has a typical Mediterranean climate. Meteorological data (temperature, rainfall) were collected over the three vegetation periods.

Table 2. Temperature and precipitation avarages at Bornova/İzmir for 3 years.

	Avg. Temperature (ºC)				Total rainfall (mm)			
Months/Years	**2014**	**2015**	**2016**	**Long term**	**2014**	**2015**	**2016**	**Long term**
June	25.0	24.6	27.7	26.0	40.3	30.9	40.3	7.5
July	28.2	28.7	29.9	28.3	0.9	0.2	0.9	28.3
August	28.3	29.3	29.4	27.9	21.1	1.0	21.1	27.9
September	24.0	26.4	25.1	23.9	10.9	12.9	10.9	23.9
October	19.3	19.7	19.2	19.1	56.0	48.1	56.0	19.1
Σ/ $\bar{X}$	25.0	25.7	26.3	25.0	129.2	93.1	129.2	106.7

(Izmir Regional Directorate of Turkish State Meteorological Service. 2016)

Trials were conducted in a Randomized Complete Block Design with 4 replications. Seeds inoculated with *Rhizobium japonicum* bacteria were sown by hand in 4 row plots with 0.70 m row spacing and 5 m row length, with 45 plants per m^2. Before sowing the seeds, the soil was fertilized with 200 kg ha^{-1} of DAP (36 kg ha^{-1} N, 92 kg ha^{-1} P). In all three production seasons, the plants were irrigated 6 times with the sprinkler irrigation system.

Harvesting was done manually, selected plants were threshed with a single plant threshing machine, and other plants were threshed with a parcel threshing machine.

Plant measurements and statistical analysis

In the research, observations and measurements were made for 9 characteristics: plant height (PH, cm), grain yield (GY, kg ha^{-1}), first pod height (FPH, cm), number of pods per plant (PPP, $plant^{-1}$), hundred-seed weight (HSW, g), days to 50% flowering (DFF, days), days to maturation (DFM, days) (Zaimoglu et al., 2004), crude protein ratio (PRT, %) and crude oil ratio (Oil, %) (AOAC, 2010).

The TOTEM STAT statistical package was used to perform analysis of variance (ANOVA) on the data collected during the field experiment (Acikgoz et al., 2004). Variance analysis of the data obtained from the research over three years was made and LSD (least significant difference) test was applied to compare the differences (Steel and Torrie, 1980). Phenotypic correlations were calculated and path analysis were applied to examine the effects of the examined features on each other and on yield (Dewey and Lu,1959).

RESULTS AND DISCUSSION

In this research, plant height (cm), first pod height (cm), number of pods per plant ($pod/plant^{-1}$), 100-seed weight (g), grain yield (kg ha-1), days to 50% flowering (day), maturation days (days), crude oil content (%) and protein content (%) characteristics of 14 soybean genotypes were examined for three years. Combined analyses of variance was performed for each characters and it was concluded that the genotype x year interaction was statistically significant at the 1% probability level in terms of all the traits examined. The importance of the interaction can be interpreted as changing environmental conditions, and especially the increase in average temperature in June and July 2016, causing different effects on genotypes. (Table 3).

Table 3: Results of combined analyses of variance (mean squares) over three years for grain yield (GY), plant height (PH), First pod height (FPH), pods per plant (PPP), days to 50% flowering (DFF), days to maturity (DFM), 100-seed weight (HSW), Oil ratio (%), Protein ratio (%).

Source	Df	PH	LPH	PPP	100-SW	GY	DFF	DFM	OIL	PRT
Years	2	7933.99**	353.25**	53199.97**	12.09ns	51252.35**	9.042**	1174.54**	10.47*	31.97*
Error 1	9	47.78	9.08	83.42	5.49	602.60	0.972	11.08	1.75	4.90
Genotypes	13	539.31**	58.80**	973.17**	36.38**	6860.77**	25.240**	65.48**	4.75**	11.29**
Years x Genotypes	26	141.22 **	10.81**	786.07**	5.15**	2707.39**	11.285**	10.11**	8.44**	19.99**
Combined eror	117	40.58	2.51	89.79	2.04	880.26	0.71	1.62	0.66	2.15

ns: non significant, *: significant at the $p \leq 0.05$ level, **: significant at the $p \leq 0.01$ level

Least significant difference (LSD) test (Steel and Torrie, 1980) was applied to compare the differences in terms of genotypes and the results are given in Table 4, Table 5 and Table 6. According to the three-year average of the soybean genotypes examined in the study, the plant height varied between 67.4 cm and 87.2 cm. Average plant height was 78.2 cm and the highest plant height was obtained from BATEM 306 and ATAEM 7 (87.9) genotypes. The results are well supported by the findings of Malik et al. (2006), Aditya et al. (2011), Akram et al. (2011) and Ilker et al. (2018a; 2018b). First pod height is one of the important parameters studied to prevent yield loss in machine harvesting. According to the three-year average of the genotypes examined in the study, the average height of the first pod was 8.2 cm. The first pod heights varied between 5.3 cm and 12.8 cm and the highest first pod height was obtained from the BATEM 317 genotype. Among the 4 registered cultivars examined in the study, only the first pod height of ATAEM 7 genotype was measured above the average. The results are in agreement with Malik et al., (2006) who recorded range of 7.13 cm to 13.67 cm FPH. When the number of pods per plant was examined, the average of the genotypes over three years was obtained as 76.1 units/plant. The number of pods per plant varied between 61.9 and 94.8 and the highest value was obtained from the KASM 03 genotype. The results of PPP observed in the study were found to be higher than the findings of Aditya et al. (2011) and Silva et al. (2015). The difference in the result might be owing to the difference in plant material and environmental condition. In terms of 100 grain weight, the average of three years of genotypes was determined as 17.3 g. The highest hundred grain weight (21.1 g) was obtained from the BDUS 04 genotype, followed by the ATAEM 7 (18.9), BDSA 05 (18.9) and KAMA (18.7) genotypes. The findings are not in agreement with Malik et al. (2060)'s findings but in agremeent with Malik et al. (2007), Silva et al. (2015), Aditya et al. (2011), Onat et al. (2017)'s findings The average grain yield of the genotypes examined in the study over three years was 3428.1 kg ha^{-1}. The genotypes with the highest grain yield were KASM 03 (3660.9 kg ha^{-1}), BATEM 317 (3654.4 kg ha^{-1}) KASM 02 (3654.0 kg ha^{-1}) and BATEM 306 (3629.4). In general, the yields of the registered cultivars included in the trial were below the average. World highest soybean yield is obtain from Turkey (FAOSTAT (2021), 4147.2 kg ha^{-1}) and while our results for grain yield are below Turkey's avarage they are higher than most of researchers findings and world average (Aditya et al. 2011; Silva et al. 2015.) The average number of flowering days in the study was 34.8 days. It was determined that registered cultivars (ARISOY, NOVA, BRAVO, ATAEM 7) bloom earlier than other genotypes. Our results in terms of days to %50 flowering earlier than some other researcher's findings (Aditya et al. (2011), Malik et al. (2006 and 2007.) The difference might be related sowing date, climate conditions. According to the three-year averages of the genotypes examined in the study, the number of maturation days was 105.3 days. The number of maturing days varied between 102.1 days and 110. 3 days. The results obtained from genotypes in agreement with Ahmad et al. (2023)'s results. Crude oil and crude protein values were measured to determine the quality characteristics of the examined genotypes. Crude protein ratios of the genotypes included in the experiment varied between 43.9% and 46.6% over three years, and the average was obtained as 45.2%. The genotype with the highest crude protein ratio was determined as BATEM 223. The obtained crude protein ratio from all genotypes is higher than the some other researcher's findings (Malik et al., 2007; Bakal et al., 2017). Crude oil ratio of genotypes varied between 18.6% and 21% over three years, and the average crude oil ratio was determined as 19.9%. It was determined that the genotype with the highest crude oil content was ARISOY. The crude oil contents obtained from all genotypes in this research was in agreement with the other studies findings (Malik et al., 2007; Bakal et al., 2017; Ilker et al., 2018a).

The correlation coefficients analysis between the traits are given in Table 7. According to results of the correlation analysis, it is seen that six traits are positively correlated with grain yield, while the other traits are negatively correlated with seed yield. The six characters are pod numbers per plant (r= 313.3*), days to 50% flowering (r= 0.270*), days to maturity (r=0.286*), plant height (r=0.027^{ns}), first pod height (r=0.181^{ns}) and crude protein ratio (r=0.112^{ns}). Significant positive correlation between pod numbers per plant with grain yield has been reported by Aditya et al. (2011), Akram et al. (2016), Balla and Ibrahim (2017), Sulistyo et al. (2017), Guleria et al. (2019), Belay et al. (2023). Positive correlation coefficients were reported between grain yield with days to 50% flowering and grain yield with days to maturity by Balla and Ibrahim (2017) (r=0.694** for DF, r=0.19 for DM) while negative correlations was reported for this characters by Aditya et al. (2011) and Akram et al. (2016). In this study the 100-seed weight showed highly negative correlation significantly with grain yield (r=-0.461**) and this result is in accordance with the findings of Silva et al. (2014) and Balla and Ibrahim (2017). In this study crude oil ratio showed non-significant correlation with grain yield while crude protein oil ratio showed non-significant and positive correlation with grain yield. This results in terms of quality characters are in agreement with Malik et al. (2007)'s findings.

Path coefficient analysis is a method to divide the correlation coefficients into direct and indirect effects. The analysis was performed to using correlation coefficients to determine the direct and indirect effects of 8 yield contributing characters and the results of analysis are given in Table 8. Path coefficient analysis showed grain yield positively and directly effected by pods number per plant (0.5532) followed by day to maturity (0.2483), plant height (0.1920), crude protein ratio (0.0403), first pod height (0.0266) and days to 50% flowering (0.0104); all of these characters had positive correlation with grain yield. The results are in accordance with the findings of Akram et al. (2011). Grain yield was negatively and directly affected by 100-seed weight (-0.1697) and crude oil ratio (-0.0097). This results are in agreement with Wamanrao et al. (2020), Balla and Ibrahim (2017) and Malik et al. (2007)'s findings.

CONCLUSION

This research was conducted to determine the soybean genotypes that high yield ability under second crop conditions and the selection criteria that can be used in soybean breeding program. In the present study, an attempt was made to determine high yielding genotypes according to three years results and find out of direct and indirect effects of the traits to grain yield under second cropping for breeding programmes. According to the results, pod number per plant can be used as a selection criterion due to its high and positively direct effect on grain yield. Beside this trait, days for maturity, plant height and days to 50% flowering traits could be considered as selection criterion for soybean breeding studies.

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Table 4. The means of soybean lines and varieties and LSD groups of plant height (PH), first pod height (FPH), pods per plant (PPP).

	PH (cm)				FPH (cm)				PPP (plant $^{-1}$)			
Genotypes	**2014**	**2015**	**2016**	**Mean**	**2014**	**2015**	**2016**	**Mean**	**2014**	**2015**	**2016**	**Mean**
ATAEM 7	105.4 A	81.5 CD	76.7 AB	87.9	6.5 BC	6.7 DEF	13.1 BC	8.8	87.9 EF	63.3 DE	34.5 G	61.9
BRAVO	93.3 BCD	66.4 G	64.2 CD	74.6	7.8 DE	5.7 EF	9.0 FGH	7.5	98.7 DE	83.5 AB	43.6 DEFG	75.3
ARISOY	92.5 BCD	70.1 FG	61.9 CD	74.8	4.0 EF	6.9 DE	10.5 DEFG	7.1	136.2 A	58.7 E	36.4 FG	77.1
NOVA	92.1 CDE	70.6 FG	62.9 CD	75.2	2.7 EF	4.6 F	9.4 EFGH	5.6	132.8 A	81.2 ABC	48.0 BCDEF	87.3
BATEM 317	95.5 BC	94.9 A	65.2 CD	85.2	14.4 A	9.4 ABC	14.5 AB	12.8	74.6 G	78.3 ABC	45.1 CDEFG	66.0
BATEM 223	85.1 DEF	85.6 BC	76.6 AB	82.4	4.2 EF	10.2 AB	11.7 CD	8.7	124.9 AB	70.8 BCDE	55.8 ABCD	83.8
BATEM 207	91.2 CDE	79.7 CDE	82.6 A	84.5	7.8 C	8.2 BCD	11.1 CDEF	9.0	81.2 FG	82.0 AB	57.9 ABC	73.7
BATEM 306	101.3 AB	90.5 AB	69.7 BC	87.2	10.1 B	10.6 A	16.4 A	12.3	110.7 CD	68.6 CDE	45.7 BCDEFG	75.0
BDUS 04	85.7 DEF	80.9 CD	62.6 CD	76.4	4.3 DEF	8.0 CD	11.4 CDE	7.9	110.4 CD	68.0 CDE	34.6 G	71.0
BDSA 05	83.3 EF	80.0 CD	64.7 CD	76.0	4.9 DE	7.3 CDE	9.1 FGH	7.1	89.1 EF	71.3 BCDE	39.1 FG	66.5
KANA	95.0 BC	76.3 DEF	75.5 AB	82.2	8.0 CD	7.4 CDE	13.2 BC	9.5	86.1 EFG	74.1 ABC	52.7 ABCDE	70.9
KAMA	81.5 F	66.0 G	56.9 E	68.1	4.1 EF	8.4 ABCD	9.9 DEFG	7.5	130.4 A	64.1 DE	41.9 EFG	78.8
KASM 03	82.2 F	63.1 G	56.9 E	67.4	3.7 F	4.6 F	7.5 H	5.3	136.9 A	84.9 A	62.6 A	94.8
KASM 02	85.9 DEF	70.8 EFG	62.0 CD	72.9	5.4 C	4.6 F	8.4 GH	6.1	116.2 BC	75.7 ABCD	58.8 AB	83.6
Mean	90.7	76.8	67.0	78.2	6.3	7.3	11.1	8.2	108.3	73.2	46.9	76.1
LSD (5%)		8.9				2.2				13.3		

Table 5. The means of soybean lines and varieties and LSD groups of 100-seedweight (HSW), grain yield per hectar (GY) and days for flowering (DFF).

	HSW (g)				GY (kg ha^{-1})				DFF (day)			
Genotypes	**2014**	**2015**	**2016**	**Mean**	**2014**	**2015**	**2016**	**Mean**	**2014**	**2015**	**2016**	**Mean**
ATAEM 7	17.8 BCD	19.4 BC	19.5 ABC	18.9	3350.0 EF	3312.0 CD	2420.8 G	3027.6	34.8 BCD	32.3 F	32.8 F	33.3
BRAVO	18.4 AB	16.2 EFG	16.1 EF	16.9	3841.0 ABCD	3128.0 DE	2854.3 EF	3274.4	34.2 CDE	32.8 EF	33.0 EF	33.3
ARISOY	15.2 FG	15.9 FG	15.6 EF	15.6	3274.0 EF	3541.8 BCD	2971.3 CDEF	3262.3	34.2 CDE	32.3 F	33.0 EF	33.2
NOVA	17.3BCDE	15.4 GH	16.7 DE	16.5	3940.0 ABC	2728.1E	3284.0 ABCD	3317.4	33.2 E	33.5 E	34.0 DE	33.6
BATEM 317	15.2 FG	16.8 DEFG	14.3 F	15.4	4034.0 AB	3893.1 AB	3036.3 BCDEF	3654.4	33.8 DE	39.3 A	39.3 A	37.4
BATEM 223	14.8 G	13.8 H	14.1 F	14.2	3826.0 ABCD	3619.3 ABC	3414.3 AB	3619.8	34.0 CDE	36.3 CD	36.8 B	35.7
BATEM 207	15.3 EFG	17.7 CDEF	16.5 DE	16.5	3661.0 BCDE	3629.4 ABC	3456.8 A	3582.4	34.8 BCD	35.3 D	35.5 C	35.2
BATEM 306	16.2 CDEFG	17.6 CDEF	16.6 DE	16.8	3882.0 ABCD	3652.2 ABC	3354.0 ABC	3629.4	33.5 E	38.5 AB	39.3 A	37.1
BDUS 04	20.2 A	22.9 A	20.2 AB	21,1	3019.0 F	3274.8 CD	2662.0 FG	2985.3	33.8 DE	36.5 C	36.8 B	35.7
BDSA 05	17.1 BCDEF	21.4 AB	18.2 BCD	18.9	3474.0 DE	3353.8 CD	2913.5 DEF	3247.1	33.2 E	38.0 B	37.0 B	36.1
KANA	17.4 BCD	17.9 CDE	17.5 CDE	17.6	3564.0 CDE	3998.4 A	3248.0 ABCDE	3603.5	36.0 A	35.3 D	34.5 CD	35.3
KAMA	17.1 BCDEF	18.7 CD	20.5 A	18.7	3774.0 ABCD	3671.9 ABC	2980.0 CDEF	3475.3	35.5 AB	33.5 E	33.5 DEF	34.2
KASM 03	18.1 BC	17.5 CDEF	16.8 DE	17.5	4170.0 A	3581.8 ABC	3230.8 ABCDE	3660.9	35.0 ABC	33.0 EF	32.8 F	33.6
KASM 02	16.0 DEFG	17.8 CDEF	18.3 BCD	17.4	3828.0 ABCD	3614.6 ABC	3519.5 A	3654.0	35.0 ABC	33.3 EF	33.3 EF	33.8
Mean	16.9	17.8	17.2	17.3	3688.4	3499.9	3096.1	3428.1	34.4	35.0	35.1	34.8
LSD (5%)		2,0				41.67				1.2		

Table 6. The means of soybean lines and varieties and LSD groups of days for maturity (DFM), crude oil ratio (OIL) and crude protein ratio (PRT).

	DFM (day)				OIL (%)				PRT (%)			
Genotypes	**2014**	**2015**	**2016**	**Mean**	**2014**	**2015**	**2016**	**Mean**	**2014**	**2015**	**2016**	**Mean**
ATAEM 7	100.7 DE	104.8 FG	104.5 F	103.3	19.4 CD	20.1 BC	20.3 ABC	20.0	47.6 AB	45.1 ABC	42.9 E	45,2
BRAVO	98.0 GHI	103.8 G	104.5 F	102.1	18.2 E	20.1 BC	19.3 CDE	19.2	47.5 AB	46.4 A	45.3 BC	46.4
ARISOY	100.0 EF	106.3 EF	104.3 F	103.5	22.1 A	20.3 BC	20.6 AB	21.0	41.8 E	44.7 ABCDE	43.1 DE	43.2
NOVA	97.0 IJ	105.3 FG	106.0 EF	102.8	19.6 CD	21.6 A	19.0 DE	20.0	46.6 B	43.0 DE	45.1 BCD	44.9
BATEM 317	106.5 A	112.5 A	112.0 A	110.3	18.6 DE	20.7 ABC	19.3 CDE	19.5	48.0 AB	44.0 BCDE	46.4 B	46.1
BATEM 223	102.2 BCD	109.8 BC	109.8 BC	107.2	22.0 A	20.0 C	13.9 F	18.6	41.9 E	45.6 ABC	52.2 A	46.6
BATEM 207	103.0 B	108.0 CDE	108.5 BCD	106.5	20.4 BC	19.9 C	20.6 AB	20.3	44.2 D	44.5 ABCDE	43.1 DE	43.9
BATEM 306	102.7 BC	109.5 BC	110.3 AB	107.5	21.1 AB	19.7 C	18.8 E	19.9	43.3 DE	45.2 ABC	46.4 B	45.0
BDUS 04	99.2 EFG	110.8 AB	108.3 CD	106.1	19.7 C	19.9 C	20.1 ABCD	19.9	48.0 AB	45.1 ABC	43.9 CDE	45.7
BDSA 05	98.5 FGH	111.8 A	109.8 BC	106.7	19.6 CD	20.3 BC	20.9 A	20.3	47.9 AB	43.9 BCDE	42.8 E	44.9
KANA	101.0 CDE	109.5 BC	109.0 BC	106.5	16.7 F	20.5 ABC	19.7 ABCDE	19.0	49.2 A	43.6 CDE	44.3 CDE	45.7
KAMA	97.0 IJ	109.0 BCD	108.8 BC	104.9	19.6 CD	21.2 AB	19.9 ABCD	20.2	46.4 BC	42.7 E	44.7 BCDE	44.6
KASM 03	97.7 HIJ	106.5 EF	105.3 EF	103.2	21.1 AB	20.3 BC	20.1 ABCD	20.5	44.5 CD	45.0 ABCD	44.0 CDE	44.5
KASM 02	96.5 J	107.5 DE	106.8 DE	103.6	19.9 C	19.6 C	19.6 BCDE	19.7	47.8 AB	45.8 AB	45.0 BCD	46.2
Mean	100.0	108.2	107.7	105.3	19.9	20.3	19.4	19.9	46.1	44.6	44.9	45.2
LSD (5%)		1.8				1.4				2.0		

Table 7. Correlation coefficients among 9 characters of 14 soybean genotypes.

	GY	**PH**	**LPH**	**PPP**	**HSW**	**DFF**	**DFM**	**OIL**
PH	0.027ns							
LPH	0.181ns	0.658**						
PPP	0.313*	-0.499**	-0.456**					
HSW	-0.461**	-0.122ns	-0.176ns	-0.221ns				
DFF	0.270*	0.394**	0.657**	-0.320*	-0.071ns			
DFM	0.286*	0.510**	0.671**	-0.366**	-0.132ns	0.835**		
OIL	-0.173ns	-0.270*	-0.175ns	0.054ns	0.206ns	-0.265*	-0.227ns	
PRT	0.112ns	0.167ns	0.115ns	-0.058ns	-0.023ns	0.238ns	0.150ns	-0.864**

ns: non significant, *: significant at the $p \leq 0.05$ level, **: significant at the $p \leq 0.01$ level

Table 8. Direct and indirect effects of 8 characters on grain yield of 14 soybean genotypes.

		Indirect effects							
Yield components	**Direct effects**	**PH**	**LPH**	**PPP**	**HSW**	**DFF**	**DFM**	**OIL**	**PRT**
PH	0.1920	-	-0.0029	0.3021	0.0033	0.0012	-0.0836	0.0005	0.008
LPH	0.0266	-0.0211	-	-0.3441	0.0141	0.0038	0.1303	0.0019	0.0007
PPP	0.5532	0.1049	-0.0166	-	0.015	-0.0014	-0.1665	-0.0015	0.0042
HSW	-0.1697	-0.0037	-0.0022	-0.049	-	0.0002	0.0256	-0.0004	-0.0018
DFF	0.0104	0.023	0.0096	-0.0772	-0.0039	-	0.1091	0.0016	0.0041
DFM	0.2483	-0.0647	0.014	-0.371	-0.0175	0.0046	-	0.0003	-0.0081
OIL	-0.0097	-0.0101	-0.0053	0.0839	-0.0074	-0.0017	-0.0083	-	-0.0353
PRT	0.0403	0.0382	0.0004	0.0576	0.0077	0.0011	-0.0497	0.0085	-

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