International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 5 Issue 2, February - 2021, Pages: 65-77

Influences of Different Soil Erosion Control Methods on Bean Production parameters and yield. Running Title: Erosion Control methods's Influences on Bean Production

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***Abstract**: Erosion negatively affects crop yields and decreases crop productivity. It removes nutrients, reduces rooting depth, and damages soil structure, resulting in negative nutrient balances and lower crop yields. A study for two years was conducted using three soil erosion control methods to appraise the method which could effectively control erosion and improve bean production characteristics on a hill more prone to erosion. Designed on three different plots (P1, P2, P3) divided in four sub plots (S1, S2, S3, S4), these methods were traditional plowing method (M1); anti-erosive hedges planting method (M2) and anti-erosive hedges coupled with anti-erosive ditches (M3). The recorded parameters were the number of: pods, full pods and grains, as well as the average yield weight. After analysis with SPSS and Advanced excel, results showed no significant difference between M1 and M2 but highlighted the significant effects of M3 method in improving the number of: pods, full pods and grains. Likewise, this method has somehow enhanced the average yield weight. These outcomes suggest M3 as the most effective method in enhancing bean production parameters and yield at Buhoro hill.*

Keywords: Soil erosion, Traditional plowing method, Anti-erosive methods, Bean plant, Production parameters.

INTRODUCTION

Soil erosion is a major environmental issue. It reduces soil productivity so slowly that the reduction may not be recognized until land is no longer economically suitable for growing crops (Krauss and Allmaras,1981). Foregoing researches affirmed that erosion negatively affects crop yields (Martha et al., 2007; Jones and Huggins, 1997), while ongoing research reported a decreased agricultural productivity due to excessive erosion (Reusser et al., 2015). Furthermore, soil erosion always reduces soil fertility and causes potential environmental hazards (Langdale and Schrader, 1982). Other researches highlighted that it removes nutrients, thins the soil layer, reduces rooting depth, and damages soil structure, resulting in negative nutrient balances and lower crop yields (Bossio et al., 2010; Zougmoré et al., 2009; Lal, 1998; Zhang et al., 2011). Owing that humans worldwide obtain more than 99.7% of their food (calories) from the land, preserving cropland and maintaining soil fertility which results in improved crop production should be of the highest importance to human welfare (David and Michael, 2013), especially in Burundi, where 93% of the population lives by agricultural production (Alain, 2004), and particularly in Ngozi, an overpopulated province with highest malnutrition rate of 71% [12]. However, to emphasize the improvement of crop bean production is more appreciable based on recent research which revealed that consumption demand of beans in Burundi is expected to increase due to high population growth, lack of protein animal source and the higher prevalence of HIV/AIDS that necessitates an improved intake to maintain good health (Bernard et al, 2014). Moreover, bean is the major cultures in Burundi which is daily consumed for the whole population with highest average consumption in the Great Lakes region of Central Africa. Furthermore, bean plays a significant role in human nutrition. It is a good source of vitamins, particularly thiamine, riboflavin, niacin, vitamin B6, and folic acid (Nirmal et al., 2010). Higher dry beans nutrients component like phenolics and antioxidant were reported in dry bean, as well as micronutrients, especially iron and zinc (Xu and Chang, 2008; Bernard et al, 2014). Nevertheless, bean production has been reduced due to erosion, especially in Ngozi at Buhoro, a hill more prone to erosion, thereby a need of controlling erosion to increase production. In Burundi, although significant erosion control researches have been undertaken, they have emphasized the use of anti-erosive ditches alone or anti-erosive hedges plantation and assessed the soil loss and productivity. Little is known on the response of crops production characteristics to anti -erosive hedges coupled with anti-erosive ditches. This study intends to comparatively appraise

International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
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the effects of different erosion control methods (including the anti-erosive hedges and anti-erosive ditches coupling) on bean crop production characteristics at Buhoro hill.

MATERIALS AND METHODS

Site description and soil properties

The experiment was carried out at Buhoro, a hill more prone to erosion, located in Gashikanwa commune of Ngozi province (Photo 1).

Photo 1. Administrative Boundaries in Burundi

The experimental site was characterized by a humid tropical climate with an altitude of 1690 m. The recorded precipitation was 1046mm with mean temperature and a slope of 20.5°C and 41% respectively. The soil texture (0-40cm) was Loam, with chemical properties summed up in the following table

Table I. Soil properties

pH_{water}	pH_{KCl}	P (mg kg^{-1})	K(méq/100g)	N (%)	C (%)
5.38	3.81	13.7	0.14	0.42	1.28

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Experiment design

The experiments have been undertaken in 2016 and 2017 and have considered three methods designed on three separated plots (P1, P2 and P3) with 290 m^2 for each. These method were: the traditional plowing method (M1) on P1, set as a control; the anti erosive hedges planting (M2) on P2; and the method constituted by the anti-erosive hedges coupled with anti-erosive ditches (M3) implemented on P3.
Before sowing, these plots were divided in four sub plot viz S1, S2, S3, and S4 (from upstream to downstream), separated by the anti erosive hedges on P2; anti-erosive hedges coupled with anti-erosive ditches on P3, while for plot P1 the separation considered just the virtual lines of these anti-erosive hedges (Photo 2).

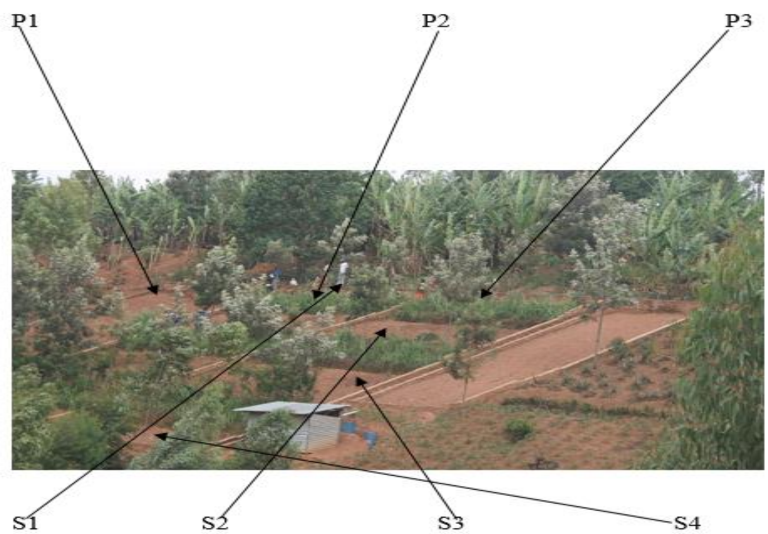

Photo 2: Experiment plots and sub plots

Sampling and data collection

For sampling, three homogeneous regions: upstream, middle and downstream were considered for each sub-plot, while two lines were chosen at each region. The recorded parameters were the number of pods, full pods, and grains. Likewise, the average yield weight was assessed.

Statistical analysis

For data analysis, advanced Excel 2007 and SPSS have been used. Comparisons between treatments were conducted through LSD (least significant difference) at $P<0.05$, while figures and table were made by using Excel.

RESULTS

Effects of erosion control methods on pods number

Pods number is an indicator closely related to the plant yield needing to be assed for crop yield projection. In this study, it has been recorded and displayed in the following figures 1 and 2.

Considering these figures, the pods number was effectively influenced by erosion control methods. Regarding S1 in 2016 (Figure 1), there is no significance difference between methods.

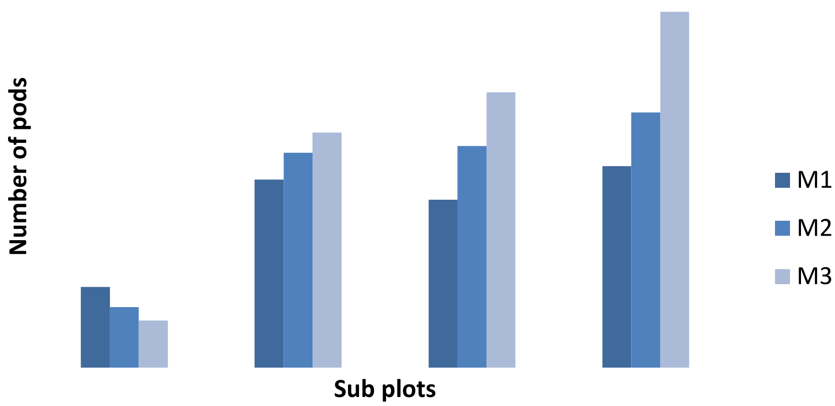

Figure 1. Effects of erosion control methods on pods number in 2016

S1: Upstream Sub plot; S2 middle Sub plot toward Upstream; S3 middle Sub plot toward downstream; S4: downstream Sub plot

M1: traditional plowing (the control); M2: anti-erosive hedges planting; M3: anti-erosive hedges coupled with anti-erosive ditches

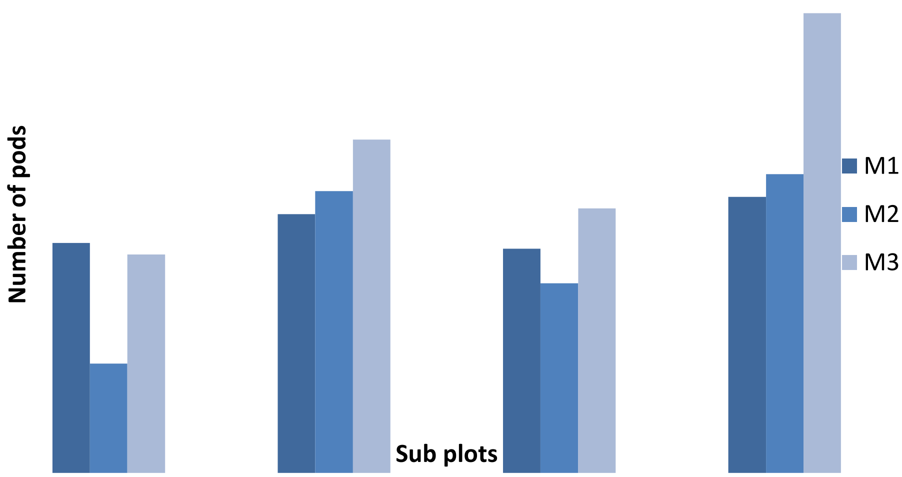

Figure 2. Effects of erosion control methods on pods number in 2017

Clearly, the method M1 recorded highest pods number of 12 pods, followed by M2 with 9 pods, while M3 method got 7 pods per plant. For S2, the maximum number of pods was recorded for M3 (35 pods) and presented significant difference (P <0.05) from the control M1. The second highest value was observed for M2 (32 pods) with significant difference from the control M1, which obtained the minimum value of 28 pods. The same trend was observed on S3, where the highest pods number was recorded by method M3, 41 pods, followed by M2, 33 pods, while the minimum value of 25 pods was observed for M1 method. As for S2 and S3, the maximum value of pods number for S4 was observed with the used method M3 (53 pods), which significantly differed (P <0.05) from the methods M2 (38 pods) and M1 (30 pods) methods.

In the second year (2017), the pods number analysis on S1 showed no significant difference between M1 and M3 methods which got the highest values of 40 and 38 pods respectively. Moreover, these methods (M1 and M3 significantly differed (P< 0.05) from M2, the method with smallest value of 19 pods. Regarding S2, the maximum pods number was observed for M3 with 58 pods, followed by method M2 of 49 pods, while M1 got the minimum by 45 pods. Similarly, Considering S3, the optimum pods number was still recorded for method M3 with 46 pods, followed by method M1 of 39 pods, and minimum for method M2 with 33 pods. On sub plot S4, the maximum number of pods was also recorded for M3 (80 pods) which significantly differed from other methods with a higher significant difference (P <0.001). The method M2 (52 pods) got the second highest value, while the method M1 obtained the lowest value of 48 pods. These outcomes revealed the effectiveness of M3 in improving pods number.

Influences of erosion control methods on full pods number

Full pods number has been assessed in this study as can be seen in figure 3 and 4

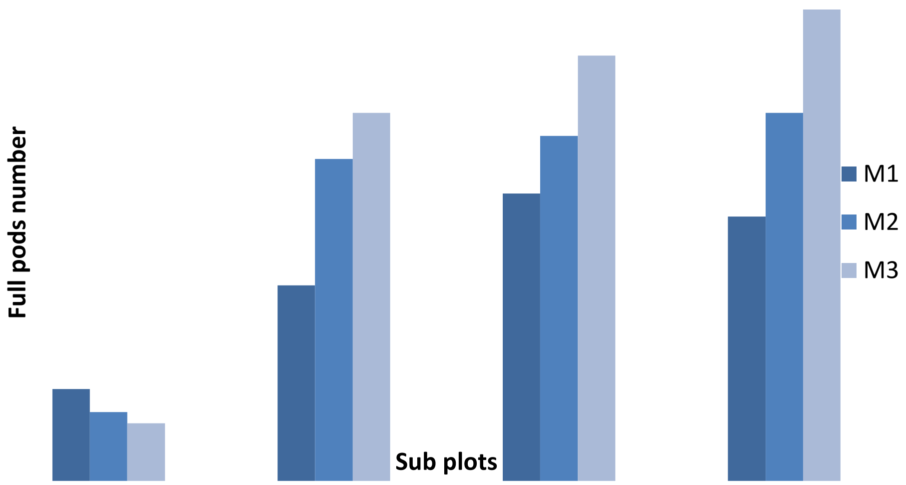

Figure 3. Influences of erosion control methods on full pods number in 2016

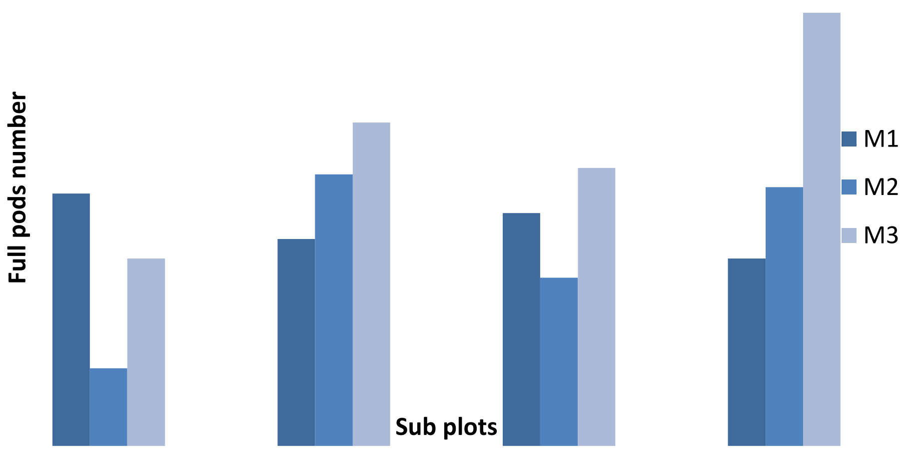

Figure 4. Influences of erosion control methods on full pods number in 2017

Considering S1 in 2016, the method M1 recorded the highest number of 8 full pods per plant, followed by M2 with 6 full pods, while M3 method obtained the minimum of 5 full pods. For S2, the first highest value was observed for M3 (32 full pods) and presented significant difference (P <0.05) from the control M1. The second highest value was recorded for M2 (28) which also significantly differed from the control M1, the method with minimum value of 17 full pods. The same trend was observed on S3, where the highest number was observed for method M3, 37 full pods, followed by M2, 30 full pods, while the minimum of 25 full pods was obtained by method M1. Considering S4, significance difference between methods was observed. Specifically, the full pods number was maximum for implemented method M3 (42 full pods), and differed from the control (M1) with higher significance difference (P <0.001). The method M2 was the following with 32 full pods, while the minimum was observed for method M1 with 23 full pods.

In 2017 (Figure 3.4), the erosion control methods have influenced significantly the full pods number. On S1, the highest number of 39 full pods was recorded for the method M1, followed by M3 with 29 full pods. These two methods significantly differed from M2 which obtained the minimum value of 12 full pods. Considering S2, the method M3 (50 full pods) got the maximum full pods number with significance difference (P <0.05) from the control M1. It was followed by M2 (42 full pods), while the minimum was recorded for method M1 (32 full pods). On S3, the highest value of full pods was recorded for M3 with 43 full pods, and second highest for M1 of 36 full pods, and lowest for methods M2 with 26 full pods. For sub plot S4, as can be seen in figure 3.4, the method M3 obtained also the maximum value of 67 full pods with higher significance difference (P <0.001) from the control M1. The second highest value was recorded for method M2 of 40 full pods which significantly differed (P <0.05) from method M1 with lowest value of 29 full pods.

Respond of grains number to different erosion control methods

The outcomes on grains number were summed up in the following figures 5 and 6 below.

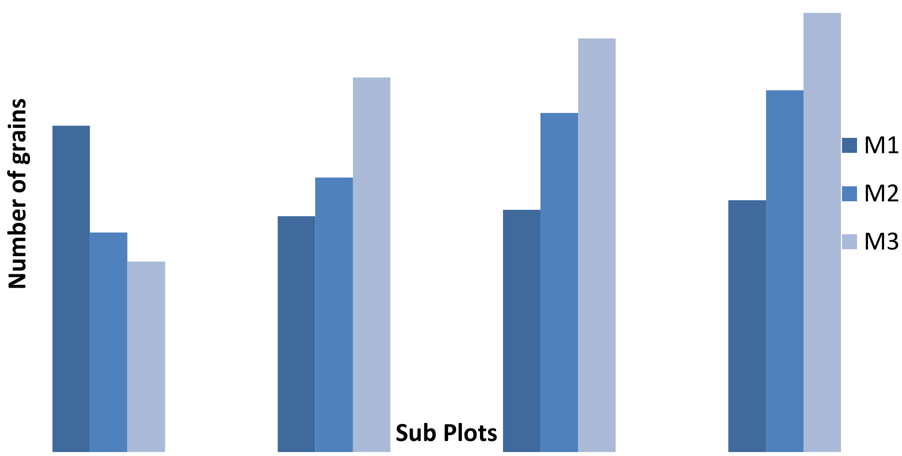

Figure 5. Response of grains number to erosion control methods in 2016

International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 5 Issue 2, February - 2021, Pages: 65-77

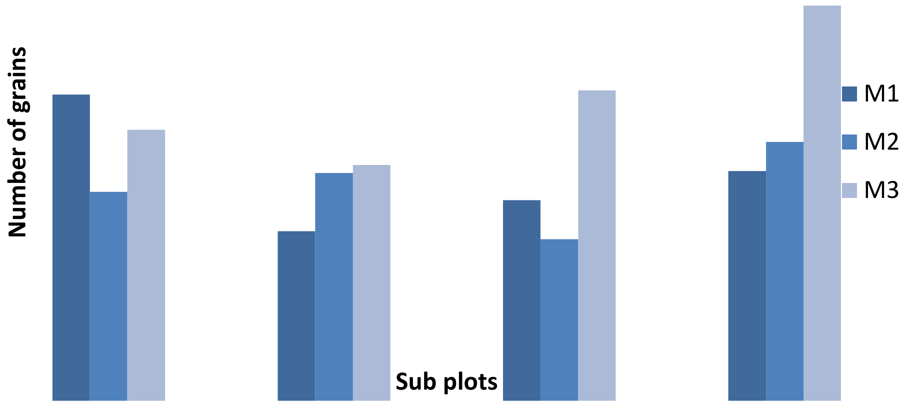

Figure 6. Respond of grains number to erosion control methods in 2017

Based on the above figure 3.5, the highest number of grains for S1was recorded by method M1 of 101 grains and significantly differed from M2 and M3 which showed grains number of 68 and 59 grains respectively. Regarding to S2, the maximum value of grains was observed for the implemented method M3 (116 grains), which showed higher significance difference ($P < 0.001$) from other methods. It was followed by methods M2 (85 grains), while the minimum of 73 was observed for method M1. The same trend was observed for S3 and S4, where the method M3 got the highest value of 128 and 136 grains respectively with higher significance difference ($P < 0.001$) from the control M1, which received the minimum value of 75 and 78 grains successively.

In 2017 (figure 6), the highest number for S1 sub plot was recorded by method M1 (148 grains), followed by method M3 (131 grains) and minimum for method M2 (101). Regarding S2, the maximum value was obtained for method M3, 144 grains, and showed higher significance difference ($P < 0.001$) from the control M1. The method M2 was the following with 110 grains, and significantly differed ($P < 0.05$) from the control M1, which got the lowest value of 82 grains. Considering S3, the highest grains number was still observed for M3 and minimum for M2 with 78 grains. For S4, the highest value was observed for method M3 with 191 grains and showed higher significance difference ($P < 0.001$) from the control M1 which got the minimum value of 111 grains.

Effects of erosion control methods on average plant weight yield

Results on yield were summarized in the following figure7

International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 5 Issue 2, February - 2021, Pages: 65-77

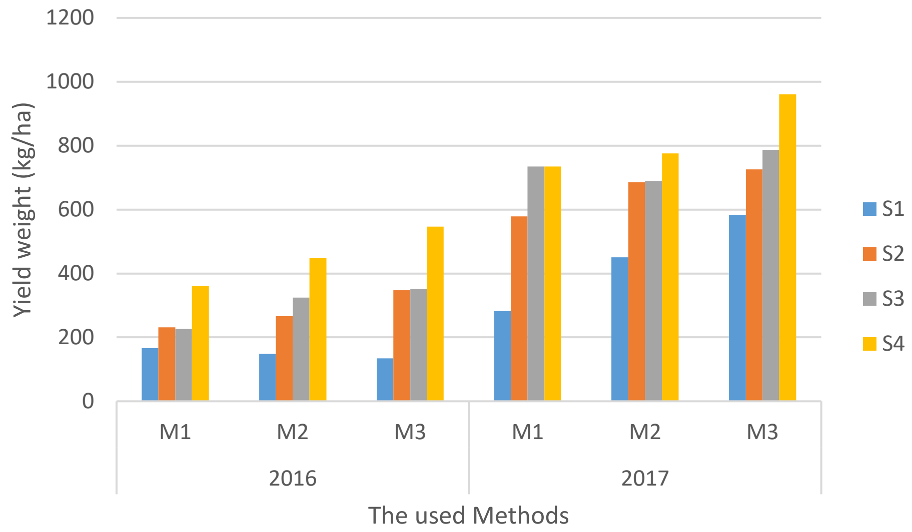

Figure 7. Effects of erosion control methods on average plant yield weight (kg/ha) in 2016 and 2017

Different letters between species (within a column) indicate significant differences at $p < 0.05$ level of significance

The results for both years displayed in figure 7 highlighted significant effects of erosion control methods. Specifically, in 2016, as it can be seen in the figure, the highest yield for S1 was recorded for the method M1 of 166.67 kg/ha and significantly differed from methods M2 and M3 of 148.19 kg/ha and 134.31 kg/ha respectively. Regarding S2, the maximum yield was observed for method M3 (347.22 kg/ha) and significantly differed ($P < 0.05$) from other methods. It was followed by method M2 (266.18 kg/ha) with significance difference from the control M1, which received the minimum of 231.46 kg/ha. Similarly, for S3, the optimum yield was still obtained for method M3 with 351.88 kg/ha. This method significantly differed from the control M1 and was followed by method M2 with 324.10 kg/ha, while the method M1 got the minimum value of 226.88 kg/ha. The same trend was observed for S4, where the highest value was recorded by the method M3 with 546.32 kg/ha. Furthermore, this method showed higher significance difference ($P < 0.001$) from the control M1 which received a minimum value of 361.11 kg/ha.

Considering 2017, the highest value for S1 sub plot was recorded for method M3 with 583.33 kg/ha and significantly differed ($P < 0.05$) from methods M2 and M1, which received 450.23 and 282.41 kg/ha respectively. Similarly, on S2, the maximum yield weight was observed for method M3 with 726.087 kg/ha and showed significance difference ($P < 0.05$) from others. It was followed by method M2 of 685.95 kg/ha, whereas method M1 got the minimum value of 578.8 kg/ha. Regarding S3, the highest value was still recorded for M3 (787.04 kg/ha), followed by M1 (734.57 kg/ha) and minimum for M2 (689.81 kg/ha). For S4, the maximum value of 961.41 kg/ha was observed for method M3 and significantly differed ($P < 0.05$) from others. The second highest was obtained for M2 with 775.46 kg/ha, and lowest value for method M1 with 734.56 kg/ha. All these outcomes on yield evolution trend showed the effectiveness of the method M3 (anti-erosive hedges coupled with anti-erosive ditches).

4. DISCUSSION

These outcomes highlighted the improvement of pods number, full pods and grains which obviously indicate an enhancement of crop yield. Specifically, although the method M3 (anti-erosive hedges coupled with anti-erosive ditches) did not significantly improved pods number, full pods and grains on sub plot S1, it was recorded as the most effective method in improving effectively these above mentioned characteristics on S2, S3, and S4 than others methods resulting in enhanced average yield weight as shown in table II and III. This was probably due to the combined effects of hedges and ditches used for M3 which could efficiently reduce the erosion aggressiveness resulting in enhanced soil nutrients and water availability, whence improved crop production characteristics and yield. This support the results of Todd (2017) who highlighted improved crop yield due to erosion control. Moreover, they endorse the finding of Víctor and Carmen (2008) who revealed increased crop production due to improved soil nutrients and water caused by erosion control. Furthermore, they support the results of Mahdi (2001) who affirmed an increased crop yield due to erosion control. Likewise, the efficiency of method M3 in improving crop production parameters was due to its effectiveness in maintaining soil productivity as affirmed by George et al. (2018) who affirmed that the significant benefit of erosion control practices is to maintain soil productivity. Enhanced crop yield due to erosion control has also been reported by Martha et al., 2007 and Loise et al., 2016.

CONCLUSION

The experimental outcomes showed that the bean production characteristics and yield were significantly enhanced by the erosion control methods. Method M3 (anti-erosive hedges coupled with anti-erosive ditches) was the most effective and could enhance significantly the number of pods, full pods and grains number. This method M3 could also effectively improve the average yield weight. Considering all tested index in this research, method M3, (anti-erosive hedges coupled with anti-erosive ditches), was the most effective method in improving the production characteristics and average yield weight of bean plant. This suggests that method M3 could improve bean production parameters and yield in Ngozi at Buhoro hill of Gashikanwa commune.

ACKNOWLEDGEMENTS

This work was financed by the Vlaamse Interuniversitaire Raad-Universitaire Ontwikkelings Samenwerking (VLIR-UOS)

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List of tables and figures

Tables

Table I. Soil properties

pH_{water}	pH_{KCl}	P (mg kg^{-1})	K(méq/100g)	N (%)	C (%)
5.38	3.81	13.7	0.14	0.42	1.28

Table II. Effects of erosion control methods on average plant yield weight (kg/ha) in 2016

Methods	Sub plots			
	S1	S2	S3	S4
M1	166.67a	231.46a	226.88a	361.11a
M2	148.19b	266.18b	324.10b	449.10b
M3	134.31b	347.22c	351.88b	546.32c

International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 5 Issue 2, February - 2021, Pages: 65-77

Table III. Effect of erosion control on average plant yield weight (kg/ha) in 2017

	Sub plots			
Methods	S1	S2	S3	S4
M1	282.41a	578.8a	734.57a	734.56a
M2	45.23b	685.95b	689.81b	775.46a
M3	583.33c	726.087c	787.04a	961.41b

Figures

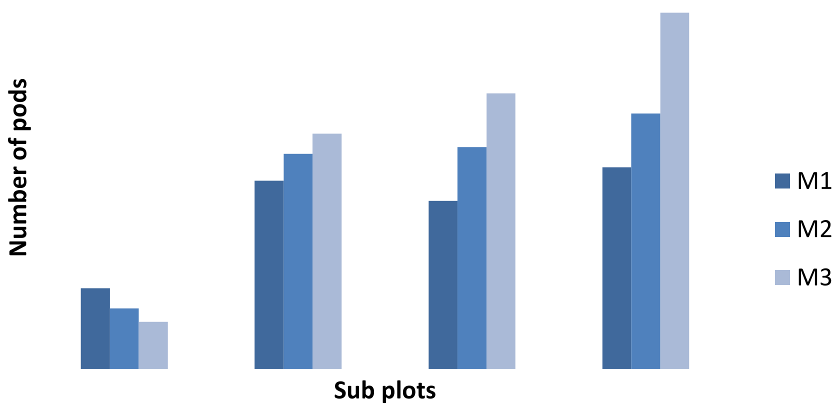

Figure 1. Effects of erosion control methods on pods number in 2016

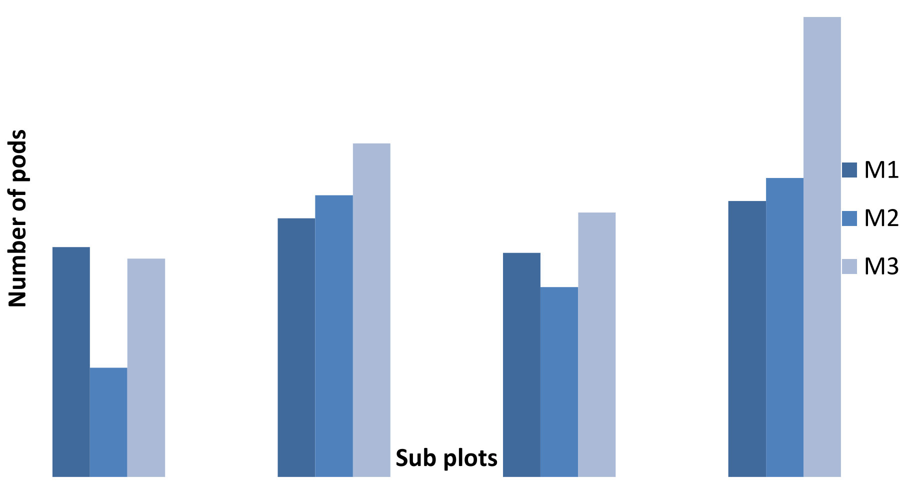

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Figure 2. Effects of erosion control methods on pods number in 2017

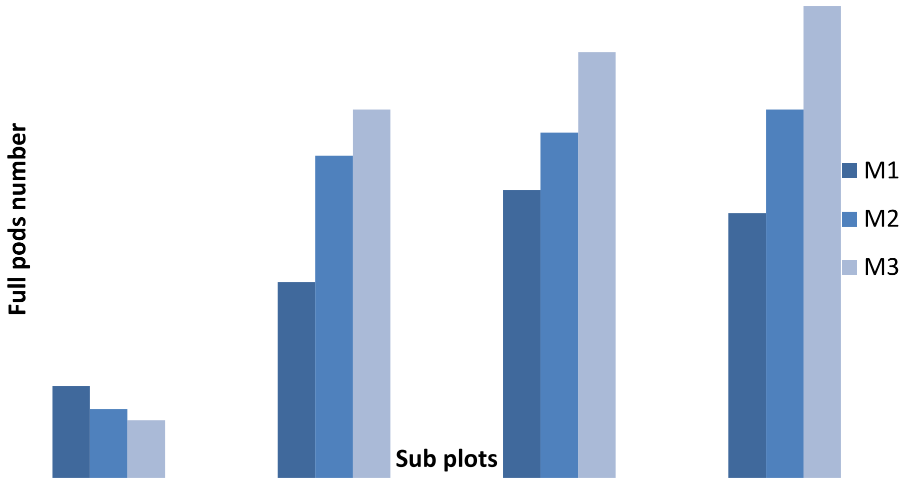

Figure 3. Influences of erosion control methods on full pods number in 2016

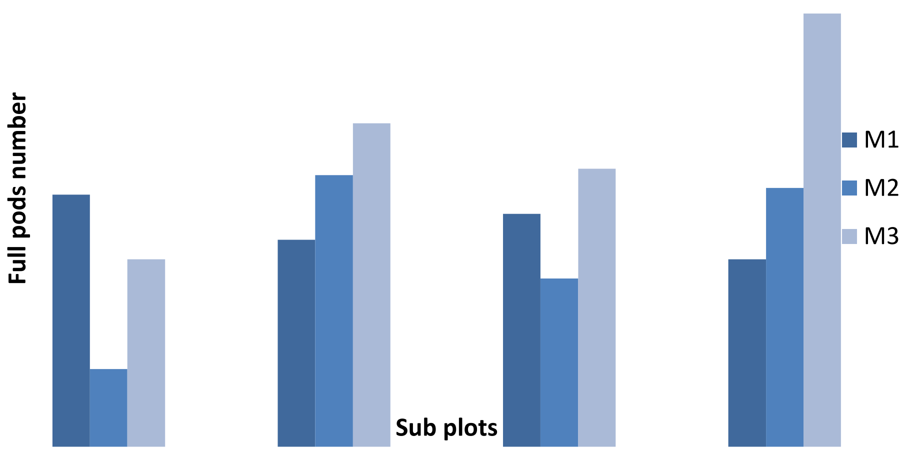

Figure 4. Influences of erosion control methods on full pods number in 2017

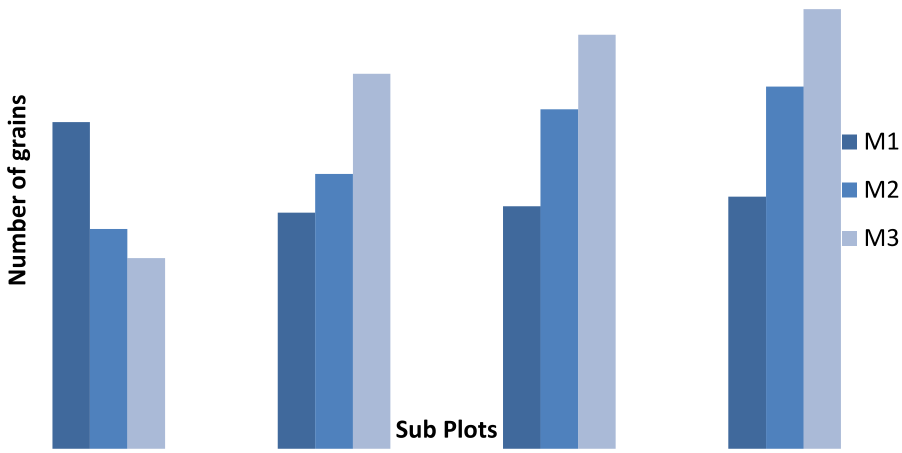

Figure 5. Response of grains number to erosion control methods in 2016

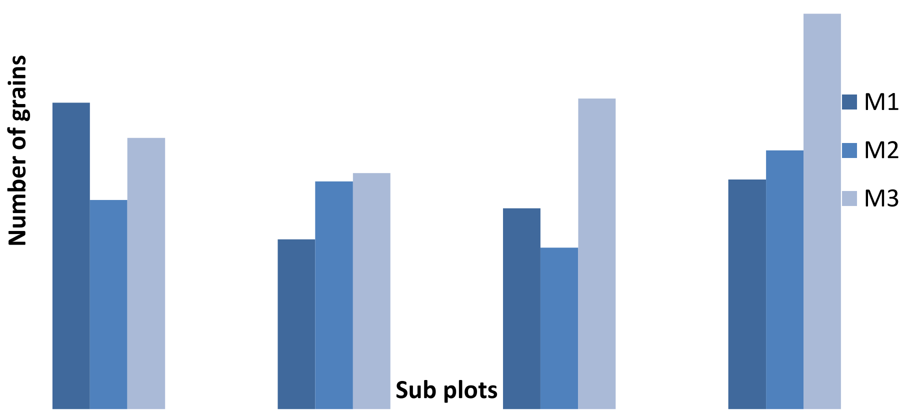

Figure 6. Respond of grains number to erosion control methods in 2017