

The Influence of Associated Crops and Inter-mound Distance on Soil and Water Conservation

Henri Grisseur Djoukeng^{1*}, Helene Soyeurt² and Aurore Degre²

¹ Departement of Rural Engineering, University of Dschang, Cameroon.

² TERRA Teaching and Research Centre, Gembloux Agro-Bio Tech, University of Liege, Belgium.

*Corresponding author email id: hgdjoukeng@gmail.com

Abstract – Agriculture in the Western and Northwest regions of Cameroon is based on mountains generally with steep slopes. Tied ridging coupled with crop association is a vital management option for improvement of crop yields and environment preservation. This study was conducted to determine the inter-mound distance and the crop combination that retain the most sediment and runoff. Three inter-mound distances (1.0 m – TA, 1.5 m – TB, and 2.0 m – TC) and three crops – potato (*Solanum tuberosum* L.), corn (*Zea mays* L.), and bean (*Phaseolus vulgaris* L.) – were selected to study their effects both in monospecific cropping and crop association, on runoff and soil loss and crop yields. The experiment was conducted in four replicates at three established crop combinations located at two sites in Western region and one site in Northwest region. Crop combinations are potato monospecific cropping (P), bean/potato association (PB), and bean/corn association (BC). Sediment and runoff sampling was performed in cropping year 2018. Crossed analysis of variance model with two fixed factors ($p < 0.05$) showed an effect of associated crops for most variables regardless production location. Significant differences ($p < 0.05$) were observed between treatments (TA compared to TB and TC) and between crop combinations (P compared to PB and BC), regardless location and slopes. No significant difference ($p > 0.05$) was observed between the TA and the TB treatments in potato yield. Since the BP crop combination improved crop yields; by practicing it, farmers would diversify their food and cash crops. A land equivalent ratio (LER) is greater than 1.0 in all crop associations, which means that there are productive advantages of associated crops.

Keywords – Environment, Mountain, Potato, Bean, Cameroon.

I. INTRODUCTION

The Cameroonian economy is essentially based on agriculture. It provides more or less direct livelihood for $\frac{3}{4}$ of the population, represents about 20% of the gross domestic product and provides 70% of exports in value. Whether food or export, Cameroon's agriculture is essentially family [1]. The dynamism of the Cameroonian agriculture makes it possible to satisfy the food needs of the local populations and a part of those of the countries of the CEMAC (Communauté Economique et Monétaire de l'Afrique Centrale / Economic and Monetary Community of Central Africa) sub-region; namely: Chad, Central African Republic, Congo Brazzaville, Equatorial Guinea and Gabon. By the way, Cameroon is commonly called "food basket of the Central African sub-region" [2] and [3].

Considered by Food and Agricultural Organization (FAO) as an activity of food sovereignty, market gardening plays a key role in most nutrition and poverty programs and contributes significantly to family incomes in Africa [4] –

[6]. Cameroon's main production area for food crops is the western highland area, which consists mainly of volcanic soils. The volcanic soils are very fertile; they grow coffee (*Coffea arabica* and *Coffea canephora*), cocoa (*Theobroma cacao*), tea (*Camellia sinensis*), tobacco (*Nicotiana tabacum*), and food crops to supply the big cities. Food crops of this area consist of potato (*Solanum tuberosum*), leek (*Brassica oleracea*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), cabbage (*Brassica oleracea*), garlic (*Allium sativum*), onion (*Allium cepa*), and carrots (*Daucus carota* subsp. *sativus*). Potato is a preferable food and cash crop and the most representative food crop [7]. Only about 15.4% of the land is arable [8]. This low percentage is due to a bad management policy of cultivable land and an almost universal isolation of cultivable areas [9] – [11]. At the same time, the food needs of the population have been covered less since more than a decade driven by demographic factors such as population growth and urbanization [12]. According to the Millennium Development Goals, the Government of Cameroon has as target to halve the proportion of people suffering from hunger [1]. Because there is not enough land to bringing under cultivation [7]; redressing this challenge will require appropriate techniques and research that will improve on the productivity of the land, and minimize environmental degradation.

Agricultural land erosion is becoming more and more the concern of countries where mountains agriculture is practiced. The development of techniques against erosion can really boost crop yields, thus the economy of those countries [13]. That is why many researchers are going on in the purpose to implement existing or new techniques, to fight against soil and water degradation for long term environmental preservation.

In addition to the works of Boukong (1997) [14] and those of Fonteh et al (1998) [15], Djoukeng (2016) [7] have implemented the tied ridging technique with a meter distance between mounds using a potato crop. These experiments had given satisfactory results in terms of runoff water and sediment retention on the cultivated plots, and in terms of crop yield increase and therefore farmers' income. The practice rate of the tied ridging technique was high during the crop years in which experiments were conducted. The adoption of the technique remains today the concern of rich farmers and elites, because the implementation of the technique induces additional costs. Elites and affluent farmers generally cultivate low-slope plots that favor less runoff and sediment transfer than the steep slopes occupied by the less affluent farmers [7]. In short-term period, if less affluent farmers haven't opportunities to implement tied ridging technique, it can't be said that the latter is an

effective mean for the sustainable conservation of soil and water in the agro ecological zone of the western highlands of Cameroon. Although previous studies were done with different cultures, they are limited to monospecific cropping. Researchers should therefore think about associated crops.

Associated crops refers to the simultaneous cultivation of two or more species on the same plot for a significant period of their growing cycle [16]. Associated crops yields are systematically greater than or equal to the average yields of the monospecific crop. Design of technical itineraries depends on the pedoclimatic characteristics of the production basin and the farmer's production objectives. Associated cropping are an effective way to fight against organic attacks [17].

The objective of this study was to determine the inter-mound distance and the crop combination that retain the most sediment and runoff, in order to improve crop yields and to preserve environment in Santa, Femock and Mélang village, Cameroon.

II. MATERIALS AND METHODS

Study Area

Santa village lies between latitudes 5° 50' – 6° 5' 19'' N and between longitudes 10° 9' – 10° 6' 49'' E, in the Northwest region of Cameroon. Femock and Mélang village lies between latitudes 5° 29' 54'' – 5° 6' 28'' N and between longitudes 10° 7' 33'' – 10° 26' 10'' E, in the Western region of Cameroon [12]. The three villages are located in a mountain range commonly called, western highlands of Cameroon, an agro-ecological zone which extends over both regions and has similar agro-climatic conditions [7].

Slopes exploited in the three experimental sites were 14%, 17% and 21% for Santa, Femock and Mélang respectively. Soils were silty in the three experimental sites.

During the experiment, rain gauge was installed in each production area. Rainfall data were recorded daily from March 20 to August 27, 2018. Rainfall of 1209, 1218 and 1215 mm were collected in Santa, Femock and Mélang respectively.

Experiment Design

The experiments were laid out in complete randomized design with three treatments. Four replications, three crop combinations namely, potato monospecific cropping (P), potato-bean (PB) and bean-corn (BC). Three treatments namely, inter-mound distances 1.0 m (TA), 1.5 m (TB) and 2.0 m (TC) and four replicates. A total land area of 2224.20 m² was used in each production area. The total land area was divided into nine blocks and each block was subdivided into three identical plots measuring 22.10 m x 1.80 m each plot. The plots length was extended by 1.0 m for runoff and sediment collecting pit. Each plot occupied an area of 41.58 m². Every block had 1.0 m apart and 0.50 m between plots.

Crop Management Practices

The crop varieties common to the western and northwest regions were chosen to conducting experiments. Crop varieties used were red skin potato locally called “Désiré”, bean GLP190 locally called “Mac-mac”, and a composite

corn locally called “Shaba”.

In potato monospecific cropping, two lines of potato were planted on each ridging with a spacing of 0.25 m, and one potato was planted in each inter-mound. The potato plants used were calibrated 20/28 for an average mass of 22.5 g.plant⁻¹. The quantities of seedlings were 2,090 kg.ha⁻¹, 2,070 kg.ha⁻¹, and 2.050 kg.ha⁻¹ for treatments TA, TB, and TC respectively.

In potato-bean association, potato' seedling density was the same as in monoculture. Bean was staggered sown in each mound with a spacing of 1.0 m and one seed in each inter-mound. The mass of 1000 bean seeds used was on average 194 g. The bean' seedling quantity was 5.13 kg.ha⁻¹, 4.93 kg.ha⁻¹ and 4.78 kg.ha⁻¹ for treatments TA, TB, and TC respectively.

In bean-corn association, seeds spacing were 0.2 m and 0.5 m for bean and corn, respectively. Bean and corn seeds were staggered sown in each mound with one seed of both in each inter-mound. The average 1000 g mass of bean and corn seeds used was 200 g and 258 g respectively. The quantity of bean seeds was 22.88 kg.ha⁻¹, 22.67 kg.ha⁻¹, and 22.52 kg.ha⁻¹ for treatments TA, TB, and TC respectively. With regard to corn seeds we had 12.35 kg.ha⁻¹, 12.09 kg.ha⁻¹, and 11.89 kg.ha⁻¹ for treatments TA, TB, and TC respectively.

Sediment and Runoff Management

Canisters of 100 liter capacity were used to collect runoff and sediment. The collection was monitored daily and was done after each rain. The quantifications were made using an electrical balance sensitive to 5 g. Each experimental plot was isolated from runoff and sediments from elsewhere. The insulation was done with old corrugated sheets and polyethylene films.

Evaluating Treatments, Crop Combinations

The baseline in calculating the rate of variation was the TA treatment in potato monoculture. The three treatments and three crop combinations were evaluated in terms of runoff and sediment retention, and crop yields.

Data Analysis

Data were analyzed by MINITAB software (version 18) using a crossed analysis of variance model (two fixed factors) with a significance level of P < 0.05. Normality and homogeneity of the variances assumptions were assessed on the residuals of the adjustments. Those assumptions were met for all data. Performances of associated crops were evaluated by the land equivalent ratio (LER) using the following equation [16] – [17]:

$$LER = \frac{\text{Yield associated crop A}}{\text{Yield crop A}} + \frac{\text{Yield associated crop B}}{\text{Yield crop B}},$$

where A and B are crops for a given combination.

III. RESULTS AND DISCUSSION

Quantity of Runoff Collected

Regardless production location, the TA treatment and the PB crop combination were the best in terms of runoff retention (Fig. 1). Runoff had decreased by 23.5% and 13.2 % compared to PB and BC crop combinations, respectively. A significant difference (p < 0.05) was observed

between all treatments and all crop combinations. Likewise, a strong significant difference ($p < 0.01$) was observed in TC treatment and P crop combination. The soils were all silty in the three production locations, the differences observed between treatments and crop combinations could be related to the slope of the cultivated land [15]. The finding also agreed with Djoukeng (2016) [7] for potato monospecific cropping. The higher incidence in runoff retention for PB and BC crop combinations could be the response of soil cover by plants and the improvement of soil structure by combined root systems [9] and [13].

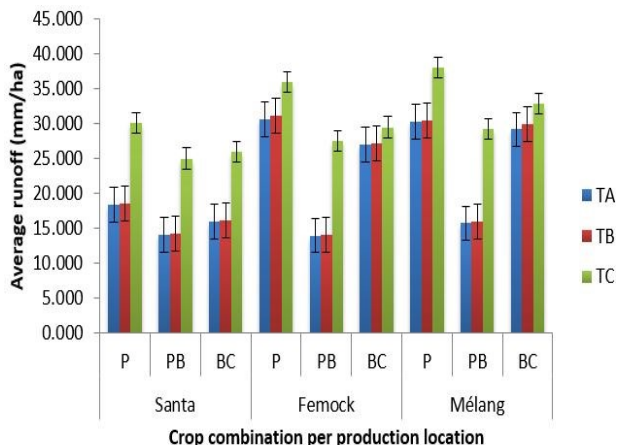


Fig. 1. Average quantity of runoff collected per location and per crop combination.

Quantity of Sediment Collected

Significant differences ($p < 0.05$) were observed between treatments and crop combinations, for instance, the TA and TB treatments had lower sediment collected than those with TC treatment (Fig. 2). We have noted that the higher the slope, the more efficient PB crop combination is visible (Fig. 2). The PB crop combination had decreased sediment collected by 33.33% and 25.82% compared to P and BC crop combinations, respectively. Given the results of previous research conducted with monospecific cropping in this agro ecological zone [7], [14] and [15], associated crops were the best mean for erosion control.

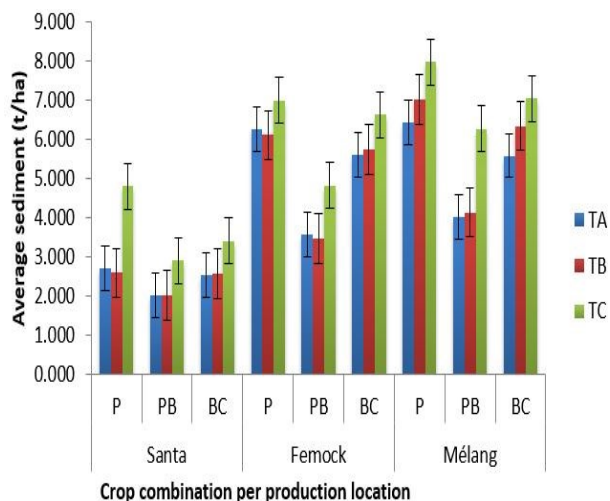


Fig. 2. Average quantity of sediment collected per production location and per crop combination.

Crop Yields

In the three production locations, potato yield decreases as slope increases (Fig. 3), results from high runoff (Fig. 1) and massive soil outflow (Fig.2). Regardless production location and inter-mound distance, the PB significantly ($p < 0.05$) increased potato yield. No significant difference ($p > 0.05$) was observed between TA and TB treatments. The PB crop combination had highest average potato yield in all production locations; increase ranged from 12% to 14%. Regardless of slope, average potato yield in PB crop combination was 24.7% greater than the average potato yield in Cameroon which is 16 t.ha⁻¹ [18]. It should be noted that this potato yield is added to that of common bean produced in same plot. For all associated crops, a land equivalent ratio (LER) is greater than 1.0 which means that there are productive advantages of crop associations [17].

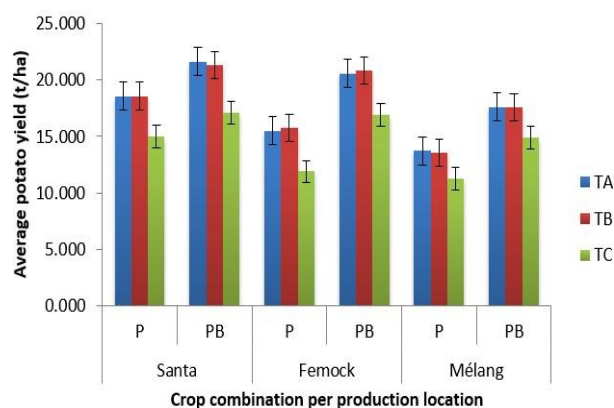


Fig. 3. Average potato yield per crop combination and per production area.

Average corn yield was significantly ($p < 0.5$) different between the three treatments (Fig. 4). Consider the three production locations, the TB and TC treatment had decreased corn yield by 1.63% and 15.71%, respectively. Although corn yield is added to that of bean, the corn yield is higher than that of pure culture in the region which is 3.5 t.ha⁻¹ [1], another benefit of associated crops.

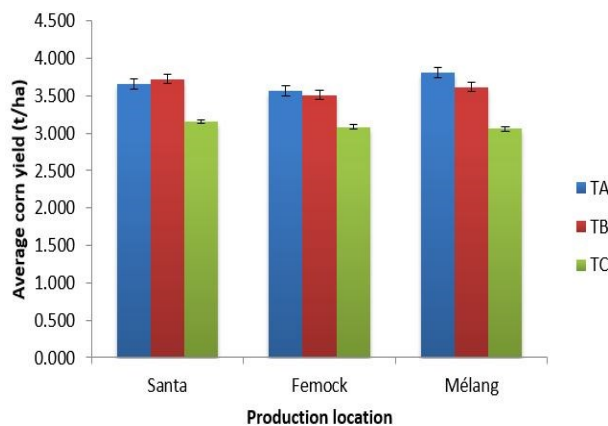


Fig. 4. Average corn yield per treatment and per production location.

Bean yield showed significant difference ($p < 0.05$) between treatments and crop combinations. The bean was more productive in the PB crop combination than that BC

combination. In fact, the seeds were 4.58 times higher in BC than in PB, and the yield was 2.55 times higher in BC than in PB. Likewise, regardless treatments and crop combinations, the bean yield in these associated crops was higher than that of pure culture in the study area, which is $1.2 \text{ t} \cdot \text{ha}^{-1}$ [1]. This increase in bean yield is an advantage of the associated crops [17].

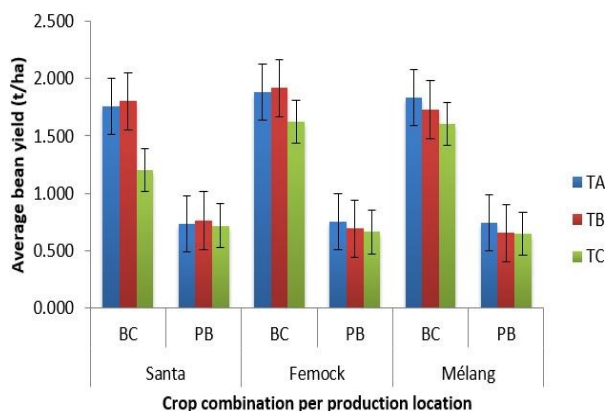


Fig. 5. Average bean yield per crop combination and per production location.

IV. CONCLUSION

This study was conducted to determine the combined effects of inter-mound distances and associated crops on runoff, sediment retention, and crop yields in the context of mountains agriculture. Significant differences were observed between treatments and between crop combinations, regardless location and slopes. Likewise, crop yields were better in associated crops than in monospecific cropping. For potato yield, no significant difference was observed between the TA and the TB treatments. The higher incidence in runoff retention for the PB and the BC crop combinations could be the response of soil cover by plants and the improvement of soil structure by combined root systems. However the BP crop combination improved crop yields; by practicing it, farmers would diversify their food and cash crops. A land equivalent ratio (LER) is greater than 1.0 in all crop associations, which means that there are productive advantages of crop associations.

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AUTHORS PROFILE'**Henri Grisseur Djoukeng** (corresponding author)

Assistant Professor

- Advanced M.Sc. in Management of Animal and Plant Resources in Tropical Areas, 2011. Gembloux Agro-Bio Tech, University of Liege, Belgium.
- Advanced M.Sc. in Total quality Management, 2013. Polytechnic faculty, university of Mons, Belgium.
- Ph.D. in Agronomic Sciences and Biological Engineering, 2016. Gembloux Agro-Bio Tech, University of Liege, Belgium.

He is working at Rural Engineering Department, University of Dschang, Cameroon. Email: hgdjoukeng@alumni.uliege.be

Dr. Ir. Djoukeng is an active member of American Society of Agricultural and Biological Engineers (ASABE), and Canadian Society for Bioengineering (CSBE) since 2013).

Helene Soyeurt

Professor

TERRA Teaching and Research Centre, Gembloux Agro-Bio Tech, University of Liège, Belgium.

Aurore Degre

Professor

TERRA Teaching and Research Centre, Gembloux Agro-Bio Tech, University of Liège, Belgium