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Effect of Banana Leaf Pruning on Banana and Bean Yield in an Intercropping System in Eastern Democratic Republic of Congo

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ABSTRACT

Banana-bean intercropping systems are used by many small-scale farmers in eastern Democratic Republic of Congo to maximize land use and intensify crop production. A study was conducted at the INERA Mulungu research station to determine the effect of banana leaf pruning on banana (*Musa* spp.) and bean (*Phaseolus vulgaris*, Fabaceae) yield. The East African highland cooking banana 'Barhabesha' was established in April 2007 at a spacing of 2 by 3 meters. The treatments consisted of different levels of banana leaf canopy coverage (5 leaves [5L] and all leaves [ALL]) and leguminous crop varieties (the bush bean 'Ngwaku Ngwaku' and the climbing bean 'AND10') which were planted in the banana plot. Bean yields were assessed during 4 cropping seasons (2008B, 2009A, 2009B and 2010A). Banana leaf pruning did not have a significant effect on time from planting to bunch harvest in either legume intercropping treatment. Banana leaf pruning did not have a significant effect on banana yield (32.3 and 28.6 t/ha for ALL; 32.2 and 26.3 t/ha for 5L for climbing and bush bean intercropping respectively). The average banana bunch weight was higher in the climbing bean (ALL: 19.4 / 5L: 19.4 kg) than in the bush bean intercropped plots (ALL: 17.2 / 5L: 16.1 kg). A reduction in the number of banana leaves (i.e. from all leaves to 5 leaves) enhanced bean yield for both legume types. Under the all leaves treatment, climbing bean yield (358 kg/ha) was slightly but not significantly higher than bush bean yield (335 kg/ha). However, it was significantly higher for the 5L treatment (512 kg/ha against 362 kg/ha). Results from a gross margin analysis of banana-bean intercropping and cropping season effects are also presented.

Keywords: gross margin analysis, legume yield

INTRODUCTION

Banana and plantain (*Musa* spp.) are the staple food for over 20 million people in the Great Lakes region of central and eastern Africa (Karamura *et al.* 1998). Banana is the second most important staple food crop after cassava in the Democratic Republic of Congo (DR Congo) (Bakelana 2004). However, in eastern DR Congo, banana is the number one staple crop in terms of cultivated area and production. Banana beer has for centuries been a traditional beverage in eastern DR Congo and no social event, happy or unhappy, can proceed without a banana beer jug (Kirkby and Ngendahayo 1985).

More than 100 million small-scale African farmers annually grow more than four million ha of beans (PABRA 2006). The per capita consumption of legumes in the Kivu provinces of eastern DR Congo is amongst the highest in the world and amounts to approximately 50-60 kg fresh legume grain per person per year (PABRA 2006). Bush and climbing beans (*Phaseolus vulgaris*, Fabaceae) are mainly cultivated and, to a lesser extent, soybean and peanuts (Tollens 2004). The common bean is an important source of protein for low-income families in rural and urban areas, providing about 38% of utilizable protein and 12-16% of daily calorie requirements (ASARECA 2010). Bean is also an increasingly important source of income for rural households (Davis *et al.* 2002). Annual sales of legume grains in Africa amounted to more than 580 million US$ in 2005 (CIAT 2008).

The intercropping of either banana or plantain with legumes is practiced in both South America and Africa (Liu *et al*. 1999). Intercropping is commonly practiced in the humid highland regions of eastern and central Africa including Uganda, Rwanda, Burundi and eastern DR Congo. Banana is commonly intercropped with both non-leguminous (e.g. taro, melon and sweet potato) and leguminous crops including cowpea (*Vigna unguiculata*), common bean (*Phaseolus vulgaris*) and soybean (*Glycine max*) (Van der Veken *et al*. 2008). In Rwanda, 50 to 60% of legumes are cultivated in association with banana (Nyabyenda and Jeremy 1987).

Intercropping aims at maximizing productivity and minimizing risks (*e.g.* due to climate change, pests and diseases) (Nyabyenda 2006) and gives a greater yield stability compared to monoculture. Moreover, it often provides a higher economic and monetary return and total production per hectare compared to monoculture and ensures greater resource use efficiency. Intercropping with legumes may also be a strategy to offset soil fertility depletion (Ouma 2009).

Crop production is primarily the conversion of solar energy to stored food energy (Pimentel and Pimentel 2008). Growth and yield of crops are related to the amount of solar radiation received during the growing period (Nyambo *et al*. 1982; Cockshull *et al*. 1992; Challa and Bakker 1998). Shade can affect plants at different growth stages. For example, rice grown in shaded plots has a higher percentage of missing hills than those grown in un-shaded plots. As a

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result, shaded plots give lower rice grain yields (Quddus and Pendleton 1991). Moula (2009) assessed the shade effect of trees on yield of different rice varieties. The yield of green straw of the local variety 'Kazol Shail' in the shaded and un-shaded plots were, respectively, 4.89 and 10.11 t ha^{-1}. Sandri *et al*. (2003) assessed the effect of shade on tomato plants grown in a greenhouse. At the last harvest, dry mass from un-shaded and shaded plants differed significantly, with values of 974.9 g m^{-2} and 762.5 g m^{-2} for total dry mass, 550.1 g m^{-2} and 419.74 g m^{-2} for fruits, and 424.75 g m^{-2} and 342.74 g m^{-2} for vegetative organs, respectively. Shading had reduced total tomato plant growth with 21.7%. Shade does however not always have a negative effect on the yield quality or quantity. For example, Bote and Struik (2011) evaluated the effect of shade on growth and production of coffee plants in Ethiopia. Shade trees protected coffee plants against adverse environmental stresses such as high soil temperatures and low relative humidity. Shade, however, also triggered differences in physiological behavior of the coffee plants, such as improved photosynthesis and increased leaf area index, resulting in better performance than possible in direct sunlight. Consequently, coffee plants grown under shade trees produced larger and heavier fruits with better bean quality than those grown in direct sun light.

In the case of *Musa*, the light reduction in banana-agroforestry systems extends the banana crop cycle duration and may reduce bunch size, especially under increased plant densities (Staver *et al*. 2007). Different authors have studied the interaction between banana leaf age and its physiological activity during the vegetative growth stage (Cayón 2001). They found that photosynthesis and transpiration rates are highest in the youngest leaves (leaves 2, 3, 4 and 5) and drastically reduced in the older leaves (leaves 6, 7, 8 and 9) (Cayón *et al*. 1998). Under optimal growing conditions, banana produces one leaf every 8-10 days (Morton 1987). To get optimal bunch formation and fruit filling, seven to eight functional leaves are required at the time of flowering (Krishnamoorthy *et al*. 2004). A bunch weight reduction of 40 to 50% can be observed on banana plants which only have four to six functional leaves at flower emergence (Echeverry 2001).

In eastern DR Congo, farmers usually intercrop banana with legumes. Some farmers cut banana leaves when planting beans to provide sufficient light for legume development. The objective of this study was to quantify the effect of banana leaf removal on legume and banana growth and yield.

MATERIALS AND METHODS

Study area

The trial was established at the Institut National pour l'Etude et la Recherche Agronomiques (INERA) Mulungu research station. Mulungu is located at 02°20.042'S, 028°47.311'E and at an altitude of 1,707 metres above sea level. The soil is a volcanic-derived Andosol with the following characteristics: pH: 6.50, OM (%): 7.3, N (%): 0.33, P (ppm): 139.8, K ($cmol_c$/kg): 2.48, Ca ($cmol_c$/kg): 12.12 and Mg ($cmol_c$/kg): 2.92. The average annual rainfall is 1500 mm distributed over two rainy seasons (April to July and September to December) (**Fig. 1**).

The East African highland cooking banana 'Barhabesha' (*Musa* AAA-EA group) was established in April 2007 at a spacing of 2 by 3 m. The treatments consisted of different levels of banana leaf canopy coverage (five leaves [5L] and all leaves [ALL]) and leguminous crop varieties (the bush bean 'Ngwaku Ngwaku' and the climbing bean 'AND10') which were planted 12 months after banana field establishment. The treatments were arranged in a randomized block design with four replications. Each plot (6 × 6 m) contained 12 banana plants and legumes were intercropped in each banana plot. Twelve lines of climbing bean and 15 lines of bush bean were established per plot. The inter- and intra-line spacings for bush and climbing beans were, respectively, 40 cm and 20 cm, and 50 and 20 cm. Bean yields were assessed during four consecutive cropping seasons (2008B, 2009A, 2009B and 2010A). Banana leaf pruning was only carried out during the months of bean cultivation and leaves were cut at weekly intervals. Banana de-suckering was carried out at the onset of the bean cropping season, while weeding was carried out at monthly intervals.

Data collection and analysis

Banana growth and yield data were assessed on all 12 plants per plot, while legume data were assessed on plants growing in a net plot of 3 × 4 meter located in the centre of each 36 m² plot. Hence, data was collected on 300 bush bean and 192 climbing bean plants per net plot.

The following characteristics were assessed for banana: plant height, pseudostem circumference at the base of the plant and at 1 m height, number of months from planting to flowering, number of months from flowering to harvest, number of hands, number of fingers in the lower row of the second lowest hand, the weight of the second lowest hand, total number of fingers in the whole bunch, bunch weight and yield. Banana plant height was measured from soil level to the point where the youngest two leaf petioles join. The data collected for beans included: germination rate, number of plants per bean net plot, pod fresh yield, bean fresh yield, bean dry yield and bean gross margin.

The bean gross margin (US$/ha) was calculated as the difference between input costs (e.g., weeding before bean planting, field demarcation, bean weeding, banana leaf pruning, banana de-suckering, bean planting, cost of the wooden sticks for climbing bean propping, climbing bean propping and bean harvest) and the proceeds of sale of bean harvest.

All data were subjected to analysis of variance using the GenStat software package (GenStat 2008). Tukey's studentised range Test was used to determine significant differences (at 5% probability level).

RESULTS AND DISCUSSION

Banana leaf pruning did not have a significant effect on time from planting to flowering and time from flowering to bunch harvest in either legume intercropping treatment (**Table 1**). Time from planting to flowering was 19.6 and 18.85 months for the all leaves treatment and 19.03 and 18.82 months for the 5 leaves treatment for climbing and bush bean respectively, while time from flowering to harvest was 4.40 and 4.73 months for the all leaves treatment and 4.72 and 4.54 months for the 5 leaves treatment for climbing and bush bean, respectively.

Leaf pruning did not have a significant effect on the total number of fingers in a bunch (**Table 1**). However, a higher number of banana fingers was observed for the climbing bean intercropping treatment (**Table 1**). In addition, leaf pruning did not have a significant effect on banana yield for respectively climbing and bush bean intercropping (32.3 and 28.6 t/ha for ALL; 32.2 and 26.3 t/ha for 5L). The average banana bunch weight was higher in the climbing bean (ALL: 19.4/5L: 19.4 kg) than in the bush bean intercropped plots (ALL: 17.2/5L: 16.1 kg) (**Table 1**). There was a tendency for better bunch attributes when banana was intercropped with climbing bean than with bush bean (**Table 1**). Blomme *et al*. (2001) studied the effect of leaf pruning on plant growth and reported a significant reduction in root system, corm and above ground plant traits, especially when only four leaves were retained. Furthermore, Mukasa *et al*. (2005) reported that leaf area of the mat had a strongly positive and significant relationship with bunch weight for eight east African *Musa* genotypes. The size of the plant and fruit bunch depends directly on the number and size of functional leaves (Echeverry 2001), thus leaf area can be used to estimate the photosynthetic capacity and to predict the performance of a banana crop (Stover and Simmonds 1987). In addition, Balbín and Zapata (2001) reported that five healthy leaves are needed for bunch development, while Cayón *et al*. (1998) stated that the five youngest banana leaves have the highest level of photosynthesis. In our study, banana leaf pruning only started at

Table 1 Effect of banana leaf pruning on banana plant growth, cropping cycle length, bunch traits and yield.

Bean type	Number of leaves	Growth traits at flower emergence						Bunch and yield traits				
		PH#	PCSL	PC1m	NMPF	NFSH	SW	NH	TNF	BW	YLD	NMFH
Climbing bean (AND10)	All leaves	330.6 c*	69.51 bc	48.85 b	19.6 a	7.19 b	2.056 a	7.05 b	98.1 a	19.39 a	32.34 a	4.4 a
	5 leaves	345.6 b	71.82 b	51.34 a	19.03 a	7.49 a	2.054 a	7.36 a	104.3 a	19.41 a	32.18 a	4.72 a
Bush bean (Ngwaku Ngwaku)	All leaves	357.4 a	75.05 a	52.36 a	18.85 a	7.25 a	1.963 a	7.04 b	89.4 b	17.19 b	28.60 ab	4.73 a
	5 leaves	324.4 c	67.13 c	46.31 c	18.82 a	7.10 b	1.695 b	6.89 b	88.6 b	16.08 b	26.33 b	4.54 a
LSD (0.05)		10.5	2.6	2	1.5	0.25	0.174	0.23	6,7	1.39	4.806	0.4
CV		7.7	9.1	10	11	8.4	22.2	8.2	17	19	18.4	9

#: PH: plant height (cm); PCSL: pseudostem circumference at soil level (cm); PC1m: pseudostem circumference at 1m (cm); NMPF: number of months from planting till flowering; NFSH: number of fingers of the second hand; SW: weight of the second hand (kg); NH: number of hands; TNF: total number of fingers; BW: bunch weight (kg); YLD: yield (tonnes/ha); NMFH: number of months from flowering to harvest.
*: Means in a column followed by the same letter are not significantly different from each other according to Tukey's HSD test (P<0.05).

Table 2 Effect of banana leaf pruning on bean germination rate, number of plants per bean net plot, pod fresh weight, bean fresh weight and bean dry weight across four bean cropping seasons.

Bean type	Number of leaves	GR#	NP	PFY	BFY	BDY
Climbing bean	All leaves	98.12 a*	147.5 b	586 b	445 b	358 b
	5 leaves	98.75 a	161.5 b	817 a	624 a	512 a
Bush bean	All leaves	98.38 a	203.1 a	566 b	451 b	335 b
	5 leaves	97.12 a	195.9 a	658 ab	502 ab	362 b
LSD (0.05)		3.3	34.31	163.5	128.3	96,2
CV		3.1	18.2	23.4	23.8	23

#: GR: germination rate (%); NP: number of plants per bean net plot (12 m²); PFY: pod fresh yield (kg/ha); BFY: bean fresh yield (kg/ha); BDY: bean dry yield (kg/ha).
*: Means in a column followed by the same letter are not significantly different from each other according to Tukey's HSD test (P<0.05)

Table 3 Gross margin analysis for legume cultivation associated with banana, according to cropping season, bean type and banana leaf pruning treatment.

Season	Bean type	Treatment	Input costs per ha (weeding, propping, leaf cutting, etc.)	Bean income per ha (US$)*	Net benefit per ha (US$)
4 seasons combined	Climbing bean	all leaves	893	667.5	-225.5
		5 leaves	898	936	38
	Bush bean	all leaves	666.6	676.5	9,9
		5 leaves	671.6	753	81.4
2008B and 2009B	Climbing bean	all leaves	893	740.3	-152.7
		5 leaves	898	1055.6	157.6
	Bush bean	all leaves	666.6	732.5	65.9
		5 leaves	671.6	1118.8	447.2
2009A and 2010A	Climbing bean	all leaves	893	591	-302
		5 leaves	898	819	-79
	Bush bean	all leaves	666.6	421.5	-245.1
		5 leaves	671.6	586.5	-85.1

*: the market price of a kg of bush or climbing beans is 1.5 US$.

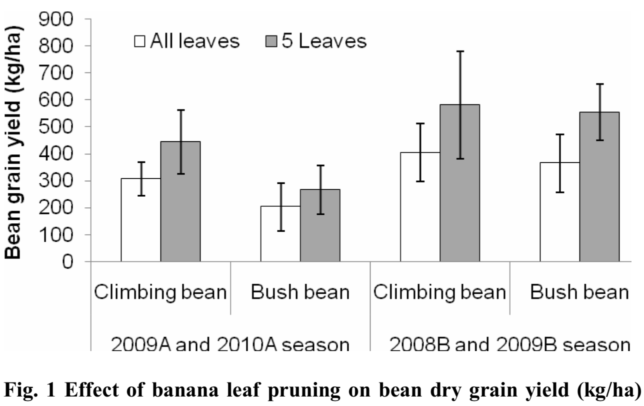

Fig. 1 Effect of banana leaf pruning on bean dry grain yield (kg/ha) across the four bean cropping seasons (2008B, 2009A, 2009B and 2010A). Values represent mean ± standard error (se). n = 8

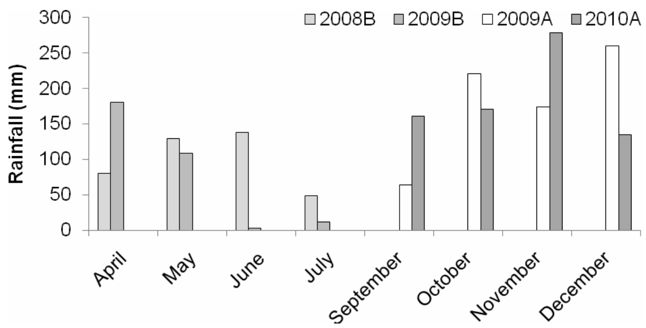

Fig. 2 Rainfall data collected at the INERA, Mulungu research station during four bean cropping seasons over the period 2008 to 2010.

12 months after banana field establishment (i.e. at the time of bean planting) and coincided with flower emergence in most banana plants. This can thus explain why moderate leaf pruning in the current study did not have a significant effect on bunch weight and yield.

No significant difference was observed in germination rate across legume type and leaf treatment (**Table 2**). A reduction in the number of banana leaves (i.e. from all leaves to five leaves) enhanced bean yield for both legume types, although this effect was more pronounced and significant for the climbing bean: 512 kg/ha compared to a bush bean yield of 362 kg/ha for the five leaves treatment (**Table 2**). Legume grain yield was higher during season B for both bush and climbing bean (**Fig. 1**). Season B is characterised by a lower rainfall level (**Fig. 2**) and this results in a lower angular leaf spot disease incidence. Angular leaf spot is a fungal disease affecting the leaves and pods of legumes (Schwartz *et al*. 1981; Wortmann and Allen 1994; de Jesus Junior *et al*. 2001).

A gross margin calculation of banana-bean intercropping revealed that bean cultivation is more profitable when banana leaves are pruned (447.15 $/ha for bush and 157.63 $/ha for climbing bean) compared to the all leaves treatment (65.9 $/ha for bush and -152.69 $/ha for climbing bean) (**Table 3**). In addition, the highest legume profits are obtained during season B than in season A. The lower net profit per hectare observed for climbing beans is mainly due to the relatively high cost of propping materials. Novel research has shown that ropes made out of banana pseudostem fibre in combination with/attached to banana leaf petioles and midribs can act as a support structure for climbing beans. In addition, live stems of cassava plants can act as a lower-cost support for climbing beans.

This study revealed that banana-legume intercropping is most profitable in the B season when rainfall is moderate. In addition, retaining a reduced number of banana leaves (five, in this study) during the months of bean intercropping does not significantly influence banana crop cycle duration and growth. As banana and beans are mainly grown for home consumption, the combination of climbing bean and five remaining banana leaves will provide the highest overall yields. However, when one looks at profitability aspects for more market-oriented households, banana-bush bean intercropping has a larger gross margin.

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