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Effects of Erosion Control Methods on Bean Growth Parameters

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Abstract

Objectives: To find out the method which could effectively control erosion to improve the crop growth parameters at Buhoro hill. **Methods/Statistical Analysis:** The experiments have considered three plots with three different erosion control methods such as the traditional plowing methods (M1) which was the control, anti-erosive hedges planting (M2) and anti-erosive hedges coupled with anti-erosive ditches (M3). The experiments were carried out in 2016 and 2017. Data were recorded at three homogeneous regions (upstream, middle and downstream) by choosing two lines at each region and analyzed through SPSS at $P<0.05$ for significative difference. **Finding**: The results showed lowest value for the control and the plot with hedges, especially for the lines near the hedges. Moreover, these outcomes highlighted the method M3 (anti-erosive hedges coupled with anti-erosive ditches) as the effective method in improving the studied parameters although the significance was not apparent in the first year. The method (M3) has effectively enhanced the leaf number; leaf area and root length than other methods, especially in the second year with a general significance difference among the treatments. Furthermore, the outcomes revealed significance effects of combining hedge and ditches method (M3) in improving stem girth and plant height for both years. Although many results reported positive effects of anti-erosive hedge planting only than the control, especially in Burundi, where the use of hedge plantation only is more frequent, to couple hedges and ditches is more effective as revealed in the present study. **Application/Improvements:** These results suggest M3, as the most effective method in improving bean growth parameters at Buhoro hill in Gashikanwa commune.

Keywords: Anti-Erosive Hedges Coupled with Anti-Erosive Ditches Method, Anti-Erosive Hedges Planting Method, Beans Plant, Growth Parameters, Soil Erosion, Traditional Plowing Method

1. Introduction

Soil erosion is a natural process in which rocks, soil or dissolved material are moved from one location to another[1]. Increased soil loss due to erosion of about 200 to 400tones/ha/year and removal of organic matter as well as important nutrients has been revealed[2,3]. Erosion reduces soil productivity so slowly that the reduction may not be recognized until land is no longer economically suitable for growing crops[4]. It negatively affects crop yields[5]. Excessive

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erosion decreases agricultural productivity due to upper nutrient loss[6] and a reduction in organic matter[7]. Erosion reduces the productivity of all natural ecosystems as well as agricultural, forest, and pasture ecosystems[8]. It generally increases runoff, resulting in decreased available soil water and reduced plant growth[9,10]. A study conducted at Iowa State University on 40 soil associations, reported reduced crop productivity due to soil erosion[8]. Previous researches affirmed plant growth inhibition by erosion and confirmed the difficulties of yield restoration on eroded soil[11,12]. Furthermore, decreased crop production on eroded soil and reduced root-zone depth due to erosion were highlighted by foregoing researches[13,14]. Overall soil erosion is an important barrier for crop growth and soil fertility. In Burundi, although previous researches have been done, they have put much emphasis on soil loss. However, information is scanty on erosion effects on crop growth. This study is a contribution; it intends to analyze the effects of different soil erosion control methods on plant bean growth parameters.

2. Materials and Methods

2.1 Site Description and Soil Properties

The experimentation site was located in Gashikanwa Ngozi province at Buhoro, a hill more prone to erosion with 1690 m of altitude, characterized by a humid tropical climate. The recorded precipitation was 1046mm with 20.5°C as mean temperature and a slope of 41%.

The soil texture (0-40cm) is Loam, with chemical properties of pH_{water} (5.38), pH_{KCl} (3.81), available P (13.7 mg kg^{-1}), available K (0.14 méq/100g), N (0.42%) and C (1.28%). This soil was chemically poor with a high risk of aluminum toxicity.

2.1.1 Experiment Design

The experiments were carried out in 2016 and 2017. Three separated plots (P1, P2 and P3) with three different erosion control methods (M1, M2 and M3) were considered. The first method, M1, was the traditional plowing method on P1, set as a control; the second, M2, was the anti-erosive hedges planting method on P2, and the third method, M3, constituted by the anti-erosive hedges coupled with anti-erosive ditches; was implemented on P3.

Before sowing, these plots were divided in four sub plot (S1, S2, S3, and S4) separated by the anti-erosive hedges on P2; anti-erosive hedges coupled with anti-erosive ditches on P3, while for plot P1 the separation considers just the virtual lines of these anti-erosive hedges (Photos 1). Moreover, the fertilizers were applied as recommended, while during the growth period, diseases and pests were normally controlled.

2.1.2 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. During the study, plant height, stem girth and leaves number were determined, as well as the leaf area and the root length.

2.1.3 Statistical Analysis

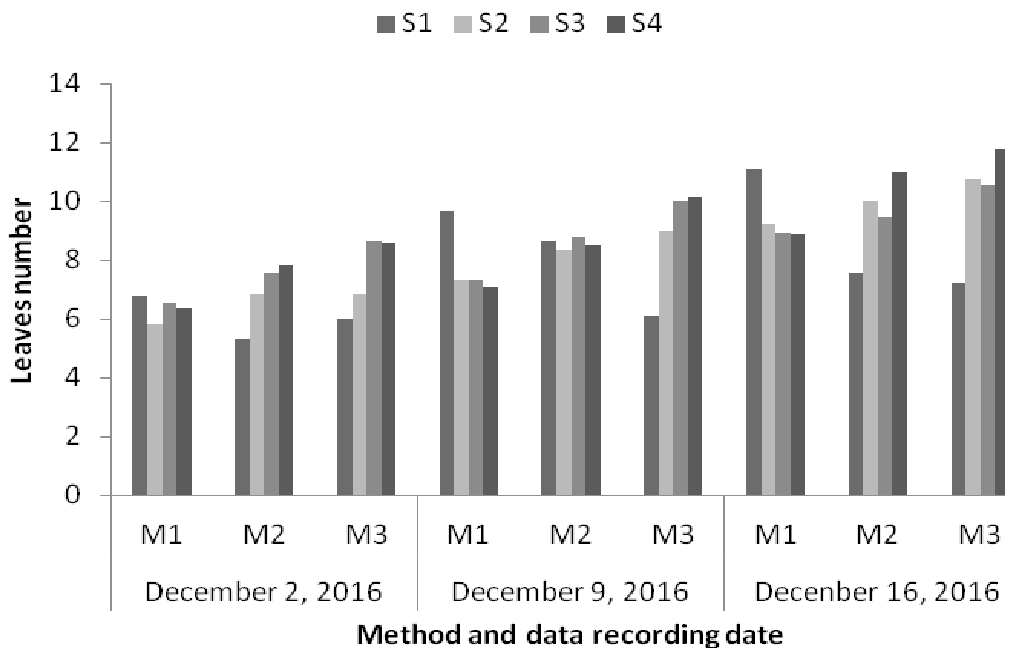
All data were processed with Applied Excel 2007 and SPSS. Figures were made by using Excel, while comparisons between treatments were conducted through LSD (least significant difference) and SPSS at $P<0.05$.

3. Results

3.1 Effects of Erosion Control Method on Leaves Number (LN)

Results on leaves number for the two years were shown in the following Figures 1 and 2. Considering these figures, although there was no significant difference, the leaves number (LN) was effectively influenced by erosion control methods; especially in the second year (2017) with M3 the first effective method than M1 and M2.

Specifically, LN changed with the sub plot location, implemented method and the tested date with a relation of LN on the 2nd December < LN on 9th December < LN



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 1. Leaves number (LN) response to erosion control Methods in 2016.

on 16th December in 2016 and LN on the 16th November < LN on 1st December < LN on 14th December in 2017.

Considering S1 (Upstream Sub plot) in 2016, the highest LN was recorded for M1 method for all tested date comparatively to M2 and M3. But in 2017, it changed, the results analysis highlighted M3 as the most effective method with maximum LN for all tested dates.

Regarding to S2 (middle Sub plot toward Upstream) in 2016 on the 2nd December, the maximum LN of 7 leaves per plant was observed for both methods M3 and M2, while M1 got the minimum by 6 leaves per plant. On 9th December, the highest value of LN was obtained for M3 with 9 leaves per plant, followed by M2 of 8 leaves, whereas M1 got the small value of 7 leaves per plant. The same trend was observed on 16th December where the maximum leaves number was recorded for M3 (11 leaves per plant) followed by M2 (10 leaves per plant), and the minimum on M1 (9 leaves per plant). In 2017, the method M3 was the most effective with higher LN for all tested date by 8, 13, and 16 leaves for the tested date respectively.

Considering S3 in 2016, the maximum LN, on the 2nd December, was observed for M3, 9 leaves per plant, followed by M2, 8 leaves per plant, while M1, 7 leaves per plant, got the minimum. On December 9th, the optimum LN of 9 leaves per plant was observed for M3, followed by M2 with 9 leaves per plante, while the minimum of 7 leaves per plant was obtained for M1. Similarly, on 16th December, the method M3 of 11 leaves per plant was the first having higher leaves, M2 method with 10 leaves per plant was the second while M1 of 9 leaves per plant was the last. In 2017, the results highlighted M3 as the most effective methods comparatively to M1 and M2 as shown

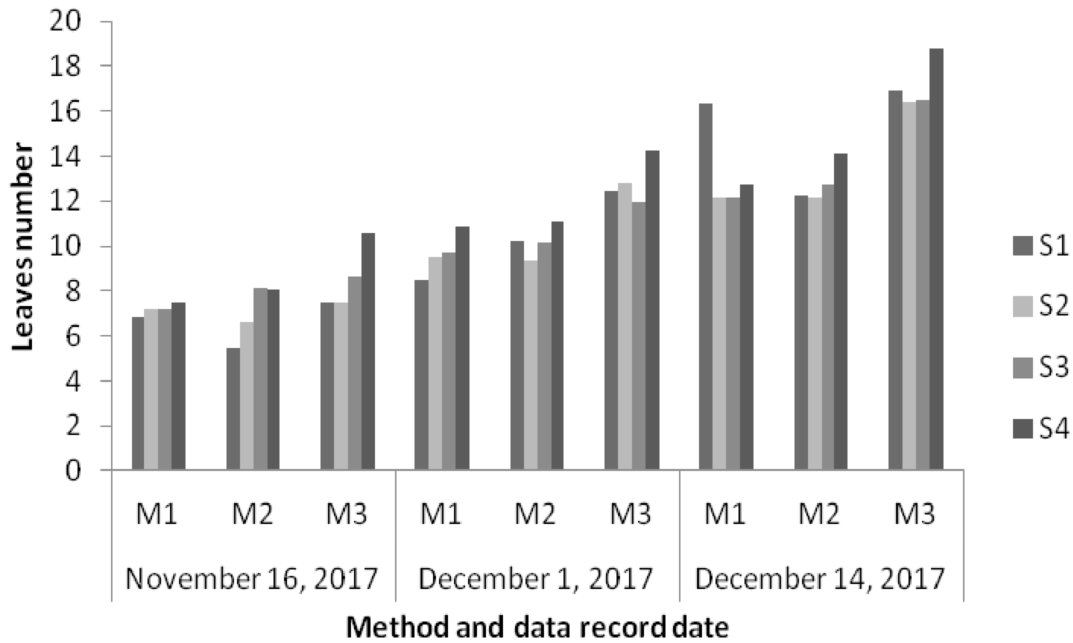


Figure 2. Effects of different erosion control methods on leaves number in 2017.

in Figure 2. This method recorded highest leaves number for all tested date and sub plot. On the sub plot S4, in both year 2016 and 2017, the maximum LN was observed for M3 on each sub plot.

Even though the difference was not significant, it is apparent that the implemented method M3 (the anti-erosive hedges coupled with anti-erosive ditches) was the effective method in enhancing leaves number.

3.2 Effects of Erosion Control Methods on Leaf Area (LA)

Leaf area evolution is summed up in Figures 3 and 4. As

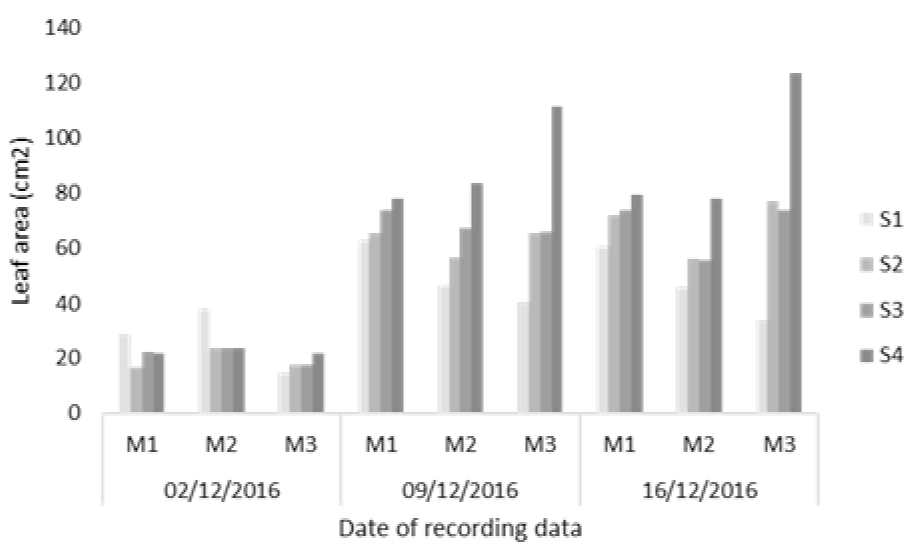


Figure 3. Effects of erosion control methods on leaf area in 2016.

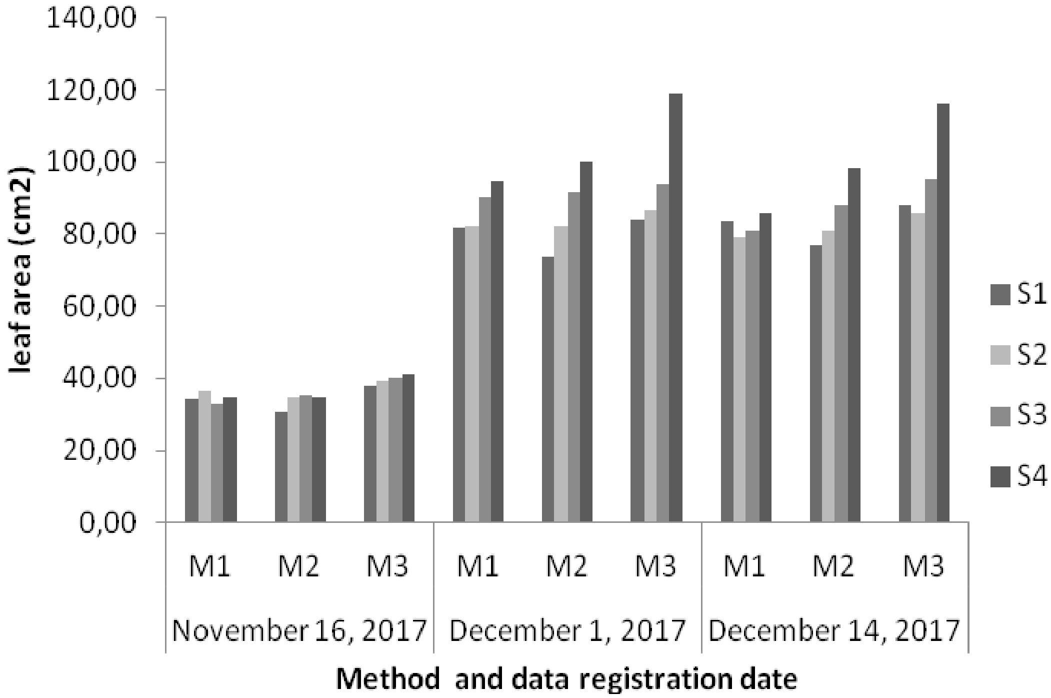


Figure 4. Effects of erosion control methods on leaf area in 2017.

for the leaves number, leaf area (LA) changed with the sub plot location, implemented method and the tested date. On S1, except for the first time where the highest LA was recorded for M2 (38.37 cm^2), the optimum leaf area in 2016 was recorded for M1 and vary from 29 to 63cm^2.

Regarding S2, the maximum LA in the first days (2nd December) was observed for M2 method (23.57 cm^2), followed by M3 (17.8 cm^2), while the minimum of 16.75 cm^2 was recorded for M1. Considering S3, the first highest LA of 23.57 cm^2 was observed for M2, the second for M1 with 22.06 cm^2, and the last of 17.66 cm^2 for M3 method. The same LA evolution trend was observed on S4, where the optimum LA was recorded for M2 method with 23.61 cm^2, followed by M3 of 21.87 cm^2, and minimum for the method M1 of 21.71 cm^2. On the 9th December, as it can be seen on Figure 3, the trend change, with a maximum leaf area evolution on M3 method recorded for S_2 with 65.17 cm^2, followed by M1 and M2 with 65.03 cm^2 for both methods. Regarding S3, M1 showed higher leaf area (73.77 cm^2), while M2 and M3 showed little discrepancy with 67.06 cm^2 and 65.03 cm^2 respectively. On S4, the maximum leaf area was observed for M3 (111.31 cm^2) and significantly differed ($p<0.05$) from the method M2 (83.29) which was the following and M1 (77.74), the last one. On the last date (16th December) of recording data in 2016, the maximum leaf area was recorded for M3 (76.71 cm^2), followed by M1 (71.6 cm^2) and minimum for M2 (55.73 cm^2). The same trend was observed for S3 where the first biggest plant of 73.78 cm^2 was obtained by M3, the second by M1 with 73.74 cm^2 and lowest for M2 of 55.58 cm^2. On S4, the optimum leaf area was still recorded for method M3 with 123.66 cm^2 and significantly differed ($p<0.05$) to M1 and M2 which obtained 79.38 cm^2 and 77.71 cm^2 respectively.

In 2017 the maximum LA on S1 was recorded for M3 (over 34 up to 86 cm^2) for all tested date, followed by M1 and minimum for M2. Likewise, the same trend was observed for other sub plots (S2, S3, and S4) in general. Like in 2016, no significant difference was observed in the first time but observed later especially on S4.

3.3 Effects of Erosion Control Methods on Stem Girth (SG)

The outcomes on stem girth were shown in Figures 5 and 6. Considering S1 in 2016, the method M3 recorded the highest SG of 0.37cm in the first days, followed by M2 of 0.35 cm, while M1 method got the minimum with 0.25

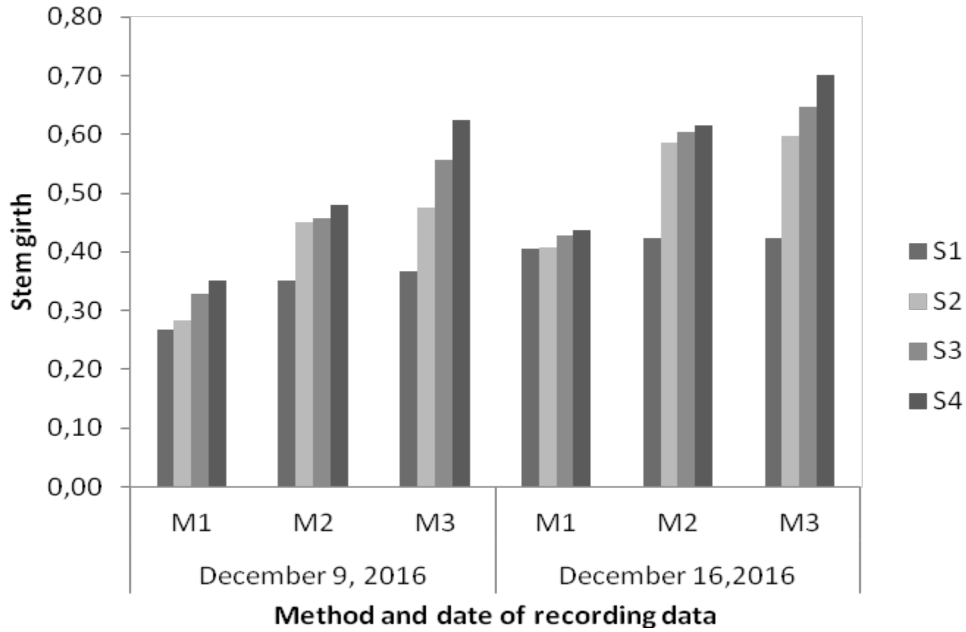


Figure 5. Stem girth as influenced by soil erosion control Methods in 2016.

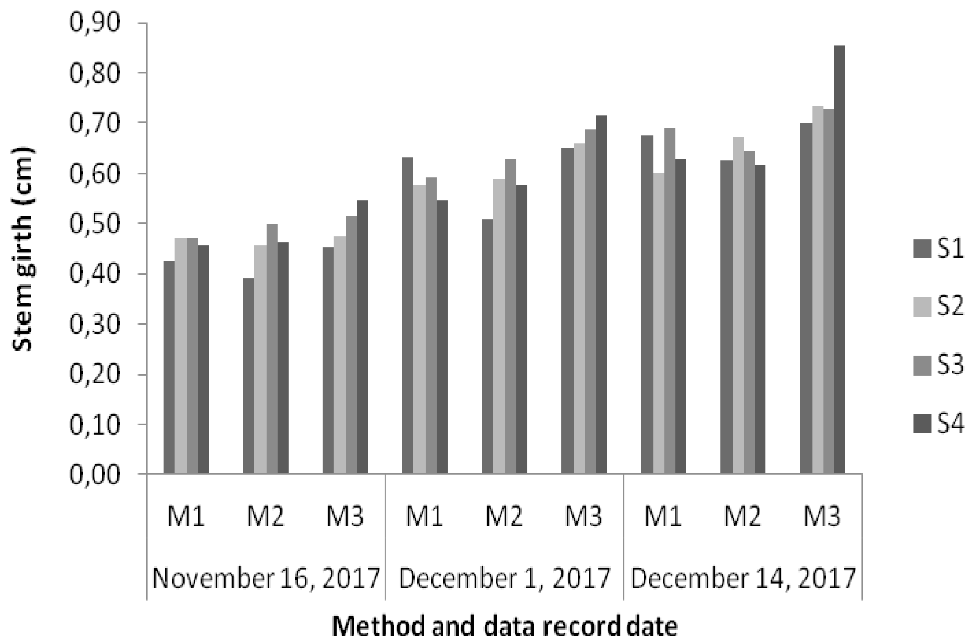


Figure 6. Erosion control method's effects on stem girth in 2017.

cm. For S2, the first highest SG was still observed for M3 (0.48cm) and presented significant difference from the control M1.

The second highest value was recorded for M2 (0.45cm) which also significantly differed from the control M1, the method with the minimum value of 0.28 cm. The same trend was observed on S3, where the highest SG value was observed for M3, 0.56cm, followed by M2, 0.46cm, and the minimum for M1 of 0.33cm. Considering S4, significance difference between methods was observed. The SG was maximum for implemented method M3 (0.62 cm), and significantly differed from the control M1 (0.35 cm) which got the minimum value.

In the second year (2017), the SG evolution on S1 was not apparent, with a little discrepancy from a used method to another. Specifically, higher value of 0.45 cm was recorded for M3 on the 16th November 2017, followed by M1 of 0.43cm and minimum for M2 with 0.39cm. The same SG evolution was observed on S2 and S4 where the maximum SG was recorded for M3, M1 and M2 respectively. Considering S3, the optimum SG of 0.51cm was still observed for M3 method, followed by method M2 with 0.50cm, and minimum for M1 method of 0.47cm. For other tested date and each sub plot, the Optimum was observed for M3 which recorded highest value of SG with significant difference on S4 at the 14th December 2017. Although significance difference was not observed for all sub plot, these outcomes revealed the effectiveness of M3 in improving plant SG than the control M1 and method M2.

3.4 Influences of Different Erosion Control Methods on Plant Height (PH)

The results on Plant Height (PH) were summarized in Figures 7 and 8. For S1 in 2016 (Figure 7), the highest PH of 12.89 cm was recorded for the M3 method in the first days (2nd December 2016) with significance difference from M1 and M2 which showed plant height of 5.21 cm and 4.76 cm respectively. On December 1st

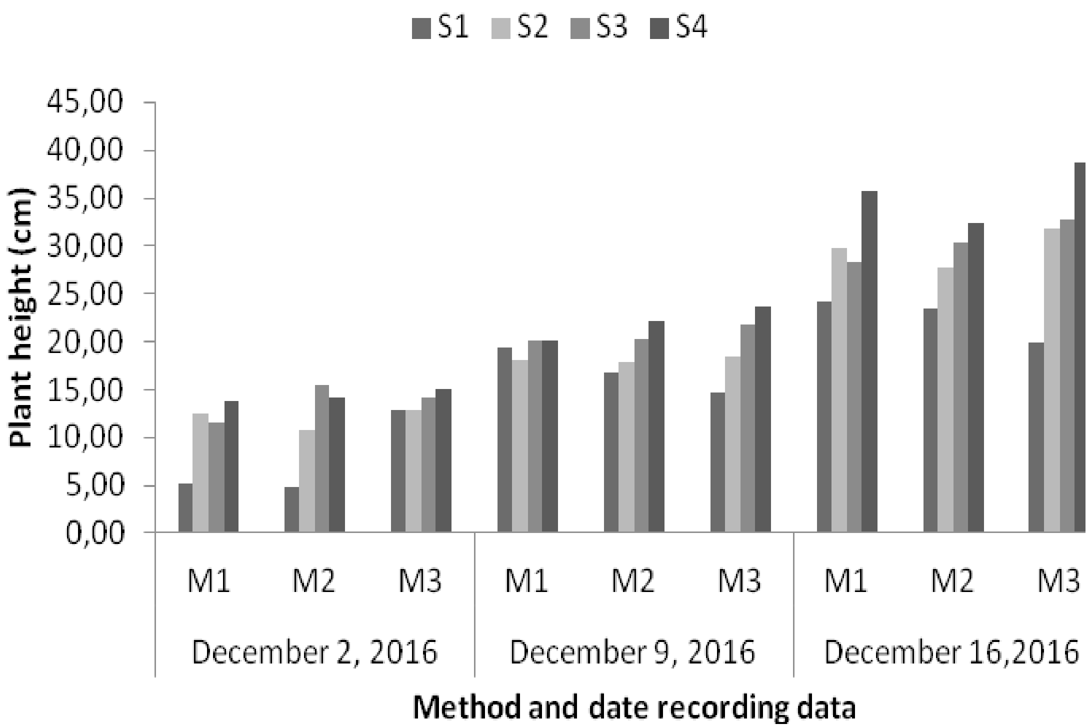


Figure 7. Plant height response to soil erosion control methods in 2016.

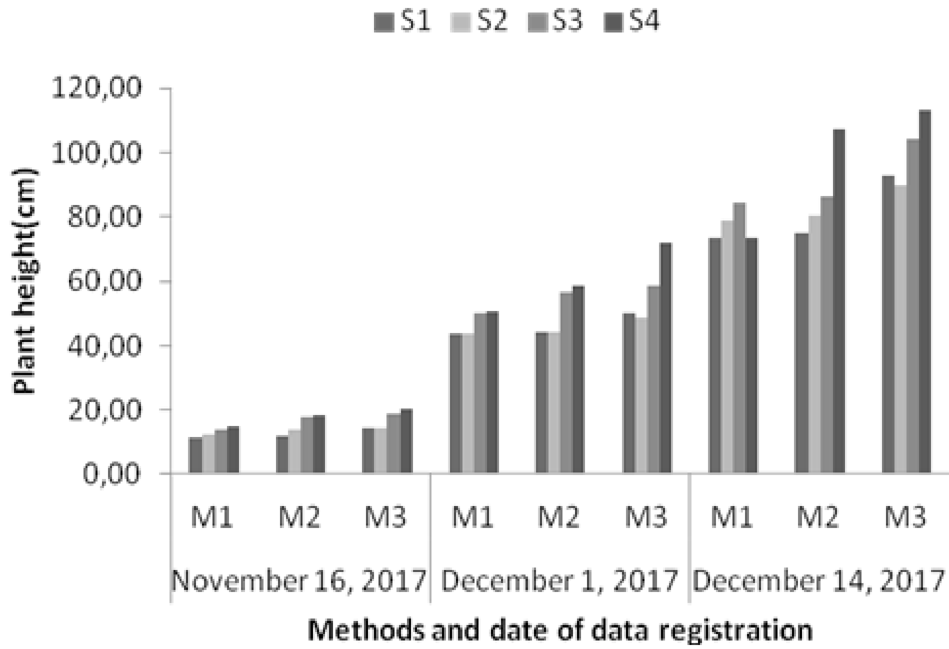


Figure 8. Influence of erosion control method to plant height in 2017.

and 16th, the maximum PH on S1 was observed for M1 comparatively to others, but there was no significance difference.

Regarding to S2, the maximum plant height on the 2nd December 2016 was observed for the implemented method M3 with 12.8cm, followed by the method M1 of 12.5 cm, while the minimum of 10.7cm was observed for M2 method. The same trend was observed on the 9th and the 16th December, 2016 where M3 method got the optimum PH of 18.4cm and 31.8cm respectively.

Considering S3, the PH was changing from a sub plot to another. Clearly, on the 2nd December, the maximum of 15.4cm was recorded for M2 method, followed by M3 with 14.2cm, and minimum for M1 of 11.6cm. On the 9th December, the highest plant was observed for M3 with 21.8cm, whereas the methods M2 and M1 got almost the same plant height of 20.2 cm and 20cm respectively.

On the 16th December, the highest PH value of 32.8 cm was observed for M3 method, followed by the one recorded for M2 (30.4 cm), while the minimum was obtained for M1 of 28.2 cm. Regarding S4, the optimum PH on each tested date was observed for M3, followed by M2 and minimum for method M1.

In 2017 (Figure 8), the used erosion control methods effectively affect plant height with M3 the most effective method than M2 and M1. For all tested date and each sub-plot, the highest plant height was recorded for M3 method which significantly differed from the control especially on S4 in the last days of recording data.

3.5 Influences of Erosion Control Methods on Root Length (RL)

The roots length (RL) was effectively influenced by erosion control methods (Figure 9 and 10).

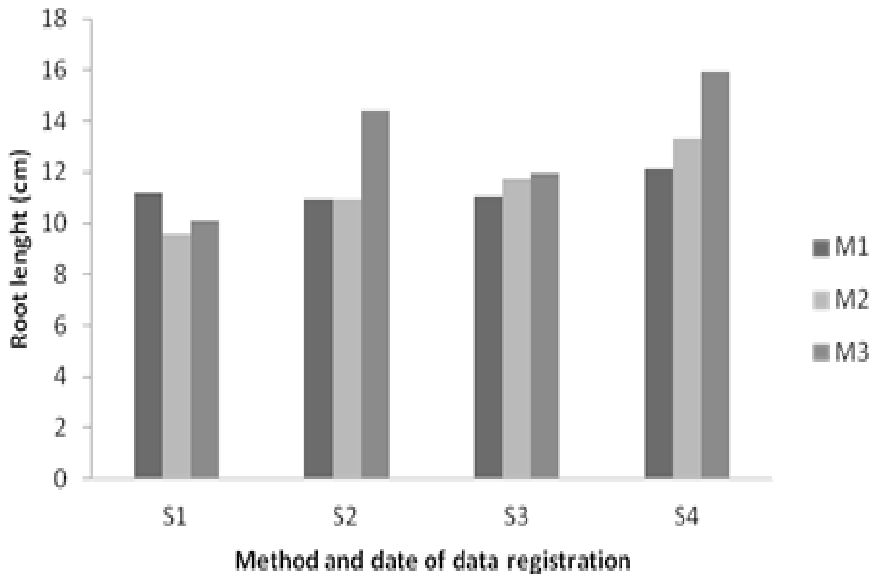


Figure 9. Response of roots length (RL) to erosion control Methods in 2016.

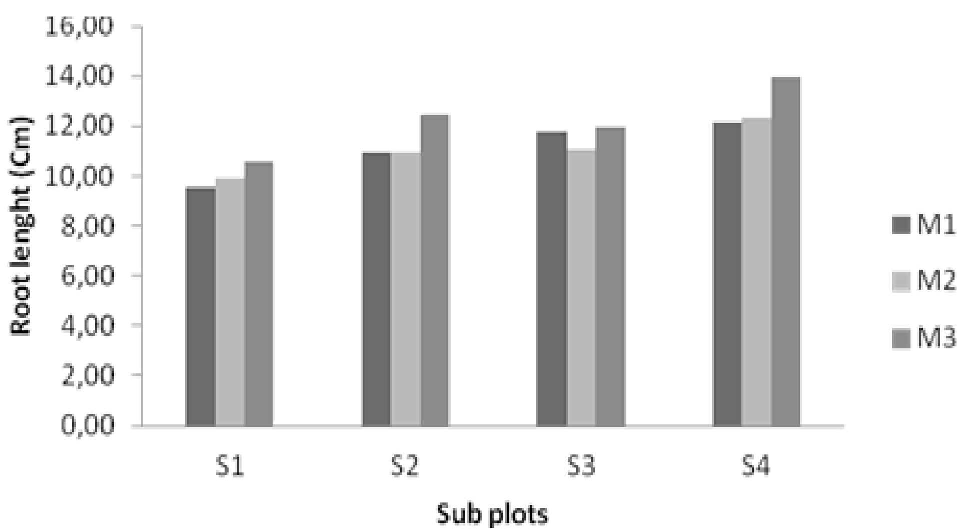


Figure 10. Effects of erosion control Methods on roots length (RL) in 2017.

In 2016 (Figure 9) on S1, the method M1 recorded the highest RL with 11.22 cm per plant comparatively to M2 and M3 which got 10.13 cm and 9.57 cm respectively. Considering S2, the maximum RL was observed for

M3 (14.43 cm) which significantly differed from others with $p<0.05$, followed by M1 (10.92 cm) and minimum for M2 (10.91 cm) respectively. Regarding S3, although there was no significance difference, the optimum RL per plant was still observed for M3 of 11.94 cm, followed by M2 and M1 with 11.75 cm and 11.05 cm respectively. On S4, the highest RL was observed for plot with M3 (15.94 cm), followed by the plot with M2 (13.32 cm), whereas the one with method M1 (12.14 cm) got the shortest roots.

In 2017, as can be seen in Figure 10, the results highlighted M3 method as the most effective method in enhancing the RL per plant comparatively to others. Although it did not differ significantly from others, M3 method recorded the highest value ranged from 11.55 cm to 15.95 cm on each sub plot.

4. Discussion

In the first year (2016), the increased LN, LA and PH observed for M3 method on the sub plots S2, S3 and S4 was probably due to the effectiveness of M3 (combination of anti-erosive hedges and ditches) in controlling erosion than other methods. The improved LA and LN result in enhanced soil protection and water availability, whence an increased plant growth. These results endorsed those of Vacca et al. (2000) who reported an improved soil protection due to increased LA with applied erosion control method[15]. Likewise, they support the results of Roose (1988) who affirmed a protected soil with enhanced vegetation leaves[16].

Furthermore, this method M3 has effectively improved the SG for all tested date and each sub plot (Figure 6) as well as the RL observed for Figure 9 on sub plot S2, S3, and S4. With improved RL and SG, the plant could assimilate sufficient nutrients resulting in improved growth. Moreover, as reported by Mamo and Bubenzer (2001a, b), Gyssels et al.(2006) and De Baets et al.(2006), the improved RL result in declined rill erodibility and soil detachment rates[17–19]. Likewise, enhanced root reinforce soil as highlighted by Anderson and Richards[21].

On S1, the reduced LN and LA observed for M3 and M2 (Figures 1 and 3) was due to the reduced leaves number on the lines near the anti-erosive hedges. Moreover, it was due to the reduced root length (Figure 9) on this S1 (with applied M2 and M3) caused by the presence of more small stones which limit the root extension resulting in reduced nutrients assimilation and plant growth parameters as well.

In the second year (2017), the general improvement of all parameters on each sub plot by M3 method could be attribute to the coupled effects of anti-erosive hedges and ditches (implemented for this method) which could effectively reduce the erosion aggressiveness by decreasing the loss of soil and nutrients hence improved soil, water and nutrient availability resulting in enhanced plant growth and other parameters. These results support those of Iijima et al. who reported improved plant growth due to erosion control[22]. Furthermore, the reduced crop growth parameters on the control M1 (traditional plowing) in 2017 was due to the loss of soil nutrients caused by erosion resulting in decreased plant growth status by Ward et al.,[23]. However further studies are needed in this area for more clarification and conclusion.

5. Conclusion

The outcomes highlighted better effects of M3 method (anti-erosive hedges planting coupled with anti-erosive ditches) especially in the second year. It has played an important role in plant growth by effectively increasing the leaf area, plant height and leaves number. Furthermore, this implemented method M3 could improve plant roots length and stem girth. This study suggested M3 method as the effective method which can be used to control erosion and reduce its aggressiveness whence enhancement of crop growth. Nowadays, erosion is a major problem worldwide, to find a method that may reduce this latter is a significant issue all over the world.

6. Acknowledgement

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