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The impact of leguminous culture system and sowing dates on the cereal yield in mountainous South-Kivu: Case of Burhale

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ABSTRACT: Despite their potential yield, the adoption of climbing beans in mountainous South Kivu is limited by the lack of technologies. Thus, appropriate technologies corresponding to poor farmer incomes should be adapted in terms of labour, soil and investment in capital so that intercropping would replace stakes and allow a better soil cover. This study was carried out at Burhale during two cultural seasons A2011 and A2012 in four sites comprising 9 trials each. The varieties used were: maize, soya-bean and beans. NPK and manure were also used. The MOJA was applied in 1st and 3rd trials and the MBILI in 2nd and 4th ones. Monoculture was practiced in 6th, 7th, 8th and 9th trials. Beans were sown 10 to 15 days after maize in 1st and 3rd trials. In 2nd, 4th and 7th trials this happened 20 to 30 days after maize. Soya-beans were sown simultaneously with maize in the 5th MBILI trial and in the 8th monoculture trial. Maize was sown on the experiment launching day. Leguminous plant yield was inferior (259.26; 271.88; 0 and 0 kg.ha^{-1} respectively for 1st, 2nd, 3rd and 4th trials) to that of monoculture (2711.11 and 1100.18kg.ha^{-1} respectively for 6th and 7th trials). Maize yield was inferior (7564.4; 5397; 10279.61 and 842.91kg.ha^{-1} respectively for 1st, 2nd, 3rd and 4th trials) to that of the 9th monoculture trial (7957.4kg.ha^{-1}). Good LERs of 1.01 and 1.25 were found for 1st and 3rd; they were bad (0.76; 0.92 and 0.69) for 2nd, 4th and 5th trials.

KEYWORDS: Land Equivalent Ratio, MOJA system, MBILI system, maize, climbing beans, Soya-beans.

1 INTRODUCTION

Agricultural development is facing several constraints such as limitation of soil, water and inputs coupled with continuous growth population and the lack of a structured market, resulting in reduced production per capita. In addition, the farmers are frequently following easy and old practices such as the relay sowing of crops, exhausting more land area, water and inputs [10]. Furthermore, this practice is commonly used for the principal crops which occupied most of the available old land area while other crops, of secondary importance, are restricted to small areas [6]. An alternative procedure to mitigate the effect of these constraints and to increase the acreage and production of such secondary crops is to intercrop them particularly in the newly reclaimed soils [22]. Intercropping is practiced in many parts of the world [4]. It is traditionally a low input agricultural system and an important characteristic of many developing countries [2]. As one of the multiple cropping systems, intercropping has been practiced by farmers for many years in various ways and most areas, and has played a very important role in agriculture [5]. It can provide yield advantages compared to sole cropping [2].

Most studies on intercropping have focused on the legume-cereal intercropping like a productive and sustainable system, its resource utilization (water, light, space) into the cropping system and reduction of negative impacts on the environment [5], [29]. In recent years attention has focused on the diversified agricultural production systems for maximizing utilization of resources as compared to the monoculture cropping systems [18]. Combinations of a cereal with a grain legume are probably the commonest of all intercropping systems, and at least in Africa and Asia, the farmer's yield objectives tend to follow a similar theme [25]. Several research works indicated the particular importance of plant density and planting pattern upon intercrop viability. Many studies have shown that intercrop components might utilize different edaphic and climatic growth resources more efficiently, potentially supporting a great number of plants which may result in more optimum plant density than those of monoculture [6], [9], [27], [31].

Compared with corresponding monoculture, yield advantages have been recorded in many intercropping systems, including maize/soya-bean [20], [33], maize/faba bean [18], maize/beans [8], [9], [12]. The improved use of resources results in greater total intercrop yields as compared to monoculture of the same species grown on the same area [11]. This is due to differences in competitive ability for growth factor between intercrop attributes in time and space and improvement of soil fertility through the addition of nitrogen (N) by biological N fixation and excretion from the legume attributes [34]. Intercropping is also expected to reduce risk of a single crop failure due to pest and disease incidence and increase food security [15], [19]. More species diversity in agricultural ecosystems can limit the plant pathogenic spread. Intercropping systems increase biodiversity like the natural ecosystems. This increase in diversity reduces pest damage and diseases [14], [16], [17].

The main disadvantages of intercropping systems may comprise planting, managing, fertilization; weed control, pest control and harvesting for both crops as it is normally done manually by small-scale famers [21].

The aim objective of this trial is to investigate whether climbing beans can be associated with maize grown using maize stalks as tutors. Specifically, this study evaluates the effects of climbing bean sowing over maize, and those of culture system (MBILI system, i.e. two legume plants between two maize rows, and MOJA system or one legume plant line between two lines of maize). A maize/soya-bean intercropping system was included as reference, and monocultures of each culture were included to calculate Land Equivalent Ratio.

2 MATERIALS AND METHODS

2.1 LOCATION

The trials were installed in the associative fields of Burhale villages, in Walungu Territory, Eastern DR Congo. Associative fields met the following characteristics: fertility, homogeneity, shared location on a slight slope and suitability for the growth of maize. Names and geographical coordinates of the four associations that housed our trials are: AJC: 02.69504˚S, 028.6503˚E, 1720m Alt; BOLOLOKE: 02.69851˚S, 028.64612˚E, 1678 m Alt; JEVODELU: 02.68572˚S, 028.63807˚E, 1662m Alt; RUCIHANGANE: 02.69030˚S, 028.64880˚E, 1662m Alt.

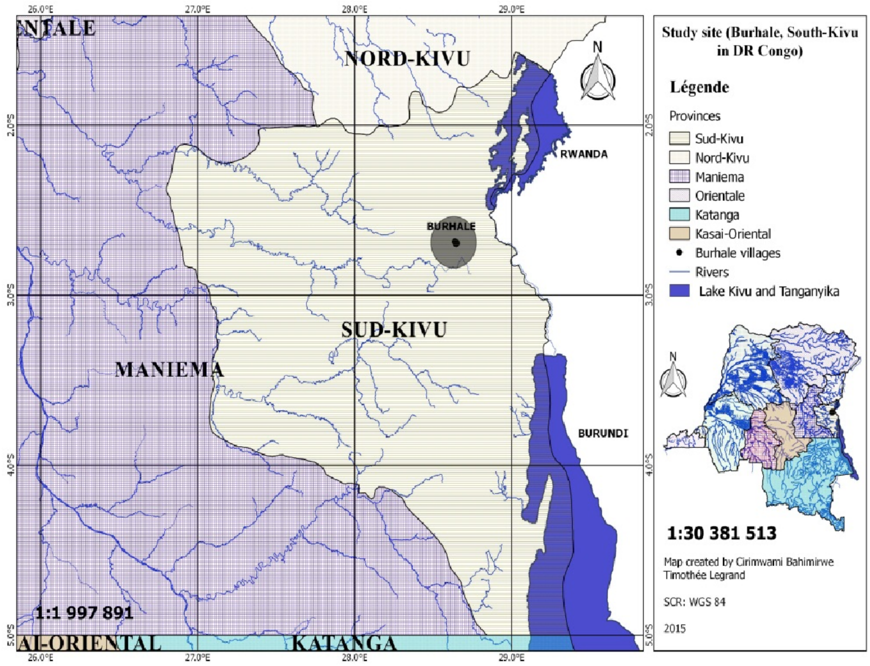

Figure 1. Study site in Burhale, South-Kivu, DR Congo

The experimental site is located in humid tropical climate tempered by altitude. According to the Kopen classification, it belongs to the climate type AW3. Field trials were conducted in September 2010 to January 2011 and in September 2011 to January 2012 with mean annual precipitation of 134. 9 mm and annual mean average temperature of 20°C.

2.2 EXPERIMENTAL LAYOUT

Seedbed preparation included plugging, harrowing with rake and cultivation. The experimental design for this study was a Latin square randomized complete block design with 4 blocks each with 9 treatments with four replicates. Within each block, plots were separated by 0.5 m distance and the total area required for a block was 375.25 m^2 or (19m x 19.75m).

Table 1.The treatment structure of the experimental design showing their specificities

Treatments	Legume species	Legume sowing date	Culture system	Spacing (cm×cm)		Plot size
				Legumes	Maize	
T_1	Climbing beans	10-15 Da	Intercropping 1 :1 (MOJA)	75x15	75x25	36m^2
T_2	Climbing beans	10-15 Da	Intercropping 2 :2 (MBILI)	33x15	75x25	40.5m^2
T_3	Climbing beans	20-30 Da	Intercropping 1 :1(MOJA)	75x15	75x25	36m^2
T_4	Climbing beans	20-30 Da	Intercropping 2 :2 (MBILI)	33x15	75x25	40.5m^2
T_5	Soya bean	Ss	Intercropping 2 :2 (MBILI)	33x15	50/100x25	40.5m^2
T_6	Climbing beans	10-15 Da	Climbing beans Monoculture	75x15	-----	30m^2
T_7	Climbing beans	20-30 Da	Climbing beans Monoculture	75x15	-----	30m^2
T_8	Soya bean	Ss	Monoculture Soybean	75x5	-----	36m^2
T_9	------	-----	Monoculture maize	75x25	-----	36m^2

Da: Days after maize; Ss: Simultaneous sowing; cm: centimeter, and m^2: square meter

2.3 SEED GENOTYPES AND FERTILIZERS

The plant materials used are maize (WH 403), Soya-bean (SB 19) and the climbing bean (AND 10). Seeds of crops were sown by hand: During both experimental periods, seedlings have taken on different dates as recorded in the structural array of treatments. Initially 2 seeds were sown per hole. Indeed, maize and soya-beans were planted in time, i.e. on September 25 at AJC, on September 26 at BOLOLOKE and RHUCIHANGANE and on September 29 at JEVODELU. Intercropping climbing beans, however, were planted in AJC associative fields 10 to 15 days after maize in treatments 1, 2 and 6 or 9 in October, whereas in other monocultures, they were planted 20 to 30 days after maize (precisely on October 16, 2011 and 2012) in treatments 4 and 7.

After the incorporation of manure in soil, the NPK 17-17-17 fertilizers were applied in a channel parallel to the line of seedling, at a distance of roughly 10 cm, and a depth of roughly 5 cm. These were covered immediately after application with a small amount of soil. In intercropping (treatments 1,2,3,4 and 5) systems, 22.5g of fertilizers were applied in each row, while in monoculture systems (treatments 6, 7, 8 and 9), 45g of fertilizers were applied in each row. During the growth period all plots were weeded manually. No serious incidence of insect or disease was observed and no pesticide or fungicide was applied to either crop.

2.4 PLANT SAMPLING AND GROWTH ANALYSIS

At the end of the growth period plants were sampled and harvested in useful plots, and Land Equivalent Ratio (henceforth LER) as well as some yield attributes were recorded.

2.5 CALCULATIONS AND STATISTICS

The relative advantage of intercropping compared to sole culture was calculated for each proportion by using LER. The LER was calculated according to: $\mathbf{LER = (Y_{im}/Y_{sm}) + (Y_{ic}/Y_{sc})}$ where Y_{im} and Y_{sm} are the yields of intercropped and monoculture maize, and Y_{ic} and Y_{sc} are the yield intercropped and monoculture beans, respectively. When LER is more than 1.0, this indicates a positive intercropping advantage which shows that interspecific facilitation is higher than interspecific competition [13]. Conversely, a disadvantage is shown if LER is < 1.0.

2.6 Statistical analyses

Data collected were subjected to the analysis of variance. Test of significance of the treatment difference was done on a basis of a *t*-test.

3 Results

3.1 Yield comparative analogy of climbing beans

Intercropping 1 and 2 has been compared to monoculture 6 where the climbing bean was sowed 10 to 15 days after the seedling of the maize; associations of cultures 3 and 4 have been compared to monoculture 7 where the climbing bean was sowed 20 to 30 days after the seedling of the maize.

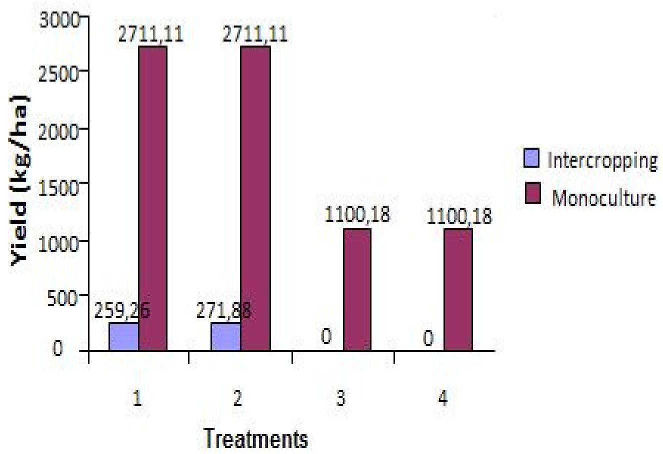

Fig. 2. Climbing beans yield in culture systems

- Climbing beans sowed in MOJA system 10 to 15 days after maize and with the use of maize feet as guardians gave good middle yield in the order of 295.26kg.ha^{-1}, whereas when they were sowed 20 to 30 days after maize, they didn't yield anything on account of a rain of hail that poured down during the blooming period.
- Also, in MBILI system, climbing beans sowed 10 to 15 days after maize and with the use of maize feet as guardians gave good outputs of the order of 271.88 kg.ha^{-1}, whereas those sowed 20 to 30 days after maize produced nothing due to excessive rains and hail that marked the blooming period.

In the end, having used wood guardians instead of maize feet in the MOJA system monoculture, the climbing beans sowed 10 to 15 days after maize gave yield far more abundant than the double of the produce from the seedling sowed 20 to 30 days after maize: the yield of the former is in the order of 2711kg.ha^{-1} while that of the latter is in the order of 1100kg.ha^{-1}. The reason for this poor harvest is the excessive rainfall that thwarts plant germination and growth as well as flowering and the replenishment of pods.

3.2 Yield comparative analogy of maize

Intercropping maize treatments 1, 2, 3 and 4 have been compared to the monoculture maize treatment 9.

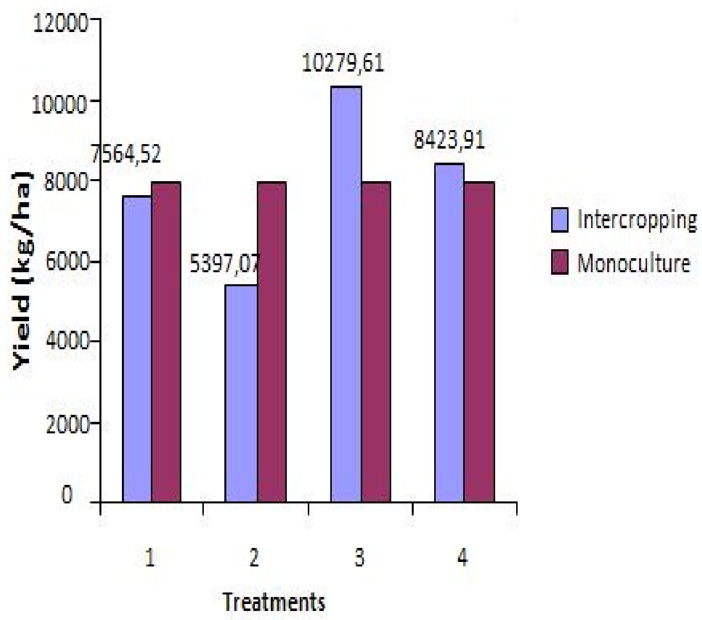

Fig. 1. Maize yield in culture systems

Maize intercropped with climbing beans in the MOJA system, where the latter are sowed 10 to 15 days after the former, gave lower outputs in the order of 7564.5kg.ha^{-1}, contrarily to the monoculture in which maize yielded 7957.4kg.ha^{-1}.

However, maize intercropped with climbing beans in the MOJA system, where the latter were sowed 20 to 30 days after the former, gave yields of 10279.6kg.ha^{-1} which are far superior to the monoculture yields (7957. 4kg.ha^{-1}) following the different periods of seedling and density of cultures. Indeed, maize seedlings, planted 10 to 15 days earlier than climbing bean ones and which are not yet well developed enough to serve as supports, suffer from the competition (with climbing bean seedlings) for nutriments and environmental resources. The reason is that climbing bean seedlings, which use them as guardians, choke them and weaken their productive capacity.

As far as sowing dates are concerned, climbing bean seedlings sowed 20 to 30 days after maize best encourage good growth and best express their vigour while exploiting environmental resources rationally. Moreover, maize intercropped with climbing beans in the MBILI system, where the former were sowed 10 to 15 days after the former, gave yields in the order of 5397kg.ha^{-1} which are inferior to those of the monoculture (7957kg.ha^{-1}). This output reduction is the consequence of the competition that occurs between maize and climbing beans as the former is used as guardians and choked by the latter.

3.3 COMPETITION RELATIONS

Table 2. Land Equivalent Ratios

Treatments	Species	Culture system	LER Values
T_1	Climbing beans + Maize	Intercropping 1 :1 (MOJA)	1.01
T_2	Climbing beans + Maize	Intercropping 2 :2 (MBILI)	0.76
T_3	Climbing beans + Maize	Intercropping 1 :1 (MOJA)	1.25
T_4	Climbing beans + Maize	Intercropping 2 :2 (MBILI)	0.92
T_5	Soya-bean + Maize	Intercropping 2 :2 (MBILI)	0.69

So far as climbing bean/maize intercropping goes, this table shows that the MOJA system intercropping offers a better exploitation and cover of soil than the MBILI system intercropping. It also shows that intercropping in the MBILI system (where climbing beans are sowed 10 to 15 days after maize) doesn't allow greater profitability due to a bad cover and exploitation of soil resources. This way, the practice of maize or climbing bean monoculture is more advantageous, because it exploits and covers soil better. However, if absolutely necessary, one can also resort to the climbing bean/maize intercropping, where the former is sowed 20 to 30 days after the latter in the MBILI system, insofar as it is beneficial and allows a good cover and more rational exploitation of soil.

As to soya-bean/maize intercropping, the table reveals that its LER is bad because there is no good cover of soil. This way, maize or soya-bean monoculture is the better option for farmers.

4 Discussion

[21] showed that the intercropping of cultures results in a yield reduction following a competition of nutriments. [24] found that the MBILI system enables a better exploitation of soil by root system. These studies are in agreement with the results of the present survey that show that, when legumes are planted next to maize rows 10 to 15 days after maize sowing according to the MBILI system, a strong competition between the two cultures ensues and the yield decreases. Delaying the introduction of legumes, on the contrary, delays the beginning of the competition between the two cultures and improves the yield. This is because the principal crops have the ability to exploit different soil layers without competing with each other [29]. There was probably a better use of resources such as light as stated by [23], nutrients [29] and water [30]. A similar result from cereal legume intercrops has been reported by other researchers [1] according to whom intercrop forage yields were greater than either species alone.

The climbing bean in intercropping system for treatments 3 and 4 gave a hopeless result. This is due to the fact that the beans were affected by excessive rains that poured down during germination, which confirms the findings of [3], [26], [7]. These researchers hold that, in case of excessive soil moisture owing to rain, the bean dies from the asphyxia of its roots and its canopy destroys itself.

LER values in intercrops 1 and 3 treatments were higher than 1.0. This shows that land utilization efficiency for maize-climbing beans intercropping was more advantageous than for sole cropping. And it confirms the findings of [32] who attained a LER greater than 1.0 in a climbing bean-maize intercropping system.

5 Conclusion

Research findings on maize/climbing bean and maize/soya-bean intercropping demonstrate that farmers in mountainous South-Kivu can practice maize/climbing bean intercropping in the MOJA system, where the climbing bean is sowed 10 to 15 days after the maize, and in the MBILI system, where the climbing bean is sowed 20 to 30 days after the maize. They also show that farmers can equally have recourse to the maize/soya-bean intercropping in the MBILI system where the two are sowed simultaneously.

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