Co-Heritability of Yield Related Traits in Soybean (*Glycine Max L.*) Across Planting Environments

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Abstract

Experiments were carried out to estimate genetic variability and co-heritability for yield contributing traits in soybean under normal (June planting) and late (July planting) environments. Eighteen soybean genotypes were evaluated in randomized complete block design with three replications as independent experiment under each environment during kharif crop season 2015 at The University of Agriculture, Peshawar. Analysis of variance across environments revealed significant differences among two environments for all traits except pod length, seeds pod-1 and harvest index. Genetic variation among soybean genotypes was also highly significant for all the traits. G × E interaction was significant for all the traits except seeds pod-1. Means for days to total pods plant-1 (26.90 vs. 21.76), seeds pod-1 (3.88 vs. 3.08), seeds plant-1 (154.64 vs. 62.86), 100-seed weight (9.01 vs. 7.43 g), biological yield (5753.00 vs. 655.50 kg ha-1) and seed yield (1021.00 vs. 162.79 kg ha-1) under normal and late environment, respectively. Genotypes E-1469 and E-1360 were high yielding under normal and late plantings, respectively. Co-heritability estimates for seed yield and pod length were 0.99 under normal, and 0.97 under late planting. For seed yield vs. total pods plant-1 co-inheritances were 0.92 under normal and 0.83 under late planting. Likewise for pair of seed yield vs. 100-seed weight co-heritability were 0.99 under normal and 0.97 under late planting, Furthermore co-heritability for seed yield vs. biological yield was 0.99 under both normal and late environment. It is found that soybean genotypes produced high yield, and showed high co-heritability for yield contributing traits under normal than late planting experiment. This high co-heritability of seed yield with pod length, total pods plant-1 and 100-seed weight under normal planting as compared to late planting, indicating genetic improvement from the joint selection of these traits in future breeding programs and these traits could be recommended as a better index to rise yield under normal (June) planting of soybean.

INTRODUCTION

Soybean (Glycine max L.) belong to leguminous family and is widely grown for its edible seed. Soybean is currently grown across the globe, with U.S.A., Brazil and Argentina being the leading producers of soybean in the world. Soybean was planted on 117.5 million hectares around the world during 2014 which produced 306.5 million tones with an average yield of 2607.6 kg ha-1 (FAO, 2014). In Pakistan, it is categorized as one of the non-conventional oilseed crops and was planted on 84 hectares only during 2014 producing about 63 tones with an average yield of 750 kg ha-1 (FAO, 2014). Soybean as an oilseed crop, is under research for more than last 20 years in all provinces of Pakistan. In Khyber Pakhtunkhwa, soybean was planted on area of about 20 hectares during 2014 with production of about 15 tones with an average yield of 750 kgha-1 (PBS, 2014). Several attempts have been made to introduce soybean for commercial planting but no encouraging success was achieved (PARC, 2016). Soybean has great potential as Spring (Zaid Rabi) and Autumn (Kharif) crop cultivation in Pakistan. Variation in yield loss due to delay in the planting is the result of variation in weather and its influence on disease. Therefore, planting date is considered to be one of the important factor for maximum crop yield. Depending upon genetic and environmental factors soybean seeds contain about 40-42% good quality protein and 18-22% oil (Krishnan, 2000).

Co-heritability is defined as the proportion of genetic and phenotypic covariance for a pair of traits. Co-heritability has dual characteristics of both heritability and genetic correlation. The use of co-heritability to express the genetic co-variation between two characters gives smaller sampling errors than the genetic correlation. The higher values of co-heritability suggest that increase in one polygenic trait will lead to simultaneous increase in the other and vice versa. The concept of co-heritability is proposed to know genetic associations within pairs of quantitative traits. Higher estimates of co-heritability indicate that genetic progress could result from the joint selection for these characters. It is a better genetic parameter than genetic correlation, as correlation does not take into account of environmental variance which is also a component of phenotypic variance to which selection is applied (Mehan and Saini, 1982). The present study was undertaken to compare performance of soybean genotypes for yield contributing traits under normal and late planting conditions and to estimate co-heritability using genetic and environmental co-variances for important yield related traits of soybean under two planting environments.

Materials and Methods

The research was conducted at Research Farm, Department of Plant Breeding and Genetics, The University of Agriculture, Peshawar, Pakistan during 2015. Eighteen soybean genotypes obtained from Agriculture Research Station, Mingora, Swat and National Agriculture Research Center, Islamabad, were evaluated as independent experiments under two sowing dates Normal (sown on 1st June) and late (sown on 2nd July). A randomized complete block design with three replications was used in each experiment. or current experimental plot for each genotype had 3 m long, three rows with spacing of 40 cm between rows. A seed rate of 70 g plot-1 (~197 kg ha-1) was used for each genotype in each experiment. Data was recorded in field on ten randomly selected plants for pod length, pods plant-1, seeds pod-1 and seeds plant-1, while data of 100-seed weight, biological yield and seed yield was taken on plot basis. Data was analyzed across two planting environments in a randomized complete block design using Statistical Analysis System (SAS) software to quantify genotype × environment interaction effects (Gomez and Gomez, 1984). Since genotype × environment interaction was significant for important yield component traits, the data was independently analyzed for each planting environment. Moreover, analysis of covariance (ANCOVA) was also performed for important yield components. Genetic and phenotypic variances and co-variances were worked out from ANOVA and ANCOVA for computation of co-heritability of traits following procedures of Pixely and Frey (1991).

Results and Discussion

Analysis of Variance

Analyzed data across environments revealed highly significant differences (P < 0.01) among normal and late planting for pods plant-1, seeds plant-1, 100-seed weight, biological yield and seed yield, while pod length and seeds pod-1 revealed non-significant differences across environments (Table 1). Moosavi et al. (2012) have noticed similar differences among four planting dates (May 27, June 5, 15, and 26) for number of pods palnt-1, seeds plant-1 and seed yield at Islamic Azad University, Iran. Similar variation in seed weight and biological yield of soybean across five planting dates (21st January, 28th January, 4th February, 11th February and 18th February) is also stated by Rehman et al. (2014). Soybean genotypes showed highly significant differences for all the traits. Similar genotypic differences for pod length are also published by Sureshrao et al. (2014) who evaluated 12 genotypes of soybean including three check cultivars (Bragg, SL-525, and PS-1042) during kharif 2011. Osekita and Olorunfemi (2014) reported significant differences among five accessions of soybean for number of pods plant-1 under wet and dry seasons. Dilnesaw et al. (2014) reported differences among 20 soybean genotypes for number of seeds pod-1 in soybean. Karasu et al. (2009) also reported significant variation among eight soybean genotypes as well as its interaction with two locations (Gorukle and Mustafakemalpaa) during two years for number of seeds plant-1. Ali et al. (2015) observed variation for traits (---) among ten accessions of soybean including two checks, planted at Agriculture Research Institute Mingora, Swat during Kharif 2013. Barasker et al. (2014) observed significant differences among 61 soybean genotypes evaluated in a randomized block design during kharif 2012. Likewise, significant genetic differences for seed yield among ten soybean genotypes obtained from different segregating population are also reported by Ghodrati (2013). Genotype × environment interaction was also highly significant for pod length, pods plant-1, seeds plant-1, 100-seed weight, biological yield and seed yield, indicating differential performance of genotypes over two planting dates, while seeds pod exhibited non-significant G × E interaction (Table 1). Likewise, Karasu et al. (2009) reported similar interaction of eight soybean genotypes with two locations and two years for pods plant-1 and seeds plant-1. Significant effect of genotypes × planting dates interactions for 100-seed weight and seed yield are also reported by Kandil et al. (2012) who evaluated six soybean cultivars at four sowing dates (20th April, 5th May, 20th May and 5th June) in RCB design replicated four times.

Table 1: Mean squares for pods plant-1, seeds pod-1, nodes plant-1, pods node-1, seeds plant-1, 100-seed weight, biological yield, seed yield, and harvest index of 18 soybean genotypes across two planting dates.

Source	Pod length	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}	100-Seed weight	Biological yield	Seed yield
Envir	0.27^{NS}	46252.08**	0.37 ^{NS}	227480.40**	67.68**	701600784.50**	19886218.99**
Reps. w/n Envir	0.48	67.57	0.05	35.01	0.02	6198.80	727.37
Geno	0.21**	726.35**	0.34**	4913.55**	7.40**	2570287.80**	306224.82**

Geno × Envir	0.27**	799.06**	0.09 NS	4090.08**	5.89**	3118730.20**	182746.27**
Error	0.05	67.38	0.05	293.28	0.08	7749.70	1033.64
R^2	0.72	0.94	0.66	0.95	0.98	0.99	0.99
CV (%)	6.57	11.06	8.78	15.74	3.46	2.74	5.43

**, NS = Significant at 5 and 1% probability level respectively.

Pod length

Pod length of soybean genotypes ranged from 3.1 to 4.6 cm under normal planting with an average of 3.7 cm, while 3.4 to 4.1 cm under late environment with an average of 3.6 cm (Table 2). Genotype E-1469 had highest pod length (4.6 cm) followed by NARC-Flow350 (4.4 cm) under normal planting. In contrast, NARC-17439 had highest pod length (4.1 cm) followed by genotype NARC-Flow825 (3.8 cm) under late planting. Averaged over two plantings, maximum pod length was observed for genotypes NARC-Flow350 (4.0 cm) and E-1469 (4.0 cm) for each followed by Kwangko (3.9 cm). Averaged over 18 genotypes pod length was 3.7 and 3.6 cm under normal and late planting, respectively.

Pods plant-1

Number of pods plant-1 of soybean genotypes ranged from 67.3 to 134.1 under normal planting with an average of 94.9 pods plant-1, while 41.7 to 70.9 under late environment with an average of 53.5 pods plant-1 (Table 2). Thus, soybean genotypes generally had more pods plant-1 under normal planting than late planting. Genotype NARC-17439 had maximum number of pods plant-1 (134.1 pods) followed by cultivar Malakand-96 (129.1 pods) under normal planting. In contrast, genotype E-1469 had highest number of pods plant-1 (70.9 pods) followed by NARC-Century (68.9 pods) under late planting. Averaged over two plantings, maximum number of pods plant-1 were observed for genotype NARC-17439 (89.7 pods) followed by 249-3130 (88.9 pods) and NARC-Century (86.5 pods). Averaged over 18 genotypes, pods plant-1 were 94.9 and 53.5 under normal and late planting, respectively, indicating a net reduction of 41 pods plant-1 due to late planting. Datt et al. (2011) also observed a wide range of plant-1 25 - 73.7 pods plant-1 in soybean. Likewise, Moosavi et al. (2012) have reported 44.7 and 14.5 pods plant-1 under early (May) and late (June) planting of soybean, respectively.

Seeds pod-1

Number of seeds pod-1 of soybean genotypes ranged from 2.0 to 3.1 under normal planting with an average of 2.8 seeds pod-1, while 2.0 to 3.2 under late environment with an average of 2.7 seeds pod-1 (Table 2). Genotype Elgin had more seeds pod-1 (3.1) followed by genotypes Valarts, Mawkee, NARC-Century, NARC-17443, 249-3130, and cultivar NARC-60 (each with 3.0 seeds pod-1) under normal planting, while under late planting genotypes NARC-Flow825 had maximum seeds pod-1 (3.2 seeds) followed by genotypes Elgin, Perry, E-1360, E-1469, cultivars Swat-84, and Malakand-96 (each with 3.0 seeds pod-1). Averaged over two plantings, maximum seeds pod-1 were observed for genotype Elgin, NARC-17443 and cultivar Malakand-96 (each with 3.0 seeds pod-1).

Seeds plant-1

Number of seeds plant-1 of soybean genotypes ranged from 86.7 to 303.5 under normal planting with an average of 154.6 seeds plant-1. Under late environment seeds plant-1 of soybean genotypes ranged from 41.3 to 98.3 with an average of 62.9 seeds plant-1 (Table 2). Hence, soybean genotypes generally produced more number of seeds plant-1 under normal than late (stress) planting. Maximum number of seeds plant-1 were produced by genotype NARC-17439 (303.5 seeds plant-1) followed by 249-3130 (224.1 seeds plant-1) under normal planting. In contrast, genotype NARC-Flow825 produced more seeds plant-1 (98.3) followed by Corosoy (89.1 seeds plant-1), and E-1469 (81.3 seeds plant-1) under late planting. Averaged over two plantings, maximum number of seeds plant-1 were observed for genotype NARC-17439 (178.1 seeds) followed by 249-3130 (146.3 seeds). Averaged over 18 genotypes, seeds plant-1 were 154.6 and 62.9 under normal and late planting, respectively, indicating a reduction of 91.9 seeds plant-1 due to late planting of soybean. Similarly, Moosavi et al. (2012) have also observed maximum number of seeds plant-1 under early sowing date (June 05) of soybean.

Table 2: Means of pod length, total pods plant-1, seeds pod-1and seeds plant-1 of 18 soybean genotypes across two planting dates.

Genotypes	Pod length (cm)		Genotype mean	Pods plant^{-1} (no.)		Genotype mean	Seeds pod^{-1} (no.)		Genotype mean	Seeds plant^{-1} (no.)		Genotype mean
	Normal	Late		Normal	Late		Normal	Late		Normal	Late	
Elgin	3.8	3.7	3.8	81.4	41.7	61.5	3.4	3.1	3.0	87.5	45.3	66.4
Perry	3.3	3.5	3.4	86.9	42.8	64.9	2.9	3.0	2.9	130.2	66.5	98.3
Corosoy	3.7	3.4	3.6	78.2	59.7	68.9	3.0	2.6	2.8	179.1	89.1	134.1
Valarts	3.3	3.7	3.5	75.1	64.8	69.9	3.0	2.8	2.9	87.8	50.8	69.3
Mawkee	4.1	3.7	3.9	81.8	43.7	62.8	3.0	2.9	2.9	129.6	55.6	92.6
Kwangko	3.7	3.6	3.7	76.5	48.7	62.6	2.1	2.9	2.5	125.8	41.3	83.6
NARC-Century	3.1	3.5	3.3	104.1	68.9	86.5	3.0	2.6	2.8	180.4	57.3	118.9
NARC-Flow350	4.4	3.6	4.0	88.9	53.4	71.2	2.2	2.9	2.5	158.9	37.4	98.2
NARC-Flow825	4.1	3.8	3.9	94.0	62.1	78.1	2.7	3.2	2.9	132.6	98.3	115.4
NARC-17443	3.9	3.7	3.8	111.9	53.9	82.9	3.0	3.0	3.0	161.6	74.7	118.2
NARC-17439	3.1	4.1	3.6	134.1	45.3	89.7	2.0	2.2	2.1	303.5	52.7	178.1
E-1360	3.5	3.5	3.5	116.5	50.6	83.6	2.6	3.0	2.8	177.8	75.0	126.4

E-1469	4.6	3.4	4.0	88.0	70.9	79.5	2.4	3.0	2.7	151.7	81.3	116.5
VFV-1	3.6	3.6	3.6	67.3	47.7	57.5	2.9	2.8	2.8	125.9	50.0	87.9
249-3130	3.3	3.6	3.4	128.8	49.0	88.9	3.0	2.6	2.8	224.1	68.6	146.3
Swat 84	3.7	3.5	3.6	76.1	52.8	64.4	2.5	3.0	2.7	86.7	57.9	72.3
Malakand 96	3.9	3.7	3.8	129.1	53.6	91.4	3.0	3.0	3.0	178.9	68.1	123.5
NARC-60	3.5	3.4	3.5	89.4	53.7	71.6	3.0	2.0	2.5	161.5	61.5	111.5
Envir Mean	3.7	3.6	-	94.9	53.5	-	2.8	2.7	-	154.6	62.9	-
Envir	NS			11.47			NS			25.96		
$LSD_{0.05}$ Geno	0.27			9.45			0.28			19.73		
G×E	0.36			13.20			0.35			7.53		

100-seed weight

Hundred seed weight of soybean genotypes ranged from 7.3 to 13.6 g under normal, while 5.2 to 9.5 g under late planting (Table 3). Hence, soybean genotypes generally had more 100-seed weight under normal than late planting. Genotype E-1469 had highest 100-seed weight (13.6 g) followed by 249-3130 (11.6 g) under normal planting, while genotype Perry had highest 100-seed weight (9.5 g) followed by NARC-17443 (9.3 g) under late planting. Averaged over two plantings, highest 100-seed weight was observed for genotype Perry (9.5 g) followed by cultivar Malakand-96 (9.4 g) and NARC-17443 (9.3 g). Averaged over 18 genotypes, 100-seed weight were 9.0 and 7.4 g under normal and late planting, respectively indicating a net reduction of 1.6 g for 100-seed due to late planting of soybean.

Biological yield

Biological yield of soybean genotypes ranged from 3720.1 to 8470.8 kg ha-1 under normal, while 347.2 to 1305.6 kg ha-1 under late environment (Table 3). Soybean genotypes generally had more biological yield under normal than late planting. Genotype Mawkee had maximum biological yield (8470.8 kg ha-1) followed by NARC-17439 (8333.3 kg ha-1) under normal planting. In contrast, genotype VFV-1 had maximum biological yield (1305.6 kg ha-1) followed by E-1360 (1215.3 kg ha-1) under late planting. Averaged over two plantings, maximum biological yield was observed for genotype Mawkee (4596.5 kg ha-1) followed by NARC-17439 (4414.6 kg ha-1). Averaged over 18 genotypes, biological yield was 5753.0 and 688.8 kg ha-1 under normal and late planting, respectively, indicating a net reduction of 5097.5 kg ha-1 due to late planting of soybean.

Seed yield

Soybean genotypes generally had more seed yield under normal planting than late planting. Seed yield of soybean genotypes ranged from 357.9 to 1811.8 kg ha-1 under normal, while 105.5 to 477.4 kg ha-1 under late environment

(Table 3). Thus yield of all soybean genotypes was reduced tremendously due to late planting. Genotype E-1469 had maximum seed yield (1811.8 kg ha-1) followed by VFV-1 (1557.3 kg ha-1) under normal planting, while under late planting genotype E-1360 had maximum seed yield (477.4 kg ha-1) followed by VFV-1 (355.3 kg ha-1). Averaged over two plantings, maximum seed yield was produced by soybean genotype E-1469 (985.2 kg ha-1) followed by VFV-1 (956.3 kg ha-1) and E-1360 (924.5 kg ha-1). Averaged over 18 genotypes, seed yield was 1021 and 162.79 kg ha-1 under normal and late plantings, respectively. High range of seed yield (2203 kg ha-1 – 4983kg ha-1) under spring planting of 10 soybean cultivars is reported by Basavaraja et al. (2005). Similarly, Moosavi et al. (2012) also observed more seed yield under early (spring) than late planting of soybean. They reported that soybean couldn't reach its potential yield due to unfavorable conditions under late planting and consequently the yield dropped. Moreover, Wiggins and Benjamin (2012) observed seed yield of 1928.7- 3033.6 kg ha-1 with the mean of 2325.7 kg ha-1 over two years (2010 and 2011) and five environments. However, Ali et al. (2013) reported maximum seed yield of 697.3 kg ha-1 of soybean during autumn planting in Pakistan.

Table 3: Means of 100-seed weight, biological yield (kg ha-1) and seed yield (kg ha-1) of 18 soybean genotypes across two planting dates.

Genotypes	**100-seed weight**		**Genotype mean**	**Biological yield (kg ha^{-1})**		**Genotype mean**	**Seed yield (kg ha^{-1})**		**Genotype mean**
	Normal	Late		Normal	Late		Normal	Late	
Elgin	8.6	5.3	5.3	5250.0	979.2	3114.6	628.0	167.2	397.6
Perry	9.4	9.5	9.5	5739.6	384.7	3062.2	1022.4	153.7	588.0
Corosoy	7.3	6.3	6.3	4138.9	937.5	2538.2	1322.0	328.9	825.4
Valarts	7.7	7.4	7.4	6770.8	347.2	3559.0	896.9	121.2	509.0
Mawkee	8.1	7.7	7.7	8470.8	722.2	4596.5	713.8	215.2	464.5
Kwangko	7.6	5.2	5.2	6152.8	627.8	3390.3	690.9	132.3	411.6
NARC-Century	9.2	5.9	5.9	4276.4	500.0	2388.2	978.4	172.8	575.6
NARC-Flow350	8.7	7.4	7.4	4134.7	520.8	2327.8	1211.7	136.5	674.1
NARC-Flow825	8.7	8.3	8.3	6270.8	527.8	3399.3	357.9	108.1	233.2
NARC-17443	10.5	9.3	9.3	4586.1	940.3	2763.2	1519.5	175.6	847.5
NARC-17439	8.3	6.3	6.3	8333.3	495.8	4414.6	597.8	159.4	378.6
E-1360	8.7	7.4	7.4	4822.2	1215.3	3018.8	1371.5	477.4	924.5
E-1469	13.6	7.7	7.7	6098.6	562.5	3330.6	1811.8	158.7	985.2

VFV-1	8.8	9.2	9.2	6039.6	1305.6	3672.6	1557.3	355.3	956.3
249-3130	11.6	5.4	5.4	3720.1	513.9	2117.0	1095.6	172.4	634.0
Swat 84	8.7	7.7	8.2	5945.8	486.1	3215.9	672.4	105.5	388.9
Malakand 96	9.5	9.3	9.4	6070.8	704.2	3387.5	946.3	194.7	570.5
NARC-60	7.5	8.4	7.9	6733.3	627.8	3680.6	983.9	195.4	589.7
Envir Mean	9.0	7.4	-	5753.0	688.8	-	1021.0	196.1	-
Envir	0.98			717.05			173.57		
LSD $_{0.05}$ Geno	0.32			101.42			37.04		
Geno×Envir	0.45			141.60			51.71		

Co-heritability

Genetic covariance among pod length and total pods plant-1 was 1.70 under normal planting and 0.41 under late planting (Table 4). Likewise, environmental covariances were 0.15 and 0.17 between the two traits under normal and late planting, respectively (Table 5). The co-heritability of pod length and total pods plant-1 was 0.92 under normal and 0.71 under late planting (Table 6). Thus, simultaneous genetic improvement in both traits will be more under normal than late planting. Chakraborty et al. (2011) observed co-heritability of 62.2 and 71.4 % for pod length among F1 and F2 generations of mungbean genotypes. Pod length and seeds pod-1 had genetic covariance of 0.0017 under normal and 0.011 under late planting (Table 4), while environmental covariances were 0.00021 and 0.013 among the two traits under normal and late environment, respectively (Table 5). The co-heritability of pod length and seeds pod-1 was 0.89 under normal and only 0.49 under late planting (Table 6). Thus, concurrent genetic improvement in both traits will be more under normal than late environment. Genetic covariance among pod length and seeds plant-1 was 6.15 under normal and 0.51 under late planting (Table 4). Similarly, environmental covariances were 0.52 and 0.31 among the two traits under normal and late planting, respectively (Table 5). The co-heritability of pod length and seeds plant-1 was 0.92 under normal vs. 0.62 under late planting (Table 6). Hence, joint improvement in these two traits will be more under normal than late planting. Pod length vs. 100-seed weight had genetic covariance of 0.15 under normal planting and 0.010 under late planting (Table 4), while environmental covariances were 0.015 and 0.015 among the two traits under normal and late environment, respectively (Table 5). The co-heritability of pod length vs. 100-seed weight was 0.91 under normal and 0.41 under late planting (Table 6). Genetic covariance among pod length and biological yield was 51.20 under normal vs. 7.11 under late planting (Table 4). Likewise, environmental covariances were 0.30 and 0.064 among the two traits under normal and late planting, respectively (Table 5). The co-heritability of pod length and biological yield was 0.99 both under normal and late planting (Table 6). Pod length vs. seed yield had genetic covariance of 42.85 under normal and 5.87 under late planting (Table 4), while environmental covariances was 0.16 among the two traits under normal and late planting, respectively (Table 5). The co-heritability of pod length vs. seed yield was 0.99 under normal, while 0.97 under late planting (Table 6). Malik et al. 1985 estimated high co-heritability (1.22) for pod length coupled with seed yield of mungbean genotypes and proposed that selection of such character would lead to gain in seed yield.

Table 4: Genetic covarience COVg (X1X2) (above diagonal for normal planting and below diagonal for late planting) among yield related traits of soybean genotypes in 2015.

	Pod Length	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}	100-seed weight	Biological yield	Seed yield
Pod Length	-	1.70	0.0017	6.15	0.15	51.20	42.85
Pods plant^{-1}	0.41	-	-0.90	829.16	10.46	219.28	123.79
Seeds pod^{-1}	0.011	0.030	-	14069.97	0.0007	100.35	10.47
Seeds plant^{-1}	0.51	54.47	734.94	-	12.61	940248.51	0
100-seed weight	0.010	0.081	0.049	6.57	-	568.11	314.65
Biological yield	7.11	515.88	13.78	43546.45	28.12	-	224647.23
Seed yield	5.87	9.39	2.75	2678.05	5.95	27251.41	-

Total pods plant-1 and seeds pod-1 had genetic covariance of -0.90 under normal and 0.03 under late planting (Table 4), while environmental covariances among these two traits were -0.13 and 0.34 under normal and late planting (Table 5), respectively. The co-heritability of total pods plant-1 vs. seeds pod-1 was 0.87 under normal and 0.081 under late planting (Table 6). Hence, improvement in both traits will be more under normal than late planting. High co-heritability (0.80) among 27 soybean lines for pods plant-1 is also reported by Malik et al. (2007). Genetic covariance among total pods plant-1 and seeds plant-1 was 829.16 under normal and 54.47 under late planting (Table 4), while environmental covariances were 124.29 and 16.59 among the two traits under normal and late planting, respectively (Table 5). The co-heritability of total pods plant-1 and seeds plant-1 was 0.87 under normal and 0.77 under late planting (Table 6). Thus, joint progress in both traits will be more under normal than late planting.Total pods plant-1 vs. 100-seed weight had genetic covariance of 10.46 under normal planting and 0.081 under late planting (Table 4). Likewise, environmental covariances were 0.26 and 0.073 among the two traits under normal and late planting, respectively (Table 5). The co-heritability among total pods plant-1 and 100-seed weight was 0.98 under normal planting and 0.53 under late planting (Table 6). Similarly, Malik et al. (1985) also observed co-heritability of 0.41 for pods plant-1 and 100-seed weight of mungbean genotypes. Hence, genetic improvement in both traits will be more under normal than late planting.Number of total pods plant-1 and biological yield had genetic covariance of 219.28 under normal and 7.11 under late planting (Table 4), while environmental covariances were 228.46 and 78.67 among the two traits under normal and late planting, respectively (Table 5). The co-heritability among total pods plant-1 and biological yield was 0.49 under normal planting and 0.87 under late planting (Table 6). Thus, concurrent improvement in both traits will be more under late planting than normal planting.Total pods plant-1 and seed yield had genetic covariance of 123.79 under normal and 9.39 under late environment (Table 4), while environmental covariances were 10.22 and 1.90 among the two traits under normal and late planting, respectively (Table 5). The co-heritability of total pods plant-1 and seed yield was 0.92 under normal and 0.83 under late planting (Table 6). Hence, genetic improvement in both traits will be more under normal than late planting. Co-heritability of 1.18 and 0.27 among pods plant-1 and seed yield was published by Malik et al. (1985) and Srivastava and Jain (1994) in mungbean and soybean, respectively.

Table 5: Environmental covarience COVe(X1X2) (above diagonal for normal planting and below diagonal for late & planting) among yield related traits of soybean genotypes in 2015.

	Pod Length	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}	100-seed weight	Biological yield	Seed yield
Pod Length	-	0.15	0.00021	0.52	0.015	0.30	0.16
Pods plant^{-1}	0.17	-	0.000	124.29	0.26	228.46	10.22
Seeds pod^{-1}	0.013	0.34	-	42230.06	0.005	1.87	1.31
Seeds plant^{-1}	0.31	16.59	2203.58	-	0.94	130.21	460814.44
100-seed weight	0.015	0.073	0.002	0.58	-	3.31	0.71
Biological yield	0.064	78.67	0.77	88.95	0.17	-	635.96
Seed yield	0.16	1.90	1.987	19778.51	0.19	33.59	-

Number of seeds pods-1 and seeds plant-1 had genetic covariance of 14069.97 under normal and 734.94 under late planting (Table 4). Likewise, environmental covariances were 42230.06 and 2203.58 among the two traits under normal and late planting, respectively (Table 5). The co-heritability among seeds pod-1 and seeds plant-1 was 0.25 both under normal as well as late planting (Table 6). Chakraborty et al. (2007) also reported low co-heritability (32.8) and (27.6 %) for seeds pod-1 among F1 and F2 generations of mungbean genotypes, respectively. Genetic covariance of number of seeds pod-1 and 100-seed weight was 0.0007 under normal and 0.049 under late planting (Table 4), while environmental covariances were 0.005 and 0.002 among the two traits under both normal and late planting, respectively (Table 5). The co-heritability of seeds pods-1 and 100-seed weight was 0.12 under normal and 0.96 under late planting (Table 6). Hence, improvement in both traits will be more under late than normal planting. Number of seeds pods-1 vs. biological yield had genetic covariance of 100.35 under normal and 13.78 under late planting (Table 4), while environmental covariances were 1.87 and 0.77 among the two traits under normal and late planting, respectively (Table 5). The co-heritability among seeds pods-1 and biological yield was 0.98 under normal and 0.95 under late environment (Table 6). Genetic covariance among number of seeds pod-1 and seed yield was 10.47 under normal and 2.75 under late planting (Table 4), while environmental covariances were 1.31 and 1.987 among the two traits under both normal and late planting, respectively (Table 5). The co-heritability of seeds pod-1 vs. seed yield was 0.89 under normal and 0.58 under late environment (Table 6). Hence, improvement in both traits will be more under normal than late planting.

Number of seeds plant-1 and 100-seed weight had genetic covariance of 12.61 under normal, while 6.57 under late planting (Table 4). Likewise, environmental covariances were 0.94 and 0.58 among the two traits under normal and late planting, respectively (Table 5). The co-heritability of seeds plant-1 and 100-seed weight was 0.93 under normal and 0.92 under late planting (Table 6). Thus, simultaneous genetic improvement in both traits will be same under late and normal planting. Genetic covariance among number of seeds plant-1 and biological yield was 940248.51 under normal and 43546.45 under late planting (Table 4), while environmental covariances among the two traits were 130.21 and 88.95 under both normal and late planting, respectively (Table 5). The co-heritability of seeds plant-1 and biological yield was 0.99 both under normal and late planting (Table 6).

Number of seeds plant-1 and seed yield had genetic covariance of -1121.29 under normal and 2678.05 under late planting (Table 4), while environmental covariances were 460814.44 and 19778.51 among the two traits under normal and late planting, respectively (Table 5). The co-heritability of seeds plant-1 and seed yield was -0.002 under normal and 0.12 under late planting (Table 6).

Genetic covariance among 100-seed weight and biological yield was 568.11 under normal and 28.12 under late planting (Table 4). Likewise, environmental covariances among the two traits were 3.31 and 0.17 under both normal and late planting, respectively (Table 5). The co-heritability of 100-seed weight and biological yield was 0.99 both under normal and late environment (Table 6). High co-heritability (1.00 %) for 100-seed weight with seed yield is also observed by Malik et al. (2007) among soybean genotypes. Hundred seed weight and seed yield had genetic covariance of 314.65 under normal planting and 5.95 under late planting (Table 4), while environmental covariances among the two traits were 0.71 and 0.19 under normal and late planting, respectively (Table 5). The co-heritability of 100-seed weight and seed yield was 0.99 under normal and 0.97 under late planting (Table 6). Thus, genetic improvement in both traits will be same under normal and late planting. Malik et al. (1985) reported that 100-seed weight is highly co-heritable (1.11) with seed yield of mungbean genotypes.

Table 6: Co- heritability (Co-h2) (Above diagonal for normal planting and below diagonal for late planting) among yield related traits of soybean genotypes in 2015.

	Pod Length	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}	100-seed weight	Biological yield	Seed yield
Pod Length	-	0.92	0.89	0.92	0.91	0.99	0.99
Pods plant^{-1}	0.71	-	0.87	0.87	0.98	0.49	0.92

Seeds pod^{-1}	0.49	0.081	-	0.25	0.12	0.98	0.89
Seeds $plant^{-1}$	0.62	0.77	0.25	-	0.93	0.99	0
100-seed weight	0.41	0.53	0.96	0.92	-	0.99	0.99
Biological yield	0.99	0.87	0.95	0.99	0.99	-	0.99
Seed yield	0.97	0.832	0.58	0.12	0.97	0.99	-

Genetic covariance among biological yield and seed yield was 224647.23 under normal and 27251.41 under late planting (Table 4). Likewise, environmental covariances among the two traits were 635.96 and 33.59 under normal and late planting, respectively (Table 5). The co-heritability of biological yield and seed yield was 0.99 both under normal as well as late planting (Table 6). Hence, improvement in both traits will be equal under normal and late planting. Srivastava and Jain (1994) reported co-heritability of 0.43 among biological yield and seed yield of mungbean and soybean, respectively.

Conclusions and Recommendations

The outcome of the present study showed wide range of variability among the genotypes. Soybean genotypes produced high yield due to more number of seeds and pods plant-1 under normal (June) as compared to late (July) planting. Genotypes E-1469 is recommended as high yielding genotype under normal planting, while E-1360 is high yielding under late planting. Seed yield showed high co-heritability with pod length, total pods plant-1 and 100-seed weight under normal planting as compared to late planting, indicating genetic improvement from the joint selection of these traits in future breeding programs and these traits could be recommended as a better index to rise yield under normal (June) planting of soybean.

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DATA AVAILIBILITY STATEMENT

All data and materials are available from the corresponding author. Therefore, at a reasonable request, the corresponding author shared it via email.

COMPETING INTERESTS

Authors have declared that no competing interests exists

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