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# Hydrological behaviour and rooting patterns of some grass species planted in sodic Vertisols under rainfed conditions

S K VERMA[1], S R S RAGHUWANSHI[2] and R K SHARMA[3]

## ABSTRACT

In a field study five grass species, viz. Marvel grass (*Dichanthium annulatum*), Para grass (*Brachiria mutica*), Vetiver grass (*Vetiveria zizinoides*), Karnal grass (*Diplachne fusca*) and Napier grass (*Penisetum perpurium*) were evaluated to asses their suitability as biological reclaiming agent and vegetative barriers for reclaiming as well as reducing soil erosion and enhancing in situ water conservation in a moderate sodic clay soil. The study reveals that lowest soil loss and runoff were observed from the plots planted with Marvel grass. From the point of view of fodder and commercial value; the order (decreasing) of performance for adoption of these grasses for sodic vertisols were Marvel, Para, Napier, Karnal and Vetiver. Rooting pattern of these five grass species were found to form the dense base at soil surface thereby retarding the runoff. Equations have been developed to estimate their root biomass density during growth for two years. These equations can be considered valid for such soils under rainfed conditions.

**Key words:** Karnal grass, Marvel grass, Napier grass, Para grass, Soil binding, Soil loss

## INTRODUCTION

The grasses play a vital role in soil and water conservation. Soil conserving capacity depends upon the grass species, particularly their root behavior and canopy development. In black alkali soils mechanical measures of bunding is expensive (Gupta and Ranade 1988) and unstable due to deterioration in soil structure. There is growing awareness to opt for vegetative measures, since the development of vegetative cover during rains strongly influences soil loss (Wischmeier and Smith 1978). Easily propagated grass species with extensive root system may be used as vegetative hedges to reduce runoff and soil loss. But little information is available on their rooting pattern. The present study was planned to assess suitability of certain grass species as vegetative barriers for enhancing in situ conservation of water and to observe roots' growth and distribution pattern of these grass species in sodic black clay soils of Nimar region. Attempts were also made to develop a dynamic root development Model for these species.

## MATERIALS AND METHODS

The investigation was initiated in April 2001 at Soil Salinity Research Station, Barwaha ($76^0$ 0' 27"E and $22^0$ 14' 48" N) district Khargone, Madhya Pradesh.The experimental soil belongs to order Vertisols (Haplusterts - Sodic phase) with high CEC 40 cmol (p+) $kg^{-1}$, ESP (40.0±2.0), low ECe (0.9 to 1.4 $dSm^{-1}$) and moderate pH (8.2–8.4). The soil is clay in texture (clay 54.6%, silt 34.4% and sand 11.0%) with almost negligible steady state infiltration rate (terminal rate). The bulk density of plough layer soil (0–15 cm) is in the range of 1.40 to 1.45 $Mgm^{-3}$.

The grasses were transplanted with uniform population in all the main plots (except control) with land slope of about 0.3% during July 2001. The experiment design is RBD with three replication and six treatments. The six treatments were five grass species, viz. Marvel grass (*Dichanthium annulatum*), Para grass (*Brachiria mutica*), Vetiver grass (*Vetiveria zizinoides*), Karnal grass (*Diplachne fusca*) and Napier grass (*Penisetum perpurium*) and control. In order to provide protection against fungal infestation the root

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portion of each slip was dipped in the 0.5% solution of Bavistin for 15 minutes. The slips were transplanted at specified distance interval (30 × 30 cm) in plots measuring 21.0 × 4.5 m and basal application of urea (50 kg N/ha), Super phosphate (40 kg $P_2O_5$/ha) and Zn $SO_4$ (25 kg/ha) has been applied at planting. One plot in each replication has been kept fallow as check.

Grasses were tested for hydrological aspects after one year of transplanting. The lower end of the plot has been provided with multi-slot divisor prepared by Central Institute of Agricultural Engineering, Bhopal (MP). The collected runoff samples were analyzed for sediment and nutrient loss. Infiltration rate was measured by placing double ring infiltro-meters in different treatments permanently in one of the replication. After the steady state condition the intake rate was measured.

Root growth and proliferation of the grass species was monitored through monoliths of 50 × 50 × 10 cm layer wise excavation to a depth of their penetrations. Roots were being recovered by washing away of soil. The total roots recovered after washings were collected from each plots in different sections at 10 cm interval. Fresh root weights was recorded and mean root diameter were measured with the help of screw gauge by taking randomly ten roots from each layers and then weighted over all the depths of root recovery. The wet roots obtained were immersed in a measuring cylinder to record the volume of fresh roots. Roots were then dried in oven at 80°C and dry root weight be recorded. Root biomass density (g/$cm^3$) for each grass species at different time interval was calculated by considering the volume of 50 ×50×50 $cm^3$ size monolith. Soil binding capacity of the roots was calculated by the method described by Bhimaya *et al.* (1956).

$$F = V/r^2$$

where 'F' is binding factor,
'V' is volume of roots ($cm^3$), and
'r' is average radius of roots (mm)

## RESULTS AND DISCUSSION

*Survival of grasses*

The date of planting and survival percentage recorded after a month of transplanting are reported in table 1. The highest survival was recorded in Para grass (94%) which was significantly higher than marvel (87%), Vetiver (67%) and Karnal grass (63%). The lowest survival was recorded with Panicum (10%) after three times of transplanting thus it was replaced by Napier on 11th August 2001. The survival of Napier (recorded later on) was satisfactory (72%). Ashok Kumar and Abrol (1986) evaluated the tolerance of several forage grasses under green house and field conditions and reported the tolerance in the order of Karnal grass, Rhodes grass, Gatton panic, Bermuda grass and Para grass.

Table 1: Date of transplanting and survival percent of different grasses

| Name of grass | Date of transplanting | Survival (%) | Remark (rank) |
|---|---|---|---|
| Marvel grass | 26.06.2001 | 87 | 2 |
| Vetiver grass | 04.07.2001 | 67 | 3 |
| Para grass | 05.07.2001 | 94 | 1 |
| Panicum grass | 06.07 or 14.07 or 27.07.2001 | 10 | Failed |
| Karnal grass | 09.07.2001 | 63 | 4 |
| Napier grass | 11.08.2001 | 72 | (in lieu of Panicum) |
| SEm ± | 0.67 | | |
| CD at 0.05 | 2.21 | | |

Table 2: Infiltration rate (mm/h) as influenced by different grasses

| Months | Marvel | Para | Vetiver | Karnal | Napier | Control |
|---|---|---|---|---|---|---|
| 6 | 0.11 | 0.22 | 0.21 | 0.13 | 0.09 | 0.11 |
| 12 | 0.07 | 0.13 | 0.12 | 0.09 | 0.14 | 0.09 |
| 18 | 0.19 | 0.09 | 0.09 | 0.13 | 0.04 | 0.06 |
| 24 | 0.18 | 0.27 | 0.31 | 0.12 | 0.10 | 0.06 |
| 30 | 0.20 | 0.23 | 0.36 | 0.23 | 0.18 | 0.10 |
| 36 | 0.20 | 0.26 | 0.32 | 0.24 | 0.12 | 0.14 |
| 42 | 0.18 | 0.22 | 0.26 | 0.20 | 0.16 | 0.12 |

*Infiltration*

The infiltration rate (Table 2) improved markedly after 42 months of grass planting this may be attributed to exude generated by roots, uptake of sodium and disintegration of roots biomass in soil. Ashok Kumar and Abrol (1979) observed improvement in soil properties by growing five grasses (Hybrid Napier, Para grass, Setaria grass, Guinea grass and Bermuda grass). They recorded highest infiltration rates in the plots having Bermuda grass followed by Para grass. Deep penetration of grass root also improves infiltration rate of soil. Similar results were reported by Mishra *et al.* (1995).

*Runoff*

The runoff data (Table 3) recorded with the help

Table 3: Effect of different grasses on runoff percentage during three rainy seasons (2002–03, 2003–04 & 2004–05) after one year of plantation

| Event | Date | Rainfall (mm) | Runoff percentage | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Marvel | Para | Vetiver | Karnal | Napier | Control |
| 2002–03 | | | | | | | | |
| 1st | 26.06.02 | 60.7 | 30.1 | 33.3 | 32.3 | 31.9 | 34.4 | 42.8 |
| 2nd | 27.06.02 | 31.0 | 6.4 | 24.1 | 26.9 | 34.1 | 38.3 | 78.1 |
| 3rd | 28.06.02 | 8.0 | 3.4 | 6.9 | 5.8 | 15.1 | 13.1 | 18.6 |
| 4th | 30.06.02 | 9.4 | 4.1 | 10.5 | 4.7 | 9.4 | 25.7 | 69.1 |
| 5th | 21.07.02 | 43.8 | 16.1 | 14.6 | 20.6 | 42.2 | 30.1 | 66.3 |
| 6th | 06.08.02 | 23.0 | 3.6 | 3.1 | 7.2 | 3.4 | 3.7 | 23.0 |
| 7th | 19.08.02 | 12.3 | 8.9 | 9.8 | 13.4 | 7.2 | 20.6 | 58.1 |
| 8th | 20.08.02 | 14.0 | 23.6 | 19.6 | 71.5 | 37.7 | 84.9 | 91.1 |
| 9th | 24.08.02 | 23.0 | 18.2 | 44.9 | 20.6 | 54.1 | 79.4 | 27.3 |
| 10th | 01.09.02 | 36.5 | 8.1 | 48.8 | 18.7 | 36.2 | 41.6 | 9.6 |
| 11th | 02.09.02 | 52.5 | 46.1 | 68.1 | 64.1 | 61.4 | 65.8 | 59.5 |
| 12th | 03.09.02 | 49.5 | 67.1 | 71.6 | 63.6 | 60.4 | 64.6 | 66.4 |
| 13th | 04.09.02 | 9.5 | 83.4 | 69.5 | 78.7 | 63.7 | 40.5 | 91.5 |
| 14th | 05.09.02 | 17.5 | 84.9 | 81.7 | 88.0 | 91.8 | 96.2 | 96.8 |
| 15th | 06.09.02 | 9.3 | 75.7 | 86.3 | 95.8 | 89.9 | 96.9 | 98.2 |
| Total | 400.0 | 32.0 | 39.3 | 40.8 | 42.6 | 49.1 | 59.8 | |
| 2003–04 | | | | | | | | |
| 1st | 23.06.03 | 36.0 | 2.9 | 1.6 | 3.0 | 2.3 | 2.4 | 2.4 |
| 2nd | 05.07.03 | 43.0 | 3.2 | 6.1 | 4.4 | 7.4 | 2.8 | 12.0 |
| 3rd | 25.07.03 | 17.5 | 11.0 | 17.0 | 13.2 | 13.8 | 11.9 | 15.1 |
| 4th | 26.07.03 | 20.0 | 31.9 | 47.9 | 33.0 | 38.2 | 39.9 | 67.7 |
| 5th | 27.07.03 | 101.5 | 28.0 | 30.3 | 24.2 | 27.4 | 29.5 | 29.9 |
| 6th | 25.08.03 | 62.0 | 38.7 | 41.5 | 37.8 | 41.5 | 37.1 | 41.9 |
| 7th | 28.08.03 | 9.5 | 38.2 | 41.7 | 78.7 | 79.9 | 82.2 | 77.6 |
| 8th | 20.09.03 | 59.4 | 51.3 | 50.4 | 48.3 | 46.7 | 52.6 | 38.3 |
| 9th | 25.09.03 | 96.5 | 31.5 | 28.7 | 29.0 | 28.7 | 32.4 | 31.9 |
| 10th | 27.09.03 | 12.5 | 46.6 | 55.4 | 60.7 | 63.4 | 67.8 | 69.5 |
| 11th | 29.09.03 | 23.3 | 36.8 | 50.5 | 38.5 | 42.3 | 43.7 | 58.1 |
| 12th | 30.09.03 | 8.8 | 46.3 | 53.8 | 67.5 | 77.5 | 83.8 | 85.0 |
| Total | 490.0 | 30.5 | 35.4 | 36.5 | 39.1 | 40.5 | 44.1 | |
| 2004–05 | | | | | | | | |
| 1st | 26.07.04 | 28.4 | 4.8 | 3.2 | 2.8 | 3.8 | 2.6 | 2.8 |
| 2nd | 29.07.04 | 16.0 | 26.2 | 26.8 | 28.6 | 29.2 | 32.3 | 28.4 |
| 3rd | 30.07.04 | 26.4 | 28.4 | 39.2 | 42.3 | 44.4 | 48.5 | 52.3 |
| 4th | 31.07.04 | 27.5 | 33.2 | 42.8 | 48.8 | 46.5 | 49.3 | 51.8 |
| 5th | 05.08.04 | 54.0 | 11.3 | 22.5 | 32.5 | 36.5 | 38.3 | 39.7 |
| 6th | 06.08.04 | 27.3 | 31.4 | 32.6 | 36.4 | 38.6 | 48.8 | 52.6 |
| 7th | 07.08.04 | 69.6 | 55.3 | 52.3 | 54.3 | 55.3 | 65.3 | 68.3 |
| 8th | 08.08.04 | 17.5 | 58.4 | 56.4 | 58.5 | 58.2 | 68.4 | 72.3 |
| 9th | 12.08.04 | 25.0 | 28.4 | 32.8 | 34.4 | 36.8 | 34.3 | 46.5 |
| 10th | 14.08.04 | 11.0 | 23.5 | 27.5 | 27.6 | 35.6 | 38.6 | 49.4 |
| 11th | 23.08.04 | 39.2 | 18.4 | 16.2 | 14.2 | 18.2 | 22.4 | 23.8 |
| 12th | 24.08.04 | 4.5 | 28.3 | 36.3 | 38.5 | 42.3 | 38.5 | 39.5 |
| 13th | 25.08.04 | 15.7 | 36.4 | 42.5 | 44.6 | 46.4 | 52.3 | 54.8 |
| 14th | 26.09.04 | 54.6 | 33.2 | 34.2 | 28.4 | 32.3 | 30.3 | 31.4 |
| 15th | 07.10.04 | 26.0 | 23.5 | 25.8 | 22.5 | 21.6 | 19.5 | 18.4 |
| Total | | 442.7 | 29.4 | 32.7 | 34.3 | 36.4 | 39.3 | 42.1 |

of multi-slot devisor showed that maximum seasonal (total) runoff occurred from control plot and it was reduced with plantation of marvel, Para and Vetiver grass. The runoff was 59.8% in the plots having no vegetation and was reduced to 32% in the plot planted with Marvel grass after a year of grass plantation in first season. Among various grasses Marvel was most effective in checking runoff (27.8%) as compared to control plot and followed by Para (20.5%) and Vetiver (19%). This effectiveness for reduction in runoff in Napier (10.7%) plot was lower among all the grasses. This may be attributed to root behaviors and its soil binding capacity of the grasses. The grasses with thinner roots (Marvel) and surface proliferations had higher effectiveness in checking of runoff and improving internal drainage. Mishra *et al.* (1995) also reported that Vetiver and Marvel grasses are most suitable grasses to protect soil from runoff even in normal soils. As compared to control the magnitude of run-off was lowered in second and third years of plantation than first year. The runoff quantity was also regulated by amount of rainfall its intensity and antecedent soil moisture content being its function. The runoff was higher when amount of rain, intensity and antecedent soil moisture was higher.

*Soil Loss*

Total sediment loss (Table 4) during 1st, 2nd and 3rd year was highest from control (8.54, 2.87 and 2.76 tons/ha, respectively) and lowest (2.94, 1.34 and 1.26 tons/ha) from the plot where Marvel grass was planted. The sediment losses were less than 40% during second year which further reduction in third year even in control plots. This may be attributed to establishment of grasses and no tillage operations. The sediment loss from field was effectively checked through plantation of grasses in comparison to fallow land. There was 65.6, 53.3 and 54.3% reduction in sediments loss due to plantation of Marvel grass, 57.9, 53.3 and 51.1% with Para grass in first, second and third years respectively as compared to control plot. It was lowest in field where Napier (13.3, 24 and 24.6%) grass was planted. The root of grasses form dense base at soil surface and thereby retards runoff and soil loss (Mishra *et al.* (1995). The lowest soil conservation with Napier grass was due to reason that it was badly damaged during the each summer and took some time to revive again after rains. The soil losses in all three years were always highest during first event of runoff and there was reduction in its magnitude with the progress of time. There was reduction in sediment loss (more than 50%) from field of all the grasses but it was less (only 25%) in the plots of Napier and control either due to establishment of planted or natural grasses or reduction in number of events during second year.

*Rooting Pattern*

Data on root development observed quarterly upto age of 21 months is presented in Table 5. A Root development by length, volume and root biomass was high in Vetiver, Para and low in Napier. However, root thickness was higher in Vetiver as compared to others at all stages. Increasing trends were observed in root length, root biomass and volume with advancement of time but it was at higher magnitude only up to 6 months and after that increase was marginal stabilizing after 15 months. It indicates development of finer roots in latter stage of growth. At all the stages after planting, maximum root biomass was recorded with Para grass and Vetiver followed by Karnal and lowest with Napier grass. The higher and almost equal root length was observed in Vetiver and Para (68 cm). R root length of grasses did not increase in the same proportions as biomass but followed the same order. Root diameter also revealed same trend. Root moisture content, which remained between 60 to 80% was almost constant at all stages of growth.

The root binding capacity computed with the data of total volume of roots, mean radius and binding capacity at seven stages of growth revealed that Para grass had the maximum binding capacity followed by Marvel and Vetiver. This may be attributed to the presence of finer roots in Para and Marvel grass, Total root volume of each grass increased with advancement of growth. The binding capacity of roots of all the grass species increased with increasing age of the grasses up to 9 months owing to increase in root volume and finer roots. Average root radius normally increased with the increasing age and higher root radius was observed for Vetiver, Para and Napier at all stages of growth.

*Prediction of Root Biomass Density*

The data on root biomass recorded at different time interval were used to develop a dynamic root development model that can be used for prediction

Table 4: Effect of different grasses on control of sediments losses (tons/ha) through erosion during 2002–03, 2003–04 and 2004–05

| Event | Rainfall intensity | Sediments loss (tons/ha) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Marvel | Para | Vetiver | Karnal | Napier | Control |
| 2002–03 | | | | | | | |
| 1st | Fast | 1.680 | 1.830 | 1.630 | 1.660 | 2.710 | 3.690 |
| 2nd | Fast | 0.130 | 0.410 | 0.400 | 0.390 | 0.460 | 1.200 |
| 3rd | Slow | 0.021 | 0.031 | 0.022 | 0.060 | 0.110 | 0.260 |
| 4th | Slow | 0.009 | 0.031 | 0.022 | 0.049 | 0.095 | 0.106 |
| 5th | Fast | 0.290 | 0.161 | 0.273 | 0.646 | 0.573 | 1.829 |
| 6th | Very slow | 0.005 | 0.002 | 0.121 | 0.009 | 0.107 | 0.428 |
| 7th | Fast | 0.002 | 0.018 | 0.026 | 0.014 | 0.062 | 0.092 |
| 8th | Slow | 0.091 | 0.047 | 0.175 | 0.006 | 0.538 | 0.264 |
| 9th | Fast | 0.128 | 0.116 | 0.222 | 0.259 | 0.390 | 0.091 |
| 10th | Slow | 0.174 | 0.340 | 0.179 | 0.248 | 0.891 | 0.053 |
| 11th | Fast | 0.146 | 0.165 | 0.469 | 0.341 | 0.571 | 0.207 |
| 12th | Fast | 0.062 | 0.108 | 0.507 | 0.181 | 0.669 | 0.205 |
| 13th | Slow | 0.084 | 0.035 | 0.068 | 0.025 | 0.024 | 0.015 |
| 14th | Fast | 0.082 | 0.136 | 0.063 | 0.058 | 0.138 | 0.068 |
| 15th | Fast | 0.039 | 0.068 | 0.041 | 0.031 | 0.072 | 0.036 |
| Total | | 2.943 | 3.498 | 4.218 | 3.977 | 7.410 | 8.544 |
| 2003–04 | | | | | | | |
| 1st | Fast | 0.015 | 0.011 | 0. | 0.056 | 0.014 | 0.173 |
| 2nd | Fast | 0.019 | 0.018 | 0.168 | 0.129 | 0.199 | 0.234 |
| 3rd | Slow | 0.051 | 0.060 | 0.089 | 0.131 | 0.086 | 0.151 |
| 4th | Slow | 0.040 | 0.037 | 0.057 | 0.084 | 0.211 | 0.198 |
| 5th | Fast | 0.307 | 0.341 | 0.616 | 0.578 | 0.814 | 0.772 |
| 6th | Slow | 0.131 | 0.162 | 0.203 | 0.136 | 0.079 | 0.190 |
| 7th | Fast | 0.068 | 0.085 | 0.131 | 0.027 | 0.079 | 0.084 |
| 8th | Fast | 0.444 | 0.278 | 0.518 | 0.261 | 0.292 | 0.438 |
| 9th | Fast | 0.190 | 0.364 | 0.108 | 0.046 | 0.240 | 0.548 |
| 10th | Slow | 0.036 | 0.022 | 0.064 | 0.068 | 0.067 | 0.036 |
| 11th | Slow | 0.040 | 0.015 | 0.019 | 0.017 | 0.090 | 0.035 |
| 12th | Very slow | 0.003 | 0.007 | 0.014 | 0.003 | 0.010 | 0.009 |
| Total | | 1.344 | 1.400 | 2.018 | 1.536 | 2.181 | 2.868 |
| 2004–05 | | | | | | | |
| 1st | Fast | 0.262 | 0.252 | 0.332 | 0.262 | 0.442 | 0.582 |
| 2nd | Fast | 0.128 | 0.118 | 0.224 | 0.124 | 0.148 | 0.214 |
| 3rd | Slow | 0.034 | 0.044 | 0.058 | 0.048 | 0.076 | 0.084 |
| 4th | Slow | 0.034 | 0.044 | 0.052 | 0.044 | 0.068 | 0.072 |
| 5th | Fast | 0.174 | 0.178 | 0.284 | 0.184 | 0.236 | 0.342 |
| 6th | Slow | 0.044 | 0.054 | 0.084 | 0.064 | 0.132 | 0.182 |
| 7th | Fast | 0.032 | 0.042 | 0.044 | 0.040 | 0.064 | 0.072 |
| 8th | Slow | 0.032 | 0.042 | 0.044 | 0.040 | 0.064 | 0.072 |
| 9th | Fast | 0.114 | 0.114 | 0.222 | 0.122 | 0.134 | 0.264 |
| 10th | Slow | 0.064 | 0.074 | 0.098 | 0.084 | 0.108 | 0.142 |
| 11th | Fast | 0.058 | 0.078 | 0.108 | 0.084 | 0.124 | 0.148 |
| 12th | Fast | 0.058 | 0.058 | 0.084 | 0.064 | 0.114 | 0.128 |
| 13th | Very slow | 0.028 | 0.032 | 0.054 | 0.038 | 0.068 | 0.074 |
| 14th | Fast | 0.084 | 0.098 | 0.108 | 0.104 | 0.132 | 0.184 |
| 15th | Fast | 0.114 | 0.124 | 0.142 | 0.134 | 0.172 | 0.204 |
| Total | | 1.260 | 1.352 | 1.938 | 1.438 | 2.082 | 2.764 |

Table 6: Observed and predicted values of root biomass density (RBD) at different time intervals

| Growth (months) | Marvel | | Para | | Vetiver | | Karnal | | Napier | |
|---|---|---|---|---|---|---|---|---|---|---|
| | O* | P* | O | P | O | P | O | P | O | P |
| 3 | 56.6 | 68.3 | 42.6 | 42.5 | 14.2 | 12.3 | 0.96 | 0.12 | 47.4 | 84.1 |
| 6 | 150.4 | 92.3 | 57.6 | 49.5 | 19.2 | 16.5 | 3.20 | 17.5 | 192.0 | 157.4 |
| 9 | 154.4 | 124.5 | 62.4 | 56.3 | 23.2 | 21.9 | 39.2 | 16.9 | 219.2 | 214.4 |
| 12 | 182.4 | 167.8 | 62.4 | 62.4 | 36.0 | 28.4 | 39.2 | 39.2 | 221.6 | 240.2 |
| 15 | 292.6 | 225.9 | 67.2 | 67.7 | 44.0 | 37.5 | 41.6 | 42.9 | 245.6 | 249.2 |
| 18 | 315.0 | 303.6 | 77.6 | 72.2 | 52.0 | 47.8 | 44.8 | 43.2 | 254.4 | 252.1 |
| 21 | 390.5 | 407.0 | 101.9 | 75.8 | 100.4 | 59.8 | 51.3 | 43.2 | 284.6 | 252.9 |

O* Observed value; P* Predicted value

The equations developed from observed data for prediction of root biomass density compute a very close value (Table 6) and it can be used for predicting root biomass in sodic clay soils. The higher 'a' value of Vetiver and Para clearly showed that these grasses are more effective in penetrating black alkali soils as compared to other grasses.

## CONCLUSIONS

It can be concluded from the study that planting of grasses like Marvel, Para and Karnal in sodic clay soils protect natural resources (sediment and nutrient losses) and are helpful in reclaiming these soils. The root growth equations developed from data are useful for prediction of root biomass production with interval of time under similar conditions and soils.

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