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Improving Soybean Variety Trial Analysis with Augmented Models

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ABSTRACT

Plant breeders intend to evaluate a large number of new varieties in order to select genotypes with great yield potential through various variety trials. Thus, a large experimental field may be needed. A prerequisite in most experimental designs is homogeneity among experimental plots within each block. However, it is sometimes difficult to ensure that experimental plots are uniform within each field block regarding soil fertility and soil conditions that may significantly impact yield and other important traits. In this study, a classical randomized complete block (RCB) with three field replications (row-blocking) was "augmented" based on the field plot layout in a one-year soybean variety trial. Data for yield and yield components of 12 soybean varieties were collected and analyzed with several augmented models. Results showed that variety had highly significant impacts on grain yield, 100-pod weight, and seed 100-pod weight. Soil heterogeneity existed in the row direction for yield. Further analyses showed that, soil conditions contributed to the significance impact of cultivar on grain yield but number of seeds, 100-pod weight, or 100-pod seed weight was not significantly affected.

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Introduction

Soybean (*Glycine max (L.) Merrill*), as one of the most widely grown leguminous crops and one of the most economically important crops in the world (Guo *et al.*, 2011), is a versatile and fascinating crop with innumerable possibilities of not only improving agriculture but also supporting industries. This crop has been seen an increase in world production through a combination of increased production area and greater yield to meet the rising demand. Increasing soybean yield has been attributed to improve agronomic practice as well as enhancement of selecting genetic potentials for higher yield of new soybeans varieties (Specht and Williams, 1984; De Bruin and Pedersen, 2008; Rowntree *et al.*, 2013). In USA, substantial increase in yield of soybeans due to successive release of new genotypes of soybeans was reported (Boerma, 1979; Specht and Williams, 1984; Rowntree *et al.*, 2013).

Over 2,700 of different crops including soybeans with improved agronomic traits have been developed and officially released to the farmers for general cultivation all over the world (Maluszynski, 2001; Shu, 2009). It is a common practice that new lines are evaluated before their official release to the farmers. Early-stage evaluation in soybean breeding programs is commonly practiced on a large number of new varieties. Thus, at the pre-screening stage, a large experimental field may be needed for evaluation and subsequently for selection of varieties with great yield potentials. A pre-requisite in most experimental designs is homogenous experimental plots within each block. However, it is sometimes difficult to ensure that experimental plots are uniform within each field block with respect to soil fertility and soil conditions that may significantly impact yield and yield components. Therefore, field observations may not be highly consistent with genetically high-yielding due to non-uniform soil condition (Keuls and Sieben, 1955).

One effective approach to overcoming soil heterogeneity problems is to augment standard experimental designs which were introduced and later extended (Federer, 1956; Federer, 1961; Federer and Raghavarao, 1975; Federer *et al.*, 2001; Federer, 2002). An augmented design sometimes occurs in plant breeding programs, which could be viewed as rectangular row-column design, equivalent to a two-dimensional control (Harshbarger and Davis, 1952; Lin and Poushinsky, 1985; Bondalapati *et al.*, 2014a). In a similar manner, a classical randomized complete block (RCB) design, a conventional one-way blocking design, could be augmented by including column and/or row effects based on a field plot layout or field management to improve statistical analyses. This "augmented RCB design" with appropriate statistical methods could help control field variation and select more promising varieties for further investigation. However, appropriate analysis for these different augmented designs is highly desired (Federer and Wolfinger, 1998). Linear mixed model approaches appear to be effective for several augmented experimental designs (Wu *et al.*, 2013; Bondalapati *et al.*, 2014b).

In this study, we considered augmenting a classical RCB design to detect the direction of soil variation (row, column, or two directions) based on the field plot layouts in a one-year soybean variety trial with 12 soybean cultivars. A linear mixed model approach was applied to analyze several augmented RCB designs. The major purpose of this study was to improve crop trial data analysis via augmenting a classical one-way blocking design.

Materials and Methods

Materials and field experiments

Twelve soybean cultivars including Wensman W 3178R2, Asgrow AG1733, Dairyland DSR-1808/R27, Wensman W, Prairie BR. PB-1843R2 3160NR2, Prairie BR. PB-1722R2, Pioneer P16T04R, Rea 78G12, Stine 16RD66, Mustang 16624, Latham L1783R2, Channel 1805R2 were grown in 2013 (Table 1). The experiment was conducted at the South Dakota State University Volga Research Farm (N 44°17.915' W 096°55.393'). A randomized complete block design with three replications following the row direction was employed. The previous crop was spring wheat. Each four-row plot was 5ft wide and 30ft long. Soil type was Brandt silty clay loam, 0-2% slope, and non-irrigated. Conventional tillage was employed. Row spacing was 30 inches with seeding rate of approximate 165,000 per ac. Weeds were controlled using dual II-Pre, Glyphosate-Post. Planting was done on June 3rd and harvested. Prior to planting, each plot was sampled by extracting from 0-15-cm. The soil test included phosphorus (P, ppm), organic matter (OM, %), potassium (K, ppm), pH, Zinc (Zn, ppm), Iron (Fe, ppm), Manganese (Mn, ppm), Copper (Cu, ppm), Calcium (Ca, ppm), Magnesium (Mg, ppm), Sodium (Na, ppm), and Cation Exchange Capacity (CEC, meq/100g). The South Dakota State University Soil Testing Lab used the Olsen (sodium bicarbonate) test procedure for routine P tests, weight loss (lost on ignition) procedure for OM, Ammonium Acetate procedure for routine K, Ca, and Mg tests, water procedure for pH, and Na tests, and DTPA solution method for Zn, Fe, Mn, and Cu. Soil testing was performed to determine physical conditions, fertility (nutrient) status, and chemical properties that may affect soybean crop production.

Data collection

Prior to field harvest, we measured height of 10 normally developed plants (PH, inches) for each plot. In addition, we cut all plants within 1-m area in the middle of second or fifth row of 6-row plot and saved these plants in one paper bag. In addition to 1-m population size, we measured the following traits: number of plants (NP/m), whole bag weight (WBW, g), and whole pod weight (WPW, g). Number of seed (NS/100-pod), 100-pod weight (HPW, g), and seed weight of 100-pod (SWHP, g) were determined by based on randomly selected 100 pods from the 1-m sample for each plot.

Table 1. Variety with corresponding replication and plot number in 2013

Variety name	Trt.No	Rep. and Plot No.		
Wensman W 3178R2	1	101	209	302
Asgrow AG1733	2	102	207	312
Dairyland DSR-1808/R27	3	103	202	310
Wensman W 3160NR2	4	104	210	311
Prairie BR. PB-1843R2	5	105	201	306
Prairie BR. PB-1722R2	6	106	212	305
Pioneer P16T04R	7	107	204	304
Rea 78G12	8	108	203	307
Stine 16RD66	9	109	205	308
Mustang 16624	10	110	211	301
Latham L1783R2	11	111	206	303
Channel 1805R2	12	112	208	309

Trt. No=Treatment number, Rep. =Replication

Table 2. Mean grain yield and yield component traits of 12 soybean cultivars tested at Volga in 2013

Variety Name	Yield and components traits							
	GY (kg/ha)	PH (cm)	NS	NP	WBW (g)	WPW (g)	HPW (g)	SHPW (g)
Asgrow AG1733	34.94	35.12	234.67	25.33	572.37	347.2	49.27	36.1
Channel 1805R2	32.71	38.23	261.67	23.67	619.97	363	55.67	39.63
Dairyland DSR-1808/R27	34.32	35.45	240.67	28.33	574.2	338.6	46.57	33.77
Latham L1783R2	34.62	35.83	231.33	25.33	572.07	319.7	43.3	31.17
Mustang 16624	30.87	36.15	240	24.67	534.23	306.8	40.07	27.87
Pioneer P16T04R	29.56	40.47	253	26.33	556.23	300.7	55.9	41.03
Prairie BR. PB-1722R2	35.69	36.12	236.33	27.33	560.53	330.2	47.53	35.1
Prairie BR. PB-1843R2	35.68	34.98	239.67	24.67	557.83	356.8	47.47	34.67
Rea 78G12	29.97	35.67	244.33	23.33	547.87	303.6	41.27	29.07
Stine 16RD66	33.3	36.32	211.67	24.67	568.87	322.2	41.17	29.6
Wensman W 3160NR2	35.97	36.15	253.33	28.33	612	362.6	53.93	39.03
Wensman W 3178R2	35.65	35.45	247.67	23.67	590.43	347.9	55.43	40.5

Table 2. Mean grain yield and yield component traits of 12 soybean cultivars tested at Volga in 2013

GY=grain yield, PH=plant height, NP=number of plants, WBW= whole bag weight, WPW=whole pod weight, NS=number of seed per pod, HPW=100-pod weight, SWHP=seed weight of 100-pod

Ohaus scout pro portable balance, 6000g, 115 Vac was used to measure weight. Grain yield (GY) were harvested from the third and fourth rows on October 1st (group 0s and 1s) and October 9th (group 2s) and then converted to bu/ac.

Statistical models and statistical methods

Three different linear models were chosen for our data analysis. These models were used to predict cultivar effects, row and column blocking effects (row-column). The response model of row, column, and row and column were used to describe the soil conditions variation in the experiment. Model one (M1) is a conventional RCB design model. Model two (M2) only includes column blocking based on the field plot layout. Model three (M3) is augmented RCB with two-way blocking effects.

Soil heterogeneity was investigated by examination of the significance of blocking or column effects with all the three models. If row and/or column effects are not significant, the soil variation can be considered homogeneous.

$$Y_{ij} = \mu + G_i + B_j + \varepsilon_{ij} \ \ldots\ldots\ldots\ldots \text{Model 1 (M1)}$$
$$Y_{ij} = \mu + G_i + C_j + \varepsilon_{ij} \ \ldots\ldots\ \ldots \text{Model 2 (M2)}$$
$$Y_{ijk} = \mu + G_i + B_j + C_k + \varepsilon_{ijk} \ldots \ \text{Model 3 (M3)}$$

Where Y_{ij} represents the yield or yield component; μ is the overall mean for the whole experiment, G_i is a genotypic effect, $G_i \sim N(0, \sigma_g^2)$; B_j is the block effect, $B_j \sim N(0, \sigma_b^2)$, C_j is the random column effect, $C_j \sim N(0, \sigma_c^2)$; and ε_{ij} represents the random error $\varepsilon_{ij} \sim N(0, \sigma_e^2)$.

For the purpose of estimating the variance components, genotype and block effects were treated as random variables. All statistical analyses were processed using R (R Core Team, 2014). An R package "minque" (Wu, 2014) incorporated with a group-based jackknife resampling approach with 10 randomly divided groups was used to estimate the variance components through the minimum norm quadratic unbiased estimation (MINQUE) method (Rao, 1971). Separate analyses were performed for each measured component trait. To assess the impact of soil conditions on yield and yield components, a stepwise regression was performed to select the best soil condition variables using the R package "leaps" (Lumley and Miller, 2004). The residuals with removal of effects from soil components were used for additional analysis. Means of cultivar yield were compared using LSD of 0.05 if a F-test was significant.

Results and Discussion

Mean performances of soybean cultivar grain yield and yield traits

Means for 12 soybean genotypes grain yield and yield traits in 2013 and presented in (Table 2). Mean grain yield ranged from 29.00 (Pioneer P16T04R) to 35.95 bu/ac (Wensman W 3160NR2). Plant height varied from 34.98 (Prairie BR. PB-1843R2) to 40.47 inches (Pioneer P16T04R). Pioneer P16T04R had the lowest yield but with the tallest plants, indicating possible negative correlation between yield and vegetative growth under this condition. Variation in plant height among varieties might have occurred due to their differences in genetic background.

The minimum number of seed was produced by Stine 16RD66 (211.67) while the maximum was Channel 1805R2 (261.67). The average number of plants varied from 23.33 m^{-1} (Rea 78G12) to 28.33 m^{-1} (Dairyland DSR-1808/R27). The highest average whole bag weight was obtained for Channel 1805R2 (619.97 g) and the lowest was Mustang 16624 (534.23g). The mean values of whole pod weight ranged from 300.7 (Pioneer P16T04R) to 363g (Channel 1805R2). The mean values for 100-pod weight varied from 40.07 (Mustang 16624) to 55.9g (Pioneer P16T04R). The highest seed weight of 100-pod was obtained with Pioneer P16T04R (41.03g) and the lowest was Rea 78G12 (29.07g).

Analysis of variance for yield and yield components traits based on the three models

Analyses of variance (ANOVA) were obtained for each of the three models for the 12 soybean cultivars yield and yield component traits and presented in (Table 3). The purposes of the ANOVA of individual yield and yield traits using three different models were to determine whether there is soil heterogeneity and to characterize its property, i.e., soil trends in the row or column direction. The adjustment by including column effects in this RCB design could be the most extended when soil variation occurred in one or two direction. This helps detect if soil fertility impacted yield and yield components. Significant effect of row blocking did not give undue advantage to some cultivar.

For model 1 (M1), grain yield, number of seed, 100-pod weight, and seed weight of 100-pod were highly influenced by cultivars. Cultivar effects on plant height were significant at the probability level of 0.01. Significant row-block effect on grain yield was detected.

Table 3. Analysis of variance for twelve soybean cultivars by model 1 (M1), model 2 (M2) and model 3 (M3) of yield traits for Volga in 2013

SoV	DF	Mean Square Error							
		GY (kg/ha)	PH (cm)	WBW (g)	NP	WPW (g)	NS	HPW (g)	SWHP (g)
					M1				
Trt	11	16.27***	7.19**	1866.60	9.18	1551	490.1***	107.09 ***	64.55***
Blk	2	51.76***	0.60	285.10	1.03	1886	28.50	11.88	12.33+
Err	22	2.58	0.82	2170.50	7.73	1026	84.50	7.52	4.80
					M2				
Trt	11	16.27+	7.19***	1866.60	9.179	1550.9	490.10***	107.09***	64.55***
Col	2	0.58	2.06+	766.40	0.486	2237.9	66.60	3.03	1.83
Err	22	7.24	0.69	2126.70	7.774	994.4	81.10	8.33	5.75
					M3				
Trt	11	16.27***	7.19***	1866.60	9.18	1550.9	490.10***	107.09***	64.55***
Blk	2	51.76***	0.60	285.10	1.03	2237.9	28.50	11.88	12.33
Col	2	0.58	2.06+	766.40	0.49	1885.5	66.6 0	3.03	1.83
Err	20	2.78	0.70	2310.9	8.45	905.2	86.30	7.97	5.10

SoV= source of variation, DF= degree of freedom, Trt= treatment (variety), Blk=Block blocking, Col = Column blocking, Err=error, GY=grain yield, PH=plant height, NP=number of plants, WBW= whole bag weight, WPW=whole pod weight, NS=number of seed per pod, HPW=100-pod weight, SWHP=seed weight of 100-pod.

'*', '**', '***','+' are significant at probability levels of 0.05, 0.01, 0.00 and 0.1 respectively

There was no evidence of significant row-blocking effect on other yield traits at the probability level of 0.05. Thus, based on M1, soil heterogeneity existed for yield in row direction while homogenous for most of the traits considered in this study.

For model 2 (M2), there was evidence showing that cultivar had highly significant impacts on plant height, number of seed, 100-pod weight, and seed of 100-pod weight. No significant column effects on yield and yield component traits were detected at the probability level of 0.05.

For model 3 (M3), there was evidence showing that cultivars had highly significant impacts on grain yield, plant height, number of seed, 100-pod weight, and seed of 100-pod weight. There was no evidence showing that row-blocking had significant impacts on yield component traits except grain yield. There was no significant column-blocking for all these traits.

The results based on the three models showed that soil heterogeneity existed in row direction for soybean grain yield. Some important soil condition variables were selected by stepwise regression approach to have had some contributions to yield and yield component traits. Soil variables (OM, pH, Zn, Fe, Mn, Mg, and Na) simultaneously contributed about 41% to the total variation of soybean grain yield (Table 4). Similarly, 11% of the total variation in plant height was attributed to P and K soil contents, 10% in number of plants to OM, P, K, Fe, Mn, Cu, and CEC, 23% of the variation in whole pod weight to OM, K, Zn and

Table 4. Stepwise regression of soil condition variables

	GY (kg/ha)	PH (cm)	NP	NS	WBW (g)	WPW (g)	HPW (g)	SHPW (g)
	4.21OM+	0.17P+	6.86OM*	1.04 P	72.39OM+	55.99Zn*	0.55P+	5.74OM+
	-13.75pH	-0.04K*	0.47P*		-1.06K+	0.16Ca*	21.28pH	0.41P+
	5.56Zn*		-0.15K**		53.31Zn	-4.10Na+	0.52Mn	0.05Mg
	0.25Fe		-0.39Fe+		-3.87Fe		-0.61Na	
	-0.40Mn		0.43Mn					
	0.05Mg		-0.57Cu+					
	-0.25Na		-0.78CEC					
R	0.41	0.10	0.11	0.04	0.08	0.23	0.13	0.15

GY=grain yield, PH=plant height, NP=number of plants, WBW= whole bag weight, WPW=whole pod weight, NS=number of seed per pod, HPW=100-pod weight, SWHP=seed weight of 100-pod.

*, **, + , are significant at probability levels of 0.05, 0.01, and 0.1 respectively

Table 5. Analysis of variance for the residuals of yield traits by model 1 (M1), model 2 (M2) and model 3 (M3) for Volga in 2013

SoV	DF	Mean Square Error							
		GY (kg/ha)	PH (cm)	NS	WBW (g)	NP	WPW (g)	HPW (g)	SWHP (g)
					M1				
Trt	11	5.88	5.90***	442.6***	1707	7.08	791.30	69.00***	46.92***
Row	2	3.13	0.25	108.9	1102	0.36	1127.20	8.15	9.79
Err	22	4.03	0.82	78.1	1586	5.24	886.50	12.75	5.47
					M2				
Trt	11	5.89	5.90***	442.60***	1707.2	7.08	791.3	69.00***	46.92***
Col	2	0.71	1.08	27.2	582.2	6.18	1000.5	3.78	1.48
Err	22	4.28	0.75	85.5	1633.7	4.77	898.0	13.15	6.23
					M3				
Trt	11	5.88	5.90***	442.6***	1707.2	7.08	791.30	69.00***	46.92***
Row	2	3.13	0.25	108.9	1101.9	0.36	1127.20	8.15	9.79
Col	2	0.36	1.08	27.2	582.2	6.18	1000.50	3.78	1.48
Err	20	4.39	0.80	83.1	1686.8	5.15	875.10	13.65	5.87

SoV= source of variation, DF= degree of freedom, Trt= treatment (variety), Row=Row blocking, Col = Column blocking, Err=error, GY=grain yield, PH=plant height, NP=number of plants, WBW= whole bag weight, WPW=whole pod weight, NS=number of seed per pod, HPW=100-pod weight, SWHP=seed weight of 100-pod.

'***' is significant at probability level of 0.00

Table 6. Least significant difference (LSD) comparisons of twelve soybean varieties in 2013 at Volga

	Variety	Means
1	Wensman W 3160NR2	35.97a
2	Prairie BR. PB-1722R2	35.69a
3	Prairie BR. PB-1843R2	35.68a
4	Wensman W 3178R2	35.65a
5	Asgrow AG1733	34.94ab
6	Latham L1783R2	34.62ab
7	Dairyland DSR-1808/R27	34.32ab
8	Stine 16RD66	33.30abc
9	Channel 1805R2	32.71bc
10	Mustang 16624	30.87cd
11	Rea 78G12	29.97d
12	Pioneer P16T04R	29.56d

LSD ($\alpha = 0.05$), = 2.72 (2013)

Table 7. Estimated variance components of yield trait for Volga in 2013

	GY	PH	WBW	NP	WPW	NS	HPW	SWHP
V				**M1**				
V_T	4.55***	2.09***	77.91	0.61	168.32	134.26***	33.17***	20.09***
V_R	4.12*	0.02	0.00	0.00	70.67	0.00	0.42	0.62
V_e	2.59	0.83	2160.29	7.69	1033.53	86.16	7.60	4.71
				M2				
V_T	2.83*	2.29***	92.39	0.46	199.94	138.40**	32.69***	19.51***
V_C	0.01	0.06	44.65	0.00	109.02	1.13	0.00	0.00
V_e	7.26	0.70	2115.95	7.80	975.24	80.69	8.43	5.82
				M3				
V_T	4.48***	2.28***	105.43	0.37	204.97	133.98***	32.74***	19.72***
V_R	4.10*	0.01	0.00	0.00	75.71	0.00	0.46	0.66
V_C	0.02	0.06	11.53	0.00	100.32	0.06	0.09	0.03
V_e	2.73	0.71	2326.83	8.49	920.27	87.32	7.94	5.10

V= variance component, V_T = Treatment (variety) variance, V_R =Row blocking variance, V_C = Column blocking variance, V_e=error variance, GY=grain yield, PH=plant height, NP=number of plants, WBW= whole bag weight, WPW=whole pod weight, NS=number of seed per pod, HPW=100-pod weight, SWHP=seed weight of 100-pod.

'*', '**', '***', are significant at probability levels of 0.05, 0.01, and 0.00 respectively

Fe, 13% of total variation in 100-pod weight to P, pH, Mn, Na, and 15% in seed weight of 100-pod to OM, P, Mg soil nutrients. The contributions of these soil variables were removed and ANOVA were performed for the residuals of each trait to reveal the genetic impact on yield traits without the effects of soil conditions. From the results in Table 5, based on all the three models, same conclusions could be drawn. Number of seed, plant height, 100-pod weight, and seed of 100-pod weight were highly influenced by cultivar. Blockings especially, row-blocking which was having effect on grain yield now had no impact on yield traits. With no blocking effects the experimental plot is considered to be homogenous; an ideal field plot for pre-screening soybean cultivars. With the soil conditions effect removed, cultivar effect on grain yield is now insignificant. Thus, the genetic performance of these cultivars was similar and their grain yield performance on a homogenous experimental plot did not see any significant difference. Selecting genotypes based on higher yield performance may be misleading. Yield traits such as plant height, number of seed, 100-pod weight and seed weight of 100-pod were consistently influenced by cultivar with and without the effects of soil conditions. Number of seed, and 100-seed weight are primary determinant of soybean production (Orf *et al.*, 1999; Specht *et al.*, 1999; Liu *et al.*, 2005) and cultivars with superior performances for these traits should be included in the selection process. These traits were not significantly influenced by soil conditions in this study.

Multiple comparisons among 12 soybean cultivars

The primary objective of a field test in early stage of genotype selection is to compare the phenotypic expression of genotypes and select the ones with desirable qualities. Least significant difference (LSD) has been commonly used to compare the significance difference between means of two varieties. The LSD values were calculated based on model 1 and the results are presented in (Table 6). The means of cultivar Wensman W 3160NR2 and Prairie BR. PB-1722R2 are not significantly different from each other. Thus, the variety (Wensman W 3160NR2) with the highest yield was statistically comparable to Prairie BR PB-1722R2, Prairie BR PB-1843R2, Wensman W 3178R2, Asgrow AG1733, Latham L1783R2, Dairyland DSR-1808/R27, and Stine 16RD66. Similarly, variety with the lowest yield (Pioneer P16T04R) was same as Rea 78G12, and Mustang 16624. On the other hand, means of cultivar Wensman W 3160NR2 and Pioneer P16T04R were statistically different.

Variance components for yield and yield component traits

Since the inclusion of column effects based on the field plot design resulted in an unbalanced data, a linear mixed model approach was also used to analyze the data due to the ability to handle unbalanced date sets (Wu *et al.*, 2013; Bondalapati *et al.*, 2014a; Wu, 2014). Assuming random effects of variety and blocks made it possible to estimate various variance components. The variance components and the proportional were estimated to assess the amount of variation and significant contributions to variable (yield or a yield components trait) due to cultivar, blocks and random error based on the models considered in this study.

Table 7 lists the estimates of cultivar, blocks and random error variance components for soybean yield and yield component traits based on the three models. Cultivar had highly significant effects on grain yield, plant height, number of seed, 100-pod weight, and seed weight of 100-pod from all the three models. Row effects had significant impact on grain yield from M1 and M3. Column effects did not have significant impact on yield and yield traits from M2 and M3. Including column effects in the model did not improve the results for all traits. Proportionately, cultivar contribution to total variation in soybean grain yield were 40%, 28%, and 40% based on M1, M2, and M3, respectively (Table 8). Similar, cultivar contributed (M1=71%, M2=75%, and M3=74%), (M1=61%, M2=63%, and M3=60%), (M1=80%, M2=79%, and M3=79%), and (M1=78%, M2=77%, and M3=77%) to the total variation in plant height, number of seed, 100-pod weight and seed weight of 100-pod respectively. These traits were mainly affected by cultivar effects. The other traits such as number of plants, whole bag weight and whole pod weight were more influenced by unknown mechanisms thus random error proportional component larger than cultivar components these traits.

Soil uniformity analysis

It is often of interest to plants breeders, the trend of soil variations to aid blocking to ensure homogeneous experimental block. Uniformity tests on soil conditions variables and soybean grain yield were performed. The estimated variance component for row and column effects are presented in Table 9. Soil variations existed in the row direction except Na at probability level of 0.05. At 0.1 alpha level of

Table 8. Estimated proportional variance components of yield traits for Volga in 2013

V	GY	PH	WBW	NP	WPW	NS	HPW	SWHP
				M1				
V_T	0.40	0.71	0.04	0.06	0.13	0.61	0.80	0.78
V_R	0.36	0.01	0.00	0.00	0.05	0.00	0.01	0.02
V_e	0.23	0.28	0.96	0.94	0.81	0.39	0.19	0.19
				M2				
V_T	0.28	0.75	0.05	0.06	0.16	0.63	0.79	0.77
V_C	0.00	0.02	0.02	0.00	0.08	0.00	0.00	0.00
V_e	0.72	0.23	0.93	0.94	0.76	0.37	0.21	0.23
				M3				
V_T	0.40	0.74	0.05	0.04	0.16	0.60	0.79	0.77
V_R	0.36	0.00	0.00	0.00	0.06	0.00	0.01	0.03
V_C	0.00	0.02	0.01	0.00	0.08	0.00	0.00	0.00
V_e	0.24	0.24	0.94	0.96	0.69	0.40	0.19	0.20

V= variance component, V_T = Treatment (variety) variance, V_R =Row blocking variance, V_C = Column blocking variance, V_e=error variance, GY=grain yield, PH=plant height, NP=number of plants, WBW= whole bag weight, WPW=whole pod weight, NS=number of seed per pod, HPW=100-pod weight, SWHP=seed weight of 100-pod.

Table 9. Estimated variance components for the soil properties in 2013 at Volga

V	GY	OM	P	K	pH	Zn	Fe	Cu	Mn	Ca	Mg	Na	CEC
V_R	3.74	0.08*	3.35*	112.84*	0.01*	0.02*	46.74*	0.002^	6.18*	86.78*	611.10*	1.50+	1.83*
V_C	0.02	0.00	0.61	52.29+	0.00	0.00	0.30	0.001	0.21	0.00	4.95	0.00	0.01
V_e	7.37	0.04	10.72	131.853	0.01	0.04	18.57	0.005	7.33	4772.45	240.80	4.99	1.04

V= variance component, V_R =Row blocking variance, V_C = Column blocking variance, V_e=error variance, GY=grain yield
*, ^, +, are Significant at 0.00, 0.05, 0.1

significance, row-columns direction existed for soil K nutrient. Potassium is a macro-nutrient needed by plants for better growth and development. Potassium, from a stepwise regression analysis, showed significant effect on plant height, number of plants, and whole bag weight. Thus, with respect to soil K nutrient, homogenous block assumption required by most standard design is violated. The results suggested that the blocking following the row direction was more appropriate than the column direction. The results were also consistent with those from our augmented experimental design analyses.

Summary

In many breeding programs augmenting the experimental design based on the field layout can be a valuable aid to improve selection precision. Yield and yield component data from a one-year soybean variety trial were analyzed by augmenting a classical RCB design for further understanding of soil variability that impacted yield and yield component traits. In order to check for the existence of soil heterogeneity, the data was analyzed based on three models. This study demonstrated that augmented models could detect heterogeneity existed in multiple directions for K soil nutrient and row direction for the soil properties considered in this study.

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