



Soil microbial community structure and system productivity in Aonla (*Emblia officinalis*) based hortipasture system

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Received: 10th January, 2012

Accepted: 20th June, 2012

Abstract

Interaction of different soil moisture conservation technique (MCT) and pasture species *i.e.* *Cenchrus ciliaris* and *Stylosanthes seabrana* productivity as well as growth stage and soil microbial community structure were studied. In hortipasture system, pasture species had direct impact on soil microbial community structure. Among soil MCT, contour staggered trench was significantly better in conserving soil moisture (5.38 and 4.28 %) at 15-30 and 0-15 cm depth and yielded higher forage (8.28t/ha) of *Cenchrus ciliaris* and maximum soil microbial population (7.70, 106.40 and 91.68) $\times 10^5$ cfu/g soil of fungi, bacteria and actinomycetes respectively. Higher microbial, fungi, bacteria and actinomycetes population was recorded with rhizospheric soil of *C. ciliaris*, while rhizosphere soil of *S. seabrana* had lowest microbial population. Active growth stage (sprout to flower initiation) of all crops significantly had higher soil microbial population than dormant stage. Soil moisture content due to different soil MCT also had significant effect on soil microbial population in all the crops.

Key words: Fodder, Hortipasture, Leaf litter, Microbial community, Primary production, Range grasses, Range legume, Rhizosphere, Staggered trench

Introduction

Aonla (*Emblia officinalis* Gaertn) is an important fruit crop of semi-arid region of India and identified as potential hortipasture system for semi arid region. Soil microorganisms (fungi and bacteria) play a fundamental role in driving nutrient cycling and carbon turn over in all terrestrial ecosystem and are very much affected by changes in land use, soil cover and management practices. Productivity and stability of soils as a medium for plant growth depend greatly on the balance between living and nonliving components.

Agricultural practices alter soil microbial biomass (Franzluebbers *et al.*, 1995) and soil microbial community composition (Caldero'n *et al.*, 2000). Biological activity indicates the potential of soil to support biochemical processes, which are essential for maintaining soil fertility (Makoi and Ndakidemi, 2008). Plants are an important determinant of soil microbial communities. The soil microbial biomass (fungi and bacteria) is involved in transformation of C within soil with variable capacity. Fungi have hyphae that allow them to move, colonize and degrade more surface litters than that of soil bacteria. Microbial characteristics of soils are sensitive indicators of soil health because of the clear relationships between microbial diversity, soil and plant quality, and ecosystem sustainability (Doran *et al.*, 1994). In terrestrial ecosystems, the above and belowground plant-litter input constitutes the main resource of energy and matter for an extraordinarily diverse community of soil organisms connected by highly complex interactions. Recycling of carbon and nutrients during decomposition is a fundamentally important ecosystem process that has major control over the carbon cycle, nutrient availability and consequently plant growth and community structure (Bardgett, 2005). The introduction of plants to soil affects the physico-chemical properties and the biological parameters of the soil environment close to the growing roots (Hinsinger *et al.*, 2006). The rhizodeposition of nutrients by plant roots supports increased microbial growth (Mougel *et al.*, 2006). Plant species and seasonal changes affect the indigenous bacterial soil communities (Costa *et al.*, 2006) and function of fungal communities (Mougel *et al.*, 2006). The effect of plant developmental stage on rhizosphere microbial communities has not been so widely investigated. The change from young seedling, flowering to senescence may influence the microbial community structure. A strong need exists for increased efforts to investigate the diversity of soil microbes for the

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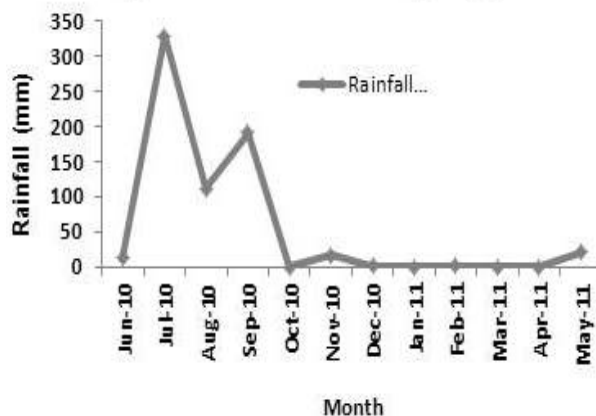
functional significance of litter decomposition in the system for long-term sustainability. While the understanding of microbial properties such as biomass, activity and diversity are important to further increase knowledge of the factors contributing to soil health, results of such analyses may be useful to extension personnel and farmers in devising practical measures of soil quality. The overall objective of this study was to determine how quality and quantity of plant litter inputs and different soil moisture techniques affecting soil microbial community structure and system productivity in aonla based hortipasture system.

Materials and Methods

Study was conducted at Central Research Farm of Indian Grassland and Fodder Research Institute Jhansi (longitude 25° 26' 08" N, latitude 78°, 30' 21" E and altitude 216 m above msl) during 2010-2011 in aonla based hortipasture system. Grafted plants of aonla 'NA7' were planted during 2007 at 8 x 8 m in 1 m³ pit, filled with soil + 30 kg farmyard manure. The soil was clay loam; containing 38.55% clay, 32.5% sand and 29.5% silt with around 2 m depth. The initial soil composition was poor in available N (140-148 kg/ha), P (3.8-4.1 kg/ha) and K (110.7 kg/ha), low in organic carbon (0.42%), almost neutral in pH (6.54). The plot size was 40 m x 24 m having 15 trees /plot (8m x 8m). The inter spaces between aonla plants was transplanted with rooted slips of *C. ciliaris* maintaining 100 cm row spacing and 30 cm plant to plant. One row of *S. seabrana* between two rows of *C. ciliaris* was sown in alternate row. Five treatments were tested in RBD. T₁: Contour staggered trenches (3 x 0.5 x 0.5m) with catchment of 25 sq. m.; T₂: Continuous contour trench of 0.5 x 0.5 m with storage capacity of 0.25 m³ (PRM) made at 5 m interval; T₃: Deep basin stone mulch, in a basin diameter of 1.5 m with storage depth of 0.4 m with 0.1m thickness of stone mulch; T₄: Vegetative barrier, transplanting of two rows of *Panicum maximum* at 50 cm spacing in criss cross between two rows of aonla and T₅: control without any moisture conservation technique. The weather parameter during the experiment period were collected (Fig -1) from meteorological observatory of IGFRI, Jhansi. The data regarding aonla plant growth parameter (height, collar diameter and canopy spread) in cm, forage yield (q/h) and soil microbial population of (fungi, bacteria and actinomycetes) soil in the rhizosphere of each crop at three growth stages (active growth, senescence and dormant) was recorded. Soil moisture (%) of each soil moisture conservation treatment was measured from pooled soil samples from all four sides for two months October and

November of 2010 at two depths (0-15 and 15-30 cm). Soil microbial count in term of colony forming unit (cfu)/g of rhizosphere soil of each crop from each treatment was done following serial dilution and plate count methods (Diaz-Ravina *et al*, 1992). All the data recorded were statistically analyzed using statistical package SAS 9.2.

Fig-1 Rainfall distribution during study period



Results and Discussion

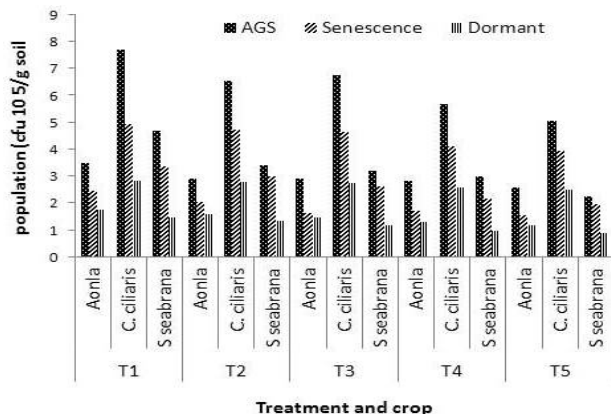
Effect of moisture conservation: All the moisture conservation treatments were significantly better than control to conserve per cent soil moisture after monsoon at both the soil depth. Among four MCT, contour staggered trench had maximum soil moisture content 4.28 percent at 0-15 cm and 5.38 per cent at 15.30 soil depth respectively during October 2010 and it was significantly better in conserving soil moisture and conserved nearly double the control (2.11 percent at 0-15 cm and 15-30cm soil depth). Continuous contour trench had soil moisture content 3.96 per cent at 0-15 cm and 4.82 percent at 15-30 cm soil depth, deep basin stone mulch (3.05 per cent at 0-15 cm and 4.67 percent at 15-30 cm soil depth) and vegetative barrier (2.83 per cent at 0-15 cm and 3.64 percent at 15-30 cm soil depth) respectively.

Effect of system productivity: Aonla plant growth and fodder productivity: Plant height, collar diameter and canopy spread were significantly higher in all the MCT than control treatment in both the year (2010 and 2011) of observation. Maximum plant height, collar diameter and canopy spread were (280.9 cm, 7.57 cm and 245.2 cm) with contour staggered trench respectively. Similarly, pasture production from two cuts from both the pasture species *i.e.* *C. ciliaris* and *S. seabrana* in term of dry matter (t/ha) was also significantly higher under all MCT plots than control. Maximum total pasture from both the cuts of both species was 8.28 t/h obtained from contour staggered trench followed by continuous contour, deep

basin stone mulch and vegetative barrier (7.27, 6.77 and 5.94) t/ha respectively. However, in control plot where rainwater was allowed to flow naturally, pasture production was only 4.07 t/ha during 2010-11. Soil moisture is a limiting factor for low productivity in arid and semi arid condition. Higher productivity in MCT plots might be due to soil moisture for longer period in the MCT plots supports the growth for long duration of pasture species. Extended growth period, receipt more sunlight and allow the crop to more photosynthesis and increases in their biological yield.

Effect on soil microbial population: Rhizosphere microbial population (fungi, bacteria and actinomycetes) 10^5 cfu/g soil was also significantly changed due to different soil MCT, crops and their growth stages. The higher fungal population (7.70, 4.70 and 3.53) $\times 10^5$ cfu / g soil was recorded with crops *C. ciliaris*, *S. seabrana* and aonla respectively in contour staggered trench at active growth stage, which was significantly higher than control (5.09, 2.27 and 2.59) $\times 10^5$ cfu / g soil and other MCT also (Fig 2a). The MCT and crop species of the aonla system influenced the fungal population in the rhizosphere soil of respective crop species individually and with interaction of its growth stages. In general, higher population of fungi was recorded with fodder species than tree. Fungal population in the rhizosphere soil varied with different MCT and crop with their growth stage. Fungal count was $1.79 - 2.60 \times 10^5$ cfu in aonla, $3.86 - 5.18 \times 10^5$ cfu in *C. ciliaris* and $1.72 - 3.19 \times 10^5$ cfu in *S. seabrana* rhizosphere soil (Table 1a). The fungal population declined significantly from active growth stage to senescence and the dormant stage, minimum being with aonla followed by *S. seabrana* and *C. ciliaris* in dormant stage and varied from $1.49 - 2.98 \times 10^5$ cfu, $1.19 - 3.31 \times 10^5$ cfu and $2.71 - 6.26 \times 10^5$ cfu respectively (Table-1c).

Fig.2a Effect of MCT and crops on fungal population



Similarly, bacterial and actinomycetes population were also influenced with different soil MCT, crop species, and their growth stage (Fig 2b and 2c). Higher count (106.40×10^5 cfu) and (32.63×10^5 cfu) /g soil population was recorded with *C. ciliaris* followed by *S. seabrana* (94.62×10^5 cfu and 90.61×10^5 cfu) and aonla (46.92×10^5 cfu and 32.63×10^5 cfu) of bacteria and actinomycetes population respectively at active growth of crops. It varied from lower to higher as (90.11 - 106.40 and 54.97 - 66.59) $\times 10^5$ cfu/ g soil, (78.13 - 94.62 $\times 10^5$ cfu and 75.51 - 90.63 $\times 10^5$ cfu) and (34.02 - 46.92 $\times 10^5$ cfu and 22.49 - 32.63 $\times 10^5$ cfu) with different MCT treatment at active growth of crops. Declined trend in bacterial and actinomycetes population was similar to fungal population and minimum population recorded when crops become dormant (Table- 1b and 1c).

Fig 2b Effect of MCT and crop on bacterial population

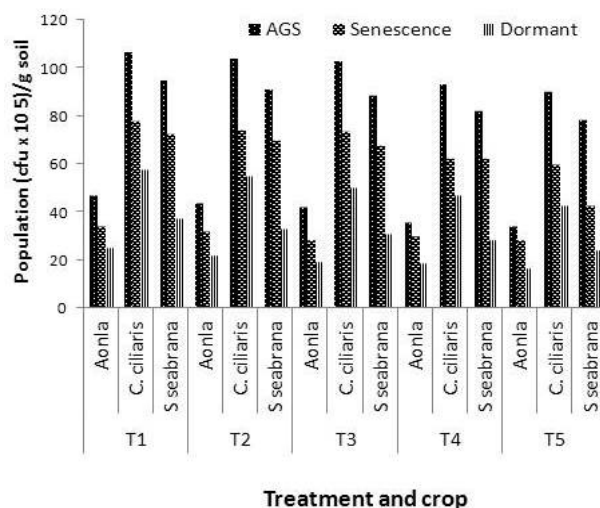
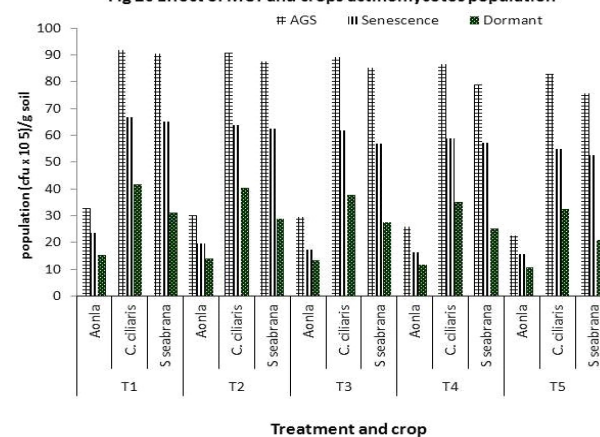


Fig 2c Effect of MCT and crops actinomycetes population



T1= Contour staggered trenches, T2= Continuous contour trench, T3= Deep basin stone mulch, T4= Vegetative barrier, T5= Control (without moisture conservation), MCT= Moisture conservation technique

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Table 1a. Effect of treatment and crop on microbial population

Treatment	Population of microbes x 10 ⁵ /g rhizosphere soil			
	Crop	Fungi	Bacteria	Actinomycetes
T ₁	<i>C. ciliaris</i>	5.18	80.48	66.61
	<i>S.seabrana</i>	3.19	68.07	62.31
	aonla	2.60	35.16	23.86
T ₂	<i>C. ciliaris</i>	4.71	77.48	64.98
	<i>S.seabrana</i>	2.61	64.43	59.59
	aonla	2.21	32.37	21.23
T ₃	<i>C. ciliaris</i>	4.55	74.17	62.87
	<i>S.seabrana</i>	2.37	60.39	57.17
	aonla	2.12	29.84	19.72
T ₄	<i>C. ciliaris</i>	4.14	67.57	60.07
	<i>S.seabrana</i>	2.07	57.29	53.72
	aonla	1.98	27.76	17.92
T ₅	<i>C. ciliaris</i>	3.86	64.05	56.73
	<i>S.seabrana</i>	1.72	48.11	49.57
	aonla	1.79	26.10	16.21
	CD > 0.05	0.41	04.69	04.20

Table 1b. Effect of treatment and crop growth stage on microbial population

Treatment	Growth stages	Population of microbes x 10 ⁵ /g rhizosphere soil		
		Fungi	Bacteria	Actinomycetes
T ₁	Active growth stage	5.31	82.65	71.64
	Senescence	3.61	61.32	51.76
	Dormant	2.04	39.75	29.38
T ₂	Active growth stage	4.32	79.39	69.49
	Senescence	3.29	58.39	48.55
	Dormant	1.93	36.49	27.75
T ₃	Active growth stage	4.12	75.68	67.14
	Senescence	3.09	55.53	46.46
	Dormant	1.83	33.19	26.16
T ₄	Active growth stage	3.85	70.22	63.73
	Senescence	2.68	51.48	44.11
	Dormant	1.65	30.93	23.86
T ₅	Active growth stage	3.31	67.42	60.28
	Senescence	2.50	43.39	40.97
	Dormant	1.55	27.45	21.27
	CD > 0.05	0.24	02.71	02.42

T1= Contour staggered trenches, T2= Continuous contour trench, T3= Deep basin stone mulch, T4= Vegetative barrier, T5= Control (without moisture conservation), MCT= Moisture conservation technique

Interaction effect of different soil MCT, fodder production and crop growth stages on soil microbial population was also significant. Different soil MCT, higher pasture production and crop growth stages influenced rhizospheric microbial population directly or indirectly in many ways. The reason may be water conservation for longer period, which support the growth and sporulation (particularly) in fungi or microbes in the soil. Higher plant growth supported by MCT influence root exudation, includes the

secretion of ions, free oxygen and water, enzymes, mucilage, and a diverse array of carbon-containing primary and secondary metabolites (Uren, 2000) in the rhizosphere which were ultimately utilized by soil microbes. Plant litter has long been recognizing as one of the important drivers of terrestrial ecosystem processes. Decomposition process brings about change in chemical constituents of organic matter that determines the species composition of successive colonize and this trend

continues until organic substrates are mineralized. Microbial activity is influenced by soil management, soil nutrition, plant litter, rhizosphere effect, and abiotic environment (Steenseth *et al.*, 2003). Hossain, *et al.*, (2010) also reported that litters from different grassland species influence the microbial population in the soil. These decomposer fungi play a vital role in maintaining the fertility and sustainability in the tropical forests. Sharma *et al.*, (2011) reported from natural and managed forest from Northeastern India that managed practices influenced the fungal species and species richness.

Host trees can modify their soil abiotic conditions through their leaf fall quality which in turn may influence the fungal community composition. Similarly, plants create positive feedbacks to nutrient cycling because of species differences in carbon deposition and competition with microbes for nutrients. Physiological traits such as relative growth rate (RGR) and specific leaf area (SLA) have been linked to the success of plant growth and to soil biota (Singh, *et al.*, 2009). They also reported presence of plants resulted in a significant increase in soil moisture content, supports growth in soil microbial communities but also influences soil abiotic properties.

Table 1c. Effect of crop and crop growth stages on microbial population

Crop	Crop growth stage	Population of microbes x 10 ⁵ /g rhizosphere soil		
		Fungi	Bacteria	Actinomycetes
<i>C. ciliaris</i>	Active growth stage	6.26	99.00	88.16
<i>C. ciliaris</i>	Senescence	4.48	68.88	61.20
<i>C. ciliaris</i>	Dormant	2.71	50.36	37.39
<i>S. seabrana</i>	Active growth stage	3.31	86.26	83.44
<i>S.seabrana</i>	Senescence	2.67	62.34	59.30
<i>S.seabrana</i>	Dormant	1.19	30.39	26.68
Aonla	Active growth stage	2.98	39.96	27.77
Aonla	Senescence	1.95	30.84	18.61
Aonla	Dormant	1.49	19.94	12.98
	CD \geq 0.05	0.18	02.10	01.88

Conclusions

From the findings of present study on effect of different soil moisture conservation techniques on production potential of under story pasture species and aonla plant growth and their influence on soil microbial community in aonla based hortipasture system, it can be concluded that soil moisture techniques help in higher fodder production and aonla growth. Similarly, the forage crops growth also enhances the microbial population directly and indirectly.

References

- Bardgett, R. D. 2005. *The biology of soil: A community and ecosystem approach*. Oxford: Oxford Univ. Press. 253 pp.
- Caldero'n, F. J., L. E. Jackson, K. M. Scow and D. E. Rolston. 2000. Microbial responses to simulated tillage and in cultivated and uncultivated soils. *Soil Biology & Biochemistry* 32: 1547–1559.
- Davies, R. J., A. C. Mathers, B. A. Stewart. 1980. Microbial populations in Pullman clay loam receiving large applications of cattle feedlot waste. *Soil Biol. Biochem.* 12: 119-124.
- Diaz-Ravina, M., M. J. Acea and T. Carballas. 1992. Seasonal fluctuation in microbial populations and available nutrients in forest soil. *Biol. Fert. Soils.* 16: 205-210.
- Doran, J. W., D. C. Coleman, D. F. Bezdicek and B. A. Stewart. 1994. *Defining Soil quality for a sustainable environment*. American Society of Agronomy, SSSA Special Publication No. 35, Madison, WI.
- Franzluebbers, F., F. M. Hons, D. A. Zuberer. 1995. Tillage and crops effects on seasonal soil carbon and nitrogen dynamics. *Soil Science Society of America Journal* 59: 1618–1624
- Grayston, S. J., G. S. Griffith, J. L. Mawdsley, C. D. Campbell, and R. D. Bardgett. 2001. Accounting for variability in soil microbial communities of temperate upland grassland ecosystems. *Soil Biol. Biochem.* 33: 533–551.
- Hinsinger, P., C. Plassard and B. Jaillard. 2006. Rhizosphere: a new frontier for soil biogeochemistry. *J Geochem Explor.* 88: 210–213.
- Hossain, M. Z., Okubo Atsushi and Shu-ichi Sugiyama. 2010. Effects of grassland species on decomposition of litter and soil microbial communities. *Ecol Res.* 25: 255–261

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- Mougel, C., P. Offre, L. Ranjard, T. Corberand, E. Gamalero, C. Robin and P. Lemanceau. 2006. Dynamic of the genetic structure of bacterial and fungal communities at different developmental stages of *Medicago truncatula* gaertn. cv. jemalong line J5. *New Phytol.* 170: 165–175.
- Singh, B. K., L. A. Dawson, C. A. Macdonald and S. M. Buckland. 2009. Impact of biotic and abiotic interaction on soil microbial communities and functions: A field study. *Applied soil ecology.* 41: 239 – 248
- Steenserth, K. L., L. E. Jackson, F. J. Calderon, M. R. Stromberg, and K. M. Scow. 2003. Microbial community composition and land use history in cultivated and grassland ecosystems of coastal California. *Soil Biology & Biochemistry* 35: 489–500.
- Uren, N. C. 2000. Types, amounts and possible functions of compounds released into the rhizosphere by soil grown plants. In *The Rhizosphere: Biochemistry and Organic Substances at the Soil Interface*, ed. R Pinton, Z Varanini, P Nannipieri. pp. 19–40. New York: Marcel Dekker.