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Seed quality of three soybean varieties as influenced by intercropping time and arrangement in maize

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The response of soybean varieties *J499*, *SCS-1* and *La suprema,* with different growth habits, to intercropping conditions when grown in association with maize H614D was evaluated in a study at Bukura Agricultural College (0° 06'' N; 34° 50'' E), Kenya. The soybean was sown either at the same time as maize or two weeks later in pure stands or intercropped with maize either in the same hill or in alternate rows. The trial was laid out in a randomized complete block design with four replications. Data collected included grain yield, 100 seed weight, percentage germination, and analytical purity among others. Among the three soybean varieties *J499* had significantly higher percentage analytical purity (92%) than *SCS1* (84%) and *La suprema* (82%). In terms of % germination, *J499* had the highest (93.3%), followed by SCS1 (87.5%) and lastly *La suprema* irrespective of the intercropping pattern and sowing time. Intercropping *La suprema* two weeks later in maize led to a 30% increase in 100-seed weight. Sowing at the same time as maize led to a significant difference in seed weight among the varieties, with J499 being the highest (15.1 g) and La suprema the lowest (12.7 g). However, no significant difference was observed when they were sown two weeks later. Among the three varieties, *J499* had the lowest number of pods per plant and *SCVS-1* the highest. Yields (Kg/ha) of soybean sown in pure stands at the same time as maize were significantly higher (509.9 Kg/ha) than that sown two weeks later (280.2 Kg/ha). The difference in yield between soybean sown at the same time as maize and that sown two weeks later in row intercropping was about 400%. For sowing times pure stands yielded significantly higher soybean yields than intercrops. From the findings it can therefore be concluded that the seed of soybean variety *J499* grown as an intercrop has suitable quality attributes to be used as seed.

Key words: Seed quality, Intercropping patterns, maize H614D, soybean varieties, sowing time.

INTRODUCTION

Farmers in the tropics cultivate their crops through intercropping, which is the most common form of traditional farming (Waddington and Karigwindi, 2001). Intercropping is as old as civilization and is a widespread practice in the warm tropical countries due to its advantages such as optimum utilization of land (Searle et al., 1981), weed suppression (Haggard-Nelson et al., 2001) and soil fertility improvement through biological nitrogen fixation by Rhizobium bacteria (Li et al., 2014; Cardoso et al., 2006; Li et al., 2007). Intercropping involving non-legume and legume combination have had significant yield advantages (Lithourgidis et al., 2006; Li et al., 2014) compared to

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monocropping system in various crop species. Yield advantages have been reported in: Maize-cowpeas (Dahmardeh et al., 2010) maize-bean (West and Griffin, 1992), sorghum (sorghum bicolor)/soybean (*Glycine max*) (Elmore and Jacobs, 1986), barley (*Hordium vulgare*/Pea (Chen et al., 2004) and Faba/barley (Ghosh et al., 2006). Nitrogen fixed by the legumes is influenced by the component crop morphology, crop density and competitive ability of the legume (Ofori and Stern, 1987). The morphological and physiological differences between non-legumes and legumes benefit their mutual association (Akuda, 2001). The cereal component crop is usually taller and has faster growing or more extensive system of fine roots (Lehman et al., 1998) and very competitive for soil nitrogen than the legumes which usually fix atmospheric N (Jensen, 1996).

Delouche (1980) and Chavez and Mendoza (1986) in their studies indicated that high temperature during the time of maturation reduces the quality of seeds. For instance Chavez and Mendoza (1986) showed that seed subjected to high temperature and high relative humidity conditions in the field declined significantly in germination after reaching physiological maturity. The resulting microclimate under the maize canopies is generally characterized by high relative humidity and temperature. Thus, shading may affect the quality of soybean seed intercropped with maize. However, intercropping has been reported by several other authors not to have any adverse effect on seed germination, seed purity or 1000-grain weight of wheat and various legumes grown in association with cereals (Neupane et al., 1997; Deshpande et al., 1992; Hilli and Kulkarni, 1988).

Seed quality is very essential for optimum stand establishment and maximum yield in soy bean. As a result, it is necessary to have different seed testing parameters that permit rapid, objective and accurate evaluation of seed quality. The quality of the seed lot is judged by the relative percentage of various components. The quality is considered superior, if pure seed percentage (analytical purity) is above 98, and other seeds and inert matter percentage as low as possible (Trivedi and Gunasekaran, 2013). Since germination test are based on pure seed components, it can readily be seen that purity analysis and germination tests complement each other (Joshi et al., 2009). Thus the actual planting value of seed can be determined only when the purity analysis and germination tests are considered together.

In Kenya most farmers use their previous harvest as seed material for subsequent planting. Is it advisable for farmers to use soybean seed produced under maize intercropping. This study was therefore conducted with the objective of evaluating the effect of intercropping time and arrangement on seed quality of three soybean varieties grown as intercrops in maize in Western Kenya.

MATERIALS AND METHODS

The study was carried out during the long rains (March to August) in 2007 at Bukura Agricultural College (0° 06" N; 34° 50" E) in Kakamega County in Western Kenya.

The experimental design was a 3*3*2 factorial in a Randomized Block Design with four replications. There were three factors namely cropping systems at three levels; sole soybean (A1), one row of soybean between two rows of maize (A2), and soybean planted in the same hill with maize (A3); soybean varieties were three; *J499*, *SCS-1* and *La suprema*; and two sowing times; same time as maize (T0) and two weeks after maize (T1) (Table 1)

The gross plot dimensions were 4 m by 3 m. At sowing time, 20 kg of nitrogen and 60-kg ha^{-1} P_2O_5 were applied along the rows of maize. Forty-five days later 60-kg ha^{-1} of nitrogen was applied to the maize as topdressing. Two seeds of maize were sown in each hill. Thinning to one plant per hill was done 18 days later.

The soybean in pure stand was drilled in rows 45 cm apart and thinned to 5 cm after four weeks. In addition to initial land preparation, weeds were controlled by hand weeding whenever it was necessary. The crops were sprayed with the insecticide Dimethoate® and the fungicides Antracol® and Dithane M45® to control pests and fungal diseases respectfully, common in the study area (Table 2).

The whole plot was harvested for determination of soybean seed yield and seed quality attributes. The plot yield was determined by weighing the threshed and winnowed grain. The moisture content was measured and the value obtained used to standardize the yields to 15% moisture content using the formula prescribed by FAO (1986):

Adjusted yield (kg/ha) = {(100 - M1) Y}/ {100 - M2}

Where, M1 = % Moisture content of seed, M2 = Standardized storage moisture content (for seed soybean = 15%) and Y = Yield in kg/ha before moisture standardization.

A sample soybean seed from each experimental plot was divided in the laboratory to obtain working samples for various laboratory tests. The samples were thoroughly mixed by passing through a seed divider several times and subsequently reconstituting. The sub-samples for various tests were obtained by successively halving the sub-samples until a sample of required weight was obtained for the seed quality tests outlined following.

Seed purity analysis

A working sample of 120 g of seed obtained from the sub-sample was placed on a purity work board. The working sample was then meticulously separated into pure seed, other crop seeds, inert matter and weed seed components in accordance with ISTA purity analysis procedures. Each component was weighed in grams and the percentage of each component calculated (ISTA, 2004).

100-seed weight

The pure seed-fraction was poured on a counting board; from the sample, 10 replicates of 100 random seeds were counted. Each replicate was weighed on a precision balance in grams to two decimal places.

Germination test

Four replicates of 100 random seeds each were obtained using a vacuum seed counter (with counting plates containing 100 holes) and placed in loose, moistened sand media in germination dishes. The seeds were sufficiently spaced on the media and covered with a thin layer of uncompressed sand. The germination dishes were then covered with transparent, moisture proof dishes and placed in a germination room maintained at 20°C. The germination count was carried out at the end of 7 days using the following parameters:

Table 1. Treatment combinations and days of planting.

Treatment code	Description
Control	Sole maize
T0A1V1	Soybean variety *J499* sown in pure stands on same day as maize
T0A1V2	Soybean variety *SCS-1* sown in pure stands on same day as maize
T0A1V3	Soybean variety *La suprema* sown in pure stands on same day as maize
T0A2V1	Soybean variety *J499* sown in alternate rows with maize on same day
T0A2V2	Soybean variety *SCS-1* sown in alternate rows with maize on same day
T0A2V3	Soybean variety *La suprema* sown same day in alternate rows with maize
T0A3V1	Soybean variety *J499* planted in same hill with maize on same day
T0A3V2	Soybean variety *SCS-1* planted in same hill with maize on same day
T0A3V3	Soybean variety *La suprema* planted in same hill with maize on same day
T1A1V1	Soybean variety *J499* planted in pure stand 14 days after maize
T1A1V2	Soybean variety *SCS-1* planted in pure stand 14 days after maize
T1A1V3	Soybean variety *La suprema* planted in pure stand 14 days after maize
T1A2V1	Soybean variety *J499* planted in alternate rows 14 days after maize
T1A2V2	Soybean variety *SCS-1* planted in alternate rows 14 days after maize
T1A2V3	Soybean variety *La suprema* planted in alternate rows 14 days after maize
T1A3V1	Soybean variety *J499* planted in same hill with maize 14 days after maize
T1A3V2	Soybean variety *SCS-1* planted in same hill with maize 14 days after maize
T1A3V3	Soybean variety *La suprema* planted in same hill with maize 14 days later

Table 2. Plant spacing and population density for maize and soybean.

Crop	Spacing	Plant/Hill	Plant population	
			Per m^2	Per Ha
Maize	75 cm x 30 cm	1	4.44	44, 444
Soybean (A1)	45 cm × 5 cm	1	44.44	4444,444
Soybean (A2)	75 cm × 5 cm	1	26	266,667
Soybean (A3)	75 cm × 30 cm	1	4.44	44,444

Number of normal seedlings, abnormal seedlings, hard seeds, fresh ungerminated seeds and dead seeds. Germination capacity of normal seeds was based on total number of seeds planted and expressed as a percentage (ISTA, 2004).

Land equivalent ratio

The production efficiency was based on Land Equivalent Ratio (LER) expressed as:

Land equivalent ratio (LER) = (Yij/Yii) + (Yji/Yjj)

Where Y is the yield per unit area, Yii and Yjj are sole crop yields of the component crops i and j and Yij and Yji are the intercrop yield (Mead and Willey, 1980). LER is the sum of the two partial land equivalent ratios. Where LER was more than 1.0, this indicates a positive intercropping advantage which shows that interspecific facilitation is higher than interspecific competition (Vandermeer, 1989).

Analyses of variance were carried out on all parameters measured, using computer package GENSTAT 5 ("General Statistic Committee 5"). Treatment means significantly different at 1 or 5% level of significance were separated using the Tukeys Test at the same level of significance. The association among various parameters was determined using Spearman's Coefficient of Rank Correlation (P=0.05) as described by Steel and Torrie (1986).

RESULTS

Effect of intercropping pattern, relative sowing time and soybean variety of % analytical purity

Treatment effects were statistically highly significant (p=0.001) for relative sowing times, intercropping patterns, varieties and the interaction between relative sowing time and intercropping patterns. Other effects were not significant.

In general the soybean pure stands gave soybean seed with significantly higher % analytical purity than the intercrops (Table 3). However, no significant difference in % analytical purity was noted on soybean seed from either of the intercrop patterns. Soybean sown simultaneously with maize also gave seed with significantly higher analytical purity than that sown two weeks later.

In general soybean variety *J499* gave significantly higher

Table 3. Effect of intercropping pattern, relative sowing time and variety on the analytical purity (%) of soybean seed.

Intercropping pattern (A)	Soybean variety (A)% analytical purity						Mean(A)
	V1		V2		V3		
	T0	T1	T0	T1	T0	T1	
(A2)	96.9	96.6	95.9	92.0	95.2	87.3	94.0[a]
(A3)	94.0	89.0	84.1	78.5	87.8	78.4	85.3[b]
(A4)	94.6	80.5	93.1	63.0	80.6	62.5	79.0[b]
Mean(V)	92[a]		84.4[b]		82.0[b]		86.1

Mean (T) : % C.V. =7.53; T0=91.3a; T1=80.9b; V1, *J499*, V2, *SCS1*; V3, *La suprema*; A1, sole maize; A2, sole soybean; A3, row between maize; A4, same hill as maize; T1, planted two weeks after maize; C.V.. coefficient of variation. Any two means having a common alphabetical letter in the same column are not significantly different at 5% level of significance

Table 4. The effect of the interaction between intercropping pattern and relative sowing time on percentage analytical purity of soybean seeds.

Intercropping pattern (A)	Relative sowing time (T) and% analytical purity		
	T0	T1	Mean
A2	96.0[a]	92.0[a]	94[a]
A3	89.0[b]	82.0[b]	86[b]
A4	89.0[b]	69.0c	79c

Relative sowing time (T)	Intercropping pattern (A)			
	A2	A3	A4	Mean
T0	96.0[a]	89.0[a]	89.0[a]	91[a]
T1	92.0[a]	82.0[b]	69.0[b]	81[b]

% C.V.=7.53; S.E.D.=3.25; A1, sole maize; A2, sole soybean; A3, Row between maize; A4,same hill as maize; T1, planted two weeks after maize; S.E.D, standard error of the difference; C.V. , coefficient of variation. Any two means having a common alphabetical letter in the same column are not significantly different at 5% level of significance

% analytical purity than *SCS1* and La *suprema* (Table 3).

As shown in Table 4 whether sown at the same time as maize or two weeks later, soybean pure stands generallygave seed with a significantly higher % analytical purity than intercrops. For all intercrops sowing soybean simultaneously with maize led to a significantly higher % analytical purity than sowing two weeks later. However, no significant differences were recorded in % analytical purity between the two sowing times in soybean pure stands (Table 4).

The later sown soybean spent more time under the maize canopy, which had a modified microclimate with lower temperatures and higher relative humidity. These conditions probably led to development of pests and diseases that affected the analytical purity.

No significant differences were noted in soybean analytical purity between the intercropped varieties indicating the fact that analytical purity may be affected by factors other than varietal differences.

Effect of intercropping pattern, relative sowing time and soybean variety on % germination

As indicated in Table 5, except for soybean variety *SCS1,* intercropping pattern had no significant effect on the % germination. *SCS1* pure stands and hill intercropping gave soybean seed with significantly higher % germination. In general, soybean variety *J449* gave significantly higher % germination than the other varieties in all cropping patterns. The germination percentage of *J499* was significantly greater than that of *La suprema* and *SCS1* when the three varieties were sown in the same hill as maize. Significantly higher percent germination was observed when *J499* was sown in mixed cropping than in monocropping. The contrast was true for *SCS1*, where monocropping gave significantly higher percentage germination than mixed cropping.

As shown in Table 6, intercrops gave higher % germination than pure stands when sown at the same time as maize. Hill intercropping gave significantly higher % germination than pure stands when sown at the same time as maize. However, between the rows intercrop was not significantly different from pure stands. When sown two weeks later, soybean pure and between the maize rows intercrop gave significantly higher % germination than hill intercrops.

Between the two relative sowing times, a significant difference in percentage germination was observed in pure

Table 5. The effect of the interaction between intercropping pattern and variety on percentage germination of soybean seeds.

Intercropping pattern (A)	Soybean variety (V) and % germination			
	V1	V2	V3	Mean
A2	89.3[a]	92.0[a]	84.4[a]	88.6[a]
A3	96.4[a]	84.3[b]	86.5[a]	89.1[a]
A4	94.3[a]	86.2[ab]	85.3[a]	88.6[a]
Soybean variety	**Intercropping pattern**			
	A2	**A3**	**A4**	**Mean**
V1	89.3[ab]	96.4[a]	94.3[a]	93.3[a]
V2	92.0[a]	84.3[bc]	86.2[ab]	87.5[b]
V3	84.4[b]	86.5[c]	85.3[b]	85.4[b]

% C.V. = 9.6; S.E.D. =4.2; V1, *J499*; V2, *SCS1*; V3, *La suprema*; A1, sole maize; A2, sole soybean; A3, row between maize; and A4, same hill as maize S.E.D, standard error of the difference; C.V. , coefficient of variation. Any two means having a common alphabetical letter in the same column are not significantly different at 5% level of significance

Table 6. The effect of the interaction between relative sowing time and intercropping pattern on percentage germination of soybean seeds.

Intercropping pattern (A)	Relative sowing time (T)/% germination		
	T0	T1	Mean
A2	85.0[b]	92.1[a]	88.6[a]
A3	89.1[ab]	89.4[a]	89.3[a]
A4	91.5[a]	77.8[b]	85.2[a]

Relative sowing time (T)	Intercropping pattern (A)			
	A2	A3	A4	Mean
T0	85.0b	89.1[a]	91.5[a]	88.5[a]
T1	92.1[a]	89.4[a]	77.8b	86.4[a]

% C.V. = 9.6 S.E.D. = 4.2. A1, sole maize; A2, sole soybean; A3, Row between maize; A4, same hill as maize; T1, planted two weeks after maize; S.E.D, standard error of the difference; C.V., coefficient of variation. Any two means having a common alphabetical letter in the same column are not significantly different at 5% level of significance.

stands and same hill intercropping, but not in row between maize intercropping (Table 9). In pure stands later sown soybean gave significantly higher percentage germination than soybean sown two weeks earlier. While for soybean sown in same hil, earlier sown soybean gave significantly higher percentage germination than that sown two weeks later.

Effect of intercropping pattern, relative sowing time and soybean variety on 100-seed weight

There was a significant difference (p=0.05) in 100-seed weight between soya bean varieties sown at the same time as maize (Table 7), with 100-seed weight of *La suprema* being significantly lower than the 100-seed weight of *J499* and *SCS1*. However, the 100-seed weight of the three varieties showed no significant difference when they were sown in maize two weeks later. The seed weight of *J499* and *SCS1* was significantly reduced when sowing was delayed by two weeks, while that of *La suprema* was significantly increased.

Effect of intercropping pattern, relative sowing time and soybean variety on grain yield

Yields of soybean sown in pure stands were significantly higher than in intercrops (Table 8). Further, a marked reduction in soybean yields was recorded when sowing was delayed by two weeks. However, no significant difference in yield was observed between the three soybean varieties.

Whether sown at the same time as maize or two weeks later soybean pure stands yielded higher than the two intercrops (Table 9). Soybean sown in pure stands at the same time as maize yielded on average four times as much grain as mixed intercrops. Yields of soybean pure

Table 7. The effect of the interaction between soya bean variety and relative sowing time on 100 seed weight (g) of soya bean.

Soya bean variety (V)	Relative sowing time (T) and 100-seed weight (g)			
		T0	T1	Mean
V1		16.1[a]	14.0[a]	15.0[a]
V2		15.8[a]	13.6[a]	14.2[b]
V3		11.0[b]	14.2[a]	12.6[c]
Relative sowing time (T)	**Soya bean variety**			
	V1	**V2**	**V3**	**Mean**
T0	16.1[a]	15.8[a]	11.0[a]	14.3[a]
T1	14.0[b]	13.6[b]	14.2[b]	13.9[a]

%C.V.=20.9 S.E.D.=0.7; V1, *J499*; V2, *SCS1*; V3, *La suprema*; T1, planted two weeks after maize; S.E.D, standard error of the difference; C.V. , coefficient of variation. Any two means having a common alphabetical letter in the same column are not significantly different at 5% level of significance

Table 8. Effect of intercropping pattern, relative sowing time and variety on yield (kg/ha) of soybean.

Intercropping pattern (A)	Soybean variety/grain yield (kg/ha)						Mean (A)
	V1		V2		V3		
	T0	T1	T0	T1	T0	T1	
(A2)	1097	766	1135	750	1058	514	887a
(A3)	158	186	208	94	187	74	151b
(A4)	322	102	225	21	119	15	134b
Mean (V)	439a		406a		328a		391

Mean (T): % C.V. =22.20; T0=501[a]; T1=280[b]. V1, *J499*; V2, *SCS1*; V3, *La suprema*; A1, Sole maize; A2, sole soybean; A3, Row between maize; A4, same hill as maize; T1, planted two weeks after maize; C.V. , coefficient of variation. Any two means having a common alphabetical letter along a column are not significantly different at 5% level of significance

Table 9. The effect of the interaction between intercropping pattern and relative sowing time on yield (kg/ha) of soybean.

Intercropping pattern (A)	Relative sowing time (T)/grain yield (kg/ha)			
		T0	T1	Mean
A2		1097[a]	766[a]	932
A3		184[b]	118[b]	151
A4		222[b]	46[b]	134
Relative sowing time (T)	**Intercropping pattern (A)**			
	A2	**A3**	**A4**	**Mean**
T0	1097[a]	184[a]	222[a]	641
T1	766[b]	118[a]	46[a]	441

% C.V. = 22.20; S.E.D. = 102.14; A1, sole maize; A2, sole soybean; A3, Row between maize; A4, same hill as maize; T1, planted two weeks after maize S.E.D, standard error of the difference; C.V. , coefficient of variation. Any two means having a common alphabetical letter in a column are not significantly different at 5% level of significance.

stands sown two weeks later were about seven times the yield of corresponding mixed intercrops. Only monocrops showed significant difference in yield as a result of delayed sowing, with earlier sown soybean yielding significantly more than later sown crop. No significant difference in yields was observed in mixed cropping as a result of variation in the sowing time.

The grain yield of soybean was significantly reduced in

Table 10. Seed yield and Land equivalent ratios of maize and soybean in sole crop, sowing time and intercropping systems.

Treatment	Yield Kg/ha		LERs
	Maize	Soybean	
T0A2V1	2960a	158g	1.16a
T0A2V2	2575a	288fg	1.14a
T0A2V3	2898a	187fg	1.17a
T0A3V1	2832a	322fg	1.27a
T0A3V2	2532a	225fg	1.07a
T0A3V3	2563a	119g	1.00a
T1A2V1	2394a	186fg	1.07a
T1A2V2	2348a	94g	0.93a
T1A2V3	2798a	74g	1.11a
T1A3V1	2479a	102g	0.99a
T1A3V2	2790a	21g	0.99a
T1A3V3	2768a	15g	0.98a
C.V%	14.46	12.20	11.66
Mean	2600.00	391.00	1.15
S.E.D	317.92	48.20	0.11

Means followed by the same letter in a column are not significantly different at the 5% level.

both intercropping patterns sown either at same time as maize or two weeks later due to the shading by maize and other interspecific interactions.

Soybean sown in any of the intercropping patterns simultaneously with maize gave significantly higher grain yield than soybean sown two weeks later. The soybean sown at the same time as maize might have escaped the competitive effects of maize. Changes in soil and weather conditions might have also contributed to the lower yields of later sown soybean.

Effect of intercropping pattern, relative sowing time and soybean variety on Land Equivalent ratio (LER)

As shown in Table 10, there were no significant differences in LERs due to treatment effects. However, in general, sowing soybean varieties at the same time as maize in intercrops led to LERs greater than one indicating the advantage of intercropping. Only soybean varieties *J499* and *La suprema* sown two weeks later between the rows gave LERs greater than one. All the other intercrops sown two weeks later in maize had LER values less than one indicating the disadvantage of intercropping due to delay in sowing (Table 10).

Effect of intercropping pattern, relative sowing time and soybean variety on Yield of maize

The treatments had no significant effect on the yield of maize (Table 10).

Correlation of growth and other parameters with yield of soybean

Several parameters measured correlated significantly with the yield of soybean. The number of pods per plant, the yield of maize and the LER were positively correlated to the yield of soybean (Table 11). The height of plants at maturity and 100-seed weight were not significantly correlated to the yield of soybean.

The number of pods per plant and analytical purity were significantly correlated with the yield of soybean indicating that treatments that affected the yield of soybean also affected these parameters. Maize and soybeans use the same environmental resources which they were competing for in mixed cropping. However, the comparison includes pure stands of both crops, which were not in interaction.

There was however no significant correlation between yield of soybean with 100-seed weight and germination percentage. Germination percentage was not significantly correlated with analytical purity. Treatments, which affect the yield of soybean, do not therefore seem to affect these parameters.

DISCUSSION

The results of the study indicated that analytical purity of soybean seed was significantly affected by intercropping with maize, relative sowing time and variety. Pure stands generally gave higher % analytical purity than intercrops probably due competition for resources by maize which affected grain filling leading to underdeveloped and dead seeds. Further the higher humidity and modified

Table 11. Spearman's rank correlation (rs) between soybean seed yields and selected parameters.

Yield correlated with	Rs	$t_{0.05}$	t-critical
Height	0.28	1.170[Ns]	2.11
Pods per plant	0.62	3.130*	2.11
Yield of maize	0.74	5.503*	2.20
LER	0.79	5.090*	2.11
100-seedweight	0.03	0.120[Ns]	2.11

Rs, Spearman's rank; Ns, not significant; *, significant (p=0.005).

temperature might have led to seed pests and diseases. Soybean variety *J499* generally gave significantly higher % analytical purity than the other varieties since it is earlier maturing and was able to escape the competitive effects of maize and produce better seed quality. Further, soybean sown at the same time as maize gave significantly higher % analytical purity than that sown two weeks later because it was also able to escape the competitive effects of maize due to separation in time. However, it is worth noting that all treatments gave a % analytical purity less than 98 which is the below the minimum standard required for quality soybean seed (Trivedi and Gunasekaran, 2013).

Except for soybean variety *SCS1,* intercropping pattern had no significant effect on the % germination. In general, soybean variety *J449* gave significantly higher % germination than the other varieties in all cropping patterns. Significantly higher per cent germination was observed when *J499* was sown in mixed cropping than in monocropping. The contrast was true for *SCS1*, where monocropping gave significantly higher percentage germination than mixed cropping. However all treatments gave a % germination greater than 70 which is the minimum standard required for quality soybean seed (Trivedi and Gunasekaran, 2013).

These finding are consistent with those of Neupane et al*.* (1997) in a related study, who observed no significant effect on wheat seed germination intercropped with lentils or mustard. However, Deshpande et al. (1992) indicated that the percentage germination of groundnut seeds was higher in pure stands than in 1:1 intercrops. Egbe (2010) observed that seed subjected to high temperatures and high relative humidity in the field declined significantly in germination after reaching physiological maturity. In this study the resulting microclimate under maize canopies was generally characterized by high relative humidity and temperature. This microclimate may have affected the seed quality of the intercropped soybean.

Hill intercropping gave significantly higher % germination than pure stands when sown at the same time as maize. Since the two crops were sown in the hill, the higher percentage would be attributed to the complementarity effect and positive interspecific interactions as explained (Li et al., 2014). When sown two weeks later, soybean pure stands and between the maize rows intercrop gave significantly higher % germination than hill intercrops probably due to minimal interspecific competition. A delay in sowing in the same apparently intensified the shading effect of maize. The percentage dead seed was higher for *La suprema* sown between the rows at the same time as maize than when the soybean was sown two weeks later as a result of intensive shading by the companion crop.

The larger seed weight of *La suprema* sown two weeks later could be explained by the fact that this variety is late maturing and was probably able to accumulate photosynthates after maize had reached physiological maturity. This is in agreement with observations of Trenbath (1976) that separation of component crops in time may increase the advantages of intercropping by reducing or postponing competition between the component species. On the other hand *La suprema* sown at the same time as maize gave the lowest seed weight due to the fact that the late maturing *La suprema* variety competed for resources at the same time with maize. The competition affected availability of resources grain filling in this variety.

These observations are consistent with those of Yunusa (1989) in maize-soybean mixtures, Narwal and Malik (1982) in sunflower-soybean mixture and Martin and Snaydon (1982) in barley and beans mixtures. Narwal and Malik (1982) for instance observed that sunflower reduced the 100-seed weight of soybean sown in the same hill and between the rows by 12 and 15% respectively. The authors concluded that the reduction in seed weight was due to moisture stress and shading, which reduced availability of photosynthates for grain filling.

The pattern of soybean yields exhibited in this study whereby the pure stand was significantly higher than the intercrops is consistent with observations of; Prasad and Rafey (1996), Edje (1984) and Tetio-Kagho (1988) in maize-soybean intercropping studies. Similar results were reported in related studies: Egbe (2010), Akuda (2001), Olufajo (1995) in sorghum-soybean mixture, and Myaka (1994) in pigeon pea-soybean mixture. Edge for instance suggested that the yield reduction of the intercropped soybean may have been associated with interspecific competition between the intercrop components for growth resources (light, water, nutrients, air, etc.) and the depressive effects of the companion crop. Use of different intercrop patterns led to variation in plant population with soybean sown at near optimum population (pure stand) yielding the highest. Fast growing and tall crops have an advantage over slower and shorter crops.

Sowing soybean in maize two weeks later led to a significant decrease in the yield of soybean for the three intercropping patterns. Mulatu and Kebede (1993) reported similar results in a related study. They observed a severe reduction in yield of haricot beans under intercropping from delayed sowing. The reduction in the yield of soybean was not significant between the two relative sowing times for the between the rows intercropping pattern indicating possibility of less intercropping competition compared to hill intercropping. As observed by Dahmardeh et al. (2010) and Long Li et al. (2014) in their studies, plant diversity may enhance ecosystem productivity through the ability of some crop species to chemically mobilize otherwise unavailable forms of limiting soil nutrients such as phosphorus and micronutrients such as iron, zinc and manganese. The relative time of sowing a component crop is an important management variable manipulated in cereal-legume intercropping systems.

The LER values of maize-soybean mixtures, based on grain yield, ranged from 0.90 to 1.27 representing an advantage in favour of intercropping. Same hill intercropping sown two weeks later in maize generally gave LER less 1 with very low partial LER contribution by soybean due to servere completion by the companion crop. However, no significant differences were noted in LER values due to treatment effects. Several workers have also obtained LER greater than 1 in maize-soybean intercropping. Dahmardeh et al. (2010) and Muoneke et al. (2007) reported higher production efficiency in various intercropping systems. The higher productivity of the intercrop system compared to the sole crop may have resulted from complementary and efficient use of growth resource by the component crops. Vandermeer (1989) noted that both competition and facilitation take place in many intercropping systems, and that it is possible to obtain the net result of land equivalent ratio (LER) where the complementary facilitation is contributing more to the interaction than the competitive interference. Thus, an LER>1 could result from low interspecific competition or strong facilitation.

The maize component contributed more to the total LERs of the mixture as shown by the partial LER of maize in the results (Table 10). Similar findings have been reported by other researchers. In cereal-legume intercropping, the cereal components usually tend to have greater competitive ability because of their relatively higher growth rate, height advantage, and more excessive root system (Zhang et al., 2007; Ofori and Stern, 1987). In addition, the leaf water potential, stomata conductance, transpiration and photosynthesis have been found to be higher in intercropped maize than the sole crop (Lima, 2000).

Maize alternating with single rows of soybean recorded higher values of LER than maize sown in the same hill with soybean, though this was not statistically significant (Table 10). This may be attributed to the fact that soybean population in between the rows was six times that of the same hill arrangement. This finding is in agreement with those of Chowdhury and Rosario (1993) who observed the highest LER when both intercrop components were at their optimum sole crop populations in maize-mung bean trial.

Results indicated that the yield of maize was not significantly affected by being grown in association with soya bean. This is findings are in close conformity with those of Hayder et al. (2003) who observed a non-significant difference on the yield on intercropped maize.

Conclusions

Sowing maize and a legume (either common beans or soya bean) is the most popular cropping system in the sugar cane growing zone of Western Kenya. The legume may be sown at the same time as maize or later and the legume maybe sown in the same hill with maize or between the rows. The seed harvested from the intercropped legume is saved for use during the next season and/or consumed. From the findings it can therefore concluded that the seed of soybean grown as an intercrop has suitable quality attributes to be used as seed.

Conflict of Interest

The authors have not declared any conflict of interest.

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