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Effect of Intercropping and Fertilizer Type on Growth and Yield of Soybean (*Glycine max* L. Merrill)

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Abstract: Studies were conducted at the Kenya Agricultural Research Institute in 2002 to determine the effect of intercropping and fertilizer type on the growth and yield of soybeans. The treatments included cropping system (sole and intercropped soybean with maize), varieties (non-herbaceous and herbaceous) and fertilizer type (organic and inorganic). The experiment was laid out as split-split plot in a randomized complete block design with three replications. Cropping system formed the main plots, the varieties sub-plots and fertilizer the sub-subplots. Results showed a significant variety by cropping system interaction. Non herbaceous variety yielded significantly higher than herbaceous when intercropped, while herbaceous yielded significantly higher as a sole crop. Inorganic fertilizer significantly depressed the growth and yield of soybean in season II because of the salt effect on plant germination. To improve soybean production, account should be taken of variety morphological characteristics, cropping system and initial fertilizer type during a particular season.

Key words: Soybean, fertilizer type, intercropping, growth, yield

INTRODUCTION

The rapidly increasing population and the declining soil fertility coupled with high malnutrition and poverty calls for urgent remedial measures especially in Kenya where only 20% of the land is of medium to high potential agricultural value. The need for the multifaceted solution led Food and Agriculture Organization (FAO) and the German Technical Cooperation (GTZ) in 1993 to promote the production of soybean (*Glycine max* L. Merril), as a source of protein, income and soil fertility improvement. The demand for the crop has grown rapidly following the Kenya Accelerated Food Production Programme awareness activities launched in 1995.

Since farmers in the tropics generally grow legumes as intercrops with maize, the choice of genotypes for this cropping system is imperative especially when dealing with crops such as soybeans whose varieties inherently vary in morphology and maturity periods (KARI, 1998; Okwiri, 2003). The broad leafed varieties with a low Nitrogen Harvest Index (NHI) tend to have residual nitrogen benefits for the accompanying intercrops and perform better in most production environments (FAO, 1994; Kasasa *et al*., 1999). Early maturing soybean varieties have negative N balance than late maturing ones (Singh *et al*., 2003; Osunde *et al*., 2003). Soybean varieties exhibiting different morphological characteristics would thus give different yields depending on the cropping system.

Soil fertility is one of the important factors affecting crop production in the tropics. While the productivity of soils in western Kenya is hampered by deficiency of nutrients such as N, P and K (Lijzenga, 1998), lack of farmers' awareness of soybean varieties suitable for intercropping further hampers production. Paradoxically, a majority of farmers cannot afford inorganic fertilisers required to enhance crop yield (Sanchez *et al*., 1997). Organic resources such as tithonia (*Tithonia diversifolia* Hemsley A. Gray) have been proposed as alternative nutrient sources (Kwabiah *et al*., 2003). Tithonia contains about 3.5% N, 0.37% P and 4.1% K on dry matter basis and has been accepted as a source of nutrients for soil fertility improvement (Jama *et al*., 2000). In fact 5 Mg ha^{-1} dry weight basis are comparable with 50 kg P ha^{-1} + 120 kg N ha^{-1} inorganic fertilizers (Kwabiah *et al*., 2003). Currently the wide use of tithonia is constrained by the limited supply arising from the reducing sizes of land holdings per capita and concomitant land fragmentation (Jama *et al*., 2000). Combining small amounts of tithonia (to supply the starter N required for spurring N fixation in legumes) and other fertilisers could increase productivity under these constrained farm conditions.

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The low concentration of P in tithonia requires integration with alternative sources. Phosphate Rock (PR) a naturally occurring, low cost and effective ore has been identified as an important alternative source of soil P (Okalebo, 1999; Kanyanjua *et al*., 2000). Widespread deposits of Minjingu PR exist in Africa (Van Kauwenbergh, 1991) and positive crop responses to its application have been reported especially in acidic soils where conventional P sources are less effective (Okalebo and Woomer, 1994; Mutuo *et al*., 1999; Woomer *et al*., 2003). An experiment was conducted to determine the effect of cropping system and fertiliser type on growth and yield of soybean.

MATERIALS AND METHODS

The study was carried out at the Kenya Agricultural Research Institute, Kakamega located at latitude 0°15' N, longitude 34°46' E and altitude of 1530 m in western Kenya during the major and minor rainy seasons of 2002. The two seasons are referred to as season I (April to August, 2002) and season II (September, 2002 to January, 2003). Average daily temperature was 21°C for both seasons and rainfall of about 1048 and 786 mm in season I and II, respectively. The site has a gentle slope, deep, well drained clay-loam soil with 540 g kg^{-1} clay, 210 g kg^{-1} sand, 250 g kg^{-1} silt, pH 5.6 (1: 2.5, soil: water suspension) and total organic C of 2.41% and classified as humic Nitisol (FAO, 1988).

The experiment was laid out as split-split plot in a randomized complete block design replicated three times with cropping system in the main plots, varieties (Nyala and Gazelle) in the sub-plots and fertilizer types in the sub-sub-plots. The fertilizer types included: control without fertilizer (F1), tithonia combined with Minjingu phosphate rock as organic fertilizer source (F2) and a combination of nitrogen, phosphorous and potassium (NPK) fertilizers as inorganic fertilizer source (F3). Plot sizes were 3×3 m with plant spacing of 0.75× 0.30 m and 0.75×0.15 m for maize (Hybrid H614) and soybean, respectively.

The soybean varieties were sourced from KARI-Kakamega and were chosen on the basis of their contrasting morphological and maturity class characteristics. Nyala is tall, less herbaceous and early maturing while Gazelle is short, herbaceous and late maturing. Tithonia was obtained locally from hedges and fields around the experimental site while phosphate rock was sourced from Minjingu Phosphate Company (MIPCO) in Nairobi. Fertilizers F2 and F3 were constituted to contain 35, 75 and 50 N, P_2O_5 and K_2O kg ha^{-1}, respectively. Fertilizer F2 was constituted by combining 29 kg P of phosphate rock with one tone dry matter of tithonia containing 35 kg N, 3.7 kg P and 41 kg K. Fertilizer F3 consisted of a mixture of Single Super Phosphate (SSP), Calcium Ammonium Nitrate (CAN) and muriate of potash (KCL).

Two seeds of each crop were planted with intercrops in the same rows as practiced by farmers. The plants were then thinned to one 35 days after emergence (35 DAE). Plots were kept free of weeds by hand weeding and no topdressing was done. Plant population and height 35 DAE were determined from the middle rows of each plot. Soybean grain yield and number of pods per plant were determined by harvesting pods from middle rows of each plot when all the leaves had fallen but the pods were still intact. The data obtained was subjected to analysis of variance (ANOVA) using general linear model in SAS, and means separated by the Duncans Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Soybean growth: Plant height differed significantly with season and cultivar. Average plant height 35 DAE in season I ranged from 14.3 to 17.2 cm for Gazelle and 15.6 to 18.8 cm for Nyala. In season II plant height however ranged from 11.2 to 14.0 cm and 12.7 to 14.4 cm, for Gazelle and Nyala, respectively (Table 1).

The differences in plant height between seasons I and II could be a result of differences in rainfall amounts. Season I received a total of 1048 mm of rainfall while season II received 786 mm. Since the cultivars were grown under the same environmental conditions, variation in height between Gazelle and Nyala could be attributed to the inherent morphological differences (Okwiri, 2003). Cropping system significantly affected growth rates of soybean. In season I, average plant height 35 DAE of the sole crop was 15.28 cm compared to 17.01 cm as intercrop probably because maize grew better as a result of good rainfall thereby causing shading and ultimately etiolation related effects on soybean intercrop. Research elsewhere (Foroutan *et al*., 1999) has shown that the cropping system (maize-soybean intercrop) enhances plant height of soybean. Unlike in season I, cropping system did not significantly affect plant height in season II probably because other factors such as water were more limiting (Lang'at, 2000). In season II, average plant height was 13.46 and 13.03 cm as sole crop and intercrop, respectively. Limited rainfall in this season could have resulted in maize out competing soybean for soil moisture hence its diminished growth as an intercrop.

In season I, the average height for Nyala was 16.02 cm compared to 14.54 cm for Gazelle as sole crops

Table 1: Effect of cropping system and fertilizer type on the height (cm) of soybean (35 DAE)

Fertilizer type	Intercrop Nyala	Intercrop Gazelle	Intercrop Mean	Sole crop Nyala	Sole crop Gazelle	Sole crop Mean
Season I						
F1	18.3^{a}	14.5^{a}	16.4^{a}	15.6^{a}	14.3^{a}	15.0^{a}
F2	17.5^{a}	17.2^{b}	17.4^{a}	16.6^{a}	14.4^{a}	15.5^{a}
F3	18.8^{a}	15.5^{a}	17.2^{a}	15.8^{a}	14.7^{a}	15.3^{a}
Season II						
F1	14.0^{a}	12.6^{a}	13.3^{a}	13.7^{a}	13.5^{a}	13.6^{a}
F2	14.0^{a}	13.2^{a}	13.6^{a}	14.4^{a}	14.0^{a}	14.2^{a}
F3	13.0^{a}	11.2^{b}	12.1^{b}	12.7^{a}	12.2^{b}	12.5^{b}

Values followed by the same letter(s) within the same column are not significantly different at $p<0.05$, DAE refers to Days After Emergence

Table 2: Effect of cropping system, variety and fertilizer type on grain yield (kg ha^{-1}) of soybean

Fertilizer Type	Intercrop Nyala	Intercrop Gazelle	Intercrop Mean	Sole crop Nyala	Sole crop Gazelle	Sole crop Mean
Season I						
F1	743.2^{a}	450.7^{a}	596.9^{a}	694.4^{a}	837.9^{a}	766.2^{ab}
F2	508.1^{b}	389.8^{a}	448.9^{a}	850.4^{a}	1026.7^{a}	938.5^{b}
F3	414.9^{b}	557.6^{a}	486.2^{a}	586.2^{a}	793.6^{a}	689.9^{a}
Season II						
F1	67.2^{ab}	63.7^{a}	65.4^{a}	108.6^{a}	162.2^{a}	135.4^{ab}
F2	76.1^{a}	54.8^{a}	65.5^{a}	151.6^{a}	148.6^{a}	150.1^{b}
F3	39.4^{b}	32.9^{a}	36.2^{b}	52.2^{a}	37.4^{a}	44.8^{a}

Values followed by the same letter(s) within the same column are not significantly different at $p<0.05$

Table 3: Effect of cropping system and fertilizer type on stand count (ha^{-1}) of soybean 35 DAE

Fertilizer type	Intercrop Nyala	Intercrop Gazelle	Intercrop Mean	Sole crop Nyala	Sole crop Gazelle	Sole crop Mean
Season I						
F1	123703^{a}	102962^{a}	113333^{a}	140370^{a}	124444^{a}	132407^{a}
F2	120370^{a}	121851^{a}	121111^{a}	134814^{a}	146666^{a}	140740^{a}
F3	105925^{a}	113333^{9}	109629^{a}	116296^{a}	120370^{a}	118333^{a}
Season II						
F1	77407^{a}	113333^{a}	95370^{a}	98148^{a}	148888^{a}	123518^{a}
F2	81111^{a}	107037^{a}	94074^{a}	87407^{a}	113333^{b}	100370^{b}
F3	29629^{b}	44444^{b}	37037^{b}	35185^{b}	55925^{c}	45555^{c}

Values followed by the same letter(s) within the same column are not significantly different at $p<0.05$, DAE refers to Days After Emergence

whereas in the intercrops, Nyala was 18.22 cm and Gazelle was 15.80 cm. The trend in height was maintained in season II. Gazelle was generally shorter than Nyala in both cropping systems. The differences could be attributed to the inherent characteristics of the varieties (Okwiri, 2003). The lack of significant variety by cropping system interaction implies that intercropping does not change the inherent growth behavior of the genotypes.

The effect of fertilizer type on the growth of soybean varied with season. During season I, there were no significant fertilizer effects on the overall plant growth. Probably the nutrient supply 35 DAE could still be met by inherent soil fertility. In season II, the average plant heights for F1, F2 and F3 were 13.35 , 13.64 and 12.10 cm for intercrop and 13.64, 14.20 and 12.54 cm for sole crop respectively. A significant variety by fertilizer type interaction was observed this season. Fertilizer F3 significantly depressed the growth of Gazelle in season II. The salt effect of nitrogen fertilizer has generally been observed especially at low moisture levels where germination and subsequent seedling emergence was reduced. The salt effects of fertilizers were however not observed in F2 probably because the fertilizer type does not exhibit the salt effects of F3.

Yield and yield components: In season I, Nyala and Gazelle gave 555 and 466 kg ha^{-1} when grown as intercrops and 710 and 886 kg ha^{-1} as sole crops (Table 2). In season II, Nyala and Gazelle gave 60 and 50 kg ha $^{-1}$ when grown as intercrops and 104 and 116 kg ha^{-1} when grown as sole crops. During season I, Nyala out-yielded Gazelle when grown as intercrop. The trend was however reversed when grown as sole crop with Nyala and Gazelle yielding about 710 kg ha^{-1} and 886 kg ha^{-1}, respectively. The varieties were not significantly different in terms of grain yield during season II probably because of moisture stress (Lang'at, 2000). From the observed trend changes, Nyala being a taller and less herbaceous variety was probably better placed to compete for light under intercropping conditions. Gazelle on the other hand is a shorter and more herbaceous variety hence easily out-competed. The variety may also have experienced enhanced self-shading hence unable to compete for light. Similar observations on lanceolate and highly branched soybean genotypes have been made earlier (Wells, 1993).

Although intercropping generally depressed grain yield, the Land Equivalent Ratio (LER), indicated a better land use efficiency in both seasons. A LER of 1.59 implied a yield advantage of 59% in season I and 193% (i.e., LER 2.93) in season II. The greater land equivalent ratios of intercrops compared to sole crops imply that more land would have been required for sole crops to achieve the same yield as in intercrops.

Unexpectedly, F1 and F2 had higher grain yield than F3 (Table 2). Fertilizer F3 was expected to have higher yield because of high solubility and nutrient availability. The unexpected result could be attributed to the salt injury that negatively influenced germination, depressed the stand count and ultimately the overall crop yield. Fertilizer F2 affected neither the stand count nor the overall yield probably because of its low solubility. This was consistent with studies elsewhere that showed that sometimes freshly applied phosphate rock may only slightly stimulate crop yield (Weil, 2000).

The response in yield of soybean varieties to fertilizer types varied with season and cropping system. During season II, Nyala had a higher yield with fertilizer F2 under intercropping whereas the increase was not significant as a sole crop. The fertilizer type did not cause any significant effect on the yield of Gazelle during season II, irrespective of the cropping system. The effect of fertilizer F3 was similar for both varieties. During season I, both fertilizer types caused a significantly lower yield in Nyala under intercrop. The fertilizers did not however have any significant effects on the yield of Gazelle whether grown as an intercrop or sole crop.

The variations in response to fertilizer between the two varieties of soybeans could be a result of different fertilizer use efficiencies. Under moisture stress and limited light conditions Nyala may have been able to utilize the phosphate rock/tithonia fertilizer type (F2) better than Gazelle. Whereas the stand counts for the soybean varieties were not affected by fertilizer type during season I, fertilizer F3 depressed the plant population during season II (Table 3).

The yield components (number of pods per plant) were also affected by the treatments. The average number of pods per plant for Nyala and Gazelle were 8.3 and 4.9, respectively. A significant interaction between cropping system and variety showed that Nyala had more pods per plant under sole crop (10.3) than intercrop (6.3). No differences were recorded for Gazelle. The higher number of pods per plant (8.1) under fertilizer type F3 compared to other fertilizer types implies that if the plant population had not been affected by the salt injury, the overall grain yield could have been higher especially for variety Nyala. The number of pods per plant in Gazelle was not affected by fertilizer type.

CONCLUSIONS

Due to the decreasing land units, integrating soybean into the maize production system is a viable option. This is true if land use efficiency is to be maximized. Since soybean is the shorter component in the intercrop, competition is therefore immense. Choice of variety is therefore an important factor in order to optimize the yield advantage. Nyala, a tall and less herbaceous variety is better placed to compete for light than the shorter and more herbaceous Gazelle. On the other hand, if the crop is grown solely, the latter variety has better resource use efficiency. It showed a better use of fertilizer and probably light when grown alone.

Soybean responded to fertilizer indicating that the soils are deficient in the nutrients required by the crop for increased yields. Although the chemical fertilizer (NPK) had the potential to increase the crop yield, this was not the case because of its negative effect on germination. The fertilizer type reduced plant population during the short rains indicating that its effect is moisture dependent. Minjingu phosphate rock combined with tithonia as biomass transfer was comparable to the NPK fertilizer in increasing yields. Gazelle showed a better use efficiency for this fertilizer type than Nyala. This was only evident in the sole crop. This shows that the varieties have different fertilizer use efficiencies. As intercrops however the trend was not maintained. As earlier mentioned, Gazelle does not compete well for light. This indicates that the use of the fertilizer type may be dependent on other factors where light plays a major role.

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