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EFFECT OF PLANT POPULATION ON YIELD OF MAIZE AND CLIMBING BEANS GROWN IN AN INTERCROPPING SYSTEM

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ABSTRACT

Increased adoption of climbing beans (*Phaseolus vulgaris* L.) in Kabale district, south-western Uganda, has been limited by scarcity of staking materials, despite the crop's higher yield potential compared to bush bean types when grown on fertile soils. There is therefore need to explore other appropriate mechanisms such as intecropping, that could substitute use of stalks. A field experiment was conducted at Kachwekano near Kabale town for two seasons: second rains of 1996 (1996b) and first rains of 1997 (1997a), to determine the appropriate plant population density (PPD) of maize that would maximize bean yield in an intercrop system. The treatments were: (a) maize PPD ranging from 25 000 to 40 000 plants ha^{-1}, and (b) bean PPD ranging from 57 142 to 95 238 plants ha^{-1}. Sole crops were planted at the recommended PPD of 44 444 and 111 111 plants ha^{-1} for maize and climbing beans, respectively. Maize in mixtures was planted in single rows 1.0 m apart. Two rows of beans were planted in the space between maize rows, 10 days after maize emergence. Plant densities were achieved by varying the within-row spacing from 0.25 to 0.40 m for maize and 0.30 to 0.50 m for beans. Maize PPD significantly affected bean yield only during the second rains (1996b), probably due to a favourable moisture regime. Bean PPD significantly affected maize yield only during the first rains (1997a), presumably due to drought stress. The highest intercrop bean yield of 1.075 t ha^{-1} was realised from a final mixture of 24 575 and 66 666 plants ha^{-1} of maize and beans, respectively, during the second rains. Intercropping significantly reduced maize yield during the second rains and bean yields in both seasons. The intercrop system had a yield advantage of 26 % (i.e., LER = 1.26) over pure stands of the component crops only during the second rains, presumably due to complementary use of resources. However, there were no yield advantages observed during the first rains probably due to drought stress. Mean total income (TI) from the mixtures was 226.8 and 31.8% higher than income from sole bean and maize crops, respectively, during the second rains. Income from the mixtures was 58.7 and 72.5 % higher than income from sole bean and maize crops, respectively, during the first rains.

Key Words: Competitive ratio, land equivalent ratio, *Phaseolus vulgaris,* Uganda, *Zea mays*

RÉSUMÉ

L'adoption croissante d'haricot grippant (*Phaseolus vulgaris* L.) dans le district de Kabale au sud-ouest de l'Ouganda, a été limitée par le manque des matériels de soutien, en dépit du potentiel élevé du rendement des plantes comparé au haricot des types forestiers lorsque cultivé sur des sols fertiles. Il y a donc un besoin d'explorer les autres mécanismes appropriés tel que l'inter culture, qui pourrait substituer l'usage des tiges. Une expérience sur terrain était conduite à Kachwekano près de la ville de Kabale pendant deux saisons : secondes pluies de 1996 (1996b) et premières pluies de 1997 (1997a), pour déterminer la densité de population des plantes appropriée (PPD) de maïs qui pourrait maximiser le rendement de haricot dans un système d'inter culture. Les traitements étaient : (a) PPD de maïs s'étendant de 25000 à 40000 plantes ha-1, et (b) PPD de haricot allant de 57142 à 95238 plantes ha-1. Seule les plantes de même nature étaient plantées à PPD recommandée de 44444 et 111111 plantes ha-1 pour le maïs et haricot respectivement. Le maïs mélangé était planté en lignes uniques de 1,0 m de distance. Deux lignes de haricot étaient plantées dans l'espace entre les lignes de maïs, 10 jours après l'emergemce du maïs. Les densités de plantes étaient atteintes en variant l'espace entre lignes de 0,25 à 0,40 m pour le maïs et 0,30 à 0,50 pour le haricot. La PPD de maïs avait significativement affecté le rendement de haricot seulement durant les secondes pluies (1996b), probablement à cause d'un régime humide favorable. La PPD de haricot a significativement affecté le rendement de maïs seulement durant les premières pluies (1997a), vraisemblablement à cause de la sècheresse. Le rendement le plus élevé de haricot en inter culture de 1,075t ha-1 était réalisé à partir d'un mélange final de 24575 et 66666 plantes ha-1 de maïs et haricot respectivement, durant les secondes pluies. L'inter culture a significativement réduit le rendement de maïs durant les secondes pluies et les rendements de haricot dans les deux saisons. Le système d'inter culture avait un avantage de rendement de 26% (c. à.d, LER=1,26) sur les témoins purs des composantes des plantes durant les secondes pluies, vraisemblablement à cause de l'usage des ressources complémentaires. Cependant, il n y avait pas des avantages de rendements observés durant les premières pluies probablement à cause de la sécheresse. La moyenne totale de revenus (IT) des de cultures mélangées était 226,8 et 31,8% élevée que le revenu des plantes d'haricot seul et maïs seul respectivement, durant les secondes pluies. Le revenu des cultures mélangées était 58,7 et 72,5% élevé que le revenu des plantes de haricot seul et maïs seul respectivement, durant les premières pluies.

Mots Clés: Proportion compétitive, proportion équivalente de terre, *Phaseolus vulgaris*, Ouganda, *Zea mays*

INTRODUCTION

In Kabale district, bush bean *(Phaseolus vulgaris)* yields are too low, ranging from 500 to 700 kg ha^{-1} (UNBP, 1988). To meet the demand of the rapidly growing population of 246 persons km^{-2} (MFPED, 1992), farmers need to adopt climbing types which can out-yield bush types by more than 100 per cent when both are grown on fertile soils at high altitude (1800 to 2300 m) (UNBP, 1992). However, scarcity of staking materials is a constraint to adoption of climbing beans. Climbing beans yield much higher with dead supports, such as, trellises and stakes than on live support (Francis and Sanders, 1978), presumably due to absence of competition for growth factors in the former case. However, trellises and stakes are scarce and thus labour intensive (Francis and Sanders, 1978; Graf *et al.*, 1991; Niringiye, 1997). Therefore, cheaper alternative ways of supporting the beans are required. This can be maize *(Zea mays)* and/or cassava *(Manihot esculentum)* plants acting as live stakes for beans grown as intercops.

Mixed intercropping is a common feature in Kabale farming systems, where bush beans and maize are planted at high and low plant densities, respectively, because beans is the main crop. Bush beans are earlier maturing than climbing types and require higher plant density and different planting patterns. Therefore, a change of growth habit from bush to climbing beans in a maize/bean intercrop system changes both temporal and spatial arrangements of the cropping system (Woolley and Davis, 1991). However, maize has been reported to be more competitive than beans for light. It shades the associated bean crop thus, depressing yield, which is reflected in reduced number of pods plant^{-1} and seeds pod^{-1} (Willey and Osiru, 1972; Davis and Garcia, 1983). Maize was reported to depress bush bean yields by 7 to 32 % (Woolley and Smith, 1992), whereas beans caused 15 to 30 % reduction in maize yield (Davis and Garcia, 1983). Reduction in bean yields may be minimised by manipulating plant density, planting pattern and relative planting dates of maize and beans. Therefore, a study on maize/climbing bean association was initiated, with a specific objective of determining the appropriate plant population density (PPD) that would maximize bean yields.

MATERIALS AND METHODS

A field experiment was conducted at Kachwekano (1°15'S, 30°E; altitude 2200 m) near Kabale town, southwestern Uganda, during 1996 long and 1997 short rains seasons. The soils are well-drained, clayey, oxidic, isomesic, typic Palehumults, with a pH of 5.8 to 6.2. Soil moisture regime is Udic-Isothermic (Yost and Eswaran, 1990). The site receives an annual rainfall of about 1000 mm with a bimodal distribution: short rains (February –

June with a peak in March/April) and long rains (August - December with a peak in September/ October). The 1996b rains and 1997a long rains are, subsequently designated as seasons 1 and 2, respectively.

One maize variety, POOL 9A, and two climbing bean varieties, Umubano (in season 1) and Gisenyi (in season 2), were used in the study. Variety POOL 9A has white, medium size grain, grows to a height of about 2.5 m, matures in about 180 days, and yields up to 7.0 t ha^{-1} at Kachwekano. Umubano is a red, small-seeded variety with a yield potential of 4.0 t ha^{-1}, whereas Gisenyi is white with black speckles, large-seeded variety, and can yield 3.5 t ha^{-1}. Both bean varieties are indeterminate (Type IV growth habit) (CIAT, 1987) and mature in about 120 days. Bean variety was changed in season 2 because Umubano is susceptible to rust (*Uromyces appendiculatus*) during the short rains, whereas Gisenyi is susceptible to anthracnose (*Colletotrichum lindemuthianum*) during the long rains. The treatments were: (a) maize PPD ranging from 25 000 to 40 000 plants ha^{-1}, and (b) bean PPD ranging from 57 142 to 95 238 plants ha^{-1}. In season 1, treatments were formed by planting maize in single rows spaced 1.0 m apart, with an intra-row spacing of 0.35, 0.30 and 0.25 m to achieve PPDs of 28 571, 33 333 and 40 000 plants ha^{-1}. Two rows of beans separated by 0.40 m were planted between the maize rows, at 0.30 m away from maize rows. Intra-row spacing for beans was 0.45, 0.40, 0.35 and 0.30 m to achieve corresponding PPDs of 63 492, 71 428, 81 632 and 95 238 plants ha^{-1}, respectively. In season 2, maize PPD of 28 571 and 40 000 plants ha^{-1} and bean PPD of 63 492 plants ha^{-1}, were replaced with 25 000 and 57 142 plants ha^{-1} of maize and beans, respectively. These were achieved with an intra-row spacing of 0.40 and 0.50 m, respectively. This change was made partly due to limited space for the trial and anticipation of inadequate rainfall during season 2.

Pure stands were planted at the recommended PPD of 44 444 and 111 111 plants ha^{-1} of maize and beans, respectively. Pure stand maize was spaced at 0.75 m x 0.30 m, while beans in pure stand was planted in double rows 0.60 m apart, with 0.20 m intra-row spacing and 0.30 m between rows in a pair, to ease placement of dead stakes. Four bean plants shared a stake. The treatments (i.e., all possible combinations of maize and bean PPD for intercrops plus two sole crops) were tested in a randomized complete block design with three replications. Planting dates of maize were 20 September 1996 and 3 March 1997. Beans in intercrops was planted 10 days after emergence (DAE) of maize, to ensure that maize plants would be ready in time to support the beans. Land preparation and weeding operations were carried out using hand-hoes. The trial was weeded twice in each season. Harvesting dates were 12 February (beans) and 2 April (maize) for 1996, and 29 July (beans) and 22 September (maize) for 1997.

Data were taken on stand count, yield and yield components, pests and diseases. All data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the MSTAT-C software (MSTAT, 1988). Treatment means were separated using the Fisher's Protected Least Significant Difference (LSD) test (Steel *et al.*, 1997). Correlation analysis was done for intercrop maize and bean grain yield. Mean yields of intercrop and sole crop of maize and beans were used to compute the Land Equivalent Ratios (LERs), total income (TI) (Andrew and Kassam, 1976) and competitive ratio (C.R.) (Willey and Rao, 1980). The LER is the area needed under sole crop to give the same amount of yield as one hectare of intercropping, at the same management level. It was calculated as the sum of the fractions of the yields of the intercrops relative to their sole crop yields:

$$LER = \frac{I_a}{S_A} + \frac{I_b}{S_B}$$

Where I_a and I_b are intercrop maize and bean yields, respectively, and S_A and S_B are their corresponding sole crop yields. IER or monetary advantage (MA), is the amount of land under sole crops required to produce the same amount of income as one hectare of intercropping, at the same management level. The LER was converted into economic terms, i.e., multiplied grain yield by price per unit of produce. Competitive ratio, one of the main indices of dominance, was calculated as the ratio of the partial LERs of the intercrop species:

$$C.R. = \frac{L_A}{L_B}$$

where L_A and L_B are the partial LERs of maize and beans, respectively. Actual rather than planned PPDs were used in the analysis of the results.

RESULTS

Weather conditions. There was more rainfall in 1996, which was fairly well distributed over five months, compared to the amount of rainfall in 1997, which was spread over only three months. Data for amount and distribution of rainfall for 1996 and 1997 are given in Tables 1 and 2.

Effect of plant population on yield and yield components of maize and climbing beans in intercrop. Average intercrop maize grain yield was 4.182 and 1.486 t ha^{-1} in seasons 1 and 2, respectively, compared to 4.605 and 1.807 t ha^{-1} for sole maize crop in seasons 1 and 2, respectively (Table 3). Grain yield per plant in intercrops was 124.7 and 52.3 g in seasons 1 and 2, respectively, compared to 103.6 and 40.6 g in sole crop. Values for number of cobs/plant, grains/cob and mean grain weight were slightly higher in intercrop than sole crop maize. Intercrop maize yield was, therefore, 9 % and 18 % lower than sole maize yield in seasons 1 and 2, respectively. Grain yield per plant in intercrops was 20% and 29% higher than in sole crop in seasons 1 and 2, respectively. Maize PPD had no significant effect on maize yield and yield components in both seasons. Maize total grain yield was significantly reduced ($P < 0.05$) by bean PPD only in season 2, whereas yield components were not significantly affected in both seasons.

Mean intercrop bean grain yield was 0.784 and 0.631 t ha^{-1} in season 1 and 2, respectively, compared to sole bean yield of 2.132 and 2.175 t ha^{-1} (Table 4). Yield plant^{-1} in intercrops was 9.8 and 8.7 g in seasons 1 and 2, respectively, compared to 19.2 and 19.6 g in sole crop. Values for number of grains pod^{-1} and mean grain weight in intercrops were slightly lower than in sole crop. Mean number of pods plant^{-1} in intercrops was 12.3 and

TABLE 1. Rainfall data (mm) for second rain season (1996)

Month	Week 1	Week 2	Week 3	Week 4	Total rainfall	Rain days
September	nil	nil	4.1	21.5	25.6	4
October	39.8	19.8	4	53.5	117.1	13
November	44.4	63.5	22.3	75.5	205.7	19
December	4.6	29.5	31.6	16.2	81.9	10
Seasonal total					519.9	55

TABLE 2. Rainfall data (mm) for first rain season (1997)

Month	Week 1	Week 2	Week 3	Week 4	Total rainfall	Rain days
February	nil	nil	nil	nil	nil	nil
March	9.4	5.6	23.9	44.8	83.7	13
April	41	23.3	32.5	120.9	217.7	21
May	32.9	49.9	22.1	na	104.9	10
June	na	na	na	na	na	na

na = Data not available; end of May and the whole of June were relatively dry

8.2 pods plant^{-1} in season 1 and 2, respectively, compared to 20 and 12.2 pods plant^{-1} in sole crop. Intercropping with maize reduced bean grain yield by 63 and 71 % in seasons 1and 2, respectively, and yield plant^{-1} by 49 and 56% in seasons 1 and 2, respectively. Number of pods plant^{-1} was reduced by 39 and 33 % in seasons 1 and 2, respectively. Values for grains pod^{-1} and mean grain weight in intercrops were slightly lower than in sole crops. A mixture of 24 576 maize and 66 667 beans plants ha^{-1} produced the highest bean grain yields of 1.075 ha^{-1} in season 1, while a mixture of 22 115 and 51 924 plants ha^{-1} of maize and beans gave 0.844 t ha^{-1} of bean grain in season 2.

Correlation between yields of intercrop maize and beans was negative and significant ($r = -0.62$, $P<0.05$) in season 1, but not significant ($r = -0.31$, $P>0.05$) in season 2. Maize was more competitive than beans, with competition ratio (CR) values of 2.6:1 and 2.4:1 in seasons 1 and 2, respectively.

Effect of plant population on yield and monetary advantages from the maize/climbing bean intercrop. Highest mean total LER values of 1.42 and 1.23 were achieved with mixtures of

TABLE 3. Effect of plant population on maize yield and its components in maize/climbing bean intercrop during second (1996) and first (1997) rain seasons

Plant population (plants ha^{-1}) Maize	Beans	Yield (t ha^{-1})*	Yield plant^{-1} (g)	Cobs plant^{-1}	Grains cob^{-1}	Mean grain weight (mg)
			1996			
24 576	66 667	3.433b	120.1	1.13b	400abc	379b
25 333	57 142	4.303ab	129.1	1.47a	435ab	410ab
25 666	53 968	4.148ab	124.4	1.37ab	443a	411ab
25 714	44 444	3.905ab	136.7	1.17ab	394bc	448a
27 200	74 286	4.321ab	108	1.33ab	415abc	375b
27 428	57 142	4.257ab	149	1.30ab	423abc	398ab
27 666	45 079	3.830ab	114.9	1.33ab	416abc	383b
27 666	70 476	4.481ab	134.4	1.47a	443a	418ab
27 820	52 428	4.271ab	149.5	1.27ab	417abc	388ab
30 800	48 571	3.899ab	97.5	1.20ab	413abc	398ab
31 200	58 775	4.212ab	105.3	1.23ab	388c	406ab
31 600	53 333	5.120a	128	1.33ab	405abc	414ab
Means		4.182	124.7	1.3	416	402.4
Sole maize		4.605	103.6	1.2	397	372
$LSD_{0.05}$		1.358	NS	0.33	44.78	60.96
CV (%)		19.17		15.08	6.36	8.95
			1997			
19 231	73 469	1.395bc	55.8	1.12	425a	258
21 154	60 862	1.632ab	63.9	1.06	375b	288
22 115	51 924	1.749a	69.6	1.15	401ab	269
22 549	46 753	1.493ab	44.8	1.06	376b	275
23 077	84 034	1.502ab	60.1	1.13	396ab	277
23 510	63 492	1.572ab	47.2	1.18	372b	262
23 524	70 745	1.099c	38.8	1.1	365b	268
24 510	81 633	1.288bc	38.6	1.16	410ab	278
Means		1.486	52.3	1.12	390	272
Sole maize		1.807	40.6	1.07	384	257
$LSD_{0.05}$		0.352	NS	NS	43.71	NS
CV (%)		14.25			6.84	

* = Means followed by the same letter within a column are not significantly different using Fisher's Protected Least Significant Difference test at 0.05 alpha level

31 600 maize and 53 333 bean plants ha^{-1} in season 1, and 21 080 maize and 51 924 beans plants ha^{-1} in season 2 (Table 5). Intercrop system had a mean total LER value of 1.26 in season 1, a yield advantage of 26 % over sole crops of component species. However, in 1997a, intercrop system had a mean total LER value of 1.0, implying that the system had no yield advantage over sole cropping of maize and the beans.

The same mixtures with highest LER values also had the highest total income (TI) value of Uganda Shillings 2.456 and 1.217 million ha^{-1} in seasons 1and 2, respectively, compared to Shs. 2.132 and 2.175 million ha^{-1} from sole beans in seasons 1 and 2, respectively (Table 6). Total income from sole maize crop was Shs. 1.842 and 0.786 million in seasons 1 and 2, respectively. When the cost of staking sole bean crop was considered, mean income from intercrops was 226.8 % and 31.8 % higher than that accruing from sole bean and maize crops, respectively, in the first season. In the second season, mean

TABLE 4. Effect of plant population on bean yield and its components in maize/climbing bean intercrop during second (1996) and first (1997) rain seasons

Plant population (plants ha^{-1})		Yield (t ha^{-1})*	Yield plant^{-1} (g)	Pods plant^{-1}	Pods plant^{-1}	Mean grain weight (mg)
Maize	Beans					
			1996			
24 576	66 667	1.075	11.3	13.87ab	13.87ab	232
25 333	57 142	0.775	9.5	12.49ab	12.49ab	226
25 666	53 968	0.633	10	11.30b	11.30b	230
25 714	44 444	0.926	14.6	17.40a	17.40a	233
27 200	74 286	0.672	7.1	9.70b	9.70b	231
27 428	57 142	0.727	8.9	10.67b	10.67b	233
27 666	45 079	0.851	11.9	12.23ab	12.23ab	240
27 666	70 476	0.754	7.9	12.50ab	12.50ab	225
27 820	52 842	0.714	10	12.90ab	12.90ab	232
30 800	48 571	0.62	8.7	11.37b	11.37b	241
31 200	58 775	0.648	7.9	11.70ab	11.70ab	226
31 600	53 333	0.665	10.5	11.00b	11.00b	234
Means		0.784	9.8	12.26	12.26	231.8
Sole beans		2.132		20	20	236.0.
$LSD_{0.05}$		ns		5.76	5.76	ns
CV (%)				27.74	27.74	
			1997			
19 231	73 469	0.647	7.9	8.70ab	8.70ab	582
21 154	60 862	0.621	8.7	7.83ab	7.83ab	560
22 115	51 924	0.844	14.8	10.30a	10.30a	582
22 549	46 753	0.575	10.1	9.03ab	9.03ab	606
23 077	84 034	0.648	6.8	6.63b	6.63b	604
23 510	63 492	0.6	8.4	9.33ab	9.33ab	571
23 524	70 745	0.521	6.4	6.43b	6.43b	603
24 510	81 633	0.587	6.2	7.40ab	7.40ab	576
Means		0.631	8.7	8.21	8.21	586
Sole beans		2.175	19.6	12.2	12.2	590
$LSD_{0.05}$		ns	ns	3.121	3.121	ns
CV (%)				21.71	21.71	

* = Means followed by the same letter within a column are not significantly different using Fisher's Protected Least Significant Difference test at 0.05 alpha level; ns = not significant

income from intercrops was 58.7% and 72.5% higher than that from sole crop of beans and maize, respectively.

DISCUSSION

Effect of bean PPD on maize yield was significant only in season 2, presumably due to competition for available soil moisture under drought conditions. The amount of rainfall in season 2 was 406 mm in only 3 months in 1997 compared to 520 mm in 5 months in season 1, yet maize takes 6 months to mature at high elevations. Very low rainfall was received during the first two weeks of March, while the period from 4th week of May until harvesting in July was relatively dry. According to Lafitte (1994), maize needs at least 500 to 700 mm of well-distributed rainfall during the growing season.

The significant reduction in maize yield attributed to intercropping with beans in season 2 was associated with a reduction in number of grains cob^{-1} and mean grain weight implying that drought stress became severe during the grain-

TABLE 5. Effect of plant population on yield advantages of maize/climbing bean intercrop during second (1996) and first (1997) rain seasons

Plant population (plants ha^{-1})		Yield (t ha^{-1})		Partial LER*		Total LER
Maize	Beans	Maize	Beans	Maize	Beans	
			1996			
24 476	66 667	3.433	1.075	0.75b	0.5	1.24
25 333	57 142	4.303	0.775	0.93ab	0.36	1.29
25 666	53 968	4.148	0.633	0.90ab	0.3	1.2
25 714	44 444	3.905	0.926	0.85ab	0.43	1.28
27 200	74 286	4.321	0.672	0.94ab	0.32	1.2
27 428	57 142	4.257	0.727	0.92ab	0.34	1.26
27 666	45 079	3.83	0.851	0.83ab	0.4	1.23
27 666	70 476	4.481	0.754	0.97ab	0.35	1.32
27 820	52 842	4.271	0.741	0.93ab	0.33	1.26
30 800	48 571	3.899	0.62	0.85ab	0.29	1.14
31 200	58 775	4.212	0.648	0.91ab	0.3	1.22
31 600	53 333	5.12	0.665	1.11a	0.31	1.42
Means		4.182	0.755	0.9	0.35	1.26
Sole maize		4.605			1	
Sole beans			2.132		1	
$LSD_{0.05}$		ns	ns	0.308 ns	ns	
CV (%)				19.17		
			1997			
19 231	73 469	1.395	0.648	0.72	0.3	1.02
21 154	60 862	1.632	0.621	0.77	0.28	1.05
22 115	51 924	1.749	0.844	0.84	0.39	1.23
22 549	46 753	1.493	0.575	0.72	0.26	0.98
23 077	84 034	1.502	0.648	0.72	0.3	1.02
23 510	63 492	1.572	0.6	0.75	0.27	1.02
23 524	70 745	1.099	0.521	0.62	0.24	0.86
24 510	81 633	1.288	0.587	0.62	0.27	0.89
Means		1.486	0.631	0.71	0.29	1
Sole maize		1.807				1
Sole beans			2.175			1

* = Means followed by the same letter within a column are not significantly different using Fisher's Protected Least Significant Difference test at 0.05 alpha level; ns = not significant

filling period. Fisher (1977) and Lorens *et al.* (1987) reported similar results. Low moisture supply between tasseling and silking leads to a delay in the exertion of silks and a reduction in seed set (Onwueme and Sinha, 1991), while drought occurring during the linear growth phase of kernel development primarily affects mean seed weight by reducing assimilate production or duration of grain filling (Lorens *et al.*, 1987).

The significant reduction of bean grain yield in the intercrop system in both seasons was associated with a reduction in both yield plant^{-1} and number of pods plant^{-1}. Weather conditions were favourable to maize in season 1, making it much more aggressive than beans in competing for growth resources. In season 2, weather did not favour rapid establishment of maize plants; consequently, bean plants relied on each other more than on maize for support. This also may have contributed to low bean yield, because seed yield and quality are highly correlated with trellis or stake height, which ensures high pod clearance (Edje, 1984). The escape mechanism of climbing allows better aeration and limits the development of foliar pathogens (Graf *et al.*, 1991); leaves are well exposed to solar radiation, thereby

TABLE 6. Effect of plant population on income from maize/climbing bean intercrop during second (1996) and first (1997) rain seasons

Intercrop population (plants ha^{-1}) Maize	Beans	Intercrop Total Income	Sole bean TI	Cost of Staking#	Sole bean TI-Staking	Sole maize TI	Intercrop TI - Sole maize TI	Intercrop TI - Sole bean TI
				1996				
24 476	66 667	2448000	2132000	1388850	743150	1842000	606000	1704850
25 333	57 142	2496000	2132000	1388850	743150	1842000	654000	1752850
25 666	53 968	2292000	2132000	1388850	743150	1842000	450000	1548850
25 714	44 444	2488000	2132000	1388850	743150	1842000	646000	1744850
27 200	74 286	2410000	2132000	1388850	743150	1842000	568000	1666850
27 428	57 142	2430000	2132000	1388850	743150	1842000	588000	1686850
27 666	45 079	2383000	2132000	1388850	743150	1842000	541000	1639850
27 666	70 476	2547000	2132000	1388850	743150	1842000	705000	1803850
27 820	52 842	2423000	2132000	1388850	743150	1842000	581000	1679850
30 800	48 571	2180000	2132000	1388850	743150	1842000	338000	1436850
31 200	58 775	2333000	2132000	1388850	743150	1842000	491000	1589850
31 600	53 333	2713000	2132000	1388850	743150	1842000	871000	1969850
Means		2456000	2132000	1388850	743150	1842000	586583	1685433
				1997				
19 231	73 469	1249000	2175000	1388850	786150	723000	526000	462850
21 154	60 862	1261000	2175000	1388850	786150	723000	538000	474850
22 115	51 924	1544000	2175000	1388850	786150	723000	821000	757850
22 549	46 753	1172000	2175000	1388850	786150	723000	449000	385850
23 077	84 034	1249000	2175000	1388850	786150	723000	526000	462850
23 510	63 492	1229000	2175000	1388850	786150	723000	506000	442850
23 524	70 745	1174000	2175000	1388850	786150	723000	451000	387850
24 510	81 633	1102000	2175000	1388850	786150	723000	379000	315850
Means		1217000	2175000	1388850	786150	723000	524500	461350

* = Market prices used to compute total income (TI) were Uganda Shillings 400/= and 1000/= per kg of maize and bean grain, respectively. Bean grain normally fetches twice the price of maize grain on Kabale markets

= Cost of stakes was set at Shs. 50/= per stake (labour to ferry and place stakes in the field inclusive). With four bean plants sharing astake, 27 778 pieces were required per hectare

considerably minimizing mutual shading (Edje, 1984; Osiru and Hahn, 1994). Root rots (fungal complex) disease which is prevalent in Kabale, may have contributed to the low bean plant density; all available bean varieties were susceptible to this devastating disease. The notorious "mouse-tail" bird, a common pest in the area that damages both flowers and tender pods, may have contributed about 10 % to the reduction in bean yields.

Correlation between bean and maize yields was negative and significant ($r = -0.62$, $P < 0.05$) in season 1, whereas it was negative but not significant ($r = -0.31$, $P > 0.05$) in season 2. Mean partial LER values were 0.90 and 0.71 for maize, compared to 0.35 and 0.29 for beans in seasons 1 and 2, respectively. This suggests that maize dominance over beans was reduced in season 2, presumably due to soil moisture deficits (and apparently low fertility).

Intercropping maize and climbing beans was more efficient in land use than pure stands of both species in season 1, presumably due to adequate soil moisture. However, the system had no yield advantages in season 2, probably due to inadequate soil moisture. This agrees with Fisher's (1979) report that maize/bush bean mixtures had no yield advantage under low rainfall conditions. Although a mixture of 31 600 maize and 53 333 bean plants ha^{-1} had the highest maize yield, LER and TI values in season 1, intercrop bean yield was low. A mixture of 24 576 maize and 66 667 beans plants ha^{-1} had the highest intercrop bean yield, although LER and TI values were lower than for the mixture mentioned earlier. Therefore, this latter mixture is more relevant to Kabale farmer's production goal of maximizing bean yield and not total income, since beans are produced mainly for home consumption. Natarajan (1989) also noted that the planting pattern (and density) which produces the highest physiological (and monetary) advantage cannot always be the one used by the farmer, because the latter's choice is likely to be influenced by other considerations such as preference for a specific component.

CONCLUSIONS

Intercrop bean yield was significantly lower than sole crop yield in both seasons, partly due to maize dominance over the beans. Bean yield was maximized from actual mixtures of 24 576 maize and 66 667 bean plants ha^{-1} in season 1, and 22 115 maize and 51 924 bean plants ha^{-1} in season 2. The intercrop system had both yield and economic advantages over pure stands of the component species in both seasons.

In order to improve intercrop bean yield, plant population should not exceed 25 000 maize and 67 000 bean plants ha^{-1} in seasons with ample rainfall. Lower plant densities, such as, a mixture of 50 % of the sole crop density of each species (i.e., 22 222 maize and 55 556 bean plants ha^{-1}) may be used in seasons/areas with rainfall deficit. When root rot-resistant climbing bean genotypes and cultural control practices from the Regional Bean Research Network (ECABREN) and CIAT become available, this will contribute to boosting yields and production. There is no known effective method for controlling the notorious "mouse-tail" bird, which damages both flowers and tender pods of beans. However, once farmers get convinced that the intercrop system works, then more will adopt it, thereby sharing the bird burden and minimizing yield loss associated with the pest.

Intercrop system yield may not be sustained without external inputs; therefore, we suggest that a study on the effect of fertiliser on performance of the system be initiated in future. For a relay intercropping system in which beans are introduced between silking and physiological maturity of maize, nitrogenous (N) fertiliser, such as diammonium phosphate (DAP) can be applied on maize and beans benefit from residual fertiliser. Control of the maize stalk borer (*Busseola fusca*) will be essential to guarantee adequate support for the beans. Before planting beans, all maize leaves below the ear will have to be stripped off, in order to increase the amount of solar radiation reaching the bean plants – the lower storey canopy in the system.

Greater yield advantages due to complementary use of resources (e.g., light, water and nutrients) are realised from crop mixtures when maturity differences of the component species are large enough. Therefore, in order to maximize bean yield, we propose that the optimum planting date for introducing climbing beans into the maize needs to be determined.

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