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Effect of Two Row Spaces on Several Agronomic Traits in Soybean [*Glycine max* (L.) Merr.]

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Abstract

Soybean [*Glycine max* (L.) Merr.] yield is responsive to changes in plant population and row spacing. The objective of this study was to compare some agronomic traits of soybean cultivated in two different row spaces in a field in St Pauls, NC. Among the traits, total seed weight showed the highest level of variation than others in both 25 cm (97.31%) and 50cm (60.23%) row space. The lowest co-efficient of variation, 5.06% at 25 cm and 11.54% at 50 cm were found for days to flowering. Mean value showed that plants grown in 25 cm row space have a higher 100-seed and total seed weight than those grown in 50 cm row space. Plants grown in 50 cm row space had a slightly increased mean plant height compared to those grown on 25 cm. Plants grown in 50 cm row space had greater pod and seed numbers compared to those grown on 25 cm. Comparisons of the agronomic parameters between 25 and 50 cm row space employed by two-tailed t test (type 2; $\alpha = 0.05$) showed that there are significant differences in days to germination, days to flowering, number of seeds, and total seed weight between plants grown in 25 cm vs. 50 cm row space; while plant height and number of pods were not differ significantly. However, further research may reveal a system for soybeans cultivation in the future which would increase the probability of obtaining maximum yields with narrow rows.

Keywords: Soybean, row space, seed yield, days to germination, flowering time.

Introduction

Soybean [*Glycine max* (L.) Merr.] is an important grain crop in the United States. Soybean yield can be achieved through cultural practices and breeding. Producers are facing narrow profit margins due to high investment to increase yield and the economic return from management decisions is vital. In recent years, there has been a growing interest in the use of narrow row as well as narrow plant spacing for the production of soybean because of high labor energy and equipment requirements for cultivation (Jordan, 2010). Row spacing and seeding recommendations may vary for each growing region and soybean cultivar; thus, many studies have sought to determine optimum row spacing and plant density for soybean under different environmental conditions.

Different agronomic settings are recommended for different locations because plant development and yield of soybeans depend on both environmental and genetic factors (Edwards and Purcell, 2005; Edwards et al., 2005). For example, in the US upper Midwest researchers hypothesized that narrow row spacing (38-cm) would produce greater yields than wide row spacing (76-cm) and economic advantages exist for narrow row soybean production (Bruin and Pederson, 2008). A Row spacing of 40 cm was recommended for early soybean production system in the mid-southern USA (Bowers et al., 2000), and a row spacing of <76 cm gave consistently higher yield than Row spacing of >76 cm (De Bruin and Pedersen, 2008) in the US mid-west and Southern Canada. Soybean yields in the primary growing region of the Midwest generally were 10-30% greater in the narrow rows (Spilde et al., 1980). Row spacing is considered more important than tillage to get optimum plant population to maximize soybean yield potential (Pedersen, 2008). However, the magnitude of the response depends on many variables such as location,

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year, cultivar, planting date, and tillage system.

Agronomic research of soybean, in general aims at improving cultural practices of crop varieties to enhance yield and reduce production cost. Therefore, testing is needed to examine the impact of row spacing on soybean yield under various growing conditions and for specific soybean population. The objective of this study was to investigate the effect of row spacing on agronomic and yield components in soybean recombinant inbred line (RIL) populations (PIxH, n = 50) derived from a cross between cultivars PI 438489B and 'Hamilton'.

Materials and Methods

Plant Material

In this study, soybean cultivars PI 438489B, 'Hamilton', and their recombinant inbred lines (n=50) were used. 'Hamilton' was developed at the Illinois Agricultural Experiment Station and released for its high yield performance (Nickell et al., 1990). PI 438489B is a plant introduction from China. The cross between PI 438489B and 'Hamilton' was performed at the University of Missouri Agronomy Research Center (Yue et al., 2001) and advanced to the $F_{6:13}$ generation by Dr. Silvia Cianzio at the Iowa State University research site at the Isabela Substation of University of Puerto Rico.

Growing Conditions

In the greenhouse, 4 seeds of parents and each RIL were sown in pots (15 x 14 cm) filled with potting soil at 25±10C temperature and under natural daylight. After 3 weeks, the plants were transferred into a field in St Pauls, NC (34°48′26″N 78°58′22″W and 170 feet above sea level; Robeson County). Two groups of plants have been grown in the greenhouse and transferred into the same field; first group was planted with 25 cm row space and the second group has been planted with 50 cm row space. The plants have been watered and kept in the field until maturity of all RILs and parents, no pesticide or herbicide was applied in the greenhouse or field.

Trait Measurements and Data Analysis

Days to germination (DG) have been recorded in the greenhouse and days to flowering (DF) have been recorded in the field. Plant heights (PH) have been recorded at maturity just before harvest. At maturity, plants have been harvested and brought to the lab to measure total number of pods per plant (NP), Total number of seeds per plant (NS), weight (g) of 100 seeds (100SW), and total seed weight (TSW). All these measurements have been recorded for both Group I (25 cm row space) and Group II (50 cm row space). Comparisons of the agronomic parameters between 25 and 50 cm row space were carried out employing a two-tailed t test (type 2) at $\alpha = 0.05$. Analysis of variance and correlation coefficients among all the traits have been calculated and results are reported in a Pearson correlation matrix using the software JMP 9.0 (SAS Institute Inc., Cary, NC, USA).

Results

Genetic Variation of RILs and Comparison with Parents

In Table 1, the mean, standard deviation, range and co-efficient of variation for the agronomic traits measured from RILs are presented; mid-parental values (MP) were also tabulated to compare with RILs values for each traits of both row spaces. Among traits total seed weight (TSW) showed the highest level of variation in both 25 cm (97.31%) and 50cm (60.23%) row space. The lowest co-efficient of variance (CV%), 5.06% at 25 cm and 11.54% at 50 cm were calculated for days to flowering (DF). The frequency distribution of RILs (Fig. 1) for the traits plant height (PH) and number of pods (NP) were about 10%,

Table 1. Mean, standard deviation, range and co-efficient of variance of the agronomic traits; days to germination (DG), days to flowering (DF) and plant height (PH) in cm, number of pods per plant (NP), number of seeds per plant (NS), 100 seed weight in g (100SW) and total seed weight in g (TSW) of in two row spaces (25 cm and 50 cm) of PI 438489B by Hamilton mid parent (MP) and their recombinant inbred lines (RILs).

Traits	Row Spacing 25cm					Row Spacing 50cm				
	MP	RILs				MP	RILs			
		Mean	SD	Range	CV%		Mean	SD	Range	CV%
DG	3.5	7.92	5.04	18-Mar	63.59	7	5.18	2.09	9-Mar	40.55
DF	78.5	76.05	8.78	60-85	11.54	85	79.78	4.04	77-88	5.06
PH	104.6	76.05	31.17	157-20	40.99	73.5	85.67	31.48	147-29	36.75
NP	94	70.87	55.46	7-227	78.25	46.5	87.82	50.02	16-216	56.95
NS	116.5	102.72	94.41	5-435	91.91	191	173.9	98.6	31-487	56.7
100 SW	13.85	7.71	7.42	3.00-13.2	32.79	4.32	4.11	1.2	1.84-7.71	29.29
TSW	10.2	7.63	7.42	0.2-30.09	97.31	8.15	7.46	4.49	0.8-19.10	60.23

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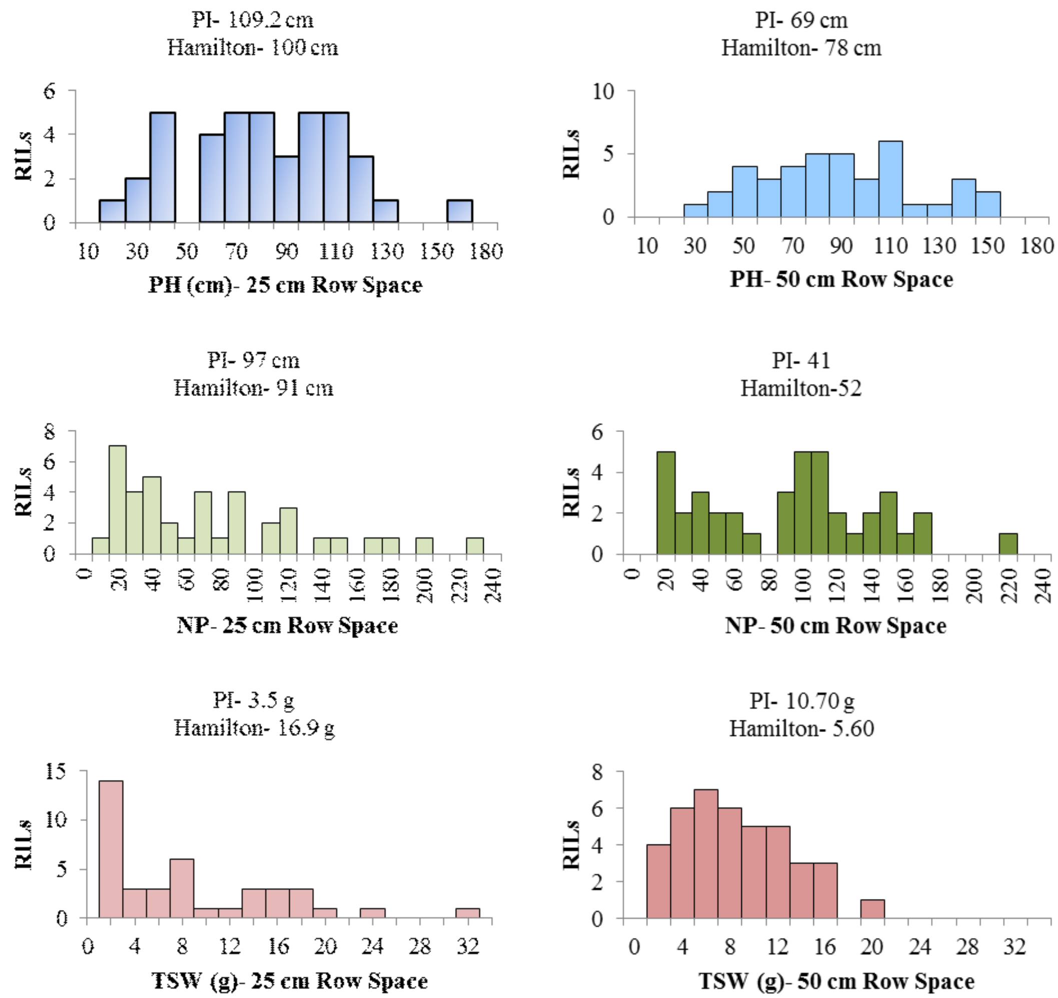

Figure 1. Frequency distributions of the agronomic traits; days to germination (DG), days to flowering (DF) and plant height (PH) in cm, number of pods per plant (NP), number of seeds per plant (NS), 100 seed weight in g (100SW) and total seed weight in g (TSW) of in two row spaces (25 cm and 50 cm) of PI 438489B by Hamilton. Parental means are given for comparison.

20% higher than parent's average; for the total seed weight (TSW), parent Hamilton has much more higher value than parent PI 438489B in 25cm row space which is opposite in 50 cm row space, however very few RILs has higher TSW in both row spaces.

Comparison of RILs Performance in the two Row Spaces

Mean value showed (Table 1, Fig. 2) that plants grown in 25 cm row space have a higher 100-seed and total seed weight than those grown in 50 cm row space. Plants grown in 50 cm row space had a slightly increased mean plant height compared to those grown on 25 cm. Plants grown in 50 cm row space had greater pod and seed numbers compared to those grown on 25 cm. However, comparisons of the agronomic parameters between 25 and 50 cm row space were carried out employing a two-tailed t test (type 2) at $\alpha = 0.05$. There are significant differences in days to germination (DG), days to flowering (DF), number of seeds (NP) and total seed weight (TSW) between plants grown in 25 cm vs. 50 cm row space (Table 2), while plant height and number of pods were not differ significantly between two row spaces according to the two-tailed t test (type 2) at $\alpha = 0.05$.

Correlation Coefficients of Agronomic Traits

Correlation coefficients were estimated for each pair-wise combination of agronomic traits from the RILs (Table 3). Days to germination (DG) was negatively correlated at $P<0.05$ with almost all traits for both row spaces except of days to flowering (DF) and number of seeds (NS) at 50 cm row space. Days to germination (DG) was negatively and significantly correlated with days to flowering (DF) ($r=-0.77$ at $P<0.05$) and plant height (PH) ($r=-0.64$ at $P<0.05$) at 25cm row space. At 25cm row space, days to flowering (DF) was not significantly correlated with any others traits. At 50 cm row space, days to flowering (DF) was negatively and significantly correlated with plant height (PH) ($r= -0.72$ at $P<0.05$), number of pods (NP) ($r= -0.59$

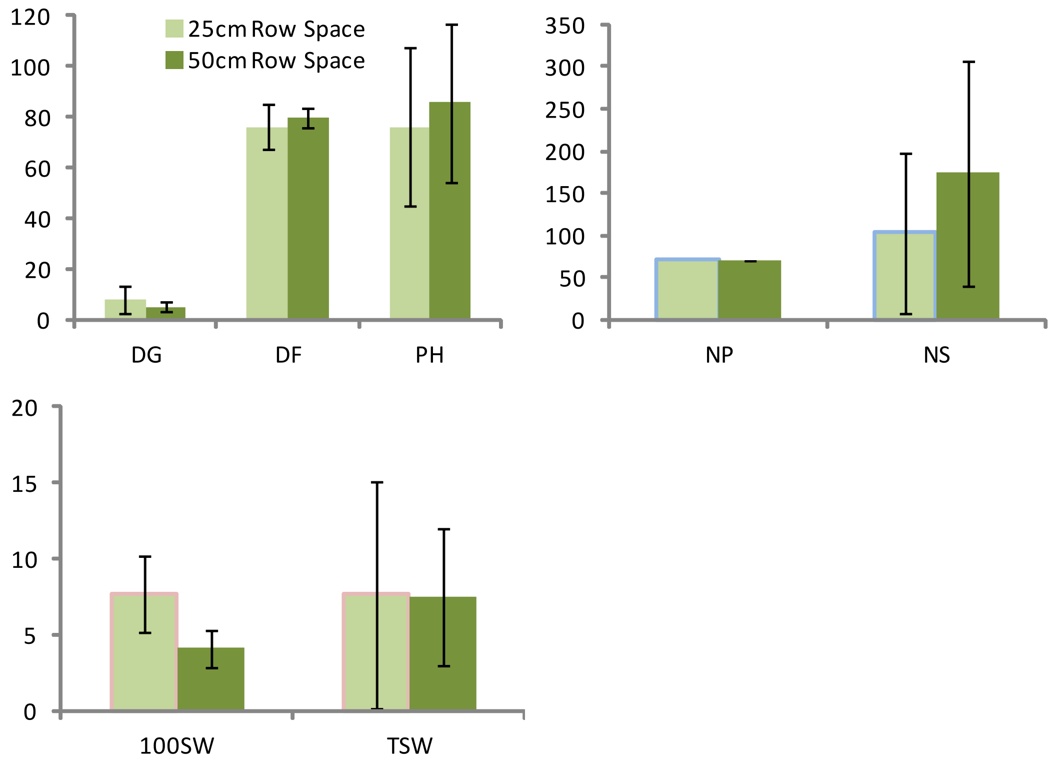

Figure 2. Comparison of mean values (n=50) for the agronomic traits; days to germination (DG), days to flowering (DF) and plant height (PH) in cm, number of pods per plant (NP), number of seeds per plant (NS), 100 seed weight in g (100SW), and total seed weight in g (TSW) in two row spaces 25 cm and 50 cm of the PIxH RIL populations. Each error bar is constructed using 1 standard deviation from the mean.

Table 2. Comparisons of the agronomic traits between 25 cm vs. 50 cm row space employed from a two-tailed t test (type 2) at $\alpha = 0.05$.

	DG	DF	PH	NP	NS	100 SW	TSW
Observations	42	42	42	42	42	42	42
df	55	59	82	81	82	55	67
t Stat	2.930	2.614	-1.032	-1.224	1.447	2.059	2.197
P(T<=t) two-tail	0.005*	0.011*	0.305	0.224	0.001*	0.043*	0.045*
t Critical two-tail	2.004	2.001	1.989	1.990	1.989	2.004	1.996

Note: * Significantly different at p< 0.05; DG- days to germination), DF- days to flowering, PH- plant height (cm), NP- number of pods per plant, NS- number of seeds per plant, 100SW 100 seed weight (g) and TSW- total seed weight (g).

at P<0.05) and total seed weight (TSW) (r= -0.58 at P<0.05).

Plant height (PH) was significantly correlated with number of pods (NP), number of seeds (NS) and total seed weight (TSW) for both row spaces except 100 seed weight (100 SW). Similarly number of pods (NP) was significantly correlated with number of seeds (NS) and total seed weight (TSW) for both row spaces. Number of seeds (NS) was also highly significantly correlated with total seed weight (TSW) but not-significantly with 100 SW in both row spaces.

Discussion

Previous studies conducted in various environments of soybean production showed that row spacing had significant effect on agronomic traits and yield (Boquet, 1990; Yunusa and Ikawelle, 1990; Bowers et al., 2000; Gan et al., 2002; Acikgoz et al., 2009). In our results total seed weight was found higher in narrower row spacing (25cm) (Table 2). De Bruin and Pedersen (2008) also documented that higher seed yield was produced from soybean planted in 38 cm row spacing than 76 cm. Soybean

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Table 3. Correlation coefficients of agronomic traits; days to germination (DG), days to flowering (DF), plant heights (PH), number of pods per plant (NP), number of seeds per plant (NS), weight (g) of 100 seeds (100SW), total seed weight (TSW) in a soybean recombinant inbred population from a cross between PI438489B and Hamilton.

25 cm Row Spacing

	DG	DF	PH	NP	NS	100SW	TSW
DG	-						
DF	-0.77*	-					
PH	-0.64*	0.48 ns	-				
NP	-0.40 ns	0.28 ns	0.69*	-			
NS	-0.43 ns	0.32 ns	0.61*	0.96*	-		
100SW	-0.23 ns	0.30 ns	0.31 ns	0.27 ns	0.23 ns	-	
TSW	-0.36 ns	0.26 ns	0.58 *	0.93*	0.94*	0.42 ns	-

50 cm Row Spacing

	DG	DF	PH	NP	NS	100SW	TSW
DG	-						
DF	0.43 ns	-					
PH	-0.31 ns	-0.72*	-				
NP	-0.13 ns	-0.59*	0.74*	-			
NS	0.03 ns	-0.47 ns	0.59*	0.78*	-		
100SW	-0.15 ns	-0.20 ns	-0.12 ns	-0.13 ns	-0.06 ns	-	
TSW	-0.07 ns	-0.58*	0.71*	0.80*	0.89*	-0.10 ns	-

* Significant at P <0.05 probability level.

plants grew taller in broader row spacing (Table 1), achieved higher number of seeds but less hundred seed weight. In agreement with our results, non-significant effect of row spacing plant height was observed; however, tall and profusely branched forage soybean plants were obtained from wide row spacing and light seeding rate, and lodging of grain soybean was obtained from higher plant density (Lueschen and Hicks, 1977; Acikgoz et al., 2009). Results of this study may provide additional evidence that row spacing recommendations for optimizing soybean production need not be as variety specific. Higher individual plant responses, number of pods and seeds scoring for soybean planted in wider row spacing may indicate less interplant competition and ground-covering canopy that allow more growth of plants. These results support the hypothesis that individual plants at low plant densities adjust by producing more branches and pods (Lueschen and Hicks, 1977). In this study individual plants at high plant densities, produced more pods and seeds but they were not significantly differ between to row spaces (Table 2). Our results showed significant differences in days to germination, days to flowering, number of seeds, and total seed weight between plants grown in 25 cm vs. 50 cm row space; while plant height and number of pods were not differ significantly.

Correlations among traits provided a better understanding of the RIL population (Table 3). Flowering time was negatively correlated with both seed germination and plant height; moderately with the former and highly with the latter. Sherrie et al. (2011) evaluated 'Essex' x 'Forrest' RIL for their responses to yield and agronomic traits found similar results. Seed germination and flowering time were strongly related to environmental conditions. In Arabidopsis, Chiang et al. (2009) reported that there is a major gene, FLC, which controls flowering and promotes temperature-controlled seed germination. These traits are probably closely related in soybean too and are regulated mainly by seasonal conditions. Environmental conditions and specifically photoperiod seems to control post-flowering development too (Grimm et al., 1994; Steward et al., 2003). This could be a reasonable explanation to the fact that the results of this study are not in accordance with a previous study which suggested that early flowering boosts the development of the reproductive system ceasing vegetative growth and as a result the plants are shorter in height (Panthee et al., 2007).

The top priority of a breeding program is yield potential. It is generally accepted that agronomic traits significantly correlated with seed yield can be helpful in selecting desired genes for particular character. This study indicated that seed yield is negatively correlated with germination time and plant height, which is opposite of studies Mussa et al. (1999) and Harris et al. (2000) who found faster seed emergence improved yield because of reduced pest damage and increased drought tolerance of the seedlings. It should be mentioned that low correlation coefficient (r<0.5), even if they are statistically significant, cannot be helpful in efficiently selecting for high yield using agronomic traits however, some agronomic traits with higher correlation values can be considered for agronomic practices for soybean.

The PI 438489B by 'Hamilton' RIL populations performed relatively well in 25 cm row spacing in North Carolina (NC) environments compared to 50 cm row spacing. The results of this study indicate higher seed yield and yield components per unit area of land that can be achieved using narrower row spacing, indicating the compensation capacity of soybeans for a wide range of row spacing without affecting yield. The observed variation in the RIL populations can be beneficial and have practical applications for soybean improvement programs.

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