EVALUATION OF SOYBEAN FOR GRAIN YIELD AND YIELD COMPONENTS AT VARYING LEVELS OF PHOSPHORUS IN MAKURDI (SOUTHERN GUINEA SAVANNA), NIGERIA

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ABSTRACT

Field experiments were conducted during the 2012 and 2013 cropping seasons at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi, Benue State, Nigeria, to evaluate soybean for grain yield and yield components at varying levels of Phosphorus (P). Treatments were 4 x 7 factorial combinations of four levels of phosphorus (0, 20, 40 and 60P) and seven varieties of soybean in a randomized complete block design with three replications. Results showed that the 40P level of phosphorus significantly improved grain yield and the yield components of nodule score, plant height, and number of pods/plant compared to other levels of P, indicating 40kgP_2O_5/ha as the most appropriate level of phosphorus required for soybean production in Makurdi and that any application beyond this level is counterproductive. Four varieties (TGX 1895-35F, Milena, TGX 1485-1D and TGX 1448-2E) with grain yield of 3.33 – 4.38t/ha at 40P (222.22kg single superphosphate fertilizer/ha) were suggested for subsequent evaluation at 0, 30, 40 and 50P prior to final recommendation for production. The two early maturing varieties (Milena and TGX 1485-1D) among them were recommended for resource poor farmers in Makurdi area (Benue State) of the southern Guinea Savanna ecology of Nigeria in view of their outstanding performance (grain yield of 2.92 – 3.11t/ha) when no fertilizer was applied. Crossing of Milena to adapted late maturing IITA improved varieties of TGX 1895-35F and TGX 1448-2E and selecting for phosphorus use efficiency in the segregating populations is further suggested.

Keywords: Phosphorus, prepodding, postpodding, southern Guinea Savanna.

INTRODUCTION

Soybean (Glycine max (L.) Merrill) is one of the most frequently cultivated crops across a wide range of agro-geographical regions from China to Brazil and from Oceania to Canada and even in Nigeria (Giller and Dashiell, 2007) because of its nutritional, industrial and economic importance. Soybean has an average protein content of 40% and is richer in protein than any of the common vegetable or animal feed sources in Nigeria. Soybean seeds also contain about 20% oil on a dry matter basis with 85% unsaturated fatty acid that is cholesterol-free (IITA, 2009).

Commercial production of soybean is concentrated in the Savanna ecology of Nigeria, particularly the southern Guinea Savanna (Akande et al., 2007; Ojo et al., 2010), where low levels of phosphorus militate against its optimal yield. Phosphorus is generally a critical element in the production of legumes and soybean in particular. Phosphorus has beneficial effects on both nodulation and nitrogen fixation capacity of soybean (Gates, 1975) and has been shown to be very important for dry matter production (Idri et al., 1989), growth, development and yield of the crop (Kakar et al., 2002). Its deficiency can limit nodulation (Carsky et al. 2001), aggravate pods abortion and reduce yield (Chiezey, 2001), with obvious negative effect on the plant root system and tolerance to stresses.

Previous studies on the evaluation of soybean in its traditional area of production in Nigeria (southern Guinea Savanna ecology) have either excluded the application of phosphorus fertilizer (Akande et al., 2007) or used low levels of it (Aduloji et al., 2009; Ojo et al., 2013) in their experiments. Moreover, these previous studies have concentrated on only IITA improved varieties in their studies. Hence there is need for information on the response of soybean across a wide range of phosphorus levels in the soil and diverse soybean genotypes towards a broad based conclusion on such evaluation. This research work was therefore initiated with the objective of evaluating soybean at varying levels of Phosphorus with a view of determining the appropriate level for its production in a southern Guinea Savanna location of Makurdi.

MATERIALS AND METHOD

Experimental site

The experiment was carried out during the 2012 and 2013 cropping seasons between the months of July and December at the Teaching and Research Farm of the Federal University of Agriculture Makurdi (latitude 7.41^0N and Longitude 8.28^0E). The location falls within the southern Guinea Savanna agro-ecological zone of Nigeria. No superphosphate or muriate of potash or any compound fertilizer had been applied to the soil in the last 5 years prior to the experiment.

Soybean genotypes

Seven varieties of soybean (four varieties from Brazil and three varieties from Nigeria) were evaluated in the experiment. Varietal Name, Source of Seed, Flower Colour and Maturity Group are summarized in Table 1. The four Brazilian varieties were obtained from Embrapa (Brazilian Agricultural Research Cooperation), while the three Nigerian varieties were obtained from IITA (Nigeria International Institute of Tropical Agriculture). All the Nigeria varieties are tropically adapted varieties of soybean developed for the country by IITA, Ibadan. The TGX 1448-2E was used as the local check because it is the popular high yielding variety that is resistant/tolerant to many abiotic and biotic stresses in the commercial soybean growing areas (Guinea Savanna ecology) of Nigeria.

Agricultural practices and Experimental layout

Treatments were 4 x 7 factorial combinations of four levels of phosphorus (0, 20, 40 and 60P) and seven varieties of soybean in a randomized complete block design with three replications. Seeds were drilled into the crest of ridges on the 1st and 6th of July 2012 and 2013 respectively, and later thinned down to 26 seedlings per meter at two weeks after planting. Four (4) rows of 4m length ridges spaced 0.75m apart constituted a plot ($12m^2$). The field was sprayed immediately after planting with 200mls Pendimethalin (pre-emergence herbicide) in 20litre of water using knapsack sprayer, while supplementary hoe weeding was carried out at 5 - 6 weeks after planting.

Single Super Phosphate (SSP) fertilizer was applied by drilling appropriate quantity of the fertilizer into the ridges beside the seedlings at two weeks after planting. No fertilizer was applied to the plots with 0P (0 level of Phosphorus).

Data collection

The following observations were recorded during the conduct of the experiment:
Days to flowering - number of days from sowing to when half of the plants in each plot flowered.
Days to podding - number of days from planting to when half of the plant population begins to produce pods in each plot.
Nodulation score at podding - random sample of five plants from each plot and recording their score on a 1 – 5 scale.
Dry Matter/plant at podding – mean weight (g) of a random sample of five plants from each plot after oven drying for 48 hours.
Leaflet count at apical node - mean number of leaflets of a random sample of five plants from each plot at the apical node.
Days to maturity - number of days from planting date to when half of the plants in each plot had dried up.
Plant height at harvest - mean height (cm) of a random sample of five plants from each plot at harvest.
Height of lowest pod - mean height (cm) of lowest pod from a random sample of five plants in each plot at harvest.
Number of pods per plant - mean number of pods from a random sample of five plants in each plot at harvest.
100 seed weight – mean of duplicate 100 seed weights (g) taken from the seed lot of each plot.
Grain yield - the weight of grains was taken after threshing and winnowing of the harvested grains in each plot which was later extrapolated to grain yield per hectare.

Statistical Analysis

All the data collected were subjected to Analysis of Variance procedures using the General Linear Model of SAS (2007).

RESULTS

The mean squares for grain yield and yield components of seven varieties of soybean at four levels of Phosphorus fertilizer in Makurdi are presented in Table 3. No significant difference in replication was observed for all the traits studied. Significant difference in phosphorus levels (0P, 20P, 40P and 60P) was observed for nodulation score at podding. Phosphorus level was also highly significantly different for plant height at harvest, number of pods per plant and grain yield. Highly significant difference in varieties was observed for almost all the characters, namely, days to flowering, days to podding, days to maturity, nodulation score at podding, leaflet count at apical node, plant height at harvest, number of pods per plant, 100 seed weight and grain yield (t/ha). Significant difference in varieties was also observed for height of lowest pod. Phosphorus X variety interaction was highly significant for only number of pods per plant and grain yield.

Nodulation score ranged from 1.75 at 20P to 2.46 at 40P per plant (Figure 1). The highest nodulation score of 2.46 at 40P was however not significantly different from the nodulation score at other levels of phosphorus except 20P. Plant height at harvest ranged from 46.96cm at 60P to 59.15cm at 40P (Figure 2).

The variety Milena was earlier (41.67) in terms of days to flowering and significantly different from the other varieties (Table 4). The late maturing variety TGX 1895-35F flowered later with significant difference in days compared to other varieties except Conqvista and Savanna.

Days to podding ranged from 57.08 days for Milena to 73.2 days for TGX 1895-35F. The number of days to podding for TGX 1895-35F was significantly different from that of other varieties.

The variety Milena was earliest (89.6) in terms of days to maturity and significantly different from the other varieties. The late maturing variety TGX 1895-35F matured later with significant difference in days from the other varieties.

Nodulation score at podding ranged from 1.383 for Milena to 2.467 for TGX 1448-2E. Nodulation score for TGX 1448-2E was significantly different from that of other varieties except for Savanna and Conqvista. The variety Savanna was also significantly different from TGX 1895-35F, Milena and IAC-21 in terms nodulation score. The trend in leaflet count at apical node is similar to that of nodulation score, as it ranged from 2.767 for Milena to 3.550 for TGX 1448-2E. The variety TGX 1448-2E was significantly different from the other varieties in terms leaflet count.

Height of lowest pod was least in Milena (6.47cm) and highest in TGX 1895-35F (8.57cm). Height of lowest pod for TGX 1895-35F was significantly different from that of Milena and no significant difference in height was observed among the other varieties. The trend in plant height at harvest was least in Milena (44.03cm) and highest in TGX 1895-35F (75.18cm). The variety TGX 1895-35F was significantly taller at harvest compared to all the other varieties.

Variety TGX 1485-1D (16.04g) recorded the highest weight in terms of 100 seed weight while Conqvista was the least with 10.38g. The 100 seed weight for TGX 1485-1D was significantly different from that of other varieties except for Milena. The variety Milena was significantly different from Conqvista, IAC-21, Savanna and TGX 1895-35F except for TGX 1448-2E while TGX 1448-2E was also significantly different from Conqvista.

The variety Conqvista recorded the least number of pods per plant (57.7) at the highest level of phosphorus (60kg) while TGX 1895-35F produced the highest number of pods per plant (257.5) at 40kg level of phosphorus (Table 5). All the varieties recorded their highest number of pods per plant at 40P and the least number of pods per plant at 0P or 60P with Milena recording the highest number of pods per plant when no phosphorus was applied.

The late maturing variety, TGX 1895-35F recorded the highest grain yield of 4.38t/ha at 40P and was closely followed by an early maturing variety, Milena, with 4.03t/ha at the same level (Table 6). All the varieties recorded their highest grain yield at 40P and the least grain yield at 0P or 60P with Milena recording the highest grain yield of 3.11t/ha at 0P (no fertilizer).

DISCUSSION

The non significant years and replication (years) observed for all the traits studied, is an indication of uniformity of the fields used for the experiments. The non significant effect of

phosphorus observed for the prepodding traits of days to flowering, days to podding, days to maturity, dry matter weight at podding and leaflet count at apical node is an indication that these traits are least affected by changes in the nutrient status of the soil. The phosphorus fertilizer used (single superphosphate) is a slow release fertilizer and couldn't have released enough phosphorus to cause significant differences in the growth of the crop between the different levels of the nutrient as at the time of recording data for prepodding traits. The significant and highly significant effect of phosphorus on post podding traits of nodulation score at podding, plant height at harvest, number of pods per plant and grain yield observed in the current work had been previously observed (Chiezey et al., 1991, 1992, 2001; Anzaku and Anzaku, 2002; Alpha et al., 2006) and attributed to the importance of phosphorus fertilizer application to soybean in the improvement of these traits. The significant difference between 40P and other levels of phosphorus (0, 20 and 60P) for these post podding traits is an indication that 40P is the most appropriate level of phosphorus for soybean production in the study area (Makurdi) and any application of phosphorus fertilizer beyond 40P is counterproductive. This observation is consistent with the findings of Seguin and Zheng (2006) that levels of phosphorus above adequate doesn't result in any significant response by soybean crop.

The highly significant and significant varietal effect observed for almost all the traits studied is consistent with previous findings on growth and grain yield in soybean for the same ecology (Akande et al., 2007; Aduloju et al., 2009; Ojo et al., 2014) and it is an indication of genetic diversity for the studied traits in the varieties evaluated.

The range of values observed for plant height, number of pods/plant and grain yield in the current work is consistent with the values reported by Ojo et al. (2013) but far exceed the upper limits in the findings of Akande et al. (2007) and Aduloju et al. (2009) for the same ecology (southern Guinea Savanna) of Nigeria. These differences had been previously attributed to variations in genotypes and locations (Ojo et al., 2013). Unlike in the previous studies where all the genotypes were sourced from IITA, the current work sourced germplasm from both IITA (Nigeria) and Embrapa (Brazil). Moreover the phosphorus application level ranged from 0P (no applied phosphorus) to 60P, exceeding the phosphorus level in all the three previous studies within the same ecology. The highest number of pods/plant and grain yield observed at added phosphorus level of $40kgP_2O_5$/ha to the indigenous soil phosphorus (3.8 – 4.6 mg/kg) of the experimental site is below the upper limit of soil concentration of 12 ppm (Bray-1 test) suggested by Ferguson et al,. (2006).

The exceptional performance of Milena and TGX 1485 – 1D when no phosphorus fertilizer was applied, contradicts the suggestion by Fageria et al., (1995) that very large quantities of P fertilizer may be required for successful soybean production and gives credibility to the assertion that soybean can be easily produced without much fertilizer input (Ojo et al., 2010). The high grain yield observed for the two early maturing varieties (Milena and TGX 1485 – 1D) when no phosphorus fertilizer was applied, is an indication of their suitability for production by resource poor farmers. The highest grain yield observed for TGX 1895-35F, Milena, TGX 1485-1D and TGX 1448-2E at 40P indicates that they should be selected for production by farmers using 222.22kg/ha of single superphosphate fertilizer in the Makurdi area (Benue State) of the southern Guinea Savanna ecology of Nigeria. Further studies on evaluation of Milena and the three IITA varieties (TGX 1895-35F, TGX 1485-1D and TGX 1448-2E) at 0, 30, 40 and 50P is required prior to final recommendation of the appropriate level of phosphorus fertilizer for optimum grain yield in the Makurdi environment (Benue State) of the southern Guinea Savanna ecology of Nigeria. Crossing of Milena to adapted late

maturing IITA improved varieties of TGX 1895-35F and TGX 1448-2E and selection for phosphorus use efficiency in the segregating populations is further suggested.

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Table 1: Varieties, Source of Seed, Flower Colour and Maturity Group of genotypes used in the experiment

Varieties	Source of Seed	Flower Colour	Maturity Group
IAC-21	Embrapa	Purple	Early
Conqvista	Embrapa	Purple	Early
Milena	Embrapa	Purple	Early
Savanna	Embrapa	Purple	Late
TGX 1448-2E	IITA	Purple	Late
TGX 1485-1D	IITA	Purple	Early
TGX 1895-35F	IITA	White	Late

Embrapa - Brazilian Agricultural Research Cooperation**.**
IITA - International Institute of Tropical Agriculture, Ibadan

Table 2: Physical and chemical properties of the experimental sites in 2012 and 2013

Soil characteristics	2012	2013
Sand (%)	87.10	73.20
Silt (%)	14.00	12.10
Clay (%)	14.20	14.70
Textural Class	Sandy Loam	Sandy Loam
PH (H_2O)	6.42	6.48
PH (KCl)	5.01	5.66
Organic Matter (%)	1.66	1.54
Organic Carbon (%)	0.96	0.89
Total Nitrogen (%)	0.75	0.09
Available P ($mgkg^{-1}$)	4.6	3.80
Exchangeable Ca ($cmolkg^{-1}$)	3.30	3.99
Exchangeable K ($cmolkg^{-1}$)	0.31	0.30
Exchangeable Mg ($cmolkg^{-1}$)	1.41	1.81
Exchangeable Na ($cmolkg^{-1}$)	0.56	0.87
CEC ($cmolkg^{-1}$)	5.30	7.60
Base Saturation (%)	85.1	89.4

Table 3: Mean Squares for grain yield and yield components of soybean evaluated at four levels of phosphorus during the 2012 and 2013 cropping seasons in Makurdi

Source of Variation	df	DF	DP	DM	NSC	DM	LCAN	HLP	PH	NPP	SDW	GYLD
Years	1	12.01	15.22	23.64	0.51	13.5	0.08	1.01	13.32	35.43	2.37	1.45
Rep (years)	4	26.62	66.15	70.70	1.12	20.90	0.14	0.01	54.60	520.10	4.93	1.10
Phosphorus	3	42.75	72.81	100.70	1.89*	233.80	0.09	4.86	558.90**	11056**	5.14	4.30**
Variety	6	241.44**	262.37**	885.10**	1.86**	220.10	0.69**	5.79*	1394.14**	5932**	47.61**	6.81**
Phosphorus X Variety	18	23.77	47.91	121.00	0.57	88.30	0.11	2.69	47.06	2909**	6.46	2.21**
pooled error	135	26.41	48.86	122.4	0.52	114.30	0.13	2.06	65.91	1195	4.93	0.83

=** significant at P<0.05 *=** significant at P<0.01 **DF =** Days to flowering **DP =** Days to podding **DM =** Days to maturity
DM = Dry matter / plant at podding (g) **NSC** = Nodulation score at podding **LCAN** = Leaflet count at apical node
HLP = Height of lowest pod **PH** = Plant height at harvest. **NPP** = Number of pods per plant **GYLD** = Grain yield (t/ha)
SDW = 100 seed weight (g)

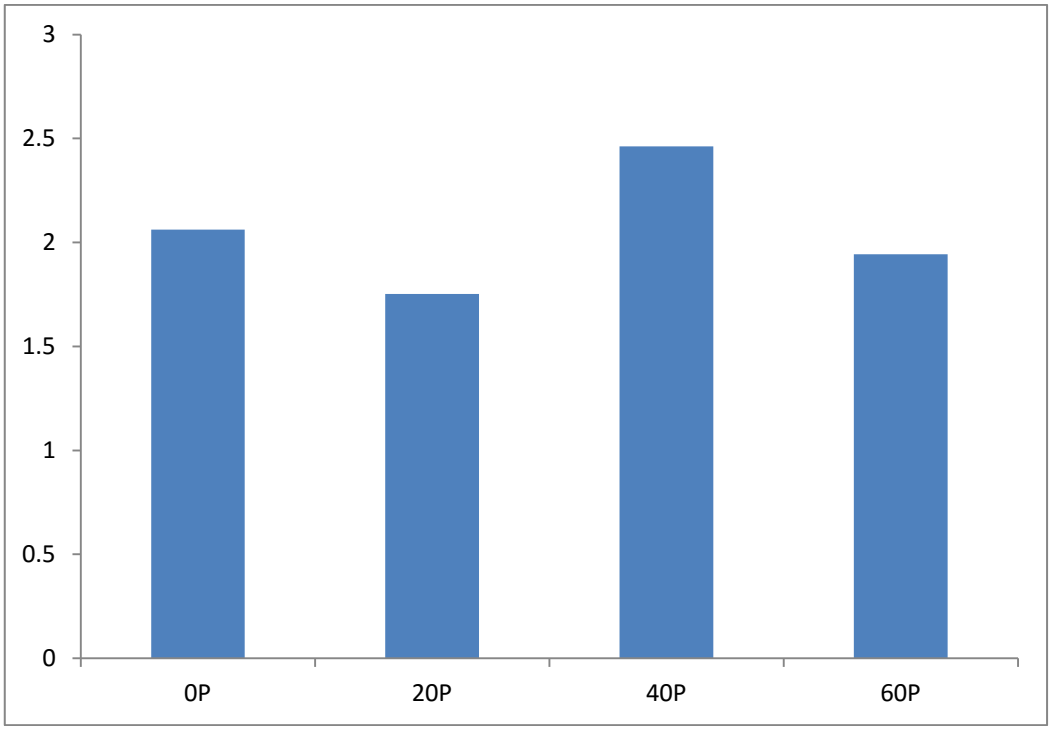

Figure 1: Nodulation score at podding

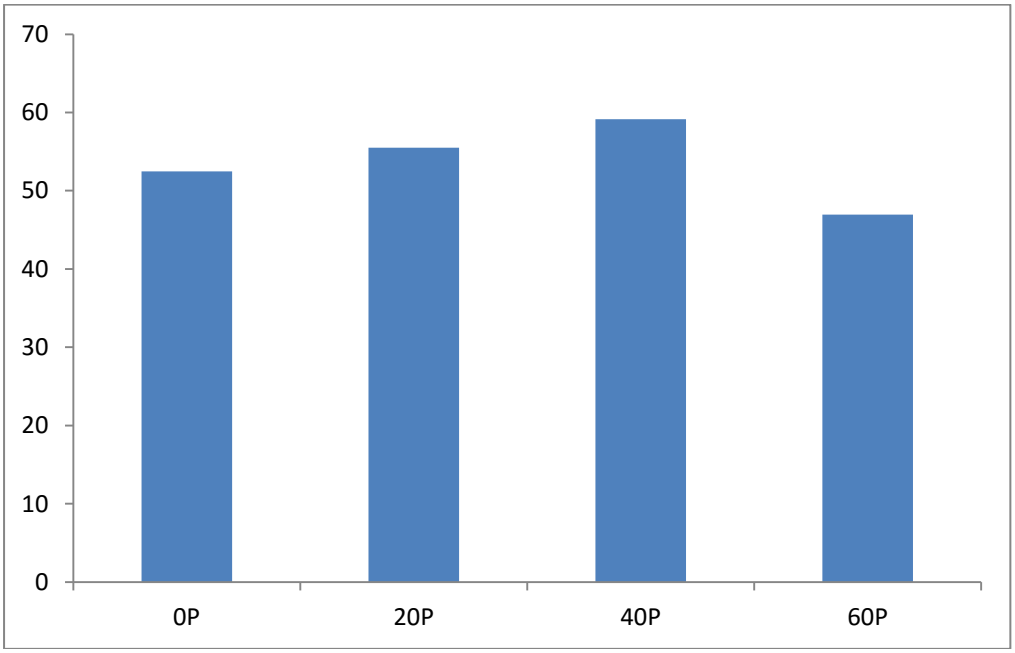

Figure 2: Plant height at harvest

Table 4: Main effect of variety on grain yield and other agronomic traits of seven varieties of soybean evaluated at four levels of phosphorus during the 2012 and 2013 cropping season in Makurdi

Varieties	DF	DP	DM	NSC	LCAN	HLP	PH	NPP	GYLD	SDW
IAC-21	50.67	64.33	102.80	1.90	3.02	8.04	50.73	99.2	1.42	11.45
Conqvista	52.83	64.67	102.20	2.38	3.00	8.03	50.77	86.2	1.87	10.38
Milena	41.67	57.08	89.60	1.38	2.77	6.47	44.03	104.4	3.52	14.92
Savanna	52.67	66.08	102.70	2.43	3.02	8.04	59.04	109.8	2.33	12.00
TGX 1448-2E	48.42	64.75	103.20	2.47	3.55	7.72	50.48	116.7	2.08	13.47
TGX 1485-1D	48.92	64.83	101.20	1.98	3.14	7.18	44.43	82.6	2.90	16.04
TGX 1895-35F	55.67	73.17	119.10	1.85	3.00	8.57	75.18	149.1	3.16	12.37
LSD(5%)	4.15	4.34	7.14	0.47	0.33	1.734	5.718	33.44	1.05	1.78

DF = Days to 50% flowering **DP =** Days to 50% podding **DM =** Days to 50% maturity
NSC = Nodulation score at 50% podding **LCAN** = Leaflet count at apical node **HLP** = Height of lowest pod (cm)
PH = Plant height at harvest (m) **NPP** = Number of pods per plant **GYLD** = Grain yield (t/ha) **SDW** = 100 seed weight (g)

Table 5: Main effect of soybean variety interaction with P level on number of pods per plant

Variety	0P	20P	40P	60P
IAC-21	84.50	98.50	113.50	100.50
Conqvista	90.00	97.90	99.30	57.70
Milena	114.80	133.10	134.30	73.50
Savanna	110.50	110.50	129.50	88.50
TGX 1448-2E	93.70	114.70	167.90	90.70
TGX 1485-1D	82.90	90.30	95.80	61.30
TGX 1895-35F	100.30	152.70	257.50	85.80
LSD(5%)	59.27			

Table 6: Main effect of soybean variety interaction with P level on grain yield

Variety	0P	20P	40P	60P
IAC-21	0.86	1.61	1.99	1.22
Conqvista	1.49	2.03	2.63	1.33
Milena	3.11	3.93	4.03	3.03
Savanna	1.78	2.48	2.93	2.11
TGX 1448-2E	1.28	1.89	3.33	2.82
TGX 1485-1D	2.92	2.92	3.52	2.23
TGX 1895-35F	1.19	3.39	4.38	2.89
LSD(5%)	1.64			