Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.3, No.10, 2013


# Response of Late Season Maize/Soybean Intercropping to Nitrogen in the Humid Environment of South Southern Nigeria

Utietiang L. Undie[1]* Donatus F. Uwah[2] Sylvia B. A. Umoetuk[2] Emmanuel E. Attoe[1] Emmanuel B. Effa[2]
1 Department of Agronomy, Cross River University of Technology, Obubra Campus, Nigeria
2 Department of Crop Science, University of Calabar, Calabar, Nigeria
*E-mail of the corresponding author: utietiangundie@gmail.com

**Abstract**
Intensification of maize/legume production during early rains in the High Rainforest region of South Southern Nigeria is limited by heavy rainfall. Production of late season maize/legume by peasant farmers is gaining prominence though yields are low due to low soil fertility and improper crop arrangement. The objective of this research was to investigate the yield performance of late season maize/soybean intercropping in response to nitrogen fertilization and spatial arrangement of the intercrops. The trial was a split-plot design in randomized complete block with three replications. Treatments consisted of five rates of nitrogen (0, 25, 50, 75 and 100 kg ha$^{-1}$) and five crop arrangements (sole maize at 53,333 plants ha$^{-1}$, sole soybean at 266,666 plants ha$^{-1}$ and maize: soybean additive mixture arrangements of 1:1, 2:2 and 1:2). Nitrogen fertilization increased yield in both maize and soybean at all the treatment levels, when grown sole or in mixtures. Application of 100 kg N ha$^{-1}$ to maize increased number of ears per plant, 100-grain weight, cob yield and grain yield by 46, 35, 138 and 153 percents, respectively in 2007, and by 15, 48, 88 and 109 percents, respectively in 2008, over no nitrogen application. Similarly, application of 100 kg N ha$^{-1}$ to soybean increased number of pods per plant, number of barren pods and 1000-seed weight by 53, 120 and 16 percents, respectively in 2007, and by 55, 99 and 14 percents, respectively in 2008, over no nitrogen application. Optimum seed yield in soybean was obtained at 50 kg N ha$^{-1}$. The yield values of 1,352.8 and 1,158.2 kg ha$^{-1}$ were higher than those obtained at 0 kg N ha$^{-1}$ by 31 and 21 percent in 2007 and 2008. Increasing the nitrogen level further to 100 kg ha$^{-1}$ depressed seed yield by 8 percent in 2007 over 0 kg ha$^{-1}$. The nitrogen x crop arrangement interaction effects on grain yield and all other parameters were not significant ($p < 0.05$). Late season maize and soybean populations may be superimposed on each other and fertilized with 50 kg N ha$^{-1}$ to take advantage of optimum soybean seed yield and 66-76 percent of the maize grain yield.
**Key words***:* maize**,** soybean, intercropping, additive mixtures, nitrogen fertilizer

## 1. Introduction

Maize (*Zea mays* L.) is an important cereal crop in the family Poaceae. It is an important source of carbohydrate in human diet and as animal feed worldwide (Onasanya *et* al., 2009). Early season maize is planted in mixture with other crops and is harvested first for subsistence or sold as fresh maize to urban dwellers. Expansion in the cultivation of the early season maize crop in the humid Tropical Rainforest agro-ecology of South Southern Nigeria is limited by lack of appropriate technologies for preservation of the fresh harvest. The large gap between demand and supply has necessitated expansion of cultivation into the late cropping season. Soybean (*Glycine max* (L.) Merrill) is a leguminous oil crop in the family *Papilionaceae*. It is an important source of protein for man and animals (Singh, 2011). As a leguminous crop, soybean is superior to other grain legumes. It has an average protein content of 43 percent and, as such, can greatly supplement human protein needs, especially in the developing countries, where animal protein is too expensive to buy and/or difficult to come by. Despite its importance, soybean is not a common crop in the farming system of the peasant farmers of the humid Southern Nigerian. This is due to heavy rainfall which predisposes the crop to rot when grown and harvested as an early season crop (Oko *et al*., 1991). But soybean crop can successfully be cultivated in the Tropical Rain Forest of Nigeria during the late planting season to take advantage of the approaching harmatan winds in preserving the crop (Oko *et al*., 1991).
Subsistence farmers in the tropics rely on mixed cropping as their crop production system (Sivaraman & Palaniappan, 1996). Recent research findings have shown that mixed cropping shall continue to be more beneficial to these small scale farmers for obvious reasons. Mixed cropping provides security in food output which is considered more important than food maximization (Brintha & Seran, 2009). It also suppresses weeds (Dimitrios *et al*., 2010), increases cash returns to the farmers and provides higher yield advantage over sole cropping (Seran & Brintha, 2010). The commonest food crops grown in this region are yams, cassava, maize, plantain and cocoyam. Three or more of these food crops in combination are common on farmers' plots with rarely any legume in the combinations. Cereal-legume mixtures have been adjudged the most productive form of intercropping since the legume does not compete with the cereal for available nitrogen but fixes and uses its own

 

nitrogen (Adu-Gyamfi et al., 2007). The cereal may also benefit from the nitrogen fixed in the root nodules of the legumes in the current year (Chalk, 1996) or subsequent years ( Giller & Wilson, 1993).

Information on fertilizer requirements of late season cereal-legume mixtures in the humid South Southern Nigeria is scanty. The information gap may be due to contrasting fertilizer requirements of the component crops or to uneven fertilizer loss due to heavy rains during the first raining season, which leaches much of the soluble soil nutrients (Aune & Lal, 1997). Available information is conflicting on the effects of increasing nitrogen availability on the productivity of legume/non-legume intercropping. Midmore (1993) reported that addition of nitrogen fertilizer to intercrops raised yields of both components, but reduced the relative advantage of intercropping. Siame *et al.* (1998) observed that the yield components and yield of maize/*Phaseolus* intercrop responded significantly to nitrogen, up to the 120 kg N/ha applied, in all the intercropping treatments. Chiezey *et al.* (2005) obtained significant increase in grain yield of sorghum grown as a component crop with soybean, but the effect of nitrogen on soybean was not significant. There is a clear indication from the above review that the cereal components must be fertilized for appreciable yield to be obtained. The response of the legume components of the intercrop, however, seems unpredictable.

Soils of the Tropical Rain Forest are heavily leached of plant nutrients during the early rains (Aune & Lal, 1997). Sustainable production of maize on these soils requires investing heavily on fertilizers. Fertilizers, where available, are used sub-optimally and this accounts for the low productivity under subsistence farming. In traditional farming, the crops in mixture are planted with no regard to proper arrangement for effective use of environmental resources. The objective of this research was to evaluate the effect of nitrogen and crop arrangement on the yield attributing characters and yield of late season maize/soybean mixtures.

## 2. Materials and Methods

The field experiments were conducted in September to December of 2007 and 2008. The study was sited at the Teaching and Research Farm of the Cross River University of Technology, Akamkpa. Akamkpa ($5^0$15"N; $8^0$22"E) lies in the tropical rainforest agro-ecology of the Equatorial climatic belt of Nigeria. The mean annual temperature of the area ranges between $23^0$C to $35^0$C with daily range of about $3^0$C. The area has distinct wet and dry seasons with mean annual rainfall ranging from 1,250 to 4,000 mm. The wet season has double rainfall peaks during July and October with a short break in rainfall, called "August break", in between the double peaks. Consequently, there are two cropping seasons (early: from March to July, and late: from August to December) in the area.

The soils of Akamkpa are formed from Basement complex, predominantly granite and gneiss, and are classified as dystic cambisol. The soils are fine, granular and sandy loam in texture and are well-drained (Ibanga *et al*., 1989). The 2007 experimental site was under cassava cultivation for five years but left fallow for one year before the commencement of the experiment.

Hybrid maize (OBA SUPER 2) and soybean (TGX 1440-IE) cultivar were used for the experiment. The experimental treatments consisted of five nitrogen levels (O, 25, 50, 75 and 100 kg N/ha) and five crop arrangements. The arrangements were sole maize, sole soybean and maize: soybean intercrop arrangements of 1:1, 2:2 and 1:2, respectively. The treatment combinations were assigned to split plots in a randomized complete block design with three replications. The five rates of nitrogen were randomly assigned to the main plots while the five types of crop arrangements were randomly allocated to the subplots. The gross main plot size was 3 m x 10 m (30 $m^2$), while the subplot size was 3 m x 2 m (6 $m^2$). The net plot size for data collection was 1 m x 1.5 m (1.5 $m^2$).

Soil samples were randomly obtained with a soil auger from a depth of 0-30 cm prior to fertilization. The samples were composited and analyzed in the Soil Science Laboratory of the Department of Soil Science, University of Calabar, Nigeria. Particle size analysis was determined by the hydrometer method using sodium hexametaphosphate (Calgon) solution as outlined by Juo (1979). The textural class was determined by the use of standard textural triangle. Soil samples for chemical analysis were air dried and ground to pass through a 23 mm sieve for the subsequent procedures and analyses. Soil pH was measured with a glass electrode pH meter in soil water suspension of 1:2.5 and organic carbon was determined by the Walkley and Black wet oxidation methods as given in Juo (1979). Total soil nitrogen was determined by the macro-kjedahl method of Bremmer (1965). Available P was determined by the method of Murphy & Riley (1962). Phosphorus was determined calorimetrically using molybdenum blue. Calcium and magnesium were estimated by the Versenate EDTA Titration method Juo (1979), while exchangeable K and Na were estimated by flame photometry (Juo, 1979). The exchangeable cations were determined on extracts obtained after leaching soil samples with neutral normal ammonium acetate solution (Juo, 1979).

The 2007 crops were planted on 22nd September, 2007 while the 2008 crops were planted on 5th September, 2008. Three seeds of each crop were sown manually per hole using a meter tape to achieve the desired distances. The seedlings were thinned to one plant per stand at one week after sowing. Interplant spacing was maintained at

 

25 cm throughout for maize and 5 cm for soybean except in 1:2 arrangement where it was 10 cm. The crops were sown as sole maize (1:0) or sole soybean (0:1) and three arrangements of maize and soybean intercropping of 1 row maize to I row soybean (1:1), 2 rows maize to 2 rows soybean (2:2) and I row maize to 2 rows soybeans (1:2). Plots in a replication were separated from each other by 1.5 m path. An additive or superimposed model was used and plant density was kept constant on a total plot area basis set at the optimum for sole crops and kept the same in intercrops. Maize was planted at 53,333 plants/ha and soybean at 266,666 plants/ha by adjusting within row spacing of the intercrops.

Rows were spaced 75 cm apart in sole maize and in sole soybean plots. Intercropped maize was 75 cm from maize to maize and 37.5 cm from maize to soybean rows in 1:1 arrangement; but 37.5 cm from maize to maize or maize to soybean in 2:2 arrangement. In 1:2 arrangement, intercropped maize was 75 cm from maize to maize but 25 cm from maize to soybean. Intercropped soybean rows were 75 cm from soybean to soybean and 37.5 cm from soybean to maize rows in 1:1 arrangement but 37.5 cm from soybean to soybean or soybean to maize in 2:2 arrangement. However, in 1:2 arrangement, intercropped soybean was 25 cm from soybean to soybean or soybean to maize.

Phosphorus as single superphosphate (7.8 percent P) and potassium as muriate of potash (49.8 percent K) were applied at the rates of 30 kg P/ha and 50 kg K/ha. The two fertilizers were uniformly broadcast and harrowed into the soil before planting. Nitrogen was applied as urea (46 percent N) at the rates as per each treatment. Half of the required dosage was applied two weeks after sowing and the remaining half was applied six weeks after sowing, all by side placement along the rows. Weeds were controlled post emergence by manual weeding with hoe at 4 and 8 weeks after sowing.

The 2007 crops were harvested on 15th December, 2007 (81 days after sowing) while the 2008 crops were harvested on 24th December, 2008 (110 days after sowing). In both years, harvesting was done manually when the maize and the soybean had reached physiological maturity. In 2007, earlier harvesting was due to earlier cessation of rainfall and subsequent dry up of the maize crop. Crop data were taken randomly from crops within the net plot measuring 1.5 $m^2$. Ten plants of maize and twenty soybean plants were taken per plot for crop attributes and for yield measurements and computations.

In maize, the *number of ears per plant* was determined at harvest by finding average number of ears borne by the plants in the sample. For *100-grain weight*, 300 oven-dried seeds were counted by hand, weighed and then divided by three. *Shelling percentage* was calculated from the 10-plant sample as (seed weight/cob weight) x 100. For *cob yield*, sampled ears were dried in the oven at $60^0$C until three consecutive constant weights were obtained. These were then weighed with an electronic scale and the weight recorded and calculated in kg $ha^{-1}$. *Grain yield* was determined by drying the seeds from each yield sample to a constant weight at $60^0$C in an oven, weighing the sample and then calculating grain yield in kg $ha^{-1}$. H*arvest index* was calculated from the ten-plant sample as (seed weight/total sample weight) x100.

In soybean, *number of pods per plant* was counted and recorded as mean number of pods borne by plants in a sample at maturity. *Percentage sterile pods per plant* was estimated as (pods with no seed/pods with at least one or more seeds) x 100. For *pod yield*, hand threshed and oven dried pods were weighed separately and the weight of the pod samples was added to the corresponding weight of their oven dried seeds and calculated as pod yield in kg $ha^{-1}$. For *seed yield*, seeds from each sample were dried in an oven at $60^0$C to a constant weight and the recorded weight calculated as grain yield in kg $ha^{-1}$. *Shelling percentage* was estimated as (seed weight/total pod sample weight) x 100.

All the data collected were subjected to statistical analysis appropriate to the split plot in a randomized complete block design using Windows Statistical Package for Social Sciences (SPSS), Version 14. Analyses of variance (ANOVA) were constructed to examine nitrogen effect and its interaction on the variables measured. Treatment means were separated and compared using Duncan's Multiple Range Test (Gomez & Gomez, 1984) at 5% probability level.

## 3. Results and Discussion

Results of the physical and chemical properties of the experimental sites showed both sites to be sandy loam in texture (Table 1). However, the 2007 site was lower in total nitrogen compared to the 2008 site. Generally, the 2007 site was lower in all the nutrient elements measured, as well as in base saturation. The soil acidity was, however, higher in 2007 site compared to 2008 site. The average monthly minimum and maximum temperatures of the site showed little variation in temperature between the months in either 2007 or 2008 (Table 2). The sowing month of September in both the years was warmer than the previous month. The highest temperatures occurred in December in both the years, which were ideal for ripening and harvesting of the crops. The average monthly rainfall showed marked variation in each of the years. In 2007, the average rainfall during planting in September was higher compared to 2008. The average rainfall during harvest (December) in 2007, on the other hand, was lower compared to 2008. Treatment effects of the two crops are presented below. Due to nonsignificant interaction between nitrogen and crop arrangements, all the nitrogen results were averaged over crop arrangement. The effects due to crop arrangement has been reported (Undie *et al*., 2012)

*3.1 Number of ears per plant, 100-grain weight and grain yield in maize*

In 2007, each increase in nitrogen rate from 0 kg to 100 kg $ha^{-1}$ resulted in significant increase in the number of ears per plant (Table 3). In 2008, raising the nitrogen level from 0 to 50 kg $ha^{-1}$ had no significant effect on the number of ears, but further increase to 75 or 100 kg N $ha^{-1}$ significantly increased the number of ears per plant at each of the levels. The 100-grain weight of maize was significantly increased at each rate of applied nitrogen from 0 to 100 kg $ha^{-1}$ in each of the years (Table 3). In both years grain yield of intercropped maize was significantly increased as the rates of nitrogen were raised from 0 to 100 kg N $ha^{-1}$ (Table 3). At the 100kg N $ha^{-1}$, grain yield obtained in 2007 was 47% lower than that obtained in 2008

*3.2 Cob yield, harvest index and shelling percentage in maize*

Cob yield increased significantly at each level of applied nitrogen in both years (Table 4). The harvest index of intercropped maize in 2007 increased with nitrogen up to the 100 kg $ha^{-1}$ (Table 4). All increases in harvest index at each level of nitrogen were significant except those between 50 and 75 kg N $ha^{-1}$ or 75 and 100 kg N $ha^{-1}$, which gave statistically similar values. In 2008, however, each increase in the nitrogen rate significantly increased the harvest index up to the 100 kg N $ha^{-1}$ used. The shelling percentage of intercropped maize was significantly affected by nitrogen in both 2007 and 2008 (Table 4). Shelling percentages increased with increased application of nitrogen up to 100 kg $ha^{-1}$. However, significant differences did not exist between 0 and 25 kg N $ha^{-1}$ in 2007 or 50 and 75 kg N $ha^{-1}$ in 2008.

*3.4 Number of pods per plant, percentage sterile pods and 1000-seed weight in soybean*

In 2007, each incremental rate of nitrogen from 0 to 75kg N $ha^{-1}$ significantly increased the number of pods, but a further increase in nitrogen rate to 100 kg $ha^{-1}$ produced pods that were statistically similar with those at 75 kg $ha^{-1}$ (Table 5). In 2008, increasing the nitrogen rates from 0 to 25 or 50 to 75 kg $ha^{-1}$ produced significant increase in number of pods per plant. Nitrogen rates at 25 and 50 or 75 and 100 kg $ha^{-1}$ produced number of pods per plant that were not statistically different. Increasing the nitrogen rates from 0 to 100 kg $ha^{-1}$ significantly increased the percentage of sterile pods per plant at each level of applied nitrogen in both years (Table 5). For 1000- seed weight, application of nitrogen from 0-100 kg $ha^{-1}$ significantly increased the weight at each of the applied rates (Table 5).

*3.5 Seed yield, pod yield and shelling percentage in soybean*

Seed yield of soybean was significantly increased at each applied rate of nitrogen from 0 to 50 kg $ha^{-1}$ (Table 6). A further increase in nitrogen rates from 50 to 75 or 100 kg $ha^{-1}$ decreased seed yield at each level over that obtained at 50 kg N $ha^{-1}$. However, the yield decrease between 75 and 100 kg N $ha^{-1}$ was not significant in 2007 but significant in 2008. In 2007 the yields obtained at 75 or 100 kg N $ha^{-1}$ were statistically the same with that obtained at 25kg N $ha^{-1}$. In 2008, the yield obtained at 75 kg N $ha^{-1}$ was statistically similar to that obtained at 0 kg N $ha^{-1}$; while that at 100 kg N $ha^{-1}$ was significantly lower than that obtained at other nitrogen rates in 2008. In both the years, the highest grain yields were obtained at 50 kg N $ha^{-1}$. Pod yield of soybean was significantly increased at each nitrogen rate applied up to the 100 kg $ha^{-1}$ in 2007 (Table 9). In 2008, pod yield increased significantly with nitrogen application up to 50 kg N $ha^{-1}$, beyond which there was a decrease but not significantly. The effect of nitrogen on shelling percentage of soybean showed that increasing nitrogen rates from 0 to 50 kg $ha^{-1}$ in 2007 significantly increased shelling percentage at each of the applied rates (Table 9). A further increase to 75 or 100 kg $ha^{-1}$ significantly decreased shelling percentage over that obtained at 50 kg N $ha^{-1}$. Shelling percentages obtained at 75 and 25 kg N $ha^{-1}$ or 100 and 0 kg N $ha^{-1}$ were statistically similar. In 2008, the highest shelling percentage was also obtained at 50 kg N $ha^{-1}$. However, the shelling percentages at 25 and 50 kg N $ha^{-1}$ were not significantly different. Similarly, the shelling percentage obtained at 100 kg N $ha^{-1}$ was significantly lower than that obtained at 50 or 75 kg N $ha^{-1}$ but statistically similar with that obtained at 0 kg N $ha^{-1}$.

Application of nitrogen had beneficial effects on yield components and grain yield of both maize and soybean as sole crops or intercrops. In maize, yield components of number of ears per plant, 100-grain weight, shelling percentage, cob yield, harvest index and grain yield were positively and linearly influenced by the application of nitrogen. Thus, at 100 kg N $ha^{-1}$, compared to O kg N $ha^{-1}$, there were 46, 35, 138 and 153 percent increases in number of ears per plant, 100-grain weight, cob yield and grain yield, respectively, in 2007. In 2008, these attributes increased by 15, 48, 88 and 109 percent at the 100 kg N $ha^{-1}$, respectively. In soybean, application of nitrogen increased number of pods per plant by 51 percent, 1000-seed weight by 16 percent, and number of sterile pods per plant by 120 percent in 2007; In 2008, nitrogen increased number of pods per plant by 55 percent, 1000-seed weight by 14 percent and number of sterile pods per plant by 99 percent. The positive increases in the yield components indicated that with nitrogen fertilization, contribution of assimilates to these attributes was greatly enhanced. Grain yield has been linked to enhanced current assimilate supply to developing yield components and kernel (Boyle *et al*. 1991). The highest values of these parameters in maize, therefore, occurred at the highest rate of nitrogen used, suggesting that the 100 kg N $ha^{-1}$ as used in this experiment might not be the optimum for the production of 'OBA SUPER 2' hybrid maize. This observation agrees with Siame *et al*. (1998) who obtained optimum grain yield at nitrogen levels above 100 kg $ha^{-1}$ as used in this experiment and recommended rates ranging from 120 to 150 kg $ha^{-1}$ for the production of sole maize, especially hybrids.

In soybean, there was an increase in the number of pods per plant at nitrogen rates beyond 50 kg $ha^{-1}$. However, these did not translated to higher grain yield at these nitrogen levels. There was high percentage sterile pods that nullified any gain in grain yield. Optimum grain yield of soybean in response to nitrogen was, therefore, at 50 kg N $ha^{-1}$. Increased availability of nitrogen might have concomitantly increased the number of sterile pods due to the shading effects of maize on soybean beyond at 50 kg N $ha^{-1}$. This optimum rate of 50 kg N/$ha^{-1}$ for soybean contrasted with the 25 kg N/$ha^{-1}$ reported by Anon (1986) and the 30 kg N/$ha^{-1}$ obtained by Kang (1975). The work of Chiezey *et al. (*2005) who obtained no significant response in soybean grain yield to nitrogen application also contrasted sharply with the current finding. The optimum nitrogen rate of 50 kg $ha^{-1}$ in this study, however, agreed with the report of Mandimba & Mondibaye (1998) who obtained optimum grain yield in soybean at 50 kg N $ha^{-1}$. The higher nitrogen demand may be due to the low inherent soil nitrogen because of heavy leaching or because this variety was grown on this soil for the first time with no inoculation.

Similar results on the importance of fertilizer usage in intercropping have been given for maize/cowpea and maize/phaseolus (Olasantan *et al*., 1997; Siame *et al*., 1998). At the optimum rate of 50 kg N $ha^{-1}$ for soybean yield as observed in this study, 66 percent in 2007 and 76 percent in 2008 of the maize grain yields were already obtained. An additional 50 kg N $ha^{-1}$ to the intercrops produced only 24 to 34 percent of the maize grain yield, indicating that the 50 kg N $ha^{-1}$ might be considered the optimum rate for the production of late season maize/soybean as intercrops in the humid agro-ecology of South Southern Nigeria.

## 4. Conclusion

This study demonstrated the role of nitrogen in grain yield and yield components of maize, soybean and maize/soybean intercropping in the humid agro-ecology of Nigeria. Although grain legumes can significantly reduce the need for nitrogen by cereals in intercropping situation, inclusion of inorganic fertilizer is necessary if the ultimate goal is to increase yield. Intercropping legumes with maize in the humid South Southern agro-ecology of Nigeria can decrease nitrogen use, leaving our environment healthier.

From the results obtained in this study, it is evident that nitrogen fertilization improved grain yields in late season intercropped maize and soybean. The 50 kg N $ha^{-1}$, which was the maximum for soybean production, might be considered the optimum rate for the production of late season maize/soybean mixture as more than 66 percent (2007) and 76 percent (2008) of the total yield of maize was obtained at this nitrogen level.

## References

Adu-Gyamfi,J.J., F.A. Myaka, W.D. Sakala, R. Odgaard, J.M. Vesterager & H. Hogh-Jensen, 2007. ""Biological Nitrogen Fixation and Nitrogen and Phosphorus Budgets in Farmer-Managed Intercrops of Maize-Pigeonpea in Semi-Arid Southern and Eastern Africa". *Plant and Soil* **295**, 127-136.

Anonymous (1986). "Notes on Farming Systems Research Programme". Cropping Scheme Meeting. Institute for Agricultural Research, Ahmadu University, Zaria.

Aune, J.B. & R. Lal, 1997. "Agricultural Productivity in the Tropics and Critical Limits of Properties of Oxisols, Ultisols and Alfisols". *Tropical Agriculture (Trinidad)* **74** (2), 96-103.

Bremmer, J. M (1965). "Total nitrogen". In: Black, C. A. (editor). *Methods of Soil Analysis* **2**(1149), 511 – 576. America Society of Agronomy. Madison, Wisconsin.

Boyle M. G.; Boyer, J.S & Morgan, P.W. (1991). "Stem infusion of liquid culture medium prevents reproductive failure of maize at low water potential". *Crop Science* **31**,1246-1252.

Brintha, I. & T.H. Seran, 2009. "Effect of Paired Row Planting of Radish (*Raphanus sativus* l.) Intercropped with Vegetable Amaranthus (*Amaranthus tricolor* L.) on Yield Components of Radish in Sandy Regosol". *Journal of Agricultural Science* **4**, 19-28.

Chalk, P. M. (1996). "Nitrogen Transfer from Legumes to Cereals in Intercropping". *Proceedings of ICRISAT '96 Workshop*, 351-374.

Chiezey, U. F.; Haruna, I. M. & Odion, E. C. (2005)."Productivity of Sorghum/Soybean Mixture and Influence of N, P and Plant Arrangement in the Northern Guinea Savanna Zone of Nigeria". *Crop Research* **29**:1-14.

Giller, K. E. & Wilson, K. J. (1993). "Nitrogen Fixation in Tropical Cropping Systems". CAB International, Wallingford, U. S. A.

Gomez, K. A. & Gomez, A. A. (1984*).* "Statistical Procedures for Agricultural Research". John Wiley and Sons, New York.

Ibanga, J. J.; Lekwa, L.; Ekoo. U. C.; Annon, M. N.; Udo-Isong, T.; Ugwu, T. O. & Ahumile, C. (1989).”Soil and Land Use Survey of Cross River State”, Cross River State Ministry of Agriculture and Natural Resource, Main Bulk Trade Investment, Calabar, Nigeria.

Juo, A. S. R. (1979). “Selected Methods for Soil and Plant Analysis”. International Institute for Tropical Agriculture Manual Series Number 1, IITA, Ibadan, Nigeria.

Kang, B. T. (1975). “Effects Of Inoculation And Fertilizer On Soybean In Western Nigeria”. *Experimental Agriculture* **11**, 23-33.

Mandimba G. R. & Mondibaye, R. (1998). “Effect of Inoculation and N-Fertilization on Soybean Grown in Congo Soils”. *Biological Agriculture and Horticulture* **13**, 197-204.

Midmore, D. (1993). “Agronomic Modification of Resource Use and Intercrop Productivity”. *Field Crops Research* **34**, 357-380.

Murphy , J. & Riley, J.A. (1965). “A Modified Single Solution for Determination of P in Natural Water”. *Annals of Chemistry* **27**, 31-37.

Oko, B. F. D.; Solomon, M. G. & Bakoh, M. Y. (1991). “A Note On The Effects Of Planting Date And Plant Density On The Productivity Of Soybean In A Humid Tropical Environment”. *Tropical Journal of Applied Science* **1**, 38-41.

Olasantan, F. O., Ezumah, H. C. & Lucas, E, O. (1997). “Response of Cassava and Maize to Fertilizer Application and a Comparison of the Factors Affecting Their Growth during Intercropping”. *Nutrient Cycling in Agro-ecosystems* **46**, 215-123.

Onasanya, R. O., Aiyelari, O. P., Onasanya A., Nwilene, F. E. & Oyelakin, O.O., 2009. “Effect of Different Levels of Nitrogen and Phosphorus Fertilizers on the Growth and Yield of Maize (*Zea Mays* L.) in Southwest Nigeria”. *International Journal Agricultural Research* **4**(6), 193-203.

Seran, T.H. & I. Brintha, 2010. “Review on Maize Intercropping”. *Journal of Agronomy* **9**, 135-145.

Siame, J.; Willey, R. W. & Morse, S. (1998). “The Response of Maize/Phaseolus Intercropping to Applied Nitrogen on Oxisols in Northern Zambia”. *Field Crops Research* ***55***, 73-81.

Undie, U. L., Uwah, D. F. & Attoe, E. E. (2012). “Effect of Intercropping and Crop Arrangement on Yield and Productivity of Late Season Maizw/Soybean Mixtures in the Humid Environment of South Southern Nigeria. *Journal of Agricultural Science* **4**(4), 37-50.

Table 1.Physical and chemical properties of the soils of the experimental sites in 2007 and 2008 late planting season at Akamkpa, South Southern Nigeria

| Properties | 2007 | 2008 |
|---|---|---|
| *Physical composition (g/kg)* | | |
| Sand | 10.0 | 5.0 |
| Silt | 13.0 | 19.7 |
| Clay | 77.0 | 75.3 |
| Textural class | sandy loam | sandy loam |
| *Chemical characteristics* | | |
| pH ($H_2O$) | 4.2 | 5.1 |
| Organic carbon (g/kg) | 1.13 | 1.63 |
| Total Nitrogen (g/kg) | 0.09 | 0.13 |
| Available Phosphorous (g/kg) | 2.75 | 3.12 |
| *Exchangeable bases (cmol/kg)* | | |
| Ca | 0.6 | 2.2 |
| Mg | 0.2 | 1.0 |
| K | 0.07 | 0.08 |
| Na | 0.04 | 0.05 |
| Exchangeable Acidity (cmol/kg) | 4.8 | 3.0 |
| ECEC (cmol/kg) | 5.71 | 6.33 |
| Base Saturation (g/kg) | 16.0 | 53 |

 

Table 2 Temperature and rainfall data at Akamkpa during experiment in 2007 and 2008

| Month | Mean Temperature (°C) | | | | Rainfall (mm) | |
|---|---|---|---|---|---|---|
| | 2007 | | 2008 | | 2007 | 2008 |
| | Min | Max | Min | Max | | |
| August | 23.3 | 28.1 | 23.3 | 28.4 | 415.5 | 509.2 |
| September | 23.7 | 28.7 | 23.4 | 29.7 | 561.7 | 122.5 |
| October | 23.0 | 29.0 | 23.0 | 30.5 | 297.9 | 315.0 |
| November | 23.0 | 30.4 | 23.7 | 31.6 | 263.2 | 102.5 |
| December | 23.5 | 30.5 | 23.4 | 31 | 33.1 | 77.1 |

Source: Nigeria Meteorological Services (NIMET), Calabar.

Table 3 Effect of nitrogen on number of ears per plant, 100-grain weight and grain yield of intercropped maize in 2007 and 2008.

| Nitrogen (kg ha$^{-1}$) | Number of ears/plant | | 100-grain weight (g) | | Grain yield (kg/ha) | |
|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 |
| 0 | 0.72e | 0.98c | 14.30e | 17.07e | 1035.4e | 1970.8e |
| 25 | 0.82d | 1.00c | 15.53d | 18.86d | 1314.4d | 2590.1d |
| 50 | 0.95c | 1.00c | 16.42c | 21.45c | 1719.8c | 3134.3c |
| 75 | 1.00b | 1.07b | 18.28b | 23.17b | 2135.0b | 3612.0b |
| 100 | 1.05a | 1.13a | 19.34a | 25.19a | 2616.3a | 4121.5a |
| SE± | 0.012 | 0.013 | 0.231 | 0.310 | 10.99 | 21.51 |

Means followed by a common letter in a column are not significantly different at 5 percent level.

Table 4 Effect of nitrogen on cob yield, harvest index and shelling percentage of intercropped maize in 2007 and 2008.

| Nitrogen (kg ha$^{-1}$) | Cob yield (kg/ha) | | Harvest index | | Shelling percentage | |
|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 |
| 0 | 1500.3e | 2739.0e | 0.19d | 0.21e | 68.4d | 72.6d |
| 25 | 1913.7d | 3436.8d | 0.23c | 0.24d | 68.9d | 75.4c |
| 50 | 2425.7c | 3916.2c | 0.27b | 0.26c | 70.7c | 79.7b |
| 75 | 2950.5b | 4533.8b | 0.28b | 0.28b | 72.4b | 80.0b |
| 100 | 3575.5a | 5139.3a | 0.31a | 0.32a | 73.4a | 80.33a |
| SE± | 21.71 | 35.55 | 0.017 | 0.002 | 0.37 | 0.39 |

Means followed by a common letter in a column are not significantly different at 5 percent level.

Table 5 Effect of nitrogen on number of pods per plant, percentage sterile pods and 1000 seed weight of intercropped soybean in 2007 and 2008.

| Nitrogen (kg ha$^{-1}$) | Number of pods per plant | | Percent sterile pods | | 1000-seed weight (g) | |
|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 |
| 0 | 0.98d | 30.48c | 18.62e | 19.97e | 10.88e | 11.33e |
| 25 | 0.14c | 38.27b | 20.07d | 20.28d | 11.45d | 11.43d |
| 50 | 0.64b | 39.25b | 29.24c | 28.55c | 11.70c | 11.77c |
| 75 | 0.15a | 46.37a | 36.03b | 34.40b | 12.13b | 12.48b |
| 100 | 0.72a | 47.39a | 41.01a | 39.66a | 12.58a | 12.87a |
| SE± | 1.108 | 1.145 | 0.603 | 0.543 | 1.09 | 0.600 |

Means followed by a common letter in a column are not significantly different at 5 percent level.

Table 6 Effect of nitrogen on seed yield, pod yield and shelling percentage of intercropped soybean in 2007 and 2008

| Nitrogen (kg ha$^{-1}$) | Seed yield (kg ha$^{-1}$) | | Pod yield (kg ha$^{-1}$) | | Shelling percentage | |
|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 |
| 0 | 1030.0c | 961.0c | 1540.3e | 1452.0c | 61.10c | 71.33c |
| 25 | 1162.0b | 1097.7b | 1631.3d | 1575.8b | 69.33b | 74.41a |
| 50 | 1352.8a | 1158.2a | 1703.3c | 1657.2a | 73.25a | 74.45a |
| 75 | 1227.3b | 948.8c | 1740.5b | 1420.6c | 68.70b | 73.28b |
| 100 | 1203.3b | 885.0d | 1775.9a | 1353.6d | 65.85c | 72.06c |
| SE± | 47.39 | 24.10 | 13.42 | 26.19 | 0.920 | 0.470 |

Means followed by a common letter in a column are not significantly different at 5 percent level.

Number of Machines, $N_M$ = 10
Maximum Utilisation, $U_{max}$ = 0.80
Smoothing Constant, α = 0.30

F = forescast rate
Y = actual rate

| Year | Month | Rate: Utilisation F | Utilisation Y | Disturbance F | Disturbance Y | Idling F | Idling Y | No. of Workers | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | 0.80 | 0.75 | 0.06 | 0.04 | 0.15 | 0.20 | **9.25** | **(9)** | |
| | Feb | 0.79 | 0.70 | 0.05 | 0.07 | 0.17 | 0.23 | **8.84** | **(9)** | |
| | Mar | 0.76 | 0.66 | 0.06 | 0.09 | 0.18 | 0.25 | **8.38** | **(8)** | lower $\delta_t$ |
| | Apr | 0.73 | 0.60 | 0.07 | 0.11 | 0.20 | 0.26 | **7.93** | **(8)** | |
| | May | 0.69 | 0.55 | 0.08 | 0.09 | 0.22 | 0.28 | **7.43** | **(7)** | |
| | Jun | 0.65 | 0.49 | 0.08 | 0.12 | 0.24 | 0.28 | **6.76** | **(7)** | decreasing $U_t$ |
| 1 | Jul | 0.60 | 0.43 | 0.09 | 0.10 | 0.25 | 0.30 | **6.18** | **(6)** | |
| | Aug | 0.55 | 0.39 | 0.10 | 0.08 | 0.27 | 0.30 | **5.42** | **(5)** | |
| | Sep | 0.50 | 0.34 | 0.09 | 0.05 | 0.28 | 0.32 | **4.65** | **(5)** | increasing $\chi_t$ |
| | Oct | 0.45 | 0.30 | 0.08 | 0.04 | 0.29 | 0.32 | **3.76** | **(4)** | |
| | Nov | 0.41 | 0.25 | 0.07 | 0.08 | 0.30 | 0.33 | **2.95** | **(3)** | |
| | Dec | 0.36 | 0.23 | 0.07 | 0.12 | 0.31 | 0.30 | **2.31** | **(2)** | |
| | Jan | 0.32 | 0.28 | 0.09 | 0.15 | 0.31 | 0.26 | **2.03** | **(2)** | |
| | Feb | 0.31 | 0.33 | 0.11 | 0.18 | 0.29 | 0.24 | **2.25** | **(2)** | |
| | Mar | 0.32 | 0.41 | 0.13 | 0.20 | 0.28 | 0.22 | **2.77** | **(3)** | higher $\delta_t$ |
| | Apr | 0.34 | 0.45 | 0.15 | 0.18 | 0.26 | 0.20 | **3.57** | **(4)** | |
| | May | 0.38 | 0.53 | 0.16 | 0.17 | 0.24 | 0.16 | **4.26** | **(4)** | |
| | Jun | 0.42 | 0.62 | 0.16 | 0.12 | 0.22 | 0.14 | **5.13** | **(5)** | increasing $U_t$ |
| 2 | Jul | 0.48 | 0.69 | 0.15 | 0.16 | 0.19 | 0.12 | **5.94** | **(6)** | |
| | Aug | 0.54 | 0.74 | 0.15 | 0.20 | 0.17 | 0.09 | **6.99** | **(7)** | |
| | Sep | 0.60 | 0.82 | 0.17 | 0.17 | 0.15 | 0.06 | **8.15** | **(8)** | decreasing $\chi_t$ |
| | Oct | 0.67 | 0.87 | 0.17 | 0.12 | 0.12 | 0.04 | **9.24** | **(9)** | |
| | Nov | 0.73 | 0.90 | 0.15 | 0.12 | 0.10 | 0.03 | **10.06** | **(10)** | |
| | Dec | 0.78 | 0.90 | 0.14 | 0.15 | 0.08 | 0.03 | **10.77** | **(11)** | |