American Journal of Multidisciplinary Research & Development (AJMRD)
Volume 2, Issue 6 (June- 2020), PP 42-49
ISSN: 2360-821X
www.ajmrd.com

Research Paper **Open Access**

Application of Hedge Techniques to Protect the Local Embankment In The Southern Belt Of Bangladesh

Mahbub Robbani[1], Fakhrul Hasan[1], Jashim Uddin[2], Nazmul Hasan Mehedi[3*], Mahamud Hasan Prince[4]

[1]*Profesor, Department of Horticulture, Patuakhali Science and Technology University, Dumki, Patuakhali-8602*
[2]*PhD Student, Department of Horticulture, Patuakhali Science and Technology University, Dumki, Patuakhali-8602*
[3]*Scientific Officer, Horticulture Division, Bangladesh Institute of Nuclear Agriculture (BINA), BAU Campus, Mymensingh-2202, Tel +8801739898728*
[4]*Scientific Officer, Ispahani Mirzapur Tea Estate, Ispahani Agro Limited, Bangladesh*
**Corresponding author: Md. Nazmul Hasan Mehedi*

ABSTRACT:- The dynamic coastlines in the southern belt of Bangladesh are threatened by the impacts of climate change, increased intensity and frequency of storms and floods, also by rising sea levels. The most effective coastal protection systems consist of different elements arranged in series, for instance natural floodplains vegetation with fodder hedge and a sound dyke line. Adoption of contour fodder hedge techniques viz. Binna/Vetiver, Para and Napier grass to the embankment protection, was conducted on a local embankment situated at Nasnapara, Kolapara upazilla in Patuakhali district of Bangladesh, where elevation varies from 5-7 m and soils are derived from granite, sandy and sit loam texture with medium bulk density and moisture content, pH (7.5-8.02), organic matter (0.03-0.44)%, Electrical Conductivity (0.44-3.55) with proportional amount of total nitrogen (0.01-0.17%), phosphorus (1.42-4.36ppm) and available sulphur (0.89-8.50ppm) both in surface and subsurface soil. Binna grass added the higher percentage of organic matter (0.376%) compared to Para (0.336%) and Napier grass (0.313%). The survival rate of Binna grass planted on countryside slopes with gradients of 32-49^0 was up to 98% where in riverside up to 95% as compared with Napier (56%) and Para (34%). At the end of February, each Binna slip produced 14 to 23 tillers on average, grass height increased up to 62-73 cm, number of roots plant^{-1} (167-231 nos.), root length (17-21 cm) four months after transplanting. Six months (one growing season) after planting, in 25th April, the grass was 97-107 cm tall again and each slip produced 17 to 27 tillers on average with root length (24-27 cm) and number of roots per plant (214-298). The napier and para grass had only 6 and 5 tillers, plant height of 49 cm and 41 cm respectively. Contour Binna hedges were quickly formed, functioning in erosion control and stabilizing embankment slopes.

Key words: coastal protection, dyke, erosion control, fodder hedge, impacts

I. INTRODUCTION

Bangladesh is one of the least developed and most densely populated countries of the world. The great majority of the people directly or indirectly depend on agriculture for earning a living. The annual growth rate of GDP is greatly dependent on agricultural produce. With the aim of increasing agricultural production, construction of earth embankments and dykes, their repairing and rebuilding for irrigation, flood control and drainage have been the history of Bangladesh since time immemorial. Densely populated coastal regions face a serious threat from sea-level rise due to climate change. The Intergovernmental Panel on Climate Change (IPCC) special report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) has highlighted with high confidence that in the absence of adaptation, “locations currently experiencing adverse impacts such as coastal erosion and inundation will continue to do so in the future due to increasing sea levels” (IPCC, 2012).

Coastal zone of Bangladesh, with its repeated cycle of floods, cyclones, and storm surges has proved to be one of the most disaster-prone areas of the world. These are recurrent natural hazards, causing loss of lands, agriculture and houses. It also destroys embankments, other hydraulic structures and livelihood along coastlines and estuaries. River bank and embankment failure occurs each and every year in our country. As the embankments and other hydraulic structures are the first and immediate defense against the storm surge, they face the most severe damages. As for example, cyclone SIDR destroyed fully 362 km and partially 1927 km of coastal embankment, whose damage value is 32 million US$ (DMB, 2008). It is estimated that due to climate change, 22,000 square kilometer (16% of the total land area) of coastal regions will go under water, which may affect 17 million (15% of the total population) of coastal population (Hossain, 2004).

In most developing countries, embankment is one of the major infrastructure projects. At present, embankment construction is in full swing in the southern belt of Bangladesh to protect coastal households and livelihood. Most of the embankments are build in the sides of seashore, riverside with extreme water current, for protection from the waterfall of hilly areas but majority of the embankments are not sustain over a long period of time because of the shortage of road protection due to limited funds, severe gully washing and collapse occurred frequently, which affected not only transportation but also agricultural production along the embankments and in the area of the lower basin. To make the embankment structures stable and workable it is essential to cover the soil surface by plantation considering the socio-economical aspects. Therefore, it was very important to develop and apply cheap and effective embankment protection techniques. Compared with "hard" engineering projects in which huge investment and complicated technology are needed to construct concrete elements, "soft" bio-engineering techniques in which slopes are fixed by plant root systems and rain splash impact is stopped by the luxuriant plants are simpler, more convenient, cheaper and good for the environment (Ao *et al.*, 1997). Findings in the experiments of slope stabilization with Vetiver by Hengchaovanich (1998) in Malaysia showed that the mean tensile strength was about 75 MPa at 0.7-0.8 mm root diameter, which is the most common diameter class for Vetiver roots. It was approximately equivalent to one sixth of the ultimate tensile strength of mild steel.

Vetiver grass techniques, was first developed by the World Bank for soil and water conservation in India in the 1980s. Cultivation of different grass to reduce the soil erosion of embankments is now increasingly being used worldwide for this purpose. For this reason, Vetiver grass is known as a wonder grass, a miracle grass and a magic grass in various parts of the world. To minimize the impact of natural disasters with the protection of a community from river erosion as well as to achieve the aim of agricultural production, sustainable and cost-effective maintenance of those embankments and allied structures is a sine qua non for Bangladesh. As embankments and other hydraulic structures are made with or construct over this coastal soil, it is also essential to know the properties of these coastal regions soil for proper nutrition of grass techniques.

II. MATERIALS AND METHODS

The application site was located at Nasnapara, Kolapara upazilla in the district of Patuakhali under AEZ 13 (Ganges Tidal Floodplain), most of Barisal, Jhalkathi, Pirojpur, Patuakhali, Barguna, Bagerhat, Khulna and Satkhira districts. It also includes the Khulna and Bagherhat sundarban forests. The sites have humid climatic conditions with an annual average temperature of 24.4^0C and mean annual rainfall is about 1700mm in the west and 3300mm in the south east, mostly concentrated in the period from May to July. The whole region lies within the cyclone zone. The soil type of the application sites is slightly calcareous loamy soils on river banks and grey or dark grey, non calcareous, heavy silty clay in the basin with medium organic matter (1.7-3.4%).

The slopes of embankment were prepared by following the proper cultivation techniques of different grasses. Weeds and stubbles were removed from the slopes. The layout was done as per experimental design with three replications. The Para and German grass cuttings were collected from Bangladesh Livestock Research Institute, Savar, Dhaka and Vetiver was collected from the locality. Cuttings (2-3 slips per clump) were planted on the earthy platforms with clump spacing of 20 cm after application of organic manure on platforms with small amounts of Ca-Mg-P fertilizer.

In case of soil analysis of the slopes of embankment, 10 composite (3 samples/spot) surface and sub-surface soil samples were collected at 0-15 cm and 15-30 cm depth respectively, during March, 2016 from the different sites of dike. Soil samples were air-dried, ground and passed through a 2 mm sieve and prepared for routine analyses of texture, pH, EC, OM, total N, exchangeable K, available P, and S. The laboratory experiment for soil analysis was conducted at the Department of Soil Science and central laboratory of Patuakhali Science and Technology University, Dumki, Patuakhali during March to May, 2017. The initial soil samples were analyzed for physical and chemical characteristics. The physical characteristic includes textural class, bulk density, moisture content and the chemical properties include soil pH, EC, organic carbon, total N, exchangeable K, available P and S content. Mechanical analysis of the soil was done by hydrometer method by Black (1965*)* and the textural class was determined by using Marshall's Triangular Coordinate following USDA system.

Soil pH was measured in a 1:2.5 soil: water ratio as described by Jackson (1973) with the help of a glass electrode pH meter (HANNA pH 211). Electrical Conductivity (EC) was measured by EC meter (HANNA EC 214) as described by Leif (Petersen, 2002). Organic carbon content of soil was determined following wet oxidation method. The amount of organic matter was calculated by multiplying the percent organic carbon with the Van Bemmelen factor 1.73 (Piper, 1950). Total N content in soil was determined by Kjeldahl method. The soil was digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 10:1:0.1). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982). Available P content of soil was extracted from soil with 0.5M $NaHCO_3$ solution at pH 8.5 (Olsen *et al.*, 1954). The P in the extract was determined by developing blue color with ascorbic acid by the reduction of phosphomolybdate complex and measuring the color by spectrophotometer at 660 nm wavelength (Olsen and Sommers, 1982). Available S content of soil was determined by extracting soil sample with $CaCl_2$ (0.15%) solution. The S content in the extract was determined turbidimeterically and the turbid was measured by spectrophotometer at 420 nm wavelength (Fox *et al.*, 1964).

For growth and development performances analysis of different planted grass on the embankment, periodic observations were practiced for data on re-greening status, survival rate, growth height (cm), tiller numbers, number of leaves per plant, root length (cm), number of roots per plant, shoot fresh weight and dry weight (g), root fresh weight and dry weight (g) and root rotting percentage.

The collected data were analyzed statistically with the help of a computer package MSTATc. The mean differences among, the hedge species were adjudged with Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

III. RESULTS AND DISCUSSION

Analysis of soil samples

Soil Chemical properties

The physico-chemical properties of soils were analyzed and presented in table 1 and 2. The soils were silt loam. The soil samples contain sand 22.2 to 35.2%, silt 47 to 62% and clay 10.3 to 20.3%. The slope of dike was less compact as the bulk density of soil was ranges from 1.00 to 1.83(g/cc). Natural moisture content was 22.75 to 73.55%. The soils were medium alkaline, soil pH ranges from 7.50 to 8.02. Salinity condition was non-saline to slightly saline. The status of soil EC was 0.44 to 3.55dS/m. Organic matter content was very low (0.03-0.44%). The critical limit of organic matter is 1.72%. Similar trend was also found with total soil N. 100% samples were below critical level (0.12%). Total nitrogen in this site ranged from 0.01 to 0.11%. The average value of N was 0.05% (±0.002).Soil available P was 1.43 to 4.36ppm. The average value of P was 2.57ppm (±0.031).The findings and previous results indicate variation of soil P status depending on ecological conditions. The site was S deficient. Critical level of S is 12 ppm. The content of S in soil was 0.89 to 8.50 ppm.The average value of S was 3.98ppm (±0.084).

Table 1. Physico-chemical properties of soil

Sample No.	Texture								Bulk density (g/cc)		Moisture content (%)	
	Surface				Subsurface							
	% Sand	% Silt	% Clay	Textural class	% Sand	% Silt	% Clay	Textural class	Surface	Subsurface	Surface	Subsurface
1	27.7	57.0	15.3	Silt loam	27.2	57.5	15.3	Silt loam	1.59	1.64	26.23	22.75
2	27.2	57.5	15.3	Silt loam	30.2	57.0	12.8	Silt loam	1.41	1.75	24.01	35.59
3	25.2	62.0	12.8	Silt loam	24.7	60.0	15.3	Silt loam	1.15	2.13	25.15	49.53
4	27.2	52.5	20.3	Silt loam	32.7	52.0	15.3	Silt loam	1.00	1.59	23.62	73.55
5	32.2	52.5	15.3	Silt loam	22.7	62.0	15.3	Silt loam	1.29	1.46	24.89	49.74
6	27.2	52.5	20.3	Silt loam	24.7	57.5	17.8	Silt loam	1.27	1.64	32.30	30.67
7	27.7	59.5	12.8	Silt loam	22.2	60.0	17.8	Silt loam	1.15	1.45	38.44	38.86
8	30.2	54.5	15.3	Silt loam	32.7	54.5	12.8	Silt loam	1.45	1.67	24.20	36.70
9	35.2	54.5	10.3	Silt loam	27.7	59.5	12.8	Silt loam	1.37	1.61	34.86	36.51
10	27.7	59.5	12.8	Silt loam	24.7	60.0	15.3	Silt loam	1.42	1.62	29.71	48.60
11	27.2	57.5	15.3	Silt loam	27.2	52.5	20.3	Silt loam	1.29	1.62	60.22	23.81
12	32.2	50.0	17.8	Silt loam	35.2	47.0	17.8	Silt loam	1.10	1.55	47.40	39.83

Table 2. Physical properties of soil

Sample No.	pH		EC (dS/m)		Organic matter (%)		Total nitrogen (%)		Available phosphorous (ppm)		Available sulphur (ppm)	
	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
1	7.66	7.96	0.93	0.68	0.29	0.14	0.03	0.10	3.75	3.47	3.19	1.53
2	8.02	7.68	2.60	0.83	0.14	0.03	0.04	0.04	2.51	1.89	5.42	4.94
3	7.37	7.55	2.18	0.44	0.93	0.12	0.03	0.06	2.38	2.10	5.61	5.60
4	7.5	7.55	0.76	0.89	0.09	0.14	0.04	0.02	2.36	1.43	3.23	5.79
5	7.64	7.57	1.64	0.87	0.17	0.29	0.08	0.01	2.63	1.96	5.86	4.20
6	7.74	7.78	1.75	0.52	0.44	0.35	0.08	0.05	4.36	4.02	3.38	2.23
7	7.62	7.75	0.87	0.54	0.14	0.06	0.11	0.03	2.87	2.41	8.50	6.71
8	7.65	7.52	0.65	0.48	0.29	0.32	0.02	0.10	2.72	2.11	3.56	1.53
9	7.97	7.55	3.55	0.89	0.32	0.26	0.02	0.06	3.30	2.75	5.60	1.53
10	7.75	7.73	1.73	0.71	0.09	0.32	0.05	0.02	2.38	1.92	5.90	2.44
11	7.66	7.87	1.70	0.80	0.14	0.12	0.02	0.01	2.13	2.35	2.42	0.89
12	7.78	7.77	0.86	0.81	0.20	0.14	0.02	0.03	2.24	1.68	3.83	1.53
Range	7.50-8.02		0.44-3.55		0.03-0.44		0.01-0.11		1.43-4.36		0.89-8.50	
Mean±se	7.69±0.007		1.15±0.032		0.23±0.008		0.05±0.002		2.57±0.031		3.98±0.084	

Effect of grass on addition of organic matter

Organic matter of soil acts as a cementing agent to bind the soil particles. It is also called the store house of all plant nutrients. A significant variation was found among the studied grass on addition of organic matter in soil. The maximum content (0.376%) of organic matter was found in soil planted with Binna grass that is 31.47%, 11.90% and 20.135 higher than soils having without grass, Para grass and Napier grass, respectively (Table 3). Addition of higher amount of organic matter in soil by Binna grass may be due to higher production of root biomass.

Table 3. Effect of grass on addition of organic matter

Treatment	Organic matter (%)	% increase
Without grass	0.286 c	-
Para grass	0.336 b	17.48 b
Napier grass	0.313 bc	9.44 c
Binna grass	0.376 a	31.47 a
CV (%)	6.98	5.64
LSD	0.039	3.29
Sẋ	0.011	0.832
Level of significance	*	**

* = Significant at 5% level of probability and ** = Significant at 1% level of probability
Values having same lowercase letter(s) in a column do not differ significantly at 5% level by DMRT

Growth and survival rates of different hedge grass

According to the observations, re-greening of seedlings was found 20 days after planting and a survival rate of 98% was recorded in Vetiver in the countryside and 95% in the riverside on December 2015. It was obvious that Vetiver grew much better than Napier (56%) and Para (34%) grass 60 days of planting.

Table 4: Effect of fodder crop species on plant height, no. of leaves plant^{-1} , no. of tillers hill^{-1}, root length, fresh weight of shoot, dry weight of shoot, fresh weight of root, dry weight of root and root rotting percentage hill^{-1} at 60 days after transplanting (DAT)

Fodder crop species	Plant height (cm)	No. of leaves plant^{-1}	No. of tillers hill^{-1}	Root length (cm)	No. of roots hill^{-1}	Fresh weight of shoot (g)	Dry weight of shoot (g)	Fresh weight of root (g)	Dry weight of root (g)	Roots rotting percentage hill^{-1}
Binna (riverside)	40.00 a	67.33 a	18.67 a	11.67 ab	123.0 a	102.3 a	24.67 a	36.00 a	24.67 a	14.67 b
Binna (countryside)	29.33 b	44.00 b	12.67 b	13.00 a	105.3 b	88.67 b	19.33 b	25.33 b	19.33 b	15.00 b
Napier grass	27.67 b	31.67 c	4.000 c	9.667 bc	21.00 d	74.33 c	15.00 c	17.33 c	15.00 c	55.33 a
Para grass	30.67 b	31.33 c	4.000 c	7.000 c	40.33 c	52.67 d	11.67 d	22.33 b	11.67 b	60.00 a
CV	7.01	11.70	13.13	13.04	4.29	5.42	9.39	9.29	9.39	7.26
LSD	4.46	10.19	2.58	3.10	6.21	8.61	3.31	4.68	3.31	5.25
Level of significance	*	*	*	*	*	*	*	*	*	*

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per 5% level by DMRT)

***** indicates significant at 5% level of probability

Plant height (cm)

Plant height was significantly ($P<0.05$) influenced by fodder crop species (Table 4,5,6). Tallest plant (40.00 cm) was obtained from the crop species Binna grass planted in riverside; whereas shortest plant height (27.67 cm) was observed in the of crop species Napier grass which was statistically identical with Binna in countryside and Para grass after 60 DAT (Table 4). At 120 DAT, tallest plant (74.33 cm) was obtained from Binna grass in riverside which was statistically similar with Binna grass in countryside (64.00 cm), on the other hand shortest plant height was observed in Para grass (41.67 cm) (Table 5). At 180 DAT, Binna grass in both riverside and countryside gave the highest plant height (107 cm and 97 cm respectively) than the Napier grass (78.67 cm) and Para grass (63.33 cm) (Table 6). Plant height is mostly governed by the genetic makeup of the plant but the environmental factors also influence it. The longest plant height in Binna grass was due to its inherent capacity against salty condition and soil properties.

Number of leaves plant^{-1}

Fodder crop species Napier (31.67) and Para (31.63) did not exert significant effect on number of leaves plant^{-1} (Table 4, 5 and 6). But the Binna in riverside (67.33) gave the highest number of leaves plant^{-1} than the Binna in countryside (44.00) after 60 DAT (Table 4). At 120 DAT, Binna grass in riverside gave the highest number of roots (157.00) and Para grass gave the lowest number of roots (43.33) (Table 5). Similarly Binna in riverside (236) showed significant result than in the Binna grass in countryside (184), Napier (108.7) and Para (65.33) at 180 days after planting (Table 6).

Number of tillers hill^{-1}

Number of tillers hill^{-1} differed significantly due to fodder crop species (Table 4,5,6). However, numerically the highest number of tillers hill^{-1} (18.67) was obtained from the Binna grass planted in the riverside and the lowest (4.00) was recorded from the both Napier and Para grass after 60 days of transplanting (Table 4). Number of tillers hill^{-1} was significantly highest in Binna grass in the riverside (23.67) than the Napier (6.67) and Para grass (5.67) at 120 DAT (Table 5). Similarly at 180 DAT, Binna in riverside (27.33) gave the highest number of tillers hill^{-1} than the Napier (7.67) and Para (4.33) (Table 6).

Root length (cm)

Root length was significantly ($P<0.05$) influenced by fodder crop species (Table 4, 5, 6). Highest root length (11.67 cm, 21.33 cm and 27 cm) was obtained from the crop species Binna grass planted in riverside; whereas shortest root length (7 cm, 8 cm and 9.67 cm) was observed in the of crop species Para grass at 60, 120 and 180 days after transplanting.

Number of roots hill^{-1}

Number of roots hill^{-1} differed significantly due to fodder crop species (Table 4, 5, 6). However, numerically the highest number of roots hill^{-1} (123.0) was obtained from the Binna grass planted in the riverside and the lowest (21.00) was recorded from the Napier grass after 60 days of transplanting (Table 4). Number of root hill^{-1} was significantly highest in Binna grass in the riverside (230.7) than the Para grass (57.33) and Napier (28.00) at 120 DAT (Table 5). Similarly at 180 DAT, Binna in riverside (298.0) gave the highest number of tillers hill^{-1} than the Para grass (75.67) and Napier grass (33.00) (Table 6).

Fresh weight of shoot (g)

Fresh weight of leaves had significant ($P<0.01$) effect on fodder crop species (Table 4, 5, 6). Highest fresh weight of shoot (102.3 g) was obtained from the Binna grass in the riverside and lowest one (52.67 g) was obtained from the Para grass at 60 days after planting (Table 4). At 120 DAT, Binna in riverside (185.7 g) gave the highest result and Para grass (72.72 g) gave the lowest result in case fresh weight of shoot. Similar significant result was found in 180 days after planting. Morphologically the leaves of Binna grass are cover the more area and thicker than Para grass and Napier grass. So, ultimately the fresh weight of leaves of Binna grass was higher than the Para and Napier grass.

Dry weight of shoot (g)

Dry weight of shoot was significantly ($P<0.01$) influenced by fodder crop species (Table 4, 5, 6). Highest dry weight of shoot (24.67 g) was obtained from Binna grass in riverside, whereas lowest one (11.67 g) was observed in the crop species of Para grass at 60 days after transplanting (Table 4). Similar significant result was found at 120 DAT. Binna in riverside gave the highest dry weight of shoot (48.67 g) and Para grass gave the lowest dry weight of shoot (17.67 g) at 160 DAT (Table 6). These results were similar in according to the fresh weight of shoot.

Table 2: Effect of fodder crop species on plant height, no. of leaves plant^{-1} , no. of tillers hill^{-1}, root length, fresh weight of shoot, dry weight of shoot, fresh weight of root, dry weight of root and root rotting percentage hill^{-1} at 120 days after transplanting (DAT)

Fodder crop species	Plant height (cm)	No. of leaves plant^{-1}	No. of tillers hill^{-1}	Root length (cm)	No. of roots hill^{-1}	Fresh weight of shoot (g)	Dry weight of shoot (g)	Fresh weight of root (g)	Dry weight of root (g)	Roots rotting percentage hill^{-1}
Binna (riverside)	74.33 a	157.0 a	23.67 a	21.33 a	230.7 a	185.7 a	40.33 a	59.33 a	16.00 a	12.67 b
Binna (countryside)	61.00 a	125.0 b	14.67 b	17.33 b	166.3 b	162.7 b	32.33 a	41.33 b	13.67 b	15.67 b
Napier grass	49.67 b	69.67 c	6.667 c	13.33 c	28.00 d	112.3 c	27.33 b	24.33 d	8.333 c	51.00 a
Para grass	41.67 c	43.33 d	5.667 c	8.000 d	57.33 c	72.72 d	12.33 c	33.67 c	12.00 b	54.33 a
CV	5.65	5.70	11.40	11.55	5.11	3.40	7.83	8.02	8.64	9.58
LSD	6.39	11.42	2.88	3.46	12.32	9.06	4.39	5.50	2.15	6.39
Level of significance	*	*	*	*	*	*	*	*	*	*

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per 5% level by DMRT)

***** indicates significant at 5% level of probability

Fresh weight of root (g)

Fresh weight of root was significantly (P<0.01) influenced by fodder crop species (Table 4, 5, 6). Significant highest fresh weight of root was determined in Binna grass in riverside (36.00 g) and the lowest fresh weight of root (17.33 g) was determined in Napier grass at 60 DAT (Table 4). At 120 days after transplanting Binna in riverside (59.33 g) also gave the highest fresh weight of root and Napier gave the lowest fresh weight of root (24.33 g) (Table 5). Similar significant result was found in 180 days after transplanting. Binna gave the highest fresh weight of roots than others due to its more number of roots and largest length of the roots.

Dry weight of root (g)

Dry weight of root also got significant (P<0.01) influenced on fodder crop species (Table 4, 5, 6). According to the fresh weight of root same type of significant result was found in case of dry weight of root. Highest dry weight of root (22.67 g) was obtained from Binna grass planting in the riverside, whereas lowest one (11.33 g) was observed in the crop species of Para grass at 160 days after transplanting (Table 6).

Table 3: Effect of fodder crop species on plant height, no. of leaves plant^{-1} , no. of tillers hill^{-1}, root length, fresh weight of shoot, dry weight of shoot, fresh weight of root, dry weight of root and root rotting percentage hill^{-1} at 180 days after transplanting (DAT)

Fodder crop species	Plant height (cm)	No. of leaves plant^{-1}	No. of tillers hill^{-1}	Root length (cm)	No. of roots hill^{-1}	Fresh weight of shoot (g)	Dry weight of shoot (g)	Fresh weight of root (g)	Dry weight of root (g)	Roots rotting percentage hill^{-1}
Binna (riverside)	107.0 a	236.0 a	27.33 a	27.00 a	298.0 a	246.7 a	48.67 a	73.67 a	22.67 a	9.000 d
Binna (countryside)	97.00 a	184.0 b	17.00 b	24.00 b	215.0 b	208.0 b	42.33 a	58.67 b	17.67 b	17.33 b
Napier grass	78.67 b	108.7 c	7.667 c	17.00 c	33.00 d	164.0 c	34.00 b	46.33 c	14.67 bc	43.00 b
Para grass	63.33 c	65.33 d	4.333 d	9.667 d	75.67 c	94.67 d	17.67 c	33.33 d	11.33 c	59.33 a
CV	5.86	7.92	14.33	12.70	4.40	3.99	9.81	8.02	11.81	9.02
LSD	10.12	23.48	4.11	4.92	13.67	14.22	6.99	8.49	3.91	5.79
Level of significance	*	*	*	*	*	*	*	*	*	*

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per 5% level by DMRT)

***** indicates significant at 5% level of probability

Root rotting percentage hill^{-1}

Root rotting percentage hill-1 was significantly (P<0.01) influenced by fodder crop species (Table 4, 5, 6). Highest root rotting percentage (60.00%) was observed in the fodder crop species Para grass whereas lowest one (14.67%) was found in the Binna grass planted in riverside which was statistically similar with Binna in countryside (15%) at 60 DAT (Table 4). Similar significant result was also found in the grass species at 120 DAT (Table 5). Para grass gave the highest root rotting percentage than the Napier and Binna grass at 160 days after transplanting (Table 6).

The very high survival rate (95%) of Vetiver *i.e.* Binna planted at spots with extremely infertile soils containing very little organic matter indicates the high adaptability and re-growth ability of Vetiver grass. If planted during the warm (20-25°C) and rainy spring time, Vetiver will grow well and get a high survival rate. Compared with local Para and Napier grass, Vetiver had a more developed deep-root system.

Key Vetiver planting technique rules were formulated from this experiment: (1) Vetiver should be planted in contour lines on embankment slopes; (2) contour platforms as well as organic manure and Ca-Mg-P fertilizer are needed for Vetiver planting on embankment slopes to ensure a high survival rate in adverse conditions. In an environment with plenty of sunshine and rainfall in Nasnapara embankment, a high survival rate may be expected with these two techniques. Steep slope gradients could be gentled down, runoff washing decreased and runoff water held by the establishment of platforms to accelerate plant growth on slope surfaces.

At the early stage of the application, erosion and washing took place on slope surfaces and sometimes Vetiver seedlings planted were washed away by runoff water. This was because of the lack of a soil anchorage system needed for slope protection due to engineering construction reasons. Better results may be expected if a soil anchorage system through stolon type grasses like Durba, Latazangla etc is arranged on the catchment surface before Vetiver is planted. Besides, replanting will be needed during the first few months after planting.

BIBLIOGRAPHY

[1]. Ao, H.X., Xia, H.P., and Liu, S.Z. 1997. Studies on the application of Vetiver hedges to landslide control for highways in Guangdong. *Vetiver Newsl.* 3(1) (in Chinese).

[2]. Black, C.A. 1965. *Methods of soil analysis Part*-II. Amer, Soc. Agron, Madison, Wisconsin, U.S.A., pp. 1372-1376.

[3]. Bremner, J.M. and Mulvaney, C.S. 1982. Nitrogen-Total. *In Methods of Soil Analysis, Part 2 (2^{nd} Edt.).* AL Miller RH and Keeney DR eds., pp. 595-624.

[4]. DMB, 2008. *"Disaster Management Bureau",* Cyclone Sidr in Bangladesh: damage, loss, and needs assessment for disaster recovery and reconstruction, a report prepared by the Government of Bangladesh assisted by the International Development Community with Financial Support from the European Commission.

[5]. Gomez KA, Gomez AA 1984: Statistical Procedures for Agricultural Research, John Wiley and Sons, New York.

[6]. Hengchaovanich, D. 1998. Application of Vetiver technology to engineering – slope stabilization and erosion minimization. *Vetiver Research and Development*, China Agriculture S & T Press, pp. 118 - 130 (in Chinese).

[7]. Hossain, A.N.H. 2004. "An overview on Impacts of Floods in Bangladesh and Options for Mitigations", *National Workshop on Options for Flood Risk and Damage Reduction in Bangladesh,* 7-9^{th} September, Dhaka.

[8]. IPCC—Intergovernmental Panel on Climate Change (2012). Summary for policymakers. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds.) Managing the risks of extreme events and disasters to advance climate change adaptation. *A special report of working groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge.

[9]. Jackson, M.L. 1967. *Soil Chemical analysis*. Prentice Hall of Ind., Pvt. Ltd., New Delhi, pp. 151-153.

[10]. Olsen SR, Sommers LE, 1982. Methods of Soil Analysis, Part 2. AL Page (Editor), Agronomy 9, ASA & SSSA, Madison, Wiscosin. pp. 403.

[11]. Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, E.A. 1954. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate.* United States Dept. Agril. Circ., pp. 929.

[12]. Petersen, L. 2002. Analytical Methods: Soil, Water, Plant Material, Fertilizer. *Soil Resources Management and Analytical Services*. Soil Resource Development Institute, Danida Kampsax, Dhaka.

[13]. Piper, C. S. 1950. *Soil and Plant Analysis*. Adelaide Univ. Press. Australia.