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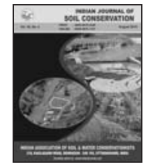

Bio-engineering measures for soil and water conservation under new tea (*Camellia sinensis* L.) plantation in Nilgiris

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ABSTRACT

An experiment was conducted during 2007-2009 in the farmer's field in the Nilgiris, the North-Western part of Tamil Nadu for evaluating different bio-engineering measures in conserving runoff and soil loss under new tea plantation. One year old B-6 tea clones were planted at double hedge spacing (135 cm x 75 cm x 75 cm) in two slope ranges (8-12 and 30-35%). Four different types of conservation measures *viz*., contour staggered trenches (CST) in the space between pairs of tea rows (walking rows), vegetative barrier (VB) of geranium in walking rows, CST and VB of geranium in alternate walking rows and CST with cover crop of beans were selected for evaluating runoff and soil loss with control. Minimum runoff of 112.2 mm in CST with cover crop of beans followed by CST (118 mm) was obtained in the slope range 8-12% with intermediate effect in the remaining treatments with similar trend in the slope of 30-35%. Minimum soil loss was found in the treatment under CST (4.9 t $ha^{-1}yr^{-1}$) followed by CST with cover crop of beans (5.3 t $ha^{-1}yr^{-1}$) in 8-12% slope. Similar trend with about 25% more annual soil loss in treatments under 30-35% slope was observed due to higher percent of runoff (23.7%). Variation in tea canopy due to treatment effect was observed in post monsoon period with maximum (34.5%) in CST with cover crop of beans and CST (35.6%) in 8-12% and 30-35% slope, respectively showing the effect of CST in canopy development.

1. INTRODUCTION

Tea (*Thea sinensis*) is cultivated in the altitude ranging from 500 to 2500 m above msl with slope range of 10 to 33% in areas with annual rainfall varying from 1150 to 6000 mm, causing excess runoff and soil loss in the initial stage of plantation. In Tamil Nadu, major tea plantation area is in the districts of Nilgiris, Coimbatore, Theni, Tirunelveli, and Kanyakumari. Among these districts, the Nilgiris stands first in terms of area (0.47 lakh ha, representing 85% of total tea area) and production (41% of total production) in South India (Madhu and Sahoo, 2009). In Nilgiris, tea is cultivated in areas having well distributed annual rainfall of about 1200 mm. The effect of rainfall is important as it affects on runoff, soil loss, and soil moisture, thereby inducing vegetative growth. The water requirement varies substantially during the growing period due to variation in crop canopy and climatic conditions (Doorenbos and Pruitt, 1977). Land management practices affect water and nutrient status in the soil, increases plant growth and yield (Ali and Talukder, 2008; Falkenmark and Rockström, 2004).

Sloping lands and banks have severe bank erosion (Rao *et al.,* 2013). Growing of tea on sloping land without any soil and water conservation measures causes enormous soil loss especially in the initial years (Madhu *et al*., 2001). The disturbance of top soil in process of new tea plantation leads to significant soil losses through runoff. Many tea estates in Darjeeling hills in the North-East India, the Nilgiris and the high range in south India have recurrently suffered from soil erosion problem. Soil erosion control in tea lands has been discussed in Sri Lanka (Krishnarajah, 1985), India (Barua, 1989 and Chinnamani, 1977) and Kenya (Othieno, 1992). In Sri Lanka, Krishnarajah (1985) reported a loss of 20 t of soil ha^{-1} within six months in absence of any earthwork. Soil loss could be as high as 28-40 t $ha^{-1}yr^{-1}$ in the absence of any vegetative canopy and soil conservation measure (Chinnamani, 1977; Madhu and Tripathi, 1997).

Manivannan and Desai (2007) studied the effect of different bio-engineering measures on runoff and soil loss in cashew plantation and reported a minimum runoff of 3.9% of rainfall and soil loss of 1.4 t ha^{-1} under continuous contour bund with vegetative barrier of *Stylosanthes scabra* + *Glyricidia maculate*. Rao *et al.* (2012) reported that bamboo type bushy plants are hydrologically better plants for higher stem flow conversion and better soil moisture. Different soil and water conservation measures were effective in incresing soil moisture level and mulching was the best with 26.2% higher moisture over control during post monsoon period (Singh *et al*., 2012). Singh *et al.* (2014) also evaluated the bamboo plantations in Yamuna ravines with soil and water conservation measures. Therefore, proper planning and implementation of soil and water conservation measures are very much needed in the initial period of plantation. The soil and water conservation measures in the initial period of plantation are to reduce the surface runoff thereby reducing the soil loss. Vegetative barrier, cover crop, contour staggered trenches and combination of mechanical measures with any biological measures are some of the conservation measures adopted for controlling surface runoff and soil loss in the initial stages of tea plantation. The CSTs of 180 cm (length) x 30 cm (width) x 45 cm (depth) are usually laid in a staggered manner in the space meant for walking rows. In some locations, vegetative barriers of vetiver, lemon grass, weeping love grass, geranium *etc.* were tried as conservation measures. The effect of conservation measures in actual field condition in new tea plantation has not been well documented. Keeping these in mind, the experiment was carried out to study the conservation efficiency of different bio-engineering conservation measures in the initial stages of tea plantation under different slope ranges in Nilgiris.

2. MATERIALS AND METHODS

Study Area

The experiment was conducted in the farmer's field at Udhagamandalam (11°26'40" N and 76°45'58" E, 2150 m above msl) in Nilgiris district of Tamil Nadu. The climate of the study area is temperate to sub-tropical, rainy with a good tropical sunshine. The long term average annual rainfall is 1276 mm distributed over South-West and North-East monsoons with most of the rainfall concentrated during June to December. The mean monthly maximum and minimum temperatures are 22.1^{0}C and 8.5^{0}C occurring in the months of April and January, respectively with average annual temperature of 15.0^{0}C. Daily mean relative humidity is about 76% most of the time, which is favorable for tea in the region.

The site selected in two slopes range (8-12 and 30-35) in the adjacent sides of same location representing the most commonly practiced slope ranges for tea in the Nilgiris. The area under each slope range was divided into 20 plots (10 x 9 m) to accommodate four treatments and one control plot with four replications. One year old B-6 tea clones were planted before the onset of North-East monsoon during the month of September in humid climate and moist soil for better establishment of young tea plants at double hedge spacing (135 cm x 75 cm x 75 cm) with plant row to row spacing of 65 cm. Four different types of conservation measures *viz.*, CST in each walking rows, VB of geranium in each walking rows, CST and VB of geranium in alternate walking rows, CST with cover crop of beans were taken for experiment (Table 1).

Planting Method

Double hedge planting (135 cm x 75 cm x 75 cm) along the contour line accommodating 13,200 plants ha^{-1} was followed. For alignment on contour, a simple device known as A-frame was used. For laying out the double hedge rows and spacing between plants, a triangular frame of equal length (0.75 m each side) was used. To use this triangular frame, points are marked at each corner of the frame and then it is inverted at the forward toe (Point C) and kept along the line AC to mark the point B again on already marked contour line. Then it is inverted at point B along the line BC, the point A is marked and the entire process is repeated as shown in Fig. 1 and all planting points were marked by pegs followed by planting holes and plantation carried out as

Table: 1
Treatment details with specification of the conservation measures

Treatments	Specification
T_1: CST in each walking rows	180 cm (length) x 30 cm (width) x 45 cm (depth) in each walking rows along the contour.
T_2: VB of geranium in each walking rows	Two rows of geranium plantation at plant to plant and row to row spacing of 30 cm in each walking rows.
T_3: Contour staggered trenches (CST) and VB of geranium in alternate walking rows	Trenches of 180 cm (length) x 30 cm (width) x 45 cm (depth) in the walking rows alternate with two rows VB of geranium at plant to plant and row to row spacing of 30 cm
T_4: CST with cover crop of beans	Trenches of 180 cm (length) x 30 cm (width) x 45 cm (depth) in each walking rows along with beans as a cover crop in the space between the double hedge rows.
T_5: Control	No conservation measures

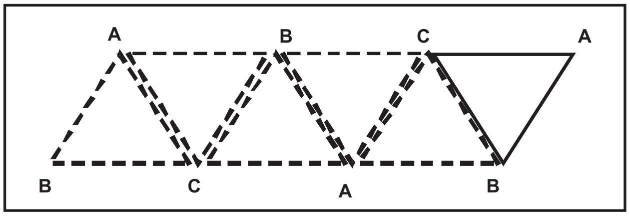

Fig. 1. Double hedge planting

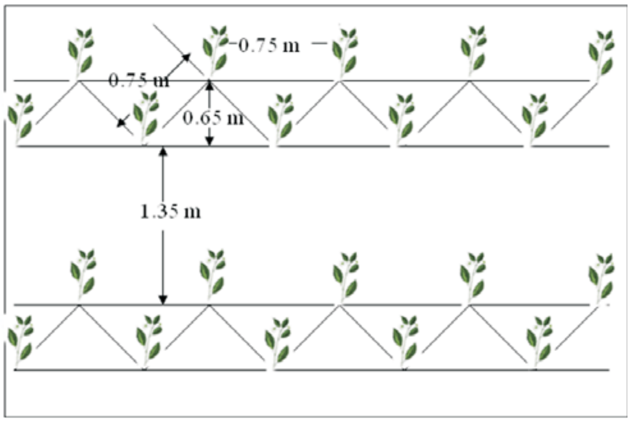

Fig. 2. Layout for the plantation of tea clones

shown in Fig. 2. Planting hole of adequate size (30 cm diameter and 45 cm depth) was made for better establishment of young plants.

Runoff Measurement and Soil Loss Estimation

The multi-slot divisor unit developed by R.V. Geib in U.S.A. (Wasi Ullah *et al*., 1972) was used for the measurement of runoff from the experimental plots. At the down end of the experimental plots, the multi-slot divisor unit consisting of 11 numbers of slots of equal dimensions was installed to monitor runoff. The runoff monitored once in 24 hours at 8.30 a.m. (IST) by measuring the depth of runoff collected in each compartment in the stilling tank as well as in the collecting tank. After all the rainfall events during 24 hours, at 8.30 a.m. (IST), the runoff collected in the stilling and collecting tanks was thoroughly mixed and immediately a representative sample was collected in bottles of 500 ml capacity. The soil was estimated from sample volume of 500 ml runoff water collected from each runoff tank after stirring to determine the silt content. All the runoff water collection units were empitied immediately after measurement of runoff water storage and sampling. Events wise rainfall analysis was made and expressed in mm and t $ha^{-1}yr^{-1}$ for runoff and soil loss, respectively.

3. RESULTS AND DISCUSSION

Rainfall and Runoff

The total quantities of rainfall received during the year 2008 and 2009 are 986 mm and 1212 mm, respectively. The total runoff was less in the first year as compared to the second year among all the treatments under both the slope ranges (8-12 and 30-35%) due to less total rainfall (Table 2). However, the percentage of runoff to rainfall is less in the second year in comparison to the first year in both the slope ranges showing the effect of establishment of conservation measures over time. A minimum runoff of 107.1 mm and 117.2 mm were obtained during 2008 and 2009, respectively under the treatment of CST with cover crop of beans from the slope range 8-12% with average of 112.2 mm. This was followed by the treatment under CST with average runoff of 118.1 mm against the maximum average runoff of 213.1 mm in control during the same period. Remaining two treatments were found to have intermediate effect in controlling the runoff in both the years in the plots under slope of 8-12%. The runoff from all treatments was found significantly different from control whereas it is non-significant between CST and CST with cover crop of beans at 5% level of significance [CD (0.05) =0.658 and 0.729 for 2008 and 2009, respectively] in 8-12% slope for both the years.

A similar trend in average runoff was obtained from the treatments in the higher slope of 30-35%. Average minimum runoff of 136.4 mm was obtained from CST with cover crop of beans followed by CST (152.1 mm) in comparison to average maximum runoff of 252.4 mm in control plot during the same period. The runoff from CST, CST with cover crop of beans and CST alternate with VB were found significantly different from control at 5% level of significance [CD (0.05) =0. 588] during 2008 whereas all

Table: 2
Runoff (mm) under different conservation measures

Year	Rainfall (mm)	Runoff (mm)				
		CST	VB (Geranium)	CST alternate with VB	CST + Beans	Control
			Slope of 8-12%			
2008	986	115.7	164.8	133.3	107.1	197.6
2009	1212	120.4	182.0	147.2	117.2	228.6
Average	1099	118.1	173.4	140.2	112.2	213.1
			Slope of 30-35%			
2008	986	140.5	195.0	159.4	130.2	225.5
2009	1212	163.8	217.5	175.9	142.5	279.3
Average	1099	152.1	206.2	167.6	136.4	252.4

the treatments are significantly different from control [CD (0.05) =0.727] during 2009. Quantities as well as percent of runoff to rainfall (about an average of 4%) were found to be higher from all the treatments as well as control in comparison to the respective treatments in the lower slope range during both the years showing the direct effect of slope in producing runoff. The average runoff data from treatment plots showed the effect of all the conservation measures in reducing the runoff considerably in both the years as compared to the control in both the slope ranges. The effect of conservation measures due to the modification of land surface by trenching and change in land use by cover crop/vegetative barrier helped in retaining a good amount of runoff within the plot could be the main factors in reducing the runoff. However, the variation in the runoff among the treatments is due to the efficiency of the measures. Runoff reduction from control to treated plots was higher in 30-35% slope in comparison to the respective reduction in 8-12% slope showing better efficiency in higher slope.

Soil Loss

The annual soil loss from all treatments and control plots under both the slopes were estimated for the experiment period and presented in Table 3. Higher soil loss was obtained during 2009 as compared to 2008 for all the treatments including control under both the slope ranges. This was due to the fact that in the year 2009, there was higher rainfall as well as higher number of runoff producing rainfall events. However, the soil loss to unit runoff depth was less in the year 2009 in comparison to the same in the year 2008 showing the effect of conservation measures and canopy development. Average annual soil loss is about 25% more in every treatment in the slope of 30-35% against the corresponding treatment in the slope of 8-12% in both the years; may be due to high percent of average runoff (23.7%) in the higher slope in comparison to the lower slope (19.6%) for all treatments. From the statistical analysis, the soil loss from CST and CST with cover crop of beans found significantly different from control as well as remaining treatments at 5% level of significance in all the slopes for both the years.

In 8-12% slope, minimum soil loss was observed in the treatment under CST in both the years with an average value of 4.9 t $ha^{-1}yr^{-1}$ followed by CST with cover crop of beans (5.3 t $ha^{-1}yr^{-1}$). This is in reverse trend to the annual runoff received from these treatments, where minimum runoff was obtained in the plot under CST with cover crop of beans followed by CST as stated earlier. This could be due to the disturbance to the soil surface while taking the cover crop of beans by which the detachment and transportation of the soil from the surface became easier and more in comparison to the one time making of trenches under CST despite less runoff. Due to the cover crop of beans followed by the intercultural operations and uprooting after harvest, the soil became light and porous to retain more rainfall in the plot, there by producing less runoff. However, the soil losses were very less in both the cases in comparison to the remaining treatments. The maximum (10.0 t $ha^{-1}yr^{-1}$) soil loss was obtained in the treatment with VB in spite of maximum runoff in control due to high disturbance to the soil surface while planting followed by intercultural operations and the time required for the establishment of vegetative barrier, therefore found to be relatively less successful from the remaining treatments. But CST alternate with vegetative barrier (7.9 t $ha^{-1}yr^{-1}$) had the intermediate effect in controlling the soil loss could be due to the effect of trenches in the alternate rows rather than much effect from vegetative barriers.

Similar trends with higher quantity of soil loss were observed from all treatments including control under slope of 30-35% in comparison to the respective treatments in slope of 8-12% may be due to accelerated runoff resulting from steeper slope. In this case also, maximum soil loss was also obtained from VB in spite of maximum runoff from control plot due to the same reason as explained earlier. Over the period, it was observed that the establishment of the vegetative barrier was poor and maintenance was difficult due to high slope. Average minimum soil loss over the experimental period was observed in CST (6.9 t $ha^{-1}yr^{-1}$) followed by CST with cover crop of beans (7.3 t $ha^{-1}yr^{-1}$) and CST alternate with

Table: 3
Annual soil loss as influenced by different conservation measures

Year	Soil loss (t $ha^{-1}yr^{-1}$)				
	CST	VB (Geranium)	CST alternate with VB	CST + Beans	Control
			Slope of 8-12%		
2008	4.10	8.30	6.67	4.21	7.23
2009	5.69	11.77	9.25	6.39	10.67
Average	4.89	10.03	7.96	5.30	8.95
			Slope of 30-35%		
2008	6.10	11.56	8.81	6.50	10.60
2009	7.73	14.42	11.00	8.06	14.14
Average	6.92	12.99	9.90	7.28	12.37

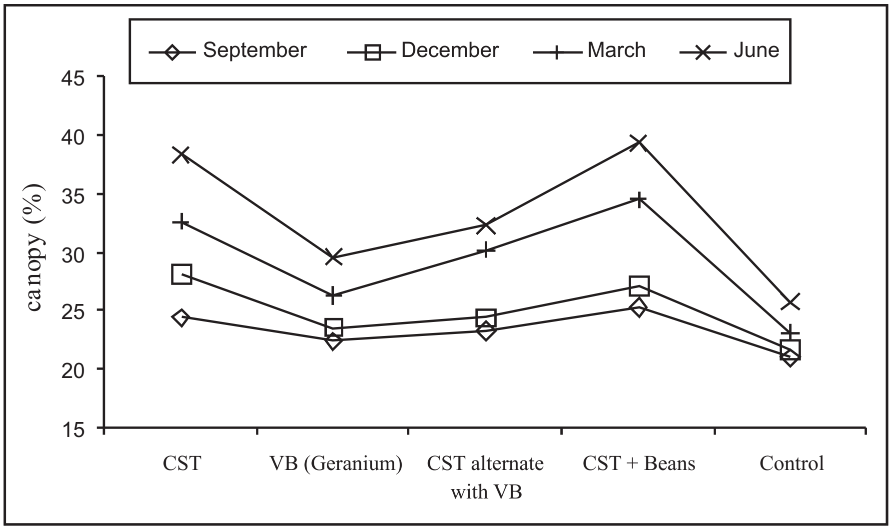

Fig.3. Canopy development in 8-12% slope

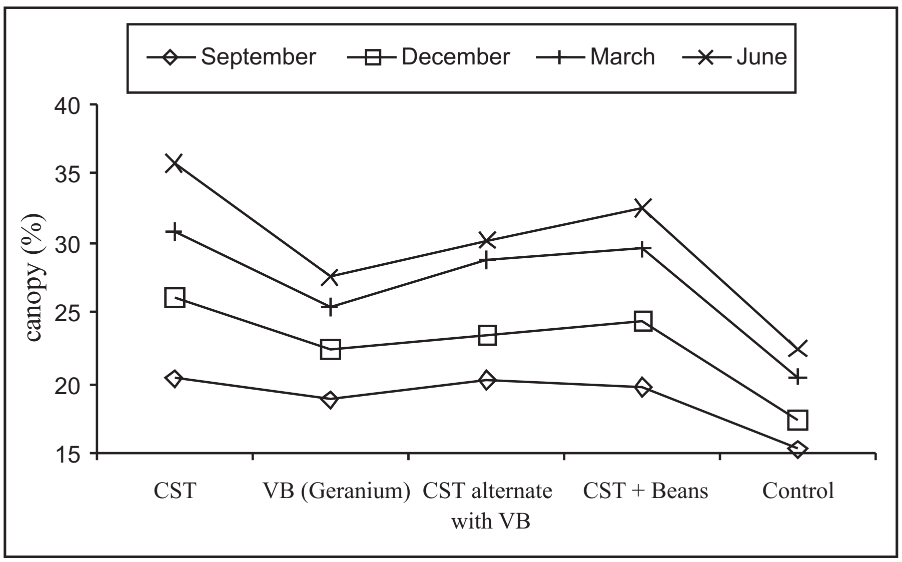

Fig.4. Canopy development in 30-35% slope

vegetative barrier (9.9 t $ha^{-1}yr^{-1}$) which shows that the CST either alone or in combination with the vegetative measures like cover crop of beans is the best in reducing soil loss when compared to other treatments.

Canopy Development

Canopy, during the experimental period, was recorded at every three months from all the treatments including control plots under both the slopes. Minimum variation in tea canopy among the treatments was observed in the first year during monsoon and immediate after which may be due to the availability of enough soil moisture irrespective of any treatment effect in the slope range of 8-12%. Afterwards, the variation in canopy due to treatment effect was realized. In the March, the maximum canopy (34.5%) was observed in the CST with cover crop of beans followed by CST (32.7%) with minimum in control and the same trend continued till June and up to first harvest (Fig. 3). From the statistical analysis, the tea canopy from all treatments was found significantly different from control at 5% level of significance [CD (0.05) =1.79)]. Unlike the observations made in the slope range of 8-12%, there was considerable variation in tea canopy between the control and remaining treatments from the beginning of the observation in slope range of 30-35%. But within the extent of monsoon, variation was less among the treatments which widened afterwards. Maximum canopy was observed in CST (35.6%) followed by CST with cover crop of beans may be due to the repeated disturbance while taking beans hampering the growth (Fig. 4).

4. CONCLUSIONS

Minimum runoff was obtained in the treatment of CST with cover crop of beans followed by CST with intermediate effect in CST alternate with vegetative barrier and vegetative barrier in controlling the runoff in both the slope ranges of 8-12 and 30-35%. However, quantities as well as percent of runoff to rainfall (about an average of 4%) were found to be higher from all the treatments in the slope of 30-35% in comparison to the respective treatments in the slope of 8-12% during both the years, showing the direct effect of slope in producing runoff. The effect of conservation measures due to the modification of land surface by trenching and change in land use by taking cover crop of beans as well as vegetative barrier helped in retaining a good amount of runoff within the plot could be the main factors in reducing the percentage of runoff in all treatments. There is about 25% increase in average annual soil loss over all treatments in the plots under slope of 30-35% than the plots in the slope of 8-12% may be due to high percent runoff (23.7%) in the higher slope in comparison to the lower slope (19.6%) over all treatments. There is significant difference in canopy development between control and treatments under both slope ranges showing the effect of conservation measures in the beginning of the tea plantation for proper establishment of tea.

REFERENCES

Ali, M.H. and Talukder, M.S.U. 2008. Increasing water productivity in corn production-A synthesis. *Agric. Water Manage.*, 95: 1201-1213.

Barua, D.N. 1989. Science and practices in tea culture. Tea Research Association, Calcutta- Jorhat, India, 493 p.

Chinnamani, S. 1977. Soil and water conservation in the hills of Western Ghats. *Soil Cons. Digest*, 5(1): 25-33.

Doorenbos, J. and Pruitt, W.O. 1977. Crop water requirement. Irrigation and Drainage Paper No.24 (revised). Rome, Italy: FAO.

Falkenmark, M. and Rockström, J. 2004. Balancing water for humans and nature: The new approach in ecohydrology. London, UK: Earthscan.

Krishnarajah, P. 1985. Soil erosion control measures for tea land in Sri Lanka. *Sri Lanka J. Tea Sci.*, 54(2): 91-100.

Madhu, M. and Tripathi, K.P. 1997. Soil and water conservation practices in tea at Nilgiris: some facts. *Indian Farm.*, 47(1): 33-36.

Madhu, M. and Sahoo, D.C. 2009. Rain water use efficiency of tea under different conservation measures in high hills of South India. In: 4th World congress on conservation agriculture, New Delhi. 211 p.

Manivannan, S. and Desai, A.R. 2007. Effect of in-situ moisture conservation practices on runoff, soil loss and initial growth of cashew (*Anacardium occidentale*). *Ind. J. Soil Cons.*, 35(2): 147-150.

Othieno, C.O. 1992. Soils. *In: Tea: Cultivation to consumption* (eds. K.C. Wilson and M.N. Clifford). Chapman & Hall, London, pp. 137-172.

Rao, B.K., Kurothe, R.S., Pande, V.C. and Kumar, Gopal. 2012. Throughfall and stemflow measurement in bamboo (*Dendrocalmus strictus*) plantation. *Ind. J. Soil Cons.,* 40(1): 60-64.

Rao, B.K., Gaur M.L., Kumar, Gopal, Kurothe, R.S. and Tiwari, S.P. 2013. Morphological Characterization and Alterations in Cross Section of Different Order Streams of Mahi Ravines. *Ind. J. Soil.Cons*., 41(1): 20-24.

Singh, A.K., Kala, S., Dubey, S.K., Rao, B.K., Gaur, M.L., Mohapatra, K.P. and Prasad, B. 2014. Evaluation of bamboo based conservation measures for rehabilitation of degradedYamuna ravines. *Ind. J. Soil Cons*., 42(1): 80-84.

Singh, R.K., Singh, B.P., Baboo, B. and Balram, S. 2012. Growth and biomass of ber (*Ziziphus mauritiana*) as influenced by various soil conservation techniques under rainfed condition. *Ind. J. Soil Cons*., 40(1) : 90-94.

Wasi Ullah, Gupta, S.K. and Dalal, S.S. 1972. Hydrological Measurements for watershed Research. Jugal Kishore and Co., Rajpur Road, Dehradun, India.