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Crop Yield and Reduction of Soil Loss with Selected Hedge Species under Different Hill Slopes in Chittagong Hill Tract

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ABSTRACT

This research was concluded at Chittagong Hill Tracts in Bangladesh to identify the effects of different hedge species and assess alley width in controlling soil erosion and crop yield. Hedgerow or alley cropping cultivation is very helpful in reducing soil erosion in the hilly area. In order to perform cataloguing the hedges and their alley, four hedge species such as Indigofera, Bogamedula, Pineapple and Napier were used. Three different slopes viz., gentle slope, moderate slope and steeps slope, two different crops like yard long bean and okra were used in this experiment. The experiment lay out was in Split Plot Design with three replications. Soil erosion was measured through spike lay out method. Wider alley width gives a better performance of yield. Grass species (Napier) responses better than tree/shrub species (*Bogamedula and Indegofera*) on crops yield. Performance of pineapple among all other hedge species on crop yield and soil loss reducing capacity was recorded the best on all slope gradients and alley width. More yields were gained from the managed plots by hedge, though the number of total plant was comparatively less in those plots than the controlled one. Slope gradients have got the most important role on crops yield and soil erosion factor. The highest yields and the lowest soil loss were recorded in gentle slope in comparison with moderate and steep slope respectively. Crops yield were significantly reduced with the increase of slope gradients.

INTRODUCTION

Soil loss or soil erosion can be severe at steep agricultural land areas in high rainfall regions and it affects crop productivity and the income of farmers. Moreover, soil erosion is the most important environmental concern in developing countries (Stocking 1995; Ananda and Herath 2003), especially in Southeast Asia (Valentin et al. 2008). Bangladesh is not free from this threat. Rainfall amount and intensity are increasing (Nearing et al. 2005) due to rapid changes in land use practices (Valentin et al. 2008), resulting in increasing soil erosion. This is mainly caused by splashing of rain, surface runoff scouring (Morgan 2005) and unsuitable land management. Use of structural techniques to prevent soil loss has been successful in developed countries, but this is not practiced in developing countries (Grimshaw and Helfer 1995) due to inability of farmers to bear the cost of soil conservation as only cheaper and sustainable methods are acceptable to farmers.

Chittagong Hill Tracts (CHT) is the largest hilly area located in the Southeast of Bangladesh. Tu et al. (2005) had been reported that alley cropping, a soil conservation measure introduced on sloping farmlands in hilly areas, can reduce soil erosion, control nonpoint source pollution, increase system output and reduce investment on slope land remarkably. It is widely implemented in the mountainous areas of both torrid and temperate zones. Effect and mechanism of erosion control by alley cropping have been studied also in China and other parts of the world. Sun et al. (1999) had also been discussed the effect of alley cropping on controlling soil erosion; he analyzed the mechanism of alley cropping controlling soil erosion and held that mechanical interception could be the main reason for reducing soil loss by alley cropping.

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The conservation of soil and water is essential for sustainable production, environment preservation and balanced ecosystem (Sarma 2000). Loss of soil by water erosion on slopping lands adversely affects the physical, chemical and biological properties of soils, leading to low crop productivity (Larson et al. 1985 and Sun et al. 1999). Change of land use and associates erosion is mostly responsible for land degradation and desertification in different part of Asia and Africa, bringing about large reduction in vegetation growth, siltation of water courses, filling of valleys and reservoirs and the formation of deltas along the coastal areas. Erosion is accompanied by deposition of alluvial materials by flooding and filling of valleys, waterways or extending coastal plains and deltas towards the sea. Contour hedgerows are also effective in controlling run off and soil erosion and improve soil physical properties. Control plots have higher run off and soil loss than those plots with hedgerow (Khisa et al. 1999). Firoz and Uddin (2001) recommended hedgerow for cultivation on sloppy land. They described that hill slope may be divided into a series of alley separated by hedgerow on contour lines, because hedgerow plants are effective in controlling soil erosion and reducing run off.

Trees and shrubs have several functions to control erosion like (i) increase soil cover, by liter and pruning (ii) provide partly permeable hedgerow barriers (iii) lead to the progressive development of terraces, through soil accumulation upslope of hedgerows (iv) increase soil resistance to erosion, by maintenance of organic matter (v) stabilize earth structures by root systems and (vi) make productive use of the land occupied by the conservation works (Young 1989). Alley cropping or hedgerow cultivation (Figure 1) is very helpful in controlling of soil erosion in the hilly area like CHT. But the dynamics of these reductions are not fully understood.

Considering the above facts, the present study was an attempt to assess the effect of different hedge species and alley width in terms of reducing soil erosion and crop yield. It is noted that the percentage reduction in soil loss depends on many parameters for example soil characteristics, rainfall characteristics, runoff characteristics etc. However, in this study only the effects of hedge species and hill slopes are considered.

MATERIALS AND METHODS

The experiment was conducted at the Soil conservation and watershed management Centre, Bandarban during 2013 - 2014. Three different slopes such as gentle slope (about 12% slope: S_1), moderate slope (about 25% slope: S_2) and steep slope (about 35% slope: S_3) and 4 different hedge species such as *Ananas comosus* (Pineapple=H_1), *Bogamedula spp* (Bogamedula=H_2), *Pennibetum Purpureum* (Napier=H_3), *Indigofera sanatrana* (Indigofera=H_4) and Control (H_5). Alley widths under each hedge species were 3.0 m, 4.0 m and 5.0 m. Each plots contained 3 lines of hedge. The experiment was laid out in Split Plot Design with three replications. The treatments were randomly allotted in each block. The dimensions of each plot of 3.0 m, 4.0 m and 5.0 m alley spacing were 28.0 m^2, 36.0 m^2 and 44.0 m^2 respectively for all slope classes. The upper and lower line of hedge is established at a distance of 0.50 m from upper and lower plot boundary maintaining contour. Another line is situated at the middle of the plot across the slope. Two different crops like okra (ladies finger) and yard long bean were used as test crops. The seeds of test crops were cultivated from a distance of 0.25 m from the upper and lower plot boundary. Recommended row to row and plant to plant distances were maintained for each crop. Hedge lines were established keeping along contour lines. Different hedge species cultivated in different slope in late May–July 2011. Plots were prepared manually and the seeds were cultivated in rows. Fertilizers were applied based on soil test value. Other management practices and different preventive measures have been taken as and when needed. Soil erosion was measured through spike

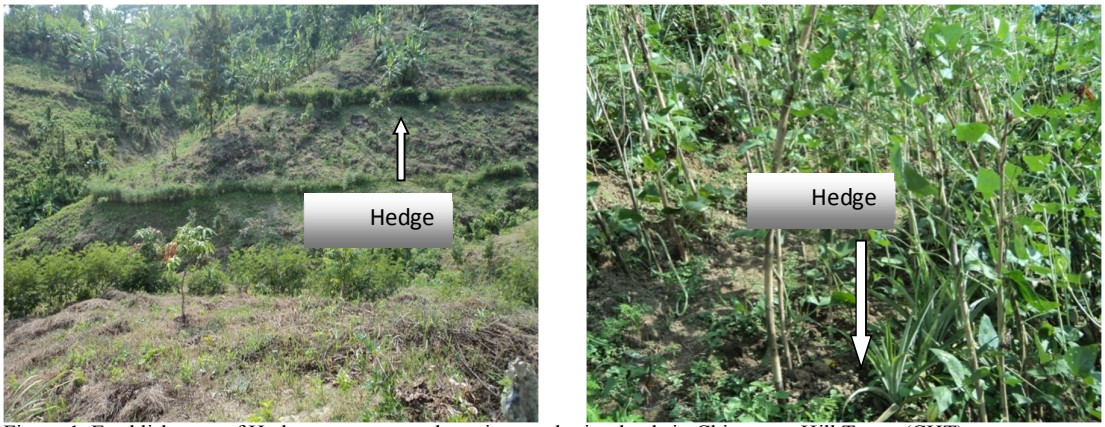

Figure 1. Establishment of Hedge row to control erosion on sloping lands in Chittagong Hill Tracts (CHT).

Table 1. Soil loss due to Okra (ladies finger) cultivation in different hill slopes and different alley width

Slope classes	Average soil loss (mm)			Soil loss (1000 kg ha^{-1})		
	3 m alley width	4 m alley width	5 m alley width	3 m alley width	4 m alley width	5 m alley width
Gentle slope (S_1)	0.92 C	0.95 C	0.98 C	10.81 C	11.19 C	11.53 C
Moderate slope (S_2)	1.06 B	1.10 B	1.14 B	12.51 B	12.98 B	13.44 B
Steep slope (S_3)	1.37 A	1.43 A	1.49 A	16.18 A	16.80 A	17.44 A
CV	4.48%	3.57%	2.87%	2.54%	4.07%	0.59%
F Test	**	**	**	**	**	**

CV= Coefficient of variance, ** = 1% level of significance, in a column having common letters do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

layout method. In every plot, six spikes were inserted; three were near upper side (top of the plot) and another three were near the lower end hedge line of the plots.

Statistical Analysis

Collected data were subjected to statistical analysis by MSTAT-C program. Analysis of variance for soil loss and crop yield was done by the F-test and the difference between treatments means were judged by Duncan's Multiple Range Test (DMRT). The data are presented in figures as means ± slandered error (SE) of three replicates.

RESULTS AND DISCUSSION

Soil loss due to Okra cultivation

The highest soil loss was recorded in 5.0 m alley width, as 17.44 kg ha^{-1}, 13.44 kg ha^{-1}, and 11.53 kg ha^{-1}followed in steep, moderate and gentle slope plots respectively (Table 1). Whereas the lowest soil loss was recorded in hedge treatment of 3.0 m alley width 8.07 kg ha^{-1}, 9.24 kg ha^{-1}, 10.36 kg ha^{-1}, 12.46 kg ha^{-1}and 25.70 kg ha^{-1}in Pineapple, Napier, Bogamedula, Indigofera and control plot respectively (Table 2). Khisa et al. (1999) had also got the same results. In accordance with their report, the plots with hedgerow had less soil loss and runoff in comparison with control plot. Considering all slope gradients and alley width, the lowest soil loss was recorded in plot where pineapple was the hedge followed by plots of Napier, Bogamedula and Indigofera. Owino and Ralph (2002) had also assessed that hedgerows (vertiver) reduce soil loss by 48% on 8% land slope.

Soil loss due to Yard Long Bean cultivation

Table 3 indicates that the highest soil loss in hedge with 5.0m alley width was 17.70 kg ha^{-1}, 13.72 kg ha^{-1}, 11.79 kg ha^{-1}in steep, moderate and gentle slope plots respectively. Whereas the lowest soil loss in hedge with 3.0 m alley width was 8.32 kg ha^{-1}, 9.53 kg ha^{-1}, 10.57 kg ha^{-1}, 12.68 kg ha^{-1}and 25.89 kg ha^{-1}in Pineapple, Napier, Bogamedula, Indigofera and control plot respectively (Table 4). Considering all slope gradients and alley width, the lowest soil loss was recorded in plot where Pineapple was the hedge followed by plots of Napier, Bogamedula and Indigofera. Babalola et al. (2007) had also reported that the hedgerows (vertiver) reduced soil loss by 68 to 75% on a 7% land slope.

Yield

Figure 2 shows the wider alley width gives a better performance of yield. Species of hedge plants have a great effect on plant growth and crops yield. Hedge plant of small height (*pineapple*) provides a better performance than that of tall hedge plant because it provides intensive light and better root binding. But higher height hedge plant provides more bio-mass than lower height hedge

Table 2. Soil loss under Okra (ladies finger) cultivation as influenced by different hedge species and different alley width

Hedge species	Average soil loss (mm)			Soil loss (1000 kg ha^{-1})		
	3 m alley width	4 m alley width	5 m alley width	3 m alley width	4 m alley width	5 m alley width
Pineapple (H_1)	0.68 E	0.71 E	0.98 C	8.07 E	8.37 E	8.80 E
Bogamedula (H_2)	0.88 C	0.99 C	1.14 B	10.36 C	10.82 C	11.26 C
Napier (H_3)	0.78 D	0.82 D	1.49 A	9.24 D	9.70 D	10.13 D
Indigofera (H_4)	1.06 B	1.11 B	0.01 D	12.46 B	13.12 B	13.67 B
Control (H_5)	2.18 A	2.23 A	0.98 C	25.70 A	26.26 A	26.82 A
CV	4.48%	3.57%	2.87%	2.54%	4.07%	0.59%
F Test	**	**	**	**	**	**

CV= Coefficient of variance, ** = 1% level of significance, in a column having common letters do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

Table 3. Soil loss due to Yard Long Bean cultivation as influenced by different Slopes and different alley width

Slope classes	Average soil loss (mm)			Soil loss (1000 kg ha^{-1})		
	3m alley width	4m alley width	5m alley width	3m alley width	4m alley width	5m alley width
Gentle slope (S_1)	0.94 C	0.97 C	1.00 C	11.04 C	11.43 C	11.79 C
Moderate slope (S_2)	1.08 B	1.13 B	1.16 B	12.76 B	13.28 B	13.72 B
Steep slope (S_3)	1.39 A	1.45 A	1.50 A	16.38 A	17.04 A	17.70 A
CV	5.36%	5.96%	6.59%	5.27%	6.20%	7.45%
F Test	**	**	**	**	**	**

CV= Coefficient of variance, ** = 1% level of significance, in a column having common letters do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

Table 4: Soil loss due to Yard Long Bean cultivation as influenced by different hedge species and different alley width

Hedge species	Average soil loss (mm)			Soil loss (1000 kg ha^{-1})		
	3m alley width	4m alley width	5m alley width	3m alley width	4m alley width	5m alley width
Pineapple (H_1)	0.71 E	0.73 E	0.77 E	8.32 E	8.64 E	9.06 D
Bogamedula (H_2)	0.90 C	0.94 C	0.97 C	10.57 C	11.10 C	11.48 C
Napier (H_3)	0.81 D	0.85 D	0.89 D	9.53 D	10.01 D	10.45 C
Indigofera (H_4)	1.08 B	1.13 B	1.18 B	12.68 B	13.32 B	13.91 B
Control (H_5)	2.19 A	2.25 A	2.30 A	25.87 A	26.51 A	27.11 A
CV	5.36%	5.96%	6.59%	5.27%	6.20%	7.45%
F Test	**	**	**	**	**	**

CV= Coefficient of variance, ** = 1% level of significance, in a column having common letters do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

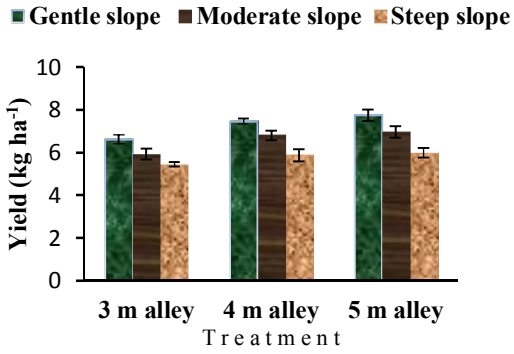

Figure 2. Effects of slope on yield of okra (ladies finger) in 3 m, 4 m and 5 m alley. Vertical bars indicate ± standard error (SE) of three replicates.

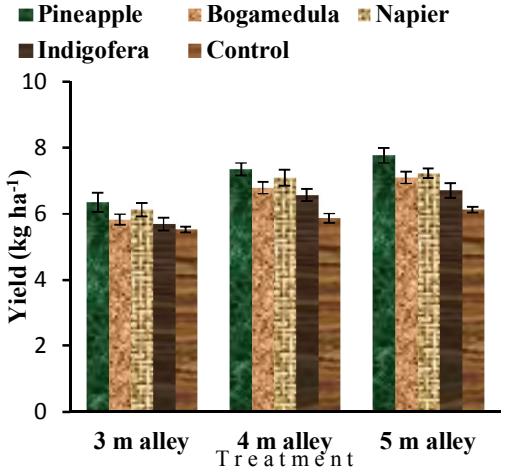

Figure 3. Effects of hedge on yield of okra (ladies finger) in 3 m, 4 m and 5 m alley. Vertical bars indicate ± standard error (SE) of three replicates.

plants. Grass species (Napier) responses better than tree/shrub species (*Bogamedula and Indegofera*) on crops yield. Performance of pineapple among all other hedge species on crop yield and soil loss reducing capacity was recorded the best on all slope gradients and alley width.

Figure 3 shows the more yields were gained from the managed plots by hedge, though the number of total plant was comparatively less in those plots than the controlled one. Hedge always plays a vital role on plant growth, crops productivity, fruit length and weight as well as reducing of soil erosion. Due to addition of biomass and comparatively less soil erosion for hedge plants, nutrient status of soil is maintained for better productivity. Slope gradients have a most important role on crops yield and soil erosion factor. The highest yields (7.74 kg ha^{-1}) and the lowest soil loss (11.04 kg ha^{-1}) were recorded in gentle slope in comparison with moderate (6.95 and 13.44 kg ha^{-1}) and steep slope (5.98 and 17.44 kg ha^{-1}) respectively. Crops yield were significantly reduced with the increment of slope gradients.

Interaction between hedge species and plants due to soil loss

Figure 4 shows the interaction between different hedge species and plants in terms of soil loss. Hedge and alley width plays a vital role on plant growth, crops productivity as well as minimizing soil erosion. Among the three alley width (3 m, 4 m and 5 m) the lowest soil loss was recorded in 3 m alley width. Therefore, we had seen the interaction between hedges and plants in 3 m alley. Among the all hedge species pineapple shows the highest soil loss reducing capacity which might be due to provides more biomass compared to other hedge species. On the other hands, okra shows the lowest soil loss in comparison with yard long bean may be superior to provide strong root distribution for soil conservation. These functions were grabs surface soil being washed away from the crop field which reduces runoff velocity. On the whole, each hedge species can remarkably reduce soil erosion followed the order of pineapple>napier>bogamedula>indigofera.

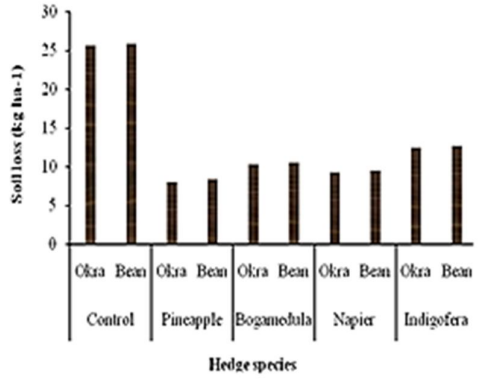

Figure 4. Interaction between different hedge species and plants due to soil loss in 3 m alley.

CONCLUSION

From the foregoing discussion, it can be concluded that the hedgerow system has shown to be an effective and most suitable method for reducing soil erosion as well as crop yield. More yields gained from the managed plots by hedge in comparison with the controlled one. The results indicated that slope gradients, hedge species and alley width have important role on soil reduction as well as on crop yield. The lowest soil loss and the highest crop yield were recorded in gentle slope than those of moderate and steep slopes respectively. Crops yield were significantly ($P \leq 0.05$) reduced with the increment of slope gradients. Among the hedge species, pineapple performed the best in reducing soil loss and higher crop yields in all slope gradients and alley width. Besides, addition of bio-mass has not only reduced soil erosion but also increased soil fertility status of the soil.

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