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Influence of Bund Planted Teak (*Tectona grandis*) on Soil Biological properties in Agroforestry System

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ABSTRACT: An investigation was carried out to assess the directional and spatial influence of bund planted teak trees on chickpea grown in association during 2020-21 in Northern Dry Zone (Zone III) of Karnataka, India. The results revealed significant positive improvement in soil biological properties in teak-based bund planting as compared to control (without trees). Significantly higher population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering (75.63 × 10^6 cfu g^{-1} soil, 45.23 × 10^3 cfu g^{-1} soil, 33.82 × 10^2 cfu g^{-1} soil and 28.10 µg TPF g^{-1} soil for 24 hours, respectively) were recorded on western direction (M_2) followed by northern direction, and significantly lower population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering (71.93 × 10^6 cfu g^{-1} soil, 39.70 × 10^3 cfu g^{-1} soil, 30.83 × 10^2 cfu g^{-1} soil, and 25.21 µg TPF g^{-1} soil for 24 hours, respectively) were recorded on southern direction (M_4) and were comparable with the eastern direction. Bund planting improved soil biological properties when compared with control. Further, positive influence of trees up to an extant of 17 m was noticed. Hence, it is suggested to have bund planting of teak at intervals of 20 m distance in the field.

Keywords: Bund planting, distance, direction, shade, light intensity and soil temperature.

INTRODUCTION

Intensive agriculture simplified the traditional agro-ecosystems by replacing the diversified biological organisms into dominated mono-system with high external inputs of energy, irrigation, agrochemicals and machinery (Tilman *et al.,* 2001). However, practice of intensive agriculture in short period helped to meet-out global food demand by increasing plant productivity per unit area but at the cost of sustainability and environment (Moss, 2008; Potts *et al.,* 2010). Thus, simplified agriculture had a deleterious effect on loss of biodiversity, water quality, health, pollution and degradation of soil.

Soils are degrading at a far faster rate, and in certain cases, soils have become infertile as a result of excessive use of synthetic fertilizers, unscientific irrigation management and use of heavy machineries. Further, lower addition of organic matter to the soil altered the soil properties which questioned the agricultural sustainability. Soils are being source of nutrients, water retention, gas exchange and shelter for large population of biological community that helps in the promotion of plant growth. Hence, to achieve sustainability in agriculture, sustained use of soil has become necessary. In this context, tree-based land-use systems getting much wider attention by both farmers and scientific communities (Chittapur and Patil 2017) and are often called as agroforestry systems. Such systems are dynamic, ecological based and natural resource management systems that improve the socioeconomic condition of the farmers by diversified and sustained production and ecological condition of the area by improving soil fertility (Jose, 2009; Chittapur and Patil 2017).

MATERIALS AND METHODS

The present investigation was carried out on farmer's field in Koppal district of Karnataka, India during 2020-21. The study site was located at 15°09' N and 76°47' E at an altitude of 572 m above mean sea level and falls under agro-climatic zone-III of Karnataka. Although the average annual rainfall of the experimental site is 11.0 mm, during the period of experimentation (2020-21), the mean annual rainfall received was 603.40 mm and the average monthly minimum and maximum temperatures were 20.42 and 32.22^{o}C, respectively. The average relative humidity fluctuated between 25.41 to 55.91 per cent.

Further, majority of the soils in the zone are deep black cotton to black soils, red soils and red sandy loamy soils are also found in some pockets. However, the soil of the study site was red sandy loam belonging to *Alfisol* with low to medium nutrients.

The farmer retained teak (*Tectona grandis*) trees on the bund perfectly in two directions *i.e.* North-South direction and East-West direction with 40 trees in each direction in a length of 120 and 115 m, respectively and the average age of the trees was 10 years. The experiment was laid out in a split plot design with three replications and 12 treatment combinations with selective randomization with one outside control (without trees). Further, directions from tree line (E-Eastern direction, W- Western direction, N- Northern direction and S- Southern direction) formed the main plots and distances from tree line (S_1- 2.0 to 7.0 m, S_2- 7.0 to 12.0 m and S_3- 12.0 to 17.0 m) formed the sub-plots.

The rhizosphere soil samples collected from experimental site were analyzed for different soil microorganisms (Bacteria, Fungi and Actinomycetes) by serial dilution and plating techniques using specific media (Table 1).

Table 1: Specific media used for enumeration of soil microorganisms.

	Group of microorganisms	Media used
1.	Bacteria (× 10^{6} cfu g^{-1} soil)	Nutrient agar
2.	Fungi (× 10^{4} cfu g^{-1} soil)	Martin's Rose Bengal agar
3.	Actinomycetes (× 10^{4} cfu g^{-1} soil)	Kusters agar

Estimation of dehydrogenase activity. Dehydrogenase activity in the soil samples was determined by the procedure described by Casida *et al*. (1964).

Light intercepted by chickpea below the tree canopy was measured with Lux meter at different distances and timings of chickpea and also soil temperature was measured with the help of soil thermometer at different distances and timings of chickpea.

Data from crop were analysed and interpreted following Fisher's method of analysis of variance of a split plot design at probability level of 0.05 using Microsoft Excel 2010 (Panse and Sukhatme 1967). The variance in split plot design were divided into the main plot (Factor Direction), sub plot (Factor Distance) and interaction (Direction × Distance), main plot analysis was computed using product of replication and main factor. Similarly sub plot analysis was computed by the product of replication and sub factor, the interaction analysis was computed by the product of main factor and sub factor at level of significance (P-0.05). Further, to know the difference between means post hoc test was performed by using Duncan's Multiple Range Test (DMRT) at probability level of 0.05 using M-STAT software. In the study, only third order interactions were considered for interpretation. The data were also subjected to't' test where the means of main factor, sub factor and interactions were compared with outside control at probability level of 0.05.

RESULTS AND DISCUSSION

The biological properties of soil comprising population of bacteria, fungi, actinomycetes and dehydrogenase activities at crop stage of 50 per cent flowering were analyzed and were found significantly differing with direction and distance and are presented in Table 2. Significantly higher population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering (75.63×10^{6} cfu g^{-1} soil, 45.23×10^{3} cfu g^{-1} soil, 33.82 × 10^{2} cfu g^{-1} soil and 28.10 µg TPF g^{-1} soil for 24 hours, respectively) were recorded on western direction (M_2) followed by northern direction. However, significantly lower population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering (71.93 ×10^{6} cfu g^{-1} soil, 39.70 × 10^{3} cfu g^{-1} soil, 30.83 × 10^{2} cfu g^{-1} soil, and 25.21 µg TPF g^{-1} soil for 24 hours, respectively) were recorded on southern direction (M_4) and were comparable with the eastern direction. The higher population could be attributed to higher canopy of trees on this direction which in turn added more organic matter and higher shade might have created lower soil temperature and higher moisture.

The spatial effect of trees on the microbial population also revealed significant differences. Significantly higher population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering (80.11 × 10^{6} cfu g^{-1} soil, 50.70 × 10^{3} cfu g^{-1} soil, 36.39 × 10^{2} cfu g^{-1} soil and 29.41 µg TPF g^{-1} soil for 24 hours, respectively) were recorded near the tree line of 2.0-7.0 m (S_1) and they decreased with the increase in distance. Whereas, significantly lower population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering (67.34×10^6 cfu g^{-1} soil, 35.52×10^3 cfu g^{-1} soil, 28.85×10^2 cfu g^{-1} soil and 24.59 µg TPF g^{-1} soil for 24 hours, respectively) were recorded at far away distance from the tree line of 12.0-17.0 m (S_3). This could be attributed to more of organic matter and differential microclimate near the tree as compared to far away from the tree and control (without trees). Similarly, Rajendra and Mertia (2005) observed higher dehydrogenase activity (9.5 to 16.8 ~p kat g^{-1} soil), root colonization (58.3 to 68.5 %) and spore density (132.5 to 234.7 spores 100 g^{-1} soil) in tree rhizosphere as compared to that of non-rhizosphere (7.4 ~p kat g^{-1} soil, 37.7 % and 44.4 spores 100 g^{-1} soil). Srinivasan and Mohan (2006) observed higher (64 %) bacterial population followed by actinomycetes (23 %) and fungi (13 %) in different soil samples in an agroforestry system as compared to the agricultural system.

Similarly, the microbial population differed significantly due to interactional effect of distance and direction. Significantly, higher population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering (82.70×10^6 cfu g^{-1} soil, 54.30×10^3 cfu g^{-1} soil, 37.99×10^2 cfu g^{-1} soil and 31.61 µg TPF g^{-1} soil for 24 hours, respectively) were recorded near the tree line on western direction (M_2S_1) followed by northern and eastern direction at similar distance. However, significantly lower population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering (66.20×10^6 cfu g^{-1} soil, 33.30×10^3 cfu g^{-1} soil, 27.59×10^2 cfu g^{-1} soil and 23.80 µg TPF g^{-1} soil for 24 hours, respectively) were recorded at far away from the tree line on southern direction (M_4S_3) and were comparable with northern and eastern direction at similar distances. Further, the study also showed significantly higher population of bacteria, fungi, actinomycetes and dehydrogenase activity at crop stage of 50 per cent flowering averaged over distance and direction as compared to the control. This may be due to higher organic matter and differential microclimate under teak based chickpea system as compared to sole chickpea. The results are in concurrence with Doddabasawa *et al.* (2018) who reported significantly higher populations of bacteria, fungi and actinomycetes in neem-based pigeonpea agroforestry systems as compared to sole pigeonpea. Similarly, Honnayya *et al.* (2020) observed significantly higher population of bacteria, fungi and actinomycetes and dehydrogenase activity (85.3×10^6, 56.7×10^3, 36.5×10^2 cfu g^{-1} and 30.2 µg TPF g^{-1}, respectively) on western direction near tree line and they decreased with increase in distance from the tree line. Bund planting improved soil bio-chemical properties when compared to control.

It can be affirmed that soil microbial population (Table 2) mostly followed soil organic matter contents and moisture thereon. Organic matter/moisture being more near the tree line (2.0-7.0 m) due to leaf shedding and creation of microclimate by shading effect of trees which favored microbial population and consequently helped in the release of more available soil nutrients. Similar view is also expressed by few researchers who reported greater microbial biomass and diversity in agroforestry system due to ameliorative effects of trees, organic matter inputs and root exudates (Gomez *et al*., 2000; Myers *et al*., 2001; Mungai *et al*., 2005).

The results on the measurement of light intensity at different growth stages and at different timings are presented in Table 3. The maximum light intensity at 30 DAS (627, 2710 and 697 kLux, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded on southern direction and were on par with northern and eastern direction. However, significantly lower light intensity (553, 2530 and 630 kLux, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded on western direction, similar trend was noticed at 60 and 90 DAS. This is mainly due to higher shade on western direction which reduced the light and in turn affected growth and development of chickpea.

The light intensity also significantly differed with difference in the distance from tree line. Significantly lower light intensity at 30 DAS (510, 2475 and 588 kLux, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded near the tree line at 2.0-7.0 m (S_1) which increased with increase in distance from the tree line. However, significantly higher light intensity at 30 DAS (673, 2770 and 738 kLux, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded at far away from the tree line of 12.0-17.0 m (S_3), similar trend was noticed at 60 and 90 DAS. This is mostly due to the reduction in light intensity may be due to canopy area of trees, which covered the annual crops. Reduction in light intensity to the annual crops may be variable according to the age of tree. These results are in agreement with the findings of Jha and Gupta (2003) who reported that open area received 96.42 per cent higher light as compared to agroforestry system because there were no trees on the field during the study period. Rana *et al.* (2011) also revealed that the open area receives higher light intensity as compared to the agroforestry system because there are no trees in the field.

Spatial and directional interaction effect also revealed significant variation in the light intensity. Significantly higher light intensity at 30 DAS (720, 2910 and 760 kLux, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded at far away from the tree line on southern direction (M4S3) and was on par with the control (without trees). However, lower light intensity was recorded near the tree line particularly on western direction (480, 2300 and 550 kLux, at 10.0 am, 2.0 pm and 6.0 pm, respectively). The similar trend was also noticed in all other growth stages of chickpea. These results are also in conformity with the earlier findings of Bhandari *et al*. (2015) in poplar based agroforestry systems, where the light intensity varied from 1.12 kLux during end of December to 31.49 kLux during the mid of March under poplar canopy. However, the light intensity in control plots ranged from 2.14 kLux during the end of December to 53.92 kLux during May. Kumar

(2003) also reported that the PAR availability was higher in open field as compared to different agroforestry systems.

Soil temperature also differed significantly with distance from the tree line and is presented in Table 4. Significantly higher soil temperature at 30 DAS (23.5, 31.7 and 20.0°C, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded on southern direction of the tree line followed by northern and eastern direction. Whereas, significantly lower soil temperature at 30 DAS (21.2, 28.7 and 18.2°C, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded on western direction of the north-south tree line, similar trend was noticed at 60 and 90 DAS.

Soil temperature also differed significantly with distance from the tree line. Significantly lower soil temperature at 30 DAS (19.3, 27.4 and 16.6°C, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded near the tree line (S_1- 2-7 m) and it increased with the increase in distance away from the tree line. However, significantly maximum soil temperature at 30 DAS (25.5, 33.3 and 21.6°C, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded at far away distance from the tree line 12.0-17.0 m (S_3). The similar trend was also noticed in all other growth stages of chickpea.

Spatial and directional interaction effect also revealed significant variation in the soil temperature. Significantly higher soil temperature at 30 DAS (26.5, 36.0 and 23.0°C, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded at far away from the tree line on southern direction (M_4S_3) as compared to any other combinations. While significantly lower soil temperature at 30 DAS (18.0, 27.0 and 16.0°C, at 10.0 am, 2.0 pm and 6.0 pm, respectively) was recorded near the tree line on western direction. Similar trend was noticed at 60 and 90 DAS. Higher soil temperature was recorded in control but on far with distance (S_3 – 12-17m) in southern and northern direction. This might be due to more shading effect on associated crop near the tree line and western direction as compared to other treatment combinations. The results are similar to those reported in cacao agroforestry systems in Brazil, where the decrease in tree cover increased the incidence of radiation, temperature and vapor pressure deficit (Niether *et al.,* 2018) while in crops with a 2.2 % canopy opening, *i.e.,* greater canopy coverage, a decrease in air temperature and soil temperature was reported as compared to crops with a 7.7 % canopy opening (Pinheiro *et al.,* 2013).

Table 2: Population of bacteria, fungi, actinomycetes and dehydrogenase activity in soil at 50 % flowering of chickpea as influenced by direction and distance from tree line in teak based agroforestry system.

Treatments	Bacteria (cfu × 10^6 g^{-1})	Fungi (cfu × 10^3 g^{-1})	Actinomycetes (cfu × 10^2 g^{-1})	Dehydrogenase activity (µg TPF g^{-1} soil for 24 hrs)
Direction (M)				
M_1	72.51^{b}	41.10^{b}	31.31^{b}	27.00^{ab}
M_2	75.63^{a}	45.23^{a}	33.82^{a}	28.10^{a}
M_3	73.30^{ab}	43.20^{ab}	32.48^{ab}	27.51^{a}
M_4	71.93^{b}	39.70^{b}	30.83^{b}	25.21^{a}
S. Em±	**0.90**	**1.32**	**0.76**	**0.71**
Distance (S)				
S_1	80.11^{a}	50.70^{a}	36.39^{a}	29.41^{a}
S_2	72.50^{b}	40.70^{b}	31.09^{b}	26.87^{b}
S_3	67.43^{c}	35.52^{c}	28.85^{c}	24.59^{c}
S. Em±	**0.78**	**1.14**	**0.66**	**0.61**
Interaction (M×S)				
M_1S_1	78.43^{ab}	48.40^{ab}	35.23^{ab}	29.77^{a-c}
M_1S_2	71.09^{c-e}	39.90^{c-e}	30.46^{cd}	26.60^{c-e}
M_1S_3	68.01^{d-f}	35.00^{de}	28.25^{d}	24.64^{de}
M_2S_1	82.70^{a}	54.30^{a}	37.99^{a}	31.61^{a}
M_2S_2	75.40^{bc}	43.80^{bc}	33.18^{bc}	27.60^{b-d}
M_2S_3	68.80^{d-f}	37.60^{c-e}	30.30^{cd}	25.10^{de}
M_3S_1	81.10^{a}	52.30^{a}	37.05^{ab}	30.60^{ab}
M_3S_2	72.10^{cd}	41.10^{cd}	31.11^{cd}	27.10^{d-e}
M_3S_3	66.70^{ef}	36.20^{de}	29.27^{d}	24.83^{e}
M_4S_1	78.20^{ab}	47.80^{ab}	35.30^{ab}	26.20^{c-e}
M_4S_2	71.40^{cd}	38.00^{c-e}	29.60^{cd}	25.64^{de}
M_4S_3	66.20^{f}	33.30^{e}	27.59^{d}	23.80^{e}
S. Em±	**1.56**	**2.28**	**1.32**	**1.23**
Rest *VS.* Control				
Control	64.70	31.65	26.20	23.01
S. Em±	**1.56**	**2.28**	**1.27**	**1.23**
C.D. (P=0.05)	**4.55**	**6.66**	**3.71**	**3.58**

***Note*:** Means with same alphabets do not differ significantly as per DMRT

M: Direction from tree row; M_1: Eastern direction; S: Distance from tree line; M_2: Western direction; S_1: 2.0-7.0 m; M_3: Northern direction; S_2: 7.0-12.0 m; M_4: Southern direction; S_3: 12.0-17.0 m

Table 3: Light intensity as influenced by direction and distance from tree line in teak based agroforestry system.

Treatments	Light intensity								
	30 DAS			60 DAS			90 DAS		
	10.00 am	2.00 pm	6.00 pm	10.00 am	2.00 pm	6.00 pm	10.00 am	2.00 pm	6.00 pm
DIRECTION (M)									
M$_1$	580^{bc}	2607^{ab}	653^{ab}	569^{bc}	2517^{ab}	639^{ab}	558^{bc}	2417^{ab}	619^{ab}
M$_2$	553^{c}	2530^{b}	630^{b}	542^{c}	2440^{b}	616^{b}	531^{c}	2340^{b}	596^{b}
M$_3$	600^{ab}	2637^{ab}	680^{a}	589^{ab}	2547^{ab}	666^{a}	578^{ab}	2447^{ab}	646^{a}
M$_4$	627^{a}	2710^{a}	697^{a}	616^{a}	2620^{a}	683^{a}	605^{a}	2520^{a}	663^{a}
S. Em±	**15**	**42**	**16**	**15**	**40**	**16**	**15**	**42**	**16**
DISTANCE (S)									
S$_1$	510^{c}	2475^{c}	588^{c}	499^{c}	2385^{c}	574^{c}	488^{c}	2285^{c}	554^{c}
S$_2$	588^{b}	2618^{b}	670^{b}	577^{b}	2528^{b}	656^{b}	566^{b}	2428^{b}	636^{b}
S$_3$	673^{a}	2770^{a}	738^{a}	662^{a}	2680^{a}	724^{a}	651^{a}	2580^{a}	704^{a}
S. Em±	**13**	**36**	**14**	**13**	**35**	**14**	**13**	**37**	**14**
INTERACTION (M × S)									
M$_1$S$_1$	500^{h}	2500de	580^{ef}	490^{h}	2410de	566^{ef}	478^{h}	2310de	546^{ef}
M$_1$S$_2$	580^{d-g}	2600^{b-d}	650^{b-e}	569^{d-g}	2510^{b-d}	636^{b-e}	558^{d-g}	2410^{b-d}	616^{b-e}
M$_1$S$_3$	660^{a-c}	2720^{a-c}	730^{ab}	649^{a-c}	2630^{a-c}	716^{ab}	638^{a-c}	2530^{a-c}	696^{ab}
M$_2$S$_1$	480^{h}	2300^{e}	550^{f}	470^{h}	2210^{e}	536^{f}	458^{h}	2110^{e}	516^{f}
M$_2$S$_2$	550^{e-h}	2590^{b-d}	630^{c-f}	539^{e-h}	2500^{b-d}	616^{c-f}	528^{e-h}	2400^{b-d}	596^{c-f}
M$_2$S$_3$	630^{b-d}	2700^{a-d}	710^{a-c}	619^{b-d}	2610^{b-d}	696^{a-c}	608^{b-d}	2510a^{-d}	676^{a-c}
M$_3$S$_1$	520^{gh}	2530^{cd}	600^{ef}	509^{gh}	2440^{cd}	586^{ef}	498^{gh}	2340^{cd}	566e^{f}
M$_3$S$_2$	600^{c-f}	2630^{b-d}	690^{a-d}	589^{c-f}	2540^{b-d}	676^{a-d}	578^{c-f}	2440^{b-d}	656^{a-d}
M$_3$S$_3$	680^{ab}	2750^{ab}	750^{a}	669^{ab}	2660^{ab}	736^{a}	658^{ab}	2560a^{b}	716^{a}
M$_4$S$_1$	540^{f-h}	2570^{b-d}	620^{d-f}	529^{f-h}	2480^{b-d}	606^{d-f}	518^{f-h}	2380^{b-d}	586^{d-f}
M$_4$S$_2$	620^{b-e}	2650^{b-d}	710^{a-c}	609^{b-e}	2560^{b-d}	696^{a-c}	598^{b-e}	2460^{b-d}	676^{a-c}
M$_4$S$_3$	720^{a}	2910^{a}	760^{a}	710^{a}	2820^{a}	746^{a}	698^{a}	2720^{a}	726^{a}
S. Em±	**27**	**73**	**28**	**26**	**70**	**28**	**26**	**73**	**27**
REST *VS.* CONTROL									
Control	730	2950	780	740	2850	755	710	2750	735
S. Em±	**27**	**71**	**29**	**25**	**70**	**31**	**30**	**81**	**30**
C.D. (P=0.05)	**78**	**207**	**84**	**74**	**203**	**90**	**88**	**235**	**87**

Note: Means with same alphabets do not differ significantly as per DMRT; M: Direction from tree row; M$_1$: Eastern direction; S: Distance from tree line; M$_2$: Western direction; S$_1$: 2.0-7.0 m; M$_3$: Northern direction; S$_2$: 7.0-12.0 m; M$_4$: Southern direction; S$_3$: 12.0-17.0 m

Table 4: Soil temperature as influenced by direction and distance from tree line in teak based agroforestry system.

Treatments	Soil temperature (°C)								
	30 DAS			60 DAS			90 DAS		
	10.00 am	2.00 pm	6.00 pm	10.00 am	2.00 pm	6.00 pm	10.00 am	2.00 pm	6.00 pm
Direction (M)									
M$_1$	22.3^{ab}	29.7^{bc}	18.7^{b}	21.8^{ab}	28.0^{b}	21.3^{ab}	21.3^{ab}	27.3^{ab}	20.3^{ab}
M$_2$	21.2^{b}	28.7^{c}	18.2^{b}	20.7^{b}	28.0^{b}	20.1^{b}	20.2^{b}	26.7^{b}	19.8^{b}
M$_3$	23.0^{a}	30.5^{ab}	19.3^{ab}	22.5^{a}	30.0^{ab}	22.0^{a}	22.0^{a}	28.5^{a}	21.0^{a}
M$_4$	23.5^{a}	31.7^{a}	20.0^{a}	23.0^{a}	31.0^{a}	22.5^{a}	22.5^{a}	29.7^{a}	21.5^{a}
S. Em±	**0.5**	**0.5**	**0.4**	**0.4**	**1.0**	**0.5**	**0.4**	**1**	**0.5**
Distance (S)									
S$_1$	19.3^{c}	27.4^{c}	16.6^{c}	18.8^{c}	26.0^{c}	18.3^{c}	18.3^{c}	25.4^{c}	17.3^{c}
S$_2$	22.8^{b}	29.5^{b}	18.9^{b}	22.3^{b}	29.0^{b}	21.8^{b}	21.7^{b}	27.5^{b}	20.8^{b}
S$_3$	25.5^{a}	33.3^{a}	21.6^{a}	25.0^{a}	32.0^{a}	24.5^{a}	24.5^{a}	31.3^{a}	23.5^{a}
S. Em±	**0.4**	**0.4**	**0.4**	**0.3**	**0.3**	**0.4**	**0.4**	**0.5**	**0.4**
Interaction (M × S)									
M$_1$S$_1$	19.0^{ef}	27.0^{f}	16.5^{gh}	18.5^{ef}	26.0^{e}	18.0^{cd}	18.0^{de}	25.0^{e}	17.0^{ef}
M$_1$S$_2$	23.0^{cd}	29.0^{d-f}	18.5^{d-g}	22.5^{cd}	28.0^{c-e}	22.0^{bc}	22.0^{bc}	27.0^{c-e}	21.0^{cd}
M$_1$S$_3$	25.0^{a-c}	32.0^{bc}	21.0^{a-c}	24.5^{a-c}	31.0^{bc}	24.0^{ab}	24.0^{ab}	30.0^{bc}	23.0^{a-c}
M$_2$S$_1$	18.0^{f}	27.0^{f}	16.0^{h}	17.5^{f}	26.0^{e}	17.0^{b}	17.0^{e}	25.0^{e}	16.0^{f}
M$_2$S$_2$	21.0^{de}	28.0^{ef}	18.0^{e-h}	20.5^{de}	27.0^{de}	20.0^{cd}	20.0^{cd}	26.0^{de}	19.0^{de}
M$_2$S$_3$	24.5^{a-c}	31.0^{cd}	20.5^{b-d}	24.0^{a-c}	30.0^{b-d}	23.5^{ab}	23.5^{ab}	29.0^{b-d}	22.5^{a-c}
M$_3$S$_1$	20.0^{ef}	27.5^{ef}	17.0^{f-h}	19.5^{ef}	27.0^{de}	19.0^{cd}	19.0^{de}	25.5^{de}	18.0^{ef}
M$_3$S$_2$	23.0^{cd}	30.0^{c-e}	19.0^{c-f}	22.5^{cd}	29.0^{c-e}	22.0^{b}	22.0^{bc}	28.0^{c-e}	21.0^{cd}
M$_3$S$_3$	26.0^{ab}	34.0^{ab}	22.0^{ab}	25.5^{ab}	33.0^{ab}	25.0^{ab}	25.0^{a}	32.1^{ab}	24.0^{ab}
M$_4$S$_1$	20.0^{ef}	28.0^{ef}	17.0^{f-h}	19.5^{ef}	27.0^{de}	19.0^{cd}	19.0^{de}	26de	18.0^{ef}
M$_4$S$_2$	24.0^{bc}	31.0^{cd}	20.0^{b-e}	23.5^{b-c}	30.0^{b-d}	23.0^{ab}	22.8^{b}	29^{b-d}	22.0^{bc}
M$_4$S$_3$	26.5^{a}	36.0^{a}	23.0^{a}	26.0^{a}	35.0^{a}	25.5^{a}	25.6^{a}	34^{a}	24.6^{a}
S. Em±	**0.8**	**0.8**	**0.7**	**0.7**	**1.0**	**0.8**	**0.7**	**1.2**	**0.8**
Rest *Vs.* Control									
Control	28.0	37.0	25.0	26.5	35.3	26	26	35	25.3
S. Em±	**0.8**	**0.9**	**2.01**	**0.7**	**1.0**	**0.8**	**1.0**	**1.0**	**0.8**
C.D. (P=0.05)	**2.3**	**0.28**	**5.88**	**1.9**	**3.0**	**2.5**	**2.0**	**3.0**	**2.2**

Note: Means with same alphabets do not differ significantly as per DMRT; M: Direction from tree row; M$_1$: Eastern direction; S: Distance from tree line; M$_2$: Western direction; S$_1$: 2.0-7.0 m; M$_3$: Northern direction; S$_2$: 7.0-12.0 m; M$_4$: Southern direction; S$_3$: 12.0-17.0 m

CONCLUSION

Present investigation observed improved soil biological properties by the trees on the farm land as compared to control (without trees). Study indicated that the extent of influence on soil biological properties depends on the planting direction, extent of density, type of species, age of the tree, phonological characteristics of tree species and most importantly tree canopy architecture. However, more improved soil biological properties were noticed near the tree line and found to be in decreasing order with increase in distance from the tree line. And yield reduction below these high shading trees is a challenge a requires a serious consideration. A careful selection of these trees can thus be helpful in devising the agroforestry system and modifying and managing the existing agroforestry system. Hence, it is suggested to have bund planting at intervals of 20 m in the field for better improvement of soil physico-chemical properties.

FUTURE SCOPE

1. Generally, the competitive effect of trees is more near the tree line. Therefore, there is need to study the effects of other management practices such as trimming of tree canopy, root pruning through trenching is needed.
2. Screening of other crops especially shade tolerant crops need to be studied.
3. Ecosystem services rendered by trees need to be quantified.

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