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Original Research Paper

Benefits of spatial arrangements and time of introducing soybean in maize under highly weathered soils of Morogoro, Tanzania

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ABSTRACT

This study assessed the performance of soybean-maize cropping systems determined by spatial arrangements and time of introducing soybean (*Glycine max* (L.) Merrill). Two factors in different levels were: (1) Time of introduction: (i) early sowing of soybean (ii) simultaneous sowing of soybean and maize (iii) mid-sowing of soybean; (2) Spatial arrangements of the component crops in the intercropping system: (i) 1:1 and (ii) 2:2. Soybean variety UYOLE 84 and Tanzania Maize Variety 1 (TMV-1) were used as test crops. The two-way interaction between cropping pattern and the time of introducing soybean for all response variables did not differ significantly ($P > 0.05$) for both maize and soybean. The mean number of seeds/cob differed significantly ($P = 0.027$) as sole maize (455), simultaneous sowing of the crops (451), mid-introduction of soybean (440), and early introduction of soybean (423). Biological yields were mid-introduction (25.7 t/ha), simultaneous sowing (23.2 t/ha), sole maize (15.6 t/ha), and early introduction of soybean (5.5 t/ha), which differed significantly ($P = 0.004$). Maize yields were mid-introduction of soybean (3.7 t/ha), and simultaneous sowing (3.6 t/ha), sole maize (2.4 t/ha) and early introduction of soybean (2.0 t/ha). In soybean the number of pods/plant was sole soybean (86 pods/plant), early introduction (81 pods/plant), simultaneous sowing (52 pods/plant), and mid-introduction (32 pods/plant). Mean number of seeds/pod were sole soybean (3.037), mid-introduction (3.005), early-introduction (2.976), and simultaneous sowing of both crops (2.950). Soybean grain yields were sole soybean (4.22 t/ha), early sowing (3.02 t/ha), simultaneous sowing (2.83 t/ha), and mid-introduction (2.34 t/ha).

Key words: crops, cropping systems, productivity, time of introduction.

INTRODUCTION

Soybean is a leguminous oil crop, which is an important source of protein for man and animals. Soybean consists of protein (36%), carbohydrates (30%), oil (20%), dietary fiber, vitamins, and minerals (Muoneke *et al.,* 2007). Soybean is the only crop that provides high quality protein comparable to meat, poultry and eggs and its by-product cake is a high-protein animal feed (Biabani *et al.,* 2008). Soybean also improves soil fertility through atmospheric N_2 fixation and becomes a major benefit in most farming systems, where soils have been exhausted and where fertilizers are not easily accessible or are sold at higher prices (Mbah and Ogidi, 2012; Mbah *et al*., 2009).

The area under soybean production in Tanzania has increased from less than 2000 ha to 7500 ha from 2002 to 2008 (Ronner and Giller, 2013). According to Ronner and Giller (2013), the regions with the greatest potential for soya bean production in Tanzania include Arusha, Kilimanjaro, Manyara, Ruvuma, Mbeya, Rukwa, Morogoro and Iringa. According to Malema (2006), in Tanzania the total national soybean production, area, yield and production has been increasing since 1983. Most farmers in Tanzania are smallholders who produce legumes in a mixture of other crops such as cereals and perennial crops because legumes do not acquire staple food priority despite the fact that they fetch exclusively higher market prices (Marandu *et al*., 2010). Cereal-legume cropping is most practiced because it allows the farming community to benefit mixed crops without risks of complete crop failure (Dolijanovic *et al.,* 2013). In addition, higher yields in cereals were the target since cereals may benefit from the nitrogen fixed in the root nodules of the legumes in the same or subsequent seasons (Undie *et al.,* 2012). Most research findings have indicated that selection of compatible crops in the intercrop, consideration of time of introducing partner crops in the system, their spatial arrangement is inevitably important for high productivity. For instance, Undie *et al.* (2012) reported that in additive intercropping where certain crop species were introduced in the intercroping system, the selection of the major crop was based on the interest in yields. The major crop becomes as important as the minor crop, which should be a variety that will not expose the major crop to high competitive pressure. According to Bantie (2014), productivity of an intercropping system depends on varieties of the partner crops, sowing density, spatial arrangement, cropping seasons and agricultural practices. Undie *et al.* (2012) argued that soybean is not grown early or sole in the season in most cropping systems because of the small land owned, lack of crop's recognition as a staple crop and possibility of rotting during early heavy rains.

Soybean production in Tanzania has been growing at 1,140 tons per year but it is estimated to be more than 5,000 tons (Malema, 2006). The major limitations reported for the low production was associated with poor soil fertility, poor production systems, and inadequate knowledge crop production and on its multiple uses such as in animal feed and food formulations, and shortage of reliable markets and low market prices (Ronner and Giller, 2013). Yet, the main cropping systems in most agricultural potential were still based on traditional mixed cropping agriculture. Apart from their small pieces of potential lands they own farmers in Tanzania do not sow mixed crops in a defined pattern. Legumes are the major crops which find their avenue of being intercropped with many other annual and perennial crops. However, farmers do not really consider the advantages of a legume crop in the cropping system. Dwomon and Quainoo (2012) reported that spatial arrangements of partner crops in an intercrop bridge the gap between planting and new harvest. Intercropping reduced risks of pests and diseases and leaf canopy reduced soil temperature and moisture loss. In Tanzania there is no information about the effect of time of introducing soybean and its spatial arrangement on the performance of component crops in humid and sub-humid tropics. Therefore, this study was meant to assess the effects of time of introducing soybean and spatial arrangement of component crops on crop performance. This was prompted by the continuous use of small pieces of lands to produce more than one crop because of the small lands own by most smallholder farmers in Tanzania. Yet, intensification has not been feasible at farmer's level in these small pieces of lands and the findings of previous studies have been debatable and inconclusive.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted during the 2014/2015 cropping long rainy season in Morogoro region, Tanzania. The experiment was set at the Sokoine University of Agriculture (SUA) Farm, which was located at latitude 6^{o} 85` South and longitude 37$^{o}$ 64` East and at an elevation of 568 m above mean sea level. Rainfall is bimodal ranging between 800 and 950 mm per annum and the soils are kaolinitic clays low in most essential nutrients and extremely acid in reaction with pH of 5.4 (Kisetu *et al*., 2013).

Experimental Design, Treatments and Experimentation

The study involved a randomized complete block design (RCBD) with three replications of 3 × 2 factorial arrangement. There were two factors in different levels: (1) Time of introduction: (i) Early sowing of soybean (ii) simultaneous sowing of soybean and maize (iii) mid-sowing of soybean; (2) Spatial arrangements of the component crops in the intercropping system: (i) 1:1 and (ii) 2:2. These factors were randomly assigned to all experimental plots. One sole maize plot formed the main-plot and six plots formed the subplots where 3 times of introducing and 2 spatial arrangements of soybean were included. Sole soybean plots were also included in each time of introduction as checks. There were 8 treatments per replicate and because the replicates were 3 these made total of 24 plots each with size of 4.0 m × 3.6 m in dimensions.

Seed sowing

Tanzania Maize Variety 1 (TMV-1) seeds were sown at once in all plots at the onset of the cropping season and this was done with the simultaneously sowing of the soybean. In the early sown soybean plots sowing of maize was done 14 days after early sowing of soybean. In addition, mid-sowing of soybean was done at 14 days after maize was sown. One maize and soybean seeds were sown per hole depending on the sowing

Plot size	Spatial arrangement	Rows		Plants	
		Maize	Soybean	Maize	Soybean
4 m × 3.6 m	Sole maize	5	0	65	0
4 m × 3.6 m	Sole soybean	0	10	0	400
4 m × 3.6 m	1:1	5	5	65	200
4 m × 3.6 m	2:2	4	4	120	160

The 1:1 means one row of maize alternating with one row of soybean and 2:2 means two rows of soybean were sown after every two rows of maize.

arrangement in all plots. Maize seeds were sown at 80 cm × 30 cm and soybean at 40 cm × 10 cm. Maize seeds were obtained from the Agricultural Seed Agency (ASA), Morogoro, Tanzania. The soybean variety UYOLE 84 was obtained from Uyole Agricultural Research Institute (ARI-Uyole) in Mbeya, Tanzania.

Management of crops in the field

Fertilizer triple superphosphate (TSP 46% P_2O_5) equivalent to 25 kg P ha^{-1} was applied in each hole (1.0 g) during seed sowing. This was to me P specifically recommended for this area of > 25 kg P ha^{-1} because soil tests indicated that soil available P is very low, < 7 mg P kg^{-1} (Kisetu *et al.,* 2013). Fertilizer urea (46% N) was applied to all maize plants at a rate equivalent to 20 kg N ha^{-1} in two equal splits at 14 and 28 days after sowing.

Data Collection

The data collected from maize and soybean included number of plants per plot at harvested stage, biological/stover yield, seeds per cob, pods per soybean plant, number of seeds per pod, and grain yields of the crops.

Data Analysis

Data were subjected to statistical analysis using GenStat software of a generalized treatment structure in randomized design. All interactions between spatial arrangement (1:1, 2:2) and time of sowing soybean (early, simultaneous and mid) were assessed using Tukey's honestly test at $P = 0.05$ while LSD values were used to compare significant means. In-depth analysis using Shapiro-Wilk test for normality distribution of residuals and Bartlett's test for homogeneity of variances were performed.

RESULTS

Effect of cropping pattern and time of introducing soybean on performance of maize

Results of the two-way interaction between cropping pattern and the time of introducing soybean indicated that all response variables did not differ significantly ($P > 0.05$). In addition, results indicated that cropping pattern had no significant effect on plants/plot ($P = 0.259$) and seeds/cob ($P = 0.841$) but this was significant for biological yield (t/ha) ($P = 0.004$) and maize yield (t/ha) ($P = 0.018$).

Furthermore, results indicated that there was significant variation in seeds/cob ($P = 0.027$), biological yield (t/ha) ($P < 0.001$) and for maize yields ($P = 0.002$) ($P = 0.004$) as the effect of time of introducing soybean. However, the number of plants/plot did not differ significantly ($P = 0.158$) with the time of introducing soybean (Table 1).

Because in most cases it is only time of introducing soybean in the cropping system which was found to be significant comparison of the means is only presented for this and excluding cropping pattern (Table 2). Results indicated that the mean number of seeds/cob differed significantly ($P = 0.027$) in the decreasing order of sole maize (455), simultaneous sowing of component crops (451), mid-introduction of soybean (440), and early introduction of soybean (423).

The biological yields as affected by the time of introducing soybean was in the order of mid-introduction (25.7 t/ha), simultaneous sowing (23.2 t/ha), sole maize (15.6 t/ha), and early introduction of soybean (5.5 t/ha). Generally, maize yields followed similar trend of biological yields and these were in the decreasing order of mid-introduction of soybean (3.7 t/ha), and simultaneous sowing (3.6 t/ha), which did not differ significantly. Moreover, maize yields obtained from sole maize (2.0 t/ha) and in maize sown under early introduction of soybean (2.4 t/ha) also did not differ significantly.

Effect of cropping pattern and time of introducing soybean on performance of soybean

Results indicated that the two-way interaction between cropping pattern and the time of introducing soybean did not differ significantly ($P > 0.05$) in influencing the response variables. In addition, cropping pattern had no significant ($P > 0.05$) effect on the studied soybean response variables. However, time of introducing soybean to the cropping system indicated significances in each response variable (Table 3). As an emphasis results also indicated that the number of seeds/pod differed significantly ($P = 0.032$) as well as grain yield (t/ha) ($P < 0.001$) as were influenced by time of introducing soybean to the system.

The cropping pattern used (1:1 and 2:2) did not have impact on the variations in performance of soybean. Therefore, for the mean separation it is only the time of introducing soybean that was used (Table 4).

Results indicated that number of pods/plant was statistically different for sole soybean (86 pods/plant)

Table 1. Mean sum squares (m.s) of response variables for maize under different time of introducing soybean.

Source of variation	d.f.	Response variables and their corresponding m.s			
		Plants/plot	Seeds/cob	Biological yield	Yield
Replication	2	23.17	453.4	58.8	0.96
Cropping pattern (CP)	1	26.04n.s	7n.s	20.5**	1.95*
Residual (a)	2	10.67	135	0.1	0.036
Time of introduction (TI)	3	25.6n.s	1184.6*	498***	4.69**
Interaction (CP×TI)	3	18.71n.s	122.4n.s	3.1n.s	0.95n.s
Residual (b)	12	12.36	272.7	8.8	0.49
Total	23				
	CP	0.259	0.841	0.004	0.018
P- value	TI	0.158	0.027	<0.001	0.002
	CP×TI	0.261	0.723	0.791	0.181

Key: Significance levels: n.s= P>0.05; *P =0.01–0.05; **P = 0.001 – P<0.01; ***P<0.001.

Table 2. Mean performance of maize under different time of introducing soybean.

Time of introduction	Response variables		
	Seeds/cob	Biological yield (t/ha)	Yield (t/ha)
Early-introduction of soybean	423.3a*	5.5a	2.4a
Mid-introduction of soybean	439.7ab	25.7c	3.7b
Simultaneous sowing of both crops	450.8b	23.2c	3.6b
Sole maize	454.7b	15.6b	2.0a
LSD (0.05)	27.85	3.4	1.2
C.V (%)	3.6	15.8	13.3

*Means along the same column bearings similar letter(s) do not differ significantly at 5% level of probably summarized from Tukey's test.

and early introduction of soybean (81 pods/plant), simultaneous sowing (52 pods/plant), and mid-introduction of soybean (32 pods/plant). In addition, the mean number of seeds/pod in sole soybean (3.037) significantly outperformed other cropping systems. The order of decrease in mean number of seeds/pod was mid-introduction of soybean (3.005), early-introduction of soybean (2.976), and simultaneous sowing of both crops (2.950). The highest soybean grain yield was recorded in sole soybean (4.22 t/ha), which was followed by early (3.02 t/ha) and simultaneous introducing soybean (2.83 t/ha) which were statistically similar. On the other hand, the lowest soybean grain yield (2.34 t/ha) was recorded under mid-introducing soybean to the cropping system (Table 4).

DISCUSSION

Maize

The findings of this study revealed that two-way interaction between cropping pattern and the time of introducing soybean did not significantly change ($P > 0.05$) variability of most maize response variables. In addition, spatial arrangement (1:1 and/or 2:2) had no differences in performance of most response variables of maize. Exception was observed for biological yield and maize yield, which could have been attributed to the reduction in maize plant population under 2:2 arrangement, but the time of introducing soybean was found to be significant. The discussion of this study is

Table 3. Mean sum squares (m.s) of response variables for soybean under different time of introducing soybean.

Source of variation	d.f.	Response variables and their corresponding m.s				
		Plants/plot	Pods/plant	Seeds/plot	Seeds/pod	Yield
Replication	2	0.542	1.04	4064	3321	0.07
Cropping pattern (CP)	1	24n.s	8.17n.s	274134n.s	1120n.s	0.012n.s
Residual (a)	2	7.125	19.04	85050	1976	0.009
Time of introduction (TI)	3	41.94*	3874.4***	68366239***	3440*	3.81***
Interaction (CP×TI)	3	4n.s	2.83n.s	241311n.s	15.97n.s	0.006n.s
Residual (b)	12	9.222	12.26	274347	24.72	0.056
Total	23					
	CP	0.208	0.58	0.214	0.421	0.369
P-value	TI	0.024	<.001	<.001	0.032	<.001
	CP×TI	0.733	0.873	0.479	0.611	0.958

Key: Significance levels: n.s= P>0.05; *P =0.01 – 0.05; ***P<0.001.

Table 4. Mean performance of soybean under different times of introducing soybean into maize+soybean intercropping pattern.

Time of introduction	Response variables				
	Plants/plot	Pods/plant	Seeds/plot	Seeds/pod	Yield (t/ha)
Early-introduction of soybean	41b*	81d	9884d	2.976b	3.02b
Mid-introduction of soybean	35a	32a	3366a	3.005c	2.34a
Simultaneous sowing of both crops	38ab	52c	5830b	2.950a	2.83b
Sole soybean	40b	86d	10447d	3.037d	4.22d
LSD (0.05)	5.2	6.4	870.9	0.019	0.4
C.V (%)	7.8	5.8	6.7	1.234	18.2

*Means along the same column bearings similar letter(s) do not differ significantly at 5% level of probably summarized from Turkey's test.

restricted only on the effect of the time of introducing soybean to the cropping system. Similar findings were obtained by Addo-Quaye *et al*., (2011) who found that the effect of the interaction between time of introduction of soybean and spatial arrangement was not significant. Many seeds/cob obtained in this study under sole maize could be attributed to the reduced/low intra-specific competition among maize plants. However, there could be some hidden intra-specific competitions among individual maize plants, which was beyond the scope of the present study opening up debate for further investigations.

The high biological maize yield recorded when soybean was introduced during mid-season could be attributed to the time given for the maize plants to explore large soil volume by production of many roots. These roots probably exhaustively competed enough for water, dissolved mineral nutrients, light and space before the establishment of soybean plants. Dolijanovic *et al.,* (2013) conducted a study to assess the dependence of the productivity of maize and soybean intercropping systems on hybrid type and plant arrangement pattern. Their findings indicated that maize had higher above-ground biomass and grain yields in alternate rows compared to strip intercropping system and sole crop. However, in a similar intercrop soybean had lower above-ground biomass and grain yields in intercrops than its pure stand. The reduction in response variables for maize and soybean was attributed to the inter- and intra-specific competition for essential nutrients, moisture, and amount of rainfall during the growing season.

Maize yields obtained from sole maize and in maize sown under early introduction of soybean did not differ significantly. However, highest yields were recorded for the maize sown under mid-introduction of soybean, and simultaneous sowing of component crops.

Addo-Quaye *et al.* (2011) found that sole maize recorded higher grain yield than the intercropped maize-soybean. Furthermore, the low maize grain yields recorded in the early introduction of soybean to the cropping season could be attributed to the inter-specific competition between the component crops, which definitely differed in their families and/or species. Maize and soybean differ in most aspects including their root characteristics and variation in accessing nutrients, light, and water resources. According to Zhang *et al.,* (2014), when maize is grown with legumes there exists complementarity effect, which depends on nitrogen fixation by the legume and spatial resource partitioning. The latter is reported by Postma and Lynch (2012) to be the result of roots foraging distinct soil domains due to the differences in root architecture. Other factors reported by Zhang *et al.*, (2014) are non-spatial niche complementarity such as different rates of nutrient uptake, nutrient use efficiency and nitrogen fixation among plant species and root classes. In the current study early sowing of soybean followed by introduction of maize to the system might have led to intense competition of soybean to the maize plants, resulting in lower yields. Similarly, Pal *et al*.. (1993) and Addo-Quaye *et al.,* (2011) reported reduced intercrop yields when they investigated the effects of component density on the yield of sorghum or maize intercropped with soybean.

Addo-Quaye *et al*., (2011) and Assefa and Ledin (2001) reported that there was greater reduction in maize grain yield when soybean was planted before maize. This was attributed to the inter-specific competition for resources such as light, nutrients, water and space. Furthermore, Hirpa (2014) also found that there was 15.5% yield reduction in maize when the number of haricot bean rows introduced between two maize rows increased from one to three. This was attributable to the aggravation of inter-specific competition in the latter case. Furthermore, Sarkodie-Addo and Abdul-Rahaman (2012) found that sowing of maize-soybean crops simultaneously or not more than a week after planting the maize in 1:1 spatial arrangement combination gave the greatest maize and soybean grain yields of 2.5 t/ha and 2.04 t/ha, respectively.

Soybean

The two-way interaction between cropping pattern and the time of introducing soybean as well as the results of cropping patterns for all response variables of soybean did not differ significantly ($P > 0.05$). These findings are contrary with those of Addo-Quaye *et al.,* (2011) who found that the effect of the interactions between time of introduction of soybean and spatial arrangement on grain yield were significant. The difference observed on these studies could be related with the variation in times of introducing soybean, which was not consistent, that are 14 days for this study and 14 and 28 days for the study conducted by Addo-Quaye *et al.,* (2011).

Soybean sown in pure stand as well as that sown early before sowing of maize recorded higher grain yields than soybean sown simultaneously with maize and that sown after maize. The highest yield in sole soybean could be attributed to the high plant population and reduced/low intra-specific competition among individual plants. In addition, the high yield obtained in early sowing of soybean in intercrop could be due to the ability of the soybean plants to establish themselves early in the season and system before high competition being posed from maize plants. Cardoso *et al.,* (2007) reported that when a legume is intercropped with maize, the extent of soil fertility enhancement through nodulation and nodule longevity is increased. This is attributed to an improved microclimate that favours the survival and effectiveness of rhizobia, exudates produced by maize stimulate nodulation, and maize absorbs more mineral N from the soil, hence stimulating nodule formation and BNF in the legume. According to Dolijanovic *et al.,* (2013), soybean is a weak competitor in a maize additive system, which reduced its grain yields in intercrop compared with the sole. They also stretchered that there was direct influence of the spatial arrangement and maize maturity on the soybean grain yields. Previous studies conducted elsewhere had similar findings too. For example, Nnoko and Doto (1980) found that planting soybean before cereal crop gave significantly higher yields than planting soybean at the same time or after the cereal, with the earlier planting schedule resulting in the highest yield. In addition, Addo-Quaye *et al.,* (2011) found that the introduction of soybean very late (28 days) into maize yielded no grains.

The low soybean grain yield obtained during mid-introduction of soybean in this study could be explained by the fact that maize by virtue of its fast growth habit and the early planting compared with soybean gave it an advantage to develop rapidly and form closed canopy. The maize plants therefore maintained a competitive advantage over the slower growing and shorter soybean plants, thereby suppressing their growth and ultimately low grain yielding. This could also have been associated with shading of the soybean seedlings by the already established maize plants leading to reduction in leaf area, crop growth rate and net assimilation rate (Sarkodie-Addo and Abdul-Rahaman, 2012).

Conclusion

This study assessed the performance of soybean-maize cropping systems determined by spatial arrangements and time of introduction. Based on the results of this study time of introducing a component crop to the system, planting density and spatial arrangement of the partner crops in the cropping land are important in determining the ultimate performance of the component crops. The driving reason to this was largely competition for and utilization of essential resources such as space, water, light and dissolved nutrients.

This study included sole, intercropped and time of introducing soybean. The findings of this study should not be generalized with other soils, locations and/or specific sites. It is therefore, recommended that:

- Further research should be conducted that accommodates some aspects of temporal and/or spatial separation, for instance, geographical and/or agro-ecological locations, and different planting dates of the component crops so that the differential influence of weather and in particular temperature on component crops could be modified.
- Further research should be conducted along with the above bullet but including different varieties of partner crops and use of economically viable fertilizers to improve yields.

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