Is There A Correlation Between Plant Height and Yield in Soybean?

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Summary
Soybean is an important crop in the US and the world. A positive correlation between plant height and yield was reported in several crop species. Our objective was to investigate whether such correlation exists in soybean using a population of 94 plants. The plants were grown in the Fayetteville State University (FSU) greenhouse for two weeks then transferred into a field in Harnett County, NC until they reach R8 stage of maturity. After harvest, plant height and yield (100-seed weight) were recorded. A correlation test was performed using SPSS statistical program. Concerning plant height and yield, RILs were classified into low yielding (1.28 – 10.28 grams) and plant height (31.2 – 59.2 cm) and high yielding (10.28 – 22.84 grams) and plant height (59.4 – 170 cm) groups. There was no correlation between yield and plant height in this population because yield and plant height are polygenic, complex, and hard to study although important to introduce in breeding programs.

Introduction
Soybean [Glycine max (L.) Merr.] is an important crop in the US and the world. It contains large amounts of proteins, oils, and other beneficial compounds (Singh and Hymowitz, 1999; Kassem et al., 2004a; Desroches et al., 2004). During the last 30 years, agronomists tried to select high yielding soybean cultivars and yield has doubled (Specht et al., 2001). However, soybean is susceptible to several diseases such as sudden death syndrome (SDS), soybean cyst nematode (SCN), and drought that severely reduce yield (Yuan et al., 2002; Cenci-bido et al., 2004; Wang et al., 2006). A positive correlation between high seed yield and plant height has been reported for several crops species including wheat (Eriksen et al., 2003), maize (Pereira and Lee, 1995), barley (Scheurer et al., 2001), sorghum (Pereira and Lee, 1995), sunflower (Bert et al., 2003), rice (Hittalman et al., 2003; Ishimaru et al., 2004), rye (Borner et al., 1999), cassava (Okogbenin and Fregene, 2003), and cultivated lettuce (Argyris et al., 2005).

In soybean and other plant species, the majority of economically important agronomic traits such as seed yield, plant height, and disease resistance are polygenic, complex, and controlled in a quantitative fashion ( Tanksley, 1993; Mansur et al., 1996; Kassem et al., 2004a,b, 2006, 2007a,b; Jacobson et al., 2007; Alcivar et al., 2007). In soybean, we hypothesized that vigorous tall plants would have an increased yield compared to shorter plants.

The objective of this study was to find out whether or not there is a correlation between plant height and yield using the ‘Essex’ by ‘Forrest’ recombinant inbred line (RIL) population (n = 94).

Materials and Methods

Plant Material
The ‘Essex’ by ‘Forrest’ RIL population (EXF, n = 94) used in this study (Lightfoot et al., 2005) was provided in 2007 (at the F5:16) by Prof. D.A. Lightfoot of SIUC. This ExF RIL population was extensively studied for sudden death syndrome (SDS) resistance, soybean cyst nematode (SCN) resistance, manganese toxicity resistance, seed yield, and several other traits (Kassem et al., 2004a,b, 2006, 2007a,b; Alcivar et al., 2007; Jacobson et al., 2008).

Growth Conditions and Trait Measurements

Growth conditions were performed as described in Jacobson et al. (2007). Briefly, one seed per pot, with 3 seed of each RIL, were grown in pots of 30 x 30 cm (diameter x depth) containing approximately 1 Kg of PRO-MIX soil. The PRO-MIX is a ready-made, peat based growing mix containing the Canadian sphagnum peat moss (75-85% by volume), lime-
stone (for pH adjustment), perlite, a wetting agent, and vermiculate. The seeds were planted in the summer in the greenhouse for two weeks then transferred into a field in Harnett County, NC. The plants were grown for a total of 128 days (May 11\textsuperscript{th} – September 16\textsuperscript{th}, 2007). The plants were kept in the greenhouse at 25±1\degree C under natural lighting and harvested at maturity of all RILs and parents Essex and Forrest (128 days; R8 growth stage). The plant heights, yield (100-seed weight), shoot, and root traits were measured at maturity of RILs and parents ‘Essex’ and ‘Forrest’, after day 128 (R8 growth stage).

**Data analysis**
Data analysis, for summary statistics and correlation test was performed using the SPSS program. The correlation test was run to find out whether there is a positive or negative correlation between plant height and yield in the soybean Essex by Forrest RIL population ($n = 78$; 16 RILs died because of severe weather in NC).

**Results and Discussion**
The ‘Essex’ by ‘Forrest’ RIL population (Lightfoot et al., 2005) was extensively studied for sudden death syndrome (SDS) resistance, soybean cyst nematode (SCN) resistance, manganese toxicity resistance, seed yield, and several other traits (Kassem et al., 2004a,b, 2006, 2007a,b; Alcivar et al., 2007; Jacobson et al., 2008).

A brief statistical description of the traits measured and investigated in this study is shown in Table 1. Because of severe drought in the North Carolina Sandhills and across the southeastern united states (National Climatic Data Center, 2007), sixteen plants died among the 94 initially planted in the greenhouse and transferred in the field. A total of 78 plants survived and data was collected from this population ($n = 78$). Plant height ranged from 31.2 cm to 170 cm with an average of 62.4 cm (Table 1) and yield (100-seed weight) ranged from 1.28 to 22.84 g with an average of 9.68 g (Table 1). Plant height and yield measured in Southern Illinois University, Carbondale, IL in 2002-2006 were much higher than those measured here in Harnett County, NC (data not shown). This might be due to the severe drought conditions of this summer 2007 which killed 16 RILs and contributed to the reduced yield and plant height as reported in certain soybean cultivars (Wang et al., 2006), and many other crop species (Vallejo and Kelly, 2004; Manickavelu et al., 2006; Derera et al., 2007). In fact, most of the Southeast, including North Carolina, was affected by exceptional drought conditions according to the National Climatic Data Center (National Climatic Data Center, 2007).

The 78 plants were classified into two groups. The low yield (1.28 – 10.28 g) and plant height (31.2 – 59.2 cm) group (Group I) and the high yield (10.3 – 22.84 g) and plant height group (59.4 – 170) group (Group II) (Figures 1 – 4).

The objective was to find out whether there is a correlation between plant height and yield in soybean using the Essex by Forrest RIL population. However, data analysis using SPSS program showed that there was no correlation between yield and plant height in this population (Tables 2, 3 and 4; Figure 5). Some RILs with high plant height have low seed yield and vice versa (Figures 1–5).

This is because yield and plant height are complex desirable traits inherited in a quantitative fashion (Yuan et al., 2002; Manickavelu et al., 2006; Derera et al., 2007; Kassem et al., 2007b; Jacobson et al., 2007; Alcivar et al., 2007). Surprisingly, our hypothesis, stating that there might be a positive correlation between plant height and yield in soybean, was rejected. To our knowledge, no other studies reported a positive or negative correlation between plant height and seed yield in soybean; however, several studies including ours reported quantitative trait loci for plant height and yield (Smalley et al., 2004; Wang et al., 2004; Guzman et al., 2007; Jacobson et al., 2007; Alcivar et al., 2007). Therefore, plant height and yield need to be investigated further at the molecular and genetic levels to be introduced in soybean breeding programs.

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**Table 1.** Statistical analysis of the R8 stage plant height (PLH) and yield (100-seed weight, YLD) traits in the RIL population and the ‘Essex’ and ‘Forrest’ parents. Shown are averages and population ranges for these traits.

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<tr>
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<td>1. Plant height (PLH, in cm)</td>
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<td>2. Yield (100-seed weight, YLD, in grams)</td>
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**Fig. 1.** Plant height of the Soybean 'Essex' by 'Forrest' Recombinant Inbred Lines (RILs) [Group 1: Low plant height]

**Fig. 2.** Plant height of the Soybean 'Essex' by 'Forrest' Recombinant Inbred Lines (RILs) [Group 2: High plant height]
Fig. 3. The Soybean 'Essex' by 'Forrest' Recombinant Inbred Lines Yield (100-seed weight in grams) [Group 1: Low yield]

Fig. 4: The Soybean 'Essex' by 'Forrest' Recombinant Inbred Lines Yield (100-seed weight in grams) [Group 1: Low yield]
Table 2 and 3. Statistical description of plant height and yield traits in soybean performed with the SPSS program.

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<tr>
<td>100 Seed Weight</td>
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Table 4. Correlation test between plant height and yield in soybean performed with the SPSS program.

Figure 5. Plot of plant height vs. yield (100-seed weight) in the ‘Essex’ by ‘Forrest’ recombinant inbred line population of soybean (n = 74).
References


Singh RJ, T Hymowitz (1999) Soybean genetic resources and