

ASSOCIATION ANALYSIS OF SEED YIELD AND OTHER AGRONOMIC TRAITS OF SOYBEAN IN DIFFERENT SOIL pH REGIMES

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Abstract

Seven soybean genotypes were screened for two years (2004 and 2005) at The Department of Crop Science, University of Nigeria, Nsukka, Nigeria to investigate the response of soybean to different levels of soil pH and to identify the underlying traits associated with low pH tolerance in soybean. The experimental design used was a 9 (soil pH levels) x 7 (soybean genotypes) factorial in a completely randomized design with three replications. Hydrochloric acid and calcium hydroxide were used as amendment materials to decrease and raise the soil pH, respectively to the desired pH levels. The regression analyses revealed that seed yield per plant; pod weight per plant; number of pods per plant and number of nodules per plant showed persistent reduction with decreasing soil pH. The correlation analyses showed that the number of leaves per plant, number of pods per plant, pod weight per plant and days to podding had positive correlations with seed yield per plant across all the soil pH levels. In addition, days to flowering, fresh root weight, dry root weight and number of nodules per plant exhibited positive and negative correlations with seed yield per plant under high and low soil pH, respectively. The correlation suggests that seed yield per plant of Nigerian soybeans under acidic soils can be indirectly improved by favourable selection of these traits under high soil pH.

Key words: Soybean, Seed Yield, Soil pH, Soil Acidity, Regression, Correlation, Trait.

Introduction

Soybean (*Glycine max* (L.) Merrill), a leguminous crop, is one of the most important and extensively grown crops that accounts for 30% of the world's processed vegetable oil and also has been employed as a source for bio-diesel fuels (Graham and Vance, 2003). Approximately one-third of the world's edible oils and two-third of the world's protein meal are derived from soybean (Golbitz, 2004; Temperly and Borges, 2006). It is considered a "miracle bean" due to its extraordinary qualities as it contains 40 – 42% good quality protein, 6% ash, 29% carbohydrate and 18 – 22% oil comprising 85% unsaturated fatty acids (free from cholesterol) with two essential fatty acids (linoleic and linolenic acid), which are not synthesized by human body (Antalina, 2000; Balasubramanian and Palaniappan, 2003). The crop can also improve soil nutrient status and farming system when grown solely and/or in combination with other crops. Nigeria is the largest producer of soybean in sub-saharan Africa (SSA) followed by South Africa (IITA, 2013); this is because the crop has gained popularity that out ranked cowpea (*Vigna unguiculata* [L.] Walp) in its potential to supply high quality protein (Akande *et al.*, 2007) and the ability to sustain the world's

increasing demand for food and forage (Alghamdi, 2004).

Although soybean has a fairly wide range of adaptation involving a wide array of soil conditions, soil acidity is one of the most important limitations to agricultural production worldwide (von Uexküll and Mutert, 1995; Kochian *et al.*, 2004). It is estimated that about 30% of the world's land surface is acidic (pH < 5.5), with up to 40% of arable land affected by soil acidity (Vonuekull and Mutert, 1995). Acidic soils can be ameliorated by the use of lime; the extra cost of liming material further limits the preference of the poor resource farmers (Uguru *et al.* 2012). In addition, poor mixing of liming materials (e.g. CaCO₃) with soil (Calder *et al.*, 1965) and over liming can reduce crop yield (Farina *et al.*, 1980; Brett, *et al.*, 2013). Bellogin *et al.* (2001) therefore reported that the most effective means to improve nodulation under low soil pH conditions is to use acid-tolerant legume cultivars. Although some aboriginal Nigeria landraces of soybean can survive under low soil fertility and relatively low pH status of the humid tropics (Maduakor, 1991), the yield is critically low due to persistent acidic nature of the tropics. Thus, it is very pertinent to study the underlying traits influencing yield of

commonly grown soybean genotypes under low soil pH environments foreffective breeding for enhanced acid tolerance.

Based on this, the objective of this study were to investigate the response of key traits of soybean to different levels of soil pH and identify the underlying traits associated with low pH tolerance in soybean.

Materials and Methods

Experimental Site

The pot experiment was conducted in 2004 and 2005 cropping seasons (April to August) at the Research and Teaching Farm of the Department of Crop Science, University of

Nigeria, Nsukka (Latitude 06° 52' N; Longitude 07° 24'E; 447.2 m above the sea level). Nsukka is characterized by lowland humid tropical conditions with bimodal annual rainfall distribution that ranges from 1155 mm to 1955 mm with a shift in the second peak of rainfall from September to October, a mean annual temperature of 29 ° C to 31 ° C and a relative humidity that ranges from 69% to 79 % (Uguru *et al.*, 2011).The monthly temperature, number of rainy days and rainfall distribution of the location during the crop growing periods are presented in Table 1.

Table 1: mean temperature (°C), rainfall (mm) and the number of rain days during the experimental period.

Month	Min.	Max	Rainy Days	Rainfall (mm)
	Temp (°C) (± SEM)**			(± SEM)**
2004				
January	21.03±0.42	32.58±0.23	1	0.05±0.05
February	22.29±0.33	34.38±0.26	0	-
March	23.52±0.228	34.00±0.44	3	1.19±0.22
April	22.80±0.25	31.90±0.32	6	1.90±1.25
May	23.55±0.33	29.90±0.33	20	8.30±2.44
June	21.76±0.2.5	28.88±0.23	13	9.37±3.32
July	20.84±0.13	27.65±0.26	18	5.37±1.80
August	20.84. ±0.13	27.65±0.26	23	5.44±1.46
September	20.47±0.20	28.13±0.22	21	11.31±2.73
October	20.84±0.21	28.23±0.28	14	4.81±1.27
November	21.67±0.32	30.00±0.22	5	2.63±1.60
December	19.74±0.56	31.94±0.23	1	0.05±0.05
2005				
January	20.23±0.35	31.68±0.36	0	-
February	22.86±0.27	34.93±0.20	2	2.522±1.897
March	23.32±0.27	34.48±0.27	2	0.484±0.459
April	23.17±0.25	33.63±0.40	10	4.936±2.651
May	22.26±0.25	30.68±0.35	11	4.597±1.519
June	21.82±0.29	29.49±0.30	18	10.79±3.30
July	20.97±0.28	29.32±0.33	20	8.267±2.602
August	20.39±0.20	37.39±0.306	17	4.048±1.765
September	21.50±0.24	28.73±0.20	19	6.935±2.307
October	21.16±0.24	30.10±0.23	16	17.71±9.87
November	21.37±0.49	32.43±0.19	1	0.3387±0.3387
December	20.71±0.30	32.42±0.21	1	0.0410±0.0410

Source: Meteorological station, Department of Crop Science, UNN

Genetic Materials

The planting materials for this study comprised one improved soybean cultivar, 'TGX1448-2E' obtained from the National Cereal Research institute (NCRI), sub- station at Yandev- Gboko, Benue State, and six accessions of soybean collected from local farmers in Adamawa, Benue and Taraba States, Nigeria, which included; 'Kyado', 'Digil', 'Gembu', 'Garkida', 'Sebore' and 'Sunkani'.

Experimental Design

The experimental design used was a factorial in a completely randomized design (CRD) with three (3) replications. The nine pH levels served as factor A while the seven (7) soybean accessions served as factor B giving a total of 63 treatment combinations. Each treatment combination was replicated three times totaling to 189 experimental units.

Trial Establishment

A total of one hundred and eighty-nine (189) polythene bags measuring 40cm in height and 19cm in diameter were used for planting the soybean. Each polythene bag was filled with 4kg of soil collected from 0-20cm depth of a 2-year fallow. The bagged soils were moistened to field capacity and amended to desired pH levels of 7, 6.5, 6.0, 5.5, 5.0, 4.5, 4.0, 3.5 and 3.0 (Table 2). Hydrochloric acid (HCL) and calcium hydroxide $\text{Ca}(\text{OH})_2$ were used as amendment materials to decrease and raise the soil pH, respectively to the desired pH levels. The quantities required to raise or reduce the soil pH were determined in the laboratory (Table 2).

Table 2: initial pH value of the soil at the beginning of the experiment

pH value	Quantity of soil amendment material
7.0	4.4g $\text{Ca}(\text{OH})_2$
6.5	3.2g $\text{Ca}(\text{OH})_2$
6.0	2.36g $\text{Ca}(\text{OH})_2$
5.5	1.2g $\text{Ca}(\text{OH})_2$
5.0	No amendment
4.5	12cm ³ HCl
4.0	36cm ³ HCl
3.5	64cm ³ HCl
3.0	152cm ³ HCl

Data collection and analysis

Data were collected on ; plant height (cm), number of leaves per plant, days to 50% flowering, days to 50% podding, number of pods per plant, number of nodules per plant, root length (cm), pod weight per plant (g), seed yield per plant (g), fresh root weight (g) and dry root weight (g). Data for the two years were pooled and used for the regression and correlation analyses. Regression was done using Microsoft excel 2010 package while correlation was performed with SPSS 16 version software.

Results and Discussion

Regression analyses of the seed yield, pod weight, number of pods and number of nodules with different soil pH

The regression equation (fig.1) of seed yield per plant (g) over different levels of soil pH was; $Y = 0.944x - 3.1261$ where Y= seed yield per plant and x= different levels of soil pH with a coefficient of determination (R^2) of 0.3458. The regression line for pod weight per plant (g) over different soil pH conditions was; $Y = 1.3061x - 4.1683$ (where Y= pod weight per plant and x= different levels of soil pH) with a coefficient of determination (R^2) of 0.3849. The prediction line of number of pods per plant over.

different soil pH was; $Y = 4.4448x - 15.432$ (where Y = number of pods per plant and x = different levels of soil pH) with a coefficient of determination (R^2) of 0.5305. The regression line of number of nodules per plant over different soil pH levels was predicted as; $Y = 5.7543x - 26.34$ (where Y = number of nodules per plant and x = different levels of soil pH) with a coefficient of determination (R^2) of 0.7476. All the traits showed persistent reduction with decreasing soil pH, with the number of nodules per plant showing the highest reduction.

Correlation analyses between seed yield and other traits

The soybean seeds did not survive at low soil pH of 3.0, 3.5 and 4.0, thus the correlation between seed yield per plant and other agronomic traits across the other soil pH levels is presented in Table 3. Number of pod per plant and pod weight per plant correlated positively with seed yield per plant across all the soil pH levels. The correlation between pod weight per plant and seed yield per plant was highly significant ($P < 0.01$) at all the pH levels, whereas the correlation between seed yield per plant and number of pods per plant was significant ($p < 0.05$) in all the soil pH levels

except at pH 7.0 and 5.0. Days to podding also correlated positively with seed yield per plant across all the soil pH level with the exception of pH 6.0. The results also showed that plant height had negative correlation with seed yield per plant at all the soil pH levels excluding pH 6.0 and 4.5. Days to flowering exhibited positive correlation with seed yield per plant at the higher soil pH values (6.5 and 7.0) but correlated negatively with seed yield per plant at the lower soil pH values (6.0, 5.5, 5.0 and 4.5). These were however not significant statistically. Number of nodules per plant correlated positively with seed yield per plant at the higher soil pH levels of 6.5 and 6.0 with exception of pH 7.0, but showed negative correlation with seed yield per plant at the lower soil pH levels (5.5, 5.0 and 4.5). Root length had positive correlation with seed yield per plant at all the soil pH levels except at pH 7.0 and 5.5. Fresh root weight and dry root weight had positive correlation with seed yield per plant at the higher soil pH conditions (6.5, 6.0 and 5.5) excluding pH 7.0 (-0.201), but they correlated negatively with seed yield per plant at the lower soil pH levels (5.0 and 4.5).

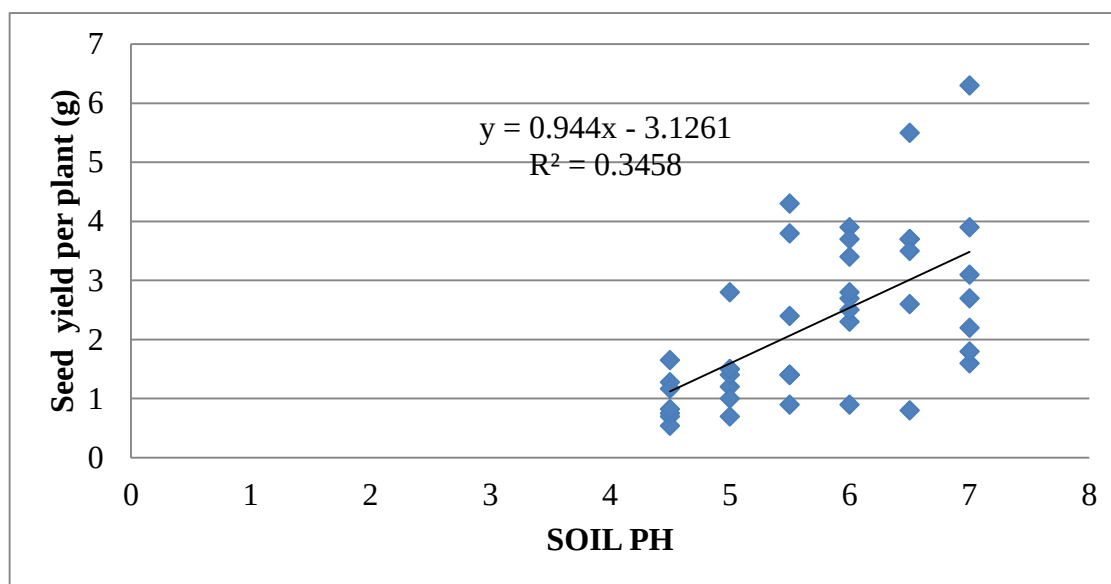


Figure 1: Regression analysis of seed yield of soybean at different soil P^H levels in 2004 and 2005

Table 3: Pearson correlation of seed yield with other agronomic traits of soybean grown under different soil P^H levels in 2004 and 2005

SOIL PH	PHT	NLV	DF	DP	NP	PW	NN	RL	FRW	DRW
7	-0.137	0.085	0.291	0.691	0.747	0.818**	-0.242	-0.201	-0.197	-0.356
6.5	-0.343	0.024	0.297	0.423	0.830*	0.901**	0.228	0.603	0.594	0.625
6.0	0.269	0.601	-0.169	-0.144	0.827*	0.887**	0.203	0.006	0.433	0.860*
5.5	-0.182	0.073	-0.202	0.139	0.896**	0.980**	-0.181	-0.581	0.037	0.244
5.0	-0.007	0.038	-0.369	0.092	0.682	0.926**	-0.073	0.014	-0.096	-0.299
4.5	0.274	0.494	-0.309	0.408	0.879**	0.983**	-0.074	0.010	-0.476	-0.534
4.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

PHT = plant height(cm), NLV = number of leaves per plant, DF = days to 50% flowering, DP = days to 50% podding, NP = number of pods per plant, PW = pod weight per plant (g), NN = number of nodules per plant, RL = root length (cm), FRW = fresh root weight (g), DRW = dry root weight (g), ND = No data taken, * = Significant at 5% probability level, ** = Significant at 1% probability level.

Correlation analyses between pod weight and other traits

The correlation of pod weight per plant with other traits is shown in Table 4. As with seed yield per plant, the number of leaves per plant and number of pods per plant correlated positively with pod weight per plant at all the soil pH. Plant height also showed consistent positive correlation with pod weight per plant, except at soil pH level 6.5 and 5.5. The result also indicated that days to flowering had negative correlation with pod weight per plant at all the soil pH levels except in soil pH 6.5. As obtained with seed yield per plant, and root length also displayed positive correlation with pod weight per plant at all the pH levels, excluding pH 7.0 and 5.5. In uniformity with seed yield per plant, fresh root weight and dry root weight had positive correlation with pod weight per plant at the higher soil pH levels (6.5, 6.0 and 5.5). There were statistically significant except at pH 7.0. They correlated negatively with pod weight per plant at the lower soil pH levels (5.0 and 4.5) as obtained in the correlation of seed yield per plant with fresh root weight and dry root weight.

The failure of the seed to germinate and grow at pH less than 4.5 could be as a result of high concentration of hydrochloric acid used which might have interacted with soil organic matter to produce phenolic inhibitory compounds that inhibited germination (Blum,

1996). Studies have also shown that Al^{3+} at different concentrations showed differential inhibitory effect on seed germination of white spruce, *Picea glauca* (Nosko *et al.*, 1988), Pigeon pea, *Cajanus cajan* (L.) Mills (Narayanan and Syamala, 1989), wheat, *Triticum aestivum* L. (Lima and Copeland, 1990) and Soybean, *Glycine max* (L.) Merrill (Uguru *et al.*, 2012). The regression analyses which indicates that persistent reduction seed yield per plant; pod weight per plant; number of pods per plant and number of nodules per plant persistent reduction with decreasing soil pH confirms the reports of Taylor (1988); Coronel *et al.* (1990); Mossor – Pietraszewska (2003) and Duressa *et al.* (2011). they reported that high levels of soil acidity can reduce root growth, reduce nutrient availability to plant, affect crop production activity and thus, resulting in poor plant growth and reduction in the agronomic yield. The reduction in number of nodules with decreasing soil pH observed in the present study agrees with report of Meng-Han *et al.* (2012) that total nodule number was highest at pH 6.8 (i.e near neutral) and reduced as the pH decreased. The substantial reduction in number of nodules with increase in soil acidity as revealed in the regression analysis could be attributed to low number of rhizobia and probably failure of rhizobia to attach and infect the root hairs (Meng – Han *et al.*, 2012) in high soil acidic conditions.

Table 4: Pearson correlation of pod weight with other agronomic traits of soybean grown under different soil P^H levels for the two years

SOIL PH	PHT	NLV	DF	DP	NP	NN	RL	FRW	DRW
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7.0	0.138	0.219	-0.008	0.318	0.759*	-0.618	0.026	-0.214	-0.235
6.5	-0.165	0.071	0.002	0.396	0.756*	0.088	0.554	0.454	0.540
6.0	0.282	0.840*	-0.189	-0.247	0.629	0.214	-0.229	0.437	0.822*
5.5	-0.106	0.228	-0.312	-0.009	0.919**	-0.246	-0.561	0.149	0.329
5.0	0.099	0.131	-0.478	0.014	0.766*	-0.226	-0.065	0.079	-0.219
4.5	0.223	0.446	-0.404	0.269	0.809*	-0.149	-0.036	-0.450	-0.487
4.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
3.5	ND	ND	ND	ND	ND	ND	ND	ND	ND

PHT = plant height (cm), NLV = number of leaves per plant, DF = days to 50% flowering, DP = days to 50% podding, NP = number of pods per plant, NN = number of nodules per plant, RL = root length (cm), FRW = fresh root weight (g), DRW = dry root weight (g), ND = No data taken, * = Significant at 5% probability level, ** = Significant at 1% probability level.

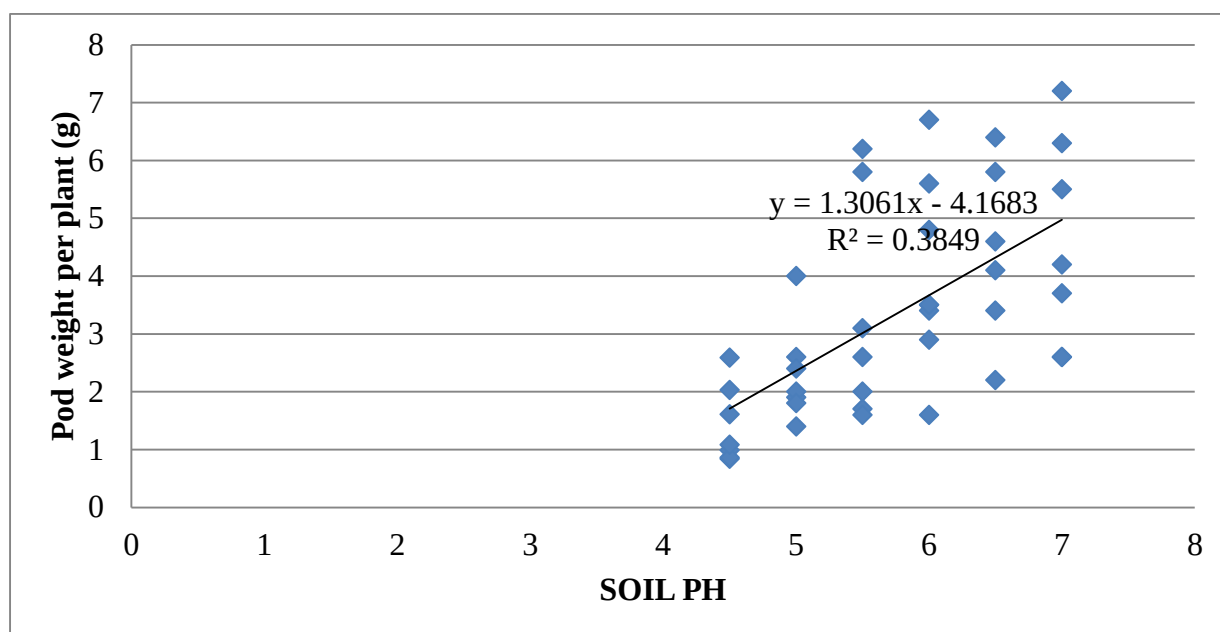


Figure 3: Regression analysis of pod weight of soybean at different soil P^H levels in 2004 and 2005

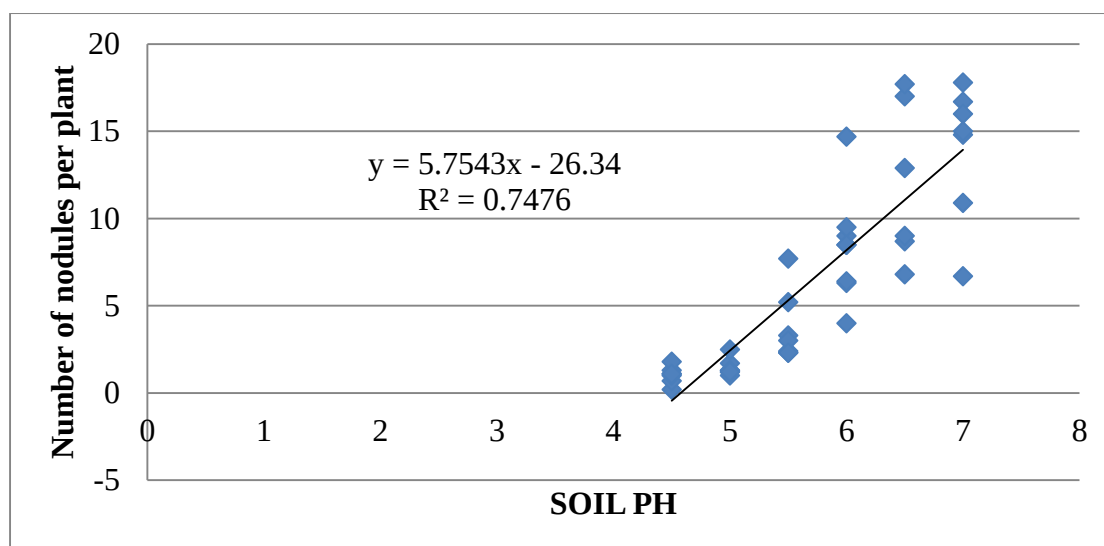


Figure 3: Regression analysis of number of nodules of soybean at different soil P^H levels in 2004 and 2005

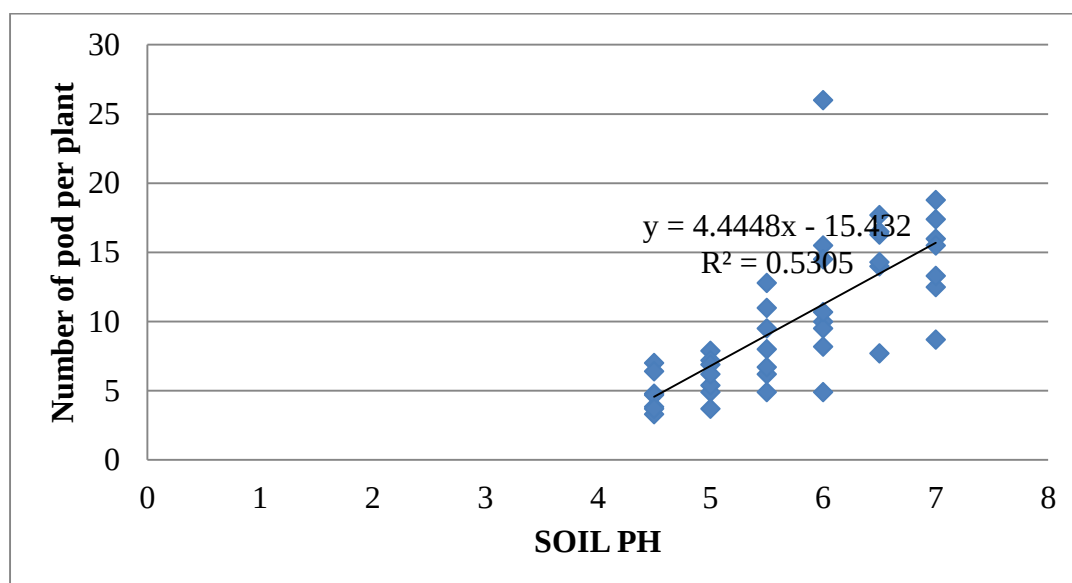


Figure 4: Regression analysis of number of pods of soybean at different soil P^H levels in 2004 and 2005

The correlation analyses showed that the number of leaves per plant, number of pods per plant, pod weight per plant and days to podding had positive correlations with seed yield per plant across all the soil pH levels indicating that any improvement in these traits could result in an increment of seed yield per plant irrespective of the soil pH. Similarly, pod weight per plant that is a precursor to seed yield per plant also correlated positively with number of leaves per plant and number of pods per plant in all the soil pH conditions. Many previous studies have previously reported positive association between numbers of pods, pod

weight and grain yield in soybean (Jadhav *et al.*, 1995; Shinde *et al.*, 1996; taware *et al.*, 1997; Ramgiry *et al.*, 1998; Malik *et al.*, 2006; Ruben and Gustavo, 2012). Therefore, pod weight is linearly related to number of pods thus, increase in pod weight will eventually translate to increase in seed yield (Khan *et al.*, 2000; Zaman *et al.*, 2011; Manggoel *et al.*, 2012; Sadeghi and Niyaki, 2012). The correlation of number of leaves, number of pods, pod weight and days to podding with seed yield per plant can also be indirectly improved by favourable selection of these traits under

high soil pH, but negative selection will be ideal under low soil pH conditions.

Conclusion

The present study showed that soybean cultivars evaluated could not survive under low soil pH (< 4.5), necessitating breeding for acid tolerance especially in the humid tropics that are associated with persistent low soil pH.

References

- Akande, S.R., Owolade, O.F. and Ayanwale, J.A. (2007). field evaluation of soybean varieties at Ilorin in Southern Guinea Savanna ecology of Nigeria. *Afri. J. Agric Res.*2:356-358.
- Alghamdi, S.S. (2004). Yield stability of some soybean genotypes across diverse environments. *Pakistan. Journal of Biological Sciences* 7(12): 2109 – 2114.
- Antalina, S. (2000).Modern processing and utilization of legumes.Recent research and industrial achievement for soybean food in Japan. Proceeding of RICE7-JIRCAS Workshop on Soybean Research. Sept. 28, Malang-Indonesia.
- Balasubramanian, P. and S. P. Palaniappan. (2003). Principles and practices of agronomy. Pub. byAgrobios (India) .45 – 46p.
- Bellogin., R.A., A. Buendia, M. Camacho, M. Chan, and T. Cubo. (2001). Effect of pH and soybean cultivars on the quantitative analysis of soybean *Rhizobia* populations. *J. Biotechnol.* 91: 243 – 55.
- Blum, U. (1996). Allelopathic Interactions Involving Phenolic Acids. *J. Nematol* 28: 259-267.
- Brett, J.F., L. Meng-Han, and M. G. Peter. (2013). Regulation of legume nodulation by acidic growth conditions.Plant Signaling and Behavior. 8(3):e23426 .
- Calder, F., L. MacLeod, R. Bishop, and C. MacEachern. (1965). Effect of limestone on pasture sward renovation with and without cultivation. *Can. J. Soil Sci.* 45: 251 – 256.
- Coronel, V.P., S. Akita, and S.Yoshida.(1990). At toxicity tolerance in rice (*Oryza sativa*) seedlings in plant nutrition.Physiological and Applications Kluwer Academic publishers. 357 – 363p.
- Duressa, D., K. Soliman, R. Taylor, and Z. Senwo. (2011). Proteomic analysis of soybean root under aluminum Stress.International Journal of Plant Genomics.Article ID 282531:12.
- Farina, M., M. Summer, C. Plank, and W. Letzsch. (1980). Exchangeable aluminum and pH as indicators of lime requirement for corn. *Soil Sci. Soc. An J.* 44: 1036.
- Graham., P.H, and C.P. Vance. 2003. Legumes importance and constraints to greater utilization to greater utilization. *Plant Physiology.*131: 872-877.
- International Institute of Tropical Agriculture (IITA).(2013). Farmer' Guide to soybean production in Northern Nigeria, Ibadan, (Nigeria).
- Jadhav, A.S., P. J. Jadhav, and S. M. Bachelhav.(1995) correlation and path coefficient analysis in soybean. *J. Maharashtra Agric. Univ.* 20: 150 – 151.
- Kochian, L.V., O. A. Hoekenga, and M. A. Piñeros. (2004). How do crop plants tolerate acid soils? Mechanisms of aluminum tolerance and phosphorous efficiency. *Annual Review of Plant Biology* 55: 459- 493.
- Lima de, M.L., and L. Copeland. (1990). The effect of aluminum on the germination of wheat seeds. *Journal of plant nutrition* 13(12): 1489 – 1497.
- Maduakor, H.O. (1991). Efficient fertilizer use for increase crop production: The Humid Nigeria Experience. *Fertilizer Research.* 29:65-79.
- Malik, M.F., A. Qureshi, S. M. Ashraf, and A. Ghafoor. (2006). Genetic variability of the main yield related characters in soybean. *Int. J. Agric. Biol.* 8: 815 – 819.
- Manggoel, W., M. I. Uguru, Ndam, O. N, and M. A. Dasbak. (2012). Genetic variability correlation and path coefficient analysis of some components of 10 cowpea (*Vigna unguiculata* L. Walp) accessions *J. Plant Breeding Crop Sci.* 4 (5): 80-86.
- Meng-Han, L., M. G. Peter, and J. F. Brett. (2012). Systematic regulation of soybean nodulation by acidic growth conditions. *American Soc. of Plant Biologists. Plant Physiol.* 160: 18 – 39.
- Mossor- Pietraszewska, T. (2003).Effect of aluminum on plant growth and metabolism.*Acta Biochemica Polonica* 48 (3): 673-686.
- Narayanan, A., and Sayamala, R. (1989). Response of Pigeon pea (*Cajanus cajan*

- L.) genotypes to aluminum toxicity. Indian Journal of plant physiology 32: 17 – 24.
- Nosko, P., Brassark, P., Kramer, J.R. and Kershaw, K.A. (1988). The effect of aluminum on seed germination and early seedling establishment, growth and respiration of white spruce (*Picea glauca*). Canadian Journal of Botany 66: 2305 – 2310.
- Ramgiry, S.R., P. Raha, and V. N. Tiwari. (1998). Genetic analysis of yield and quality attributes in soybean (*Glycine max* (L.) Merrill). Adv. Plant Sci. 11: 83 – 86.
- Ruben, A.V.R., and A. L. M. Gustavo. (2012). Phenotypic Correlation and path analysis for yield in soybean (*Glycine max* (L.) Merrill). ACTA Agronomica. 61(4): 322 – 332.
- Sadeghi, M.S., and Niyaki, S.A.N. (2012). Genetic correlation and path coefficient Analysis of oil and its components in peanut (*Arachis hypogaea* L.) genotypes under drought and non- drought condition. J. Basic Appl. Sci Res . 2 (7): 6561 -6565.
- Shinde, A.K., Birari, S.P., Bhave, S.G., and Joshi, R.M. (1996). Correlation and Path Coefficient analysis in soybean (*Glycine max* (L.) Merrill). Annl. Agric. Res. 17: 28 – 32.
- SPSS Inc. Released. (2007). SPSS for Windows, Version 16.0. Chicago, SPSS Inc.
- Taware, S.P., G. B. Halvankar, and V. M. Raut. (1997). Variability, correlation and path analysis in some germplasm lines of soybean (*Glycine max*.) with high oil content. Indian J. Agric. Sci. 67: 476 – 477.
- Taylor, G.J. (1988). The physiology of aluminum tolerance in higher plants commun. Soil Sci. Plant Aerial 19: 1179 – 1194.
- Temperly, R.J., and R. Borges. (2006). Tillage and crop rotation impact on soybean grain yield and composition. Agron. J.: 98:99- 1004.
- Uguru, M. I., K. P. Baiyeri and S. C. Aba (2011). Indicators of climate change in the derived savannah niche of Nsukka, South-eastern Nigeria. AgroScience 10 (1): 1-10.
- Uguru, M.I., B. C. Oyiga, and E. A. Jandong. (2012). Responses of some soybean genotypes to different soil pH regimes in two planting seasons. The African Journal of Plant Science and Biotechnology. 6 (1): 26-37.
- Von Uexkull, H.R. and Mutert, E. (1995). Global extent, development and economic impact of acid soils. In R.A. Date, N.J. Grundon; GE. Raymet; M.E. Probert (eds) plant-soil interactions at low pH: principles and management. Kluwer Academic publisher, Dordrecht, The Netherlands pp. 5-19.
- Zaman, M.A. Tuhina-Khatun, M., Ullah, M.Z., Moniruzzamm, M. and Alan, K.H (2011). Genetic variability and Path Analysis of Groundnut (*Arachis hypogaea*) Agric. 9(1-2).