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Evaluation of the Association and Rotation of Maize with Legumes, in Direct Sowing in the Democratic Republic of Congo

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Abstract

A study was carried out to find, in the intercropping system, the combination for optimizing maize production put into the direct seeding mulch-based cropping systems (DMC). Eight varieties of maize and two legumes were put into intercropping and rotated systems respectively in first and second season, following a factorial system with four replicates. In the second season, maize was sowed on mulch from sole crops and intercrops of first season. The results showed that in the first and second seasons, maize sole crop and maize on maize + cowpea mulch were more productive (2350.19 kg·ha^{-1} and 2974.82 kg·ha^{-1} respectively) than maize on maize + soybean mulch. But, Mudishi 3-soya and 07SADVE variety on maize + cowpea mulch obtained the greatest benefit for the various association systems (cost/benefit ratio = 4.04 and 2.01 respectively). Maize varieties have doubled, tripled or quadrupled their yields when rotated with cowpea and soybean, and the high yields observed in this study resulted in significant benefits in increasing their ratios whether in combination or in rotation. These new agricultural production techniques could free the farmer from tillage by leaving the cover plants to ensure equivalent work (DMC).

Subject Areas

Agricultural Science

Keywords

Maize, Soybean, Cowpea, Intercropping, Mulch, INERA, DR Congo

1. Introduction

Intercropping was defined as an agricultural practice of growing two or more crops in the same space at the same time. Increasing productivity per unit area can be an important reason for growing two or more crops together [1]. It can be seen as practices application of diversification, competition and facilitation of species in cropping systems [2]. Cereal-legume intercropping plays an important role in food production worldwide. Crop intercropping is commonly practiced because of various advantages such as greater yield stability [3] [4], when one crop fails, the other can still give a reasonable yield [5], a higher efficient land occupation, a high capacity for competition against weeds; legumes can cover their need for atmospheric nitrogen (N_2) [6] and thus is less competitive for soil nitrogen [4] [7] [8] [9].

In the Democratic Republic of Congo, in general, and in the Province of Central Kongo in particular, the production of legume residues remains low as a result of the export of organic matter out of the field and the practice of waste incineration. According to [10], research that had been carried out for more than 30 years [11] [12] had shown the causes and factors of the physical and chemical degradation of new land; Their findings had suggested a number of locally capable methods of delaying degradation, limiting losses, and even restoring acceptable fertility potential. In the current cropping system, a crop rotation system with the integration of cover crops has also been proposed in addition to the combination of crops, In order to solve the problems of depletion of cultivated soil [13] [14]. Studies conducted in the world have shown that the direct seeding mulch-based cropping system (DMC) ensures a good productivity of the cultivated surfaces and gives many advantages in the soil management [15] [16] [17]. To be successful, these cropping systems must produce high biomass, particularly in the first years of direct seeding.

Although the effects of mulch on the soil are well known [18] [19], but with a low protection, one may wonder what the real impact of this technique on rainfed maize yield and on the evolution of long-term fertility in our fields. Information on the associations and rotations of the different varieties of maize and pulses is very poor and does not allow sufficient information on these crops.

This study aims to acquire knowledge on the response of maize crops in association and rotation with food legumes used as cover crops in order to determine the type of cover to be used in order to better evaluate their effects on maize yield.

2. Material and Method

2.1. Experimental Site, Description and Characterization of Soil

This study was conducted at the Mvuazi Research Station during the 2011-2012 cropping season. Mvuazi is in the Kongo Central province of DRC with longitude 14˚54'E, latitude 5˚21'S and altitude 470 m. The soil of Mvuazi belongs to the Sudano-Guinean climate zone of the AW4 type [20]. This soil is characterized by low organic matter content and low water holding capacity resulting in low nitrogen availability. This soil valley develops a humiferous horizon 15 - 25 cm thick, black (fresh) or brownish (dry) with a well-pronounced subangular or grumulous structure. And this horizon is often overhauled by crops.

Mean annual temperatures vary between 24˚C and 30˚C with rainfall ranging from 800 to 1200 mm. The climatic data recorded during the experimental period are presented in Figure 1.

In this study, soil samples were collected and were analyzed to determine the NPK content and pH. These analyzes were made at the laboratory of Crop Nutrition Laboratory Services on July 20, 2011, and gave as contents: 0.21% for nitrogen N, 14 ppm for phosphorus P, 105 ppm for potassium K and a pH 5.76. The selected chemical and physical parameters for soils at experimental site are presented in Table 1.

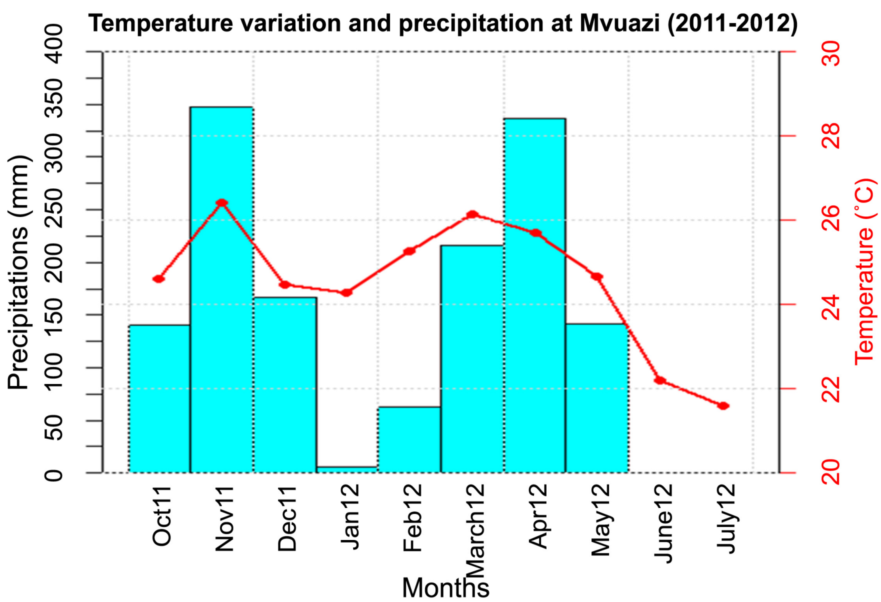

Figure 1. Temperature variation and precipitation amount during the study period.

Table 1. Selected chemical and physical parameters for soils at experimental site.

Parameters (unit)	Soil pH	P1 (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	S (ppm)	Cu (ppm)	B (ppm)
Results	5.76	14	105	1505	229	55	23	12.30	0.21
Guide Low	6.00	30	268	1651	165	100	20	2.00	1.00
Guide high	7.00	100	537	2064	264	250	200	10.00	2.00
Parameters (unit)	**Zn (ppm)**	**Na (ppm)**	**Fe (ppm)**	**CEC (meq/100g)**	**OC (meq/100g)**	**Silt (%)**	**Sand (%)**	**Clay (%)**	**N (%)**
Results	7.98	47	194	13.76	4.07	13	49	39	0.21
Guide Low	4.00	0	150	15.00	-	30	30	20	0.20
Guide high	20.00	158	350	30.00	-	50	55	55	0.50

2.2. Experimental Design and Plant Material

The trial was conducted under the split-plot design with 4 replications and the main factor consisted to intercropping and rotation treatments and the second factor was maize variety. Eight maize varieties (Mudishi-1, Mudishi-3, 07 SADVE, 08 SADVE1, 09 SADVE-F2, ZM523, VP0538 and Samaru) From CIMMYT/IITA and INERA were sown at a spacing of 1 m × 0.25 m in sole crop and intercrop with a density of 80,000 plants·ha^{-1}, according to [21], in the main plots of 6 m × 4 m of sizes. Soybean (Vuangi variety) and Cowpea (Diamand variety) were simultaneously planted with maize, at a spacing of 0.33 m × 0.055 m in sole crop and intercrop with a density of 360,000 plants·ha^{-1}. The pure culture for each variety was used as a control treatment. At the end of the first season (2011-2012), all the plots were mown and the residue was used as mulch: corn only, corn + cowpea and corn + soybeans. At the beginning of the second season (2012), corn was planted on a 5 cm thick mulch [22], without till. So, the experiment was installed in the same plots with a weed mulch plots control.

The parameters observed for this experiment are: maize and legumes yield, number of plants per plot, marketable ears biomass of and unmarketable ears biomass for all maize varieties, edible seed biomass, inedible seed biomass, empty pod biomass for two legume species studied. All of these parameters were observed at the maturity of maize and legume varieties, harvest and post-harvest.

2.3. Statistical Analyzes

Data collected were submitted to analysis of variance following the linear model (aov(y~Trait sec*Trait princ + error (replication/Trait princ)) using agricolae package of R 3.1.3 and least significant difference (LSD) test at 5% probability level was used to compare the treatment means. An economic analysis was carried out to show the profitability of DMC systems.

3. Results and Discussion

3.1. Intercropping Effect on Number of Plants, Biomass and Maize Yield in First Season

The number of plants varied from 56.21 for the maize sole crop to 38.6 for intercrop with cowpea. The sole crops of Mudishi1, Mudishi 3 and Samaru proved to be more effective with more than 60 plants per plot. This analysis of variance revealed significant differences ($p < 0.05$) between treatments and varieties (**Table 2**).

As for the marketable biomass, the difference was significant ($p < 0.05$) between treatments, but highly significant among varieties ($p < 0.001$), a peculiarity for Mudishi-3 variety which produced more than 73% of marketable biomass in all treatments. For unmarketable biomass, the difference was not significant between treatments. More losses were observed in sole crop than in intercrop (**Table 2**).

Table 2. Intercropping and sole crop effects on the different maize varieties for number of plants, marketable ears biomass, unmarketable ears biomass and yield in first season.

Varieties	Treatments	Number of plants	Marketable ears biomass (%)	Unmarketable ears biomass (%)	Yield ($kg \cdot ha^{-1}$)
07SADVE	Sole crop	56.00ab	68.22a	68.72b	2665.86a
08SADVE1	Sole crop	41.75b	68.51a	68.54b	2129.52a
09SADVEF2	Sole crop	54.75ab	67.12ab	69.91b	2128.00a
Mudishi1	Sole crop	61.00.a	70.20a	69.32b	2402.40a
Mudishi3	Sole crop	61.50a	74.77a	76.51a	2283.62a
Samaru	Sole crop	61.50a	72.81a	72.26ab	2849.44a
VP0538	Sole crop	54.50ab	68.68a	73.44ab	2277.22a
ZM523	Sole crop	58.75a	67.88a	72.30ab	2065.53a
Mean	**Sole crop**	**56.21a**	**69.77b**	**71.37a**	**2350.19a**
07SADVE	Cowpea	46.25a	70.57a	70.53ab	1999.73a
08SADVE1	Cowpea	33.75b	68.56b	62.47b	1298.92a
09SADVEF2	Cowpea	35.5ab	68.25b	69.3ab	965.13a
Mudishi1	Cowpea	34.75ab	70.63a	70.9ab	753.60ab
Mudishi3	Cowpea	46.25a	73.87a	75.98a	1351.04a
Samaru	Cowpea	46.00a	74.13a	74.52a	2028.88a
VP0538	Cowpea	31.50b	73.31a	71.67ab	1133.73a
ZM523	Cowpea	35.25ab	70.10a	68.84ab	1212.45a
Mean	**Cowpea**	**38.65c**	**71.17a**	**70.52a**	**1342.93c**
07SADVE	Soybean	52.50a	69.33ab	69.44a	2206.49a
08SADVE1	Soybean	41.50c	68.20b	63.70a	2040.76a
09SADVEF2	Soybean	45.50b	68.97b	70.00a	1843.63a
Mudishi 1	Soybean	47.00b	70.64ab	72.51a	2113.15a
Mudishi3	Soybean	52.25a	75.05a	75.92a	2291.12a
Samaru	Soybean	47.50b	71.94ab	69.13a	2113.9a
VP0538	Soybean	44.00bc	72.64a	73.63a	1984.68a
ZM523	Soybean	40.00c	70.57ab	72.84a	2062.06a
Mean	**Soybean**	**46.28b**	**70.91ab**	**70.89a**	**2081.97b**
Effect of varieties		0.01605*	3.56^{e-11}***	2.194^{e-06}***	0.4757
Effect of treatments		1.996^{e-08}***	0.02226*	0.7206	9.842^{e-05}***
Effect of varieties × treatments		0.8762	0.4624	0.6274	0.9962
CV		18.03	2.76	5.39	32.13
LSD		7.19	1.39	2.93	

Signification statistique: 0 "***" 0.001 "**" 0.01 "*" 0.05 "†" 0.1 "ns" 1.

About grain yield, a significant difference was observed ($p < 0.001$) between treatments (Table 1). Sole crop was greater (2350.2 $kg \cdot ha^{-1}$) than the respective yield in mixture: 1342.9 kg·ha^{-1} for cowpea and 2081.9 kg.ha^{-1} for soybeans. Therefore, the highest maize yield was from sole crop of Samaru with 2849.44 kg·ha^{-1}. The performance results corroborate those of the number of plants and the biomass of the ears. These results was be similar that obtained by [23] in trials at the SUWAN farm in Thailand, where the yield of maize grown in sole crop was 31.9% higher than maize-soybean. A low density of plants per unit area leads to a decrease in yield [4] [24]. The rate of sowing of each crop in the combination is adjusted below its maximum rate to optimize plant density. If the maximum rate of each crop was used, the yield would not be good due to overpopulation. By reducing the rates of each seedling, the crops have a chance to produce well within intercropping [25]. The challenge is how much can be reduced seeding rates. According to [26] and [27], the spatial arrangement of maize and legumes (intercropping or maize cropping after legume harvesting) does not affect maize yield. A reasonable leaf area index (LAI) is essential to maintain high photosynthesis and yield [28]. Prasad and Brook [29] reported that the increase in corn plant density had a significant effect on LAI in corn-soya intercropping.

3.2. Intercropping Effect on Number of Plants, Biomass and Legumes Yield in First Season

Sole crop yield of soybean was higher (1802.23 kg·ha^{-1}) than that observed in intercrop with maize (809.31 kg·ha^{-1}) in general, with the association 08SADVE1-soya (932.37 kg·ha^{-1}) in particular. However, sole crop yield of cowpea produced less (17.82 kg·ha^{-1}) than the intercrop with maize (48.39 kg·ha^{-1}), although the highest yield was obtained in the intercrop with Samaru (96.14 kg·ha^{-1}). Variance analyzes of legume seed yield showed very significant differences ($p < 0.01$) between varieties and interactions, and highly significant differences ($p < 0.001$) between treatments (**Table 2**). This reduction in soybean and cowpea yields under intercropping could be due to interspecific competition between the intercrop components for water, light, air and nutrients, and also the aggressive effects maize (C_4 species) on soybean and cowpea, a C_3 species [30] [31]. According to Heibsch *et al.* [32], crops with C_4 photosynthetic pathways have been known to be dominant when intercropped with C3 species like soybean and cowpea. The shading of legumes by the maize plants (taller) may also have contributed to the reduction of the yields of intercropped soybean and cowpea. Olufajo [33] and Matusso [34] reported that shading by the taller plants in mixture could reduce the photosynthetic rate of the lower growing plants and thereby reduce their yields. As for biomass, highly significant differences ($p < 0.001$) were observed between treatment for empty pods and edible seeds (**Table 3**). The cowpea monoculture yielded 5.5% compared to 4.41% in combination for edible seeds. The soybean monoculture yielded 47.44% edible seed biomass, compared to the association with 46.13%. Analysis of mean numbers of seedlings and inedible biomass showed no differences between treatments, varieties, and interactions (**Table 3**). The reduction of yield of the legumes components observed in this study was also reported by other researchers [35].

Table 3. Effect of the combination of crops on the number of plants per plot and the biomass of legumes in the first season.

Varieties	Treatments	Number of plants	Edible seed biomass (%)	Inedible seed biomass (%)	Empty pod biomass (%)	Yield (kg·ha^{-1})
Cowpea	**Sole crop**	**632.75**	**5.50b**	**11.88**	**24.69a**	**17.82b**
Soybean	**Sole crop**	**554.25**	**47.44a**	**5.03**	**26.80a**	**1802.23a**
07SADVE	Cowpea	525.75	12.68b	4.75	18.22a	76c
08SADVE1	Cowpea	555.00	3.13c	9.15	30.76a	15.78c
09SADVEF2	Cowpea	583.75	2.09c	6.06	15.85a	39.67c
Mudishi1	Cowpea	541.50	3.09c	7.003	16.51a	38.29c
Mudishi3	Cowpea	577.75	0.84c	7.84	17.54a	19.78c
Samaru	Cowpea	493.75	4.09bc	5.52	17.51a	96.14c
VP0538	Cowpea	489.00	5.49bc	4.64	18.34a	33.28c
ZM523	Cowpea	545.00	3.88c	5.07	16.44a	68.2c
Mean	**Cowpea**	**538.93**	**4.41bc**	**6.25**	**18.89a**	**48.39c**
07SADVE	Soybean	468.5	46.99a	6.62	30.04b	546.92b
08SADVE1	Soybean	535.25	49.37a	5.12	27.41b	932.37a
09SADVEF2	Soybean	557.5	49.02a	4.32	28.8b	885.49a
Mudishi1	Soybean	489.25	45.85a	6.38	27.17b	859.44a
Mudishi3	Soybean	617.75	44.92a	9.11	28.19b	817.77a
Samaru	Soybean	450	41.85a	10.53	28.28b	718.81ab
VP0538	Soybean	497.5	45.62a	5.74	29.64b	838.61a
ZM523	Soybean	579.75	45.48a	6.52	30.34b	875.07a
Mean	**Soybean**	**524.43**	**46.13a**	**6.79**	**28.73b**	**809.31a**
Effect of varieties		0.2541	0.4973	0.8859	0.819	0.0046**
Effect of treatments		0.4217	<2^{e-16}***	0.8342	3.936^{e-05}***	<2.2^{e-16}***
Effect of varieties × treatments		0.9731	0.5685	0.6336	0.521	0.0013**

Signification statistique: 0 "***" 0.001 "**" 0.01 "*" 0.05 "†" 0.1 "ns" 1.

Matusso [34] reported that the reduction was mainly due to maize shading effects on soybean, which caused the legume component to allocate its photosynthates to vegetative growth and height increasing for competing with taller maize.

3.3. Mulch Effect on Yield, Number of Plants and Maize Biomass in Second Season

Mean for the number of plants varied between 58.12 (maize mulch + cowpea) and 60.09 (maize mulch), and for the biomass of salable spikes varied between 49.30 (maize + Cowpea mulch) and 50.77 (maize mulch). For example, maize yield were higher on maize + cowpea mulch (2974.82 kg·ha^{-1}) followed by maize mulch (2686.77 kg·ha^{-1}) and maize + soybean mulch (2624.50 kg·ha^{-1}). Analysis of the variance of all parameters showed no significant differences ($p > 0.1$) between varieties, treatments and interactions (Table 4). The observations from the present study indicated that crop rotation and residue management practices can affect maize performance significantly. Edmeades [36] reported similar results from multilocals field experiments in Ghana, which showed that in the

Table 4. Mulch effects on different maize varieties for number of plant, marketable ears biomass, unmarketable ears biomass and yield in second season.

Varieties	Treatments	Number of plants	Marketable ears biomass (%)	Unmarketable ears biomass (%)	Yield ($kg \cdot ha^{-1}$)
07SADVE	maize mulch	60.75	49.81	47.41	2658.50
08SADVE1	maize mulch	64.75	50.07	55.74	2905.80
09SADVEF2	maize mulch	57.75	57.03	48.23	2586.80
Mudishi1	maize mulch	53.00	50.84	43.17	2467.00
Mudishi3	maize mulch	62.50	47.99	48.11	3474.60
Samaru	maize mulch	59.25	54.67	50.05	2689.00
VP0538	maize mulch	61.25	48.55	61.70	2222.40
ZM523	maize mulch	61.50	47.26	47.44	2490.10
Mean	**maize mulch**	**60.09**	**50.77**	**50.23**	**2686.77**
07SADVE	maize + cowpea	63.50	48.90	52.44	3662.80
08SADVE1	maize + cowpea	55.00	47.74	47.87	2494.40
09SADVEF2	maize + cowpea	60.75	43.39	48.35	3034.10
Mudishi1	maize + cowpea	61.50	49.85	50.41	2682.40
Mudishi3	maize + cowpea	56.75	52.32	52.86	2897.80
Samaru	maize + cowpea	55.25	55.63	53.56	3120.20
VP0538	maize + cowpea	56.25	45.68	47.02	2847.30
ZM523	maize + cowpea	56.00	50.93	50.45	3059.60
Mean	**maize + cowpea**	**58.12**	**49.30**	**50.37**	**2974.82**
07SADVE	maize + soybean	60	47.54	48.54	2729.20
08SADVE1	maize + soybean	60.5	49.55	47.29	2548.40
09SADVEF2	maize + soybean	67.5	55.46	49.27	3503.40
Mudishi1	maize + soybean	58	53.02	48.45	2604.80
Mudishi3	maize + soybean	56.25	53.79	46.21	2435.30
Samaru	maize + soybean	55.75	49.44	54.22	2503.10
VP0538	maize + soybean	57.25	51.9	42.42	2430.30
ZM523	maize + soybean	54	44.18	49.95	2241.50
Mean	**maize + soybean**	**58.65**	**50.61**	**48.29**	**2624.50**
Effect of varieties		0.7018	0.4566	0.9333	0.7053
Effect of treatments		0.6284	0.6554	0.8318	0.2600
Effect of varieties × treatments		0.6519	0.3442	0.3797	0.7952

Signification statistique: 0 "***" 0.001 "**" 0.01 "*" 0.05 "†" 0.1 "ns" 1.

absence of fertilizer, maize yields following maize sole crop fell significantly, but that this yield drop could be completely compensated by fertilizers or by a cowpea crop. Cowpeas improve maize yield by the nitrogen they fix and by unspecified improvements in soil conditions. Higher yields under maize-legume rotation would have been expected as legumes are known to fix nitrogen, thereby improving the soil nitrogen economy and enhancing the growth of subsequent crops [37]. The differences in maize response to the different rotations could also be attributed to the differences in biomass additions to the soil. Increased residue returned to the soil generally led to increased yields, whereas complete residue removal was very detrimental to maize growth and yield [38].

3.4. Variation in Maize Yield in Intercropping and on Mulch

These variations are of the order of 14.32% on maize mulch in sole crop, 121.52% on maize + cowpea mulch and 26.06% on maize + soybean mulch. Maize was seeded on maize + cowpea mulch doubled, tripled or quadrupled its yield compared to those obtained in intercropping during the first season. Analysis of the variance on the mean variation in yield of maize in combination and on mulch revealed highly significant differences between varieties, treatments and interactions ($p < 0.001$) (**Table 5**). These strong variations would be due to the improvement of the fertility of the soil by the effect of crop rotation. Many studies have reported the highly beneficial effects of seed pulses on soil nitrogen content and cereal grain yields [39] [40]. CIPEA's work in Mali showed that the introduction of cowpea into the rotation resulted in a 60% increase in millet grain yields compared with results obtained in the first year of cultivation [41]. This situation has already been reported by Hardter *et al.* [42], although the maize-cowpea crop had yields lower than in rotation, continuous sole crop have lower productivities. Carsky *et al.* [43] showed higher grain yield of cereal following legume than continuous cropping of cereal in the Nigerian savanna. The increases in the cereal yield were attributed to the biologically fixed N from the legumes. But for such a positive effect to occur, it is expected that the amount of fixed N returned by the legumes to the soil must be greater than the amount of soil N in the harvested grain [44] [45].

According to Bandyopadhyay and De [46], this soil fertility can be explained by residual effects on cereals succeeding legumes in the rotation and by the underground transfers of nutrients in the rhizosphere during intercropping. It appears that the use of the cropping system under cover crop (or mulch) increases the maize yield as demonstrated by Scopel [47]. It turned out that most varieties behaved in the same way in each of the treatments. The Mudishi1 variety increased its yield by more than 250% when it was planted on cowpea and maize mulch (**Table 6**). Compared to the results presented in intercropping system, the presence of the mulch significantly influenced the grain yield. This situation shows that even at low doses of mulch (5 cm of residue thickness), a considerable effect can be observed on the behavior of the plants. These results are similar to those reported by Van Asten *et al.* [22]. These results could be explained that sowing under cover crop (or mulch) improves the fertility of the cultivated soils and, in particular, Productivity of the cultivated areas. Mckenney *et al.* [48], Mary *et al.* [49], Abiven [50], Schroth *et al.* [51] showed increased nitrogen availability due to degradation and mineralization of legume mulch compared to bare soil.

Table 5. Intercrops and mulches effects on performance in the first and second seasons.

Varieties	Treatments	Yield (kg·ha^{-1})		
		Season 1	Season 2	Accroissement (%)
07SADVE	Sole crop	2665.86a	2658.50	−0.28d
08SADVE1	Sole crop	2129.52a	2905.80	36.45b
09SADVEF2	Sole crop	2128.00a	2586.80	21.56b
Mudishi1	Sole crop	2402.40a	2467.00	2.69c
Mudishi3	Sole crop	2283.62a	3474.60	52.15a
Samaru	Sole crop	2849.44a	2689.00	−5.63d
VP0538	Sole crop	2277.22a	2222.40	−2.41d
ZM523	Sole crop	2065.53a	2490.10	20.56b
Mean	**Sole crop**	**2350.19a**	**2686.77**	**14.32c**
07SADVE	Cowpea	1999.73a	3662.80	83.16c
08SADVE1	Cowpea	1298.92a	2494.40	92.04c
09SADVEF2	Cowpea	965.13a	3034.10	214.37a
Mudishi1	Cowpea	753.60ab	2682.40	255.94a
Mudishi3	Cowpea	1351.04a	2897.80	114.49b
Samaru	Cowpea	2028.88a	3120.20	53.79d
VP0538	Cowpea	1133.73a	2847.30	151.14b
ZM523	Cowpea	1212.45a	3059.60	152.35b
Mean	**Cowpea**	**1342.93c**	**2974.82**	**121.52a**
07SADVE	Soybean	2206.49a	2729.20	23.69b
08SADVE1	Soybean	2040.76a	2548.40	24.88b
09SADVEF2	Soybean	1843.63a	3503.40	90.03a
Mudishi1	Soybean	2113.15a	2604.80	23.27b
Mudishi3	Soybean	2291.12a	2435.30	6.29d
Samaru	Soybean	2113.90a	2503.10	18.41c
VP0538	Soybean	1984.68a	2430.30	22.45b
ZM523	Soybean	2062.06a	2241.50	8.70d
Mean	**Soybean**	**2081.97b**	**2624.50**	**26.06b**
Effect of varieties		0.4757	0.7053	0.4937
Effect of treatments		9.842^{e-05}***	0.2600	1.55^{e-06}***
Effect of varieties × treatments		0.9962	0.7952	0.7580

Signification statistique: 0 "***" 0.001 "**" 0.01 "*" 0.05 "†" 0.1 "ns" 1.

Table 6. Economic analysis of maize varieties in combination with legumes.

Varieties	Treatments	Gross return ($)	Net return ($)	Cost/return ratio (%)
07SADVE	Cowpea	3459.53ab	2223.66ab	2.80
08SADVE1	Cowpea	2191.17bc	955.30bc	1.77
09SADVEF2	Cowpea	1674.65bc	438.79bc	1.36
Mudishi1	Cowpea	1319.82c	83.96c	1.07
Mudishi3	Cowpea	2284.71bc	1048.84bc	1.85
Samaru	Cowpea	3541.70bc	2305.83ab	2.87
VPO538	Cowpea	1945.02bc	709.15bc	1.57
ZM523	Cowpea	2134.42bc	898.55bc	1.73
Mean	**Cowpea**	**2330.48ab**	**1088.43ab**	**1.88**
07SADVE	Soybean	4589.01a	3307.14a	3.58
08SADVE1	Soybean	4955.21a	3673.34a	3.87
09SADVEF2	Soybean	4548.52a	3266.65a	3.55
Mudishi1	Soybean	4954.32a	3672.45a	3.86
Mudishi3	Soybean	5181.48a	3899.61a	4.04
Samaru	Soybean	4721.18a	3439.31a	3.68
VPO538	Soybean	4705.47a	3423.60a	3.67
ZM523	Soybean	4895.21a	3613.35a	3.82
Mean	**Soybean**	**4842.89a**	**3554.62a**	**3.76**
07SADVE	Sole crop	1333.15c	120.48c	1.10
08SADVE1	Sole crop	865.94c	−346.72c	0.71
09SADVEF2	Sole crop	643.41c	−569.25c	0.53
Mudishi1	Sole crop	502.40c	−710.27c	0.41
Mudishi3	Sole crop	900.69c	−311.97c	0.74
Samaru	Sole crop	1352.58c	139.92c	1.12
VPO538	Sole crop	755.81c	−456.85c	0.62
ZM523	Sole crop	808.30c	−404.37c	0.67
Mean	**Sole crop**	**899.77b**	**−2551.71b**	**0.74**
Effect of varieties		0.6241	0.6241	0.5963
Effect of treatments		$<2^{e-16}$***	$<2^{e-16}$***	4.834^{e-16}
Effect of varieties × treatments		0.9695	0.9695	0.9665

Signification statistique: 0 "***" 0.001 "**" 0.01 "*" 0.05 "†" 0.1 "ns" 1. Average procurement price per kg of maize = $0.67; cowpea = $1; soybean = $1.

An organic matter and minerals enrichment through residual recycling was studied by Owens and Edwards [52] and Uzoh *et al.* [53] on maize-soybean-cowpea rotation, highlighting the recycling of carbon and nitrogen through the production of Vegetable biomass of legume.

3.5. Economic Analysis of Maize Varieties in a Combination and Rotation System on Legume Mulch

The economic analysis of different crops indicated gains for maize-cowpea ($1088.43) and maize-soybean ($3554.62) intercrops, losses for maize sole crops except for 07SADVE and Samaru varieties for which we observed gains in order of $121.09 and $140.62 respectively. On the different intercropping systems, the maximum net return were $USD 3919.12 (Mudishi 3-soya) and minimum were $712.70 (VPO538-cowpea). The greatest cost/benefit ratio of the Mudishi 3-soybean intercrop (4.04) indicates the low investment cost in operating expenses, while highest deficit observed in Mudishi 1 variety sole crop ($713.82) showing the high investment cost in operating expenses. Analysis of the variance of gross return, benefit, and benefit/cost ratio in intercropping economic analysis revealed highly significant differences ($p < 0.001$) between treatments (**Table 6**).

Maize varieties with soybeans in intercropping system produced higher values gross return and net return than maize-cowpea associations and the different sole crop, probably due to yields obtained in each crops. The large benefit produced in the maize/soybean intercrop compared to other systems could probably be the result of the high yield and price of legumes compared to maize [27]. Similar observations were made by Egbe [54] in pigeon pea-sorghum and pigeon pea-maize, and Banik (1996) in wheat-gram, wheat-pea and wheat-lentil intercrops. Njoroge *et al.* [55] estimated the net profit of coffee associated with food products by subtracting all variable costs from gross profits. Similarly, Egbe [54] had estimated the total profit and the marginal benefit/cost ratio from investment on different farm inputs used in pigeon pea/sorghum intercropping system by computing returns per naira invested. In an innovative, improved intercropping system, named MBILI (kiswahili for "two", and an acronym for "Managing Beneficial Interactions in Legume Intercrops"), also known as a two-by-two staggered arrangement [56], the MBILI system resulted in robust increases in crop yields and net benefits, in comparison with the conventional intercropping system. The MBILI system did not entail larger labour costs and Woomer [57] showed that the MBILI system was profitable across a wide range of smallholders' croplands in western Kenya, and that, when combined with a fertilizer application at a modest rate; the benefit-cost ratio was higher relative to other recommended technologies in the area.

In contrast, analysis of the variance of gross return, benefit, and benefit/cost ratio in mulch crops system revealed no significant differences ($p > 0.1$) between varieties, treatments and interactions (**Table 7**). On the different mulch cropping systems, maximum net return were $USD 1234.03 (07SADVE-cowpea) with a cost/benefit ratio of 2.01 and the minimum benefits were $USD 268.95 (VPO538 sole crop).

Residue production by preceding crop is an important factor in defining the magnitude of rotation benefit conferred to subsequent crop [58]. This is because

Table 7. Economic analysis of corn varieties on legume mulch.

Varieties	Treatments	Gross return ($)	Net return ($)	Cost/return ratio (%)
07SADVE	maize + cowpea	2441.89	1227.89	2.01
08SADVE1	maize + cowpea	1662.90	448.90	1.37
09SADVEF2	maize + cowpea	2022.71	808.71	1.67
Mudishi1	maize + cowpea	1788.24	574.24	1.47
Mudishi3	maize + cowpea	1931.88	717.88	1.59
Samaru	maize + cowpea	2080.11	866.11	1.71
VPO538	maize + cowpea	1898.23	684.23	1.56
ZM523	maize + cowpea	2039.74	825.74	1.68
Mean	**maize + cowpea**	**1993.13**	**773.06**	**1.63**
07SADVE	maize + soybean	1819.48	605.48	1.5
08SADVE1	maize + soybean	1698.90	484.90	1.4
09SADVEF2	maize + soybean	2335.61	1121.61	1.92
Mudishi1	maize + soybean	1736.53	522.53	1.43
Mudishi3	maize + soybean	1623.53	409.53	1.34
Samaru	maize + soybean	1668.74	454.74	1.37
VPO538	maize + soybean	1620.21	406.21	1.33
ZM523	maize + soybean	1494.33	280.33	1.23
Mean	**maize + soybean**	**1758.41**	**538.34**	**1.44**
07SADVE	maize mulch	1772.34	558.34	1.46
08SADVE1	maize mulch	1937.19	723.19	1.6
09SADVEF2	maize mulch	1724.51	510.51	1.42
Mudishi1	maize mulch	1644.65	430.65	1.35
Mudishi3	maize mulch	2316.42	1102.42	1.91
Samaru	maize mulch	1792.64	578.64	1.48
VPO538	maize mulch	1481.61	267.61	1.22
ZM523	maize mulch	1660.05	446.05	1.37
Mean	**maize mulch**	**1800.13**	**580.06**	**1.48**
Effect of varieties		0.7053	0.7053	0.7053
Effect of treatments		0.2600	0.2600	0.2600
Effect of varieties × treatments		0.7952	0.7952	0.7952

Signification statistique: 0 "***" 0.001 "**" 0.01 "*" 0.05 "†" 0.1 "ns" 1. Average procurement price per kg of maize = $0.67; cowpea = $1; soybean = $1.

Legume crop residues contain organic N and other nutrients, which are released after decomposition by soil microbes for the subsequent crop through mineralization [59]. And the quality of residue is very important in determining mineralization and nutrient release and then yield. Some of the residue parameters include C/N ratio, nutrient content etc. Uzoh *et al.* [53] reported that maize residues contained more carbon and less nitrogen than legumes residues and mineralization and release of nutrients were higher in plots amended with legumes residue as velvet-bean.

4. Conclusion

This study was to acquire knowledge on the profitability and response of maize crop in intercrop and rotation with legumes based on DMC to determine the optimum combination of yield grain and total grain biomass. The residual effects of cowpea crops have been shown to have considerably increased maize yield. As for the production of pulses in combination with maize, soybeans were more efficient than cowpeas. All maize varieties each presented a combination that maximized productivity. The varieties 09SADVE F2, Mudishi1, Mudishi3, VPO538 and Zm523 have doubled, tripled or quadrupled their yields when rotated with cowpea. Maize sole crop, which produces poor mulch, resulted in low yields in the second season, resulting in losses of more than 5%. The high yields observed in this study resulted in significant benefits in increasing their ratios whether in combination or in rotation.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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