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Impact of INM and intercrop on soil properties under Teak (*Tectona grandis* L. f.) based agroforestry system

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Abstract
The present investigation entitled "Impact of integrated nitrogen management and intercrop on soil properties under Teak (*Tectona grandis* L. f.) based agroforestry system" was carried out during summer season of the year 2019 and 2020. Okra var. GAO-5 grown as an intercrop at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India. The trial was framed with twelve different treatments comprised of combinations of vermicompost, neem cake and chemical fertilizers in various proportions *i.e.* 25 per cent, 50 per cent, 75 per cent and 100 per cent of recommend does of nitrogen in the form of organic and inorganic fertilizers under teak plantation and open condition in Randomized Block Design (RBD) consisting of three replications. Minimum soil pH (7.46), EC (0.652) and maximum available nitrogen (333.05 kg ha^{-1}) and SOC (0.860%) content in soil were noted in T_8: 100% RDN through Vermicompost under teak based agroforestry system. While, available phosphorus content (92.90 kg ha^{-1}) in soil at harvest of okra crop was recorded maximum in T_9: 100% RDN through Neem cake under teak based agroforestry systems. At the time of okra harvest available potassium content in soil was found maximum (734.04 kg ha^{-1}) in T_{12}: 75% RDN from Neem coated urea + 25% RDN through Vermicompost in open condition. Whereas, maximum soil pH (7.76), EC (0.921) and lowest available nitrogen (265.22 kg ha^{-1}), phosphorus (69.46 kg ha^{-1}), SOC (0.477%) was noted in T_{11}: 100% RDF through chemical fertilizer in open condition. Moreover, lowest available potassium in soil (537.30 kg ha^{-1}) was registered in T_{10}: sole tree crop. From the study it can be concluded that majority of the soil chemical properties are improved under teak based agroforestry system as compared to open filed condition.

Keywords: Soil properties, integrated nitrogen management, fertilizer, okra, teak, agroforestry system

Introduction
The tree based land-use agroforestry system is an ideal scientific approach in restoring soil fertility and improving its quality in several ways. Agroforestry systems have the potential to reduce erosion and run-off, and to maintain soil organic matter, improve soil physical properties and augment nitrogen fixation and promote efficient nutrient cycling (Nair, 1984) [15]. Agroforestry holds considerable potential as a major land use management alternative for conserving soil as well as improving and maintaining the soil fertility and productivity. Presence of tree species on farm land plays a vital role in increases the organic matter through addition of leaf litter, reduce nutrient losses through run off and enhance nutrient use efficiency. One of the major advantages of agroforestry in terms of improving or sustaining soil productivity was through its effect on soil conservation.

In vegetable production, chemical fertilizers are being used increasingly because of the quick availability of the nutrients to the plants. Indiscriminate use of inorganic fertilizers has resulted in decreased nutrient uptake, poor quality of vegetables and deterioration of soil health (Agarwal, 2003) [1]. Therefore, Vermicompost and Neem cake can be considered as an effective means of disposing solid wastes and improving crop production through better soil fertility. Concentrated organic manures that are rich in plant nutrients could replace the inorganic fertilizers on equivalent nutrient basis. Hangarge *et al*. (2002) [8] reported that recycling of organic waste through Vermicomposting, ordinary composting and enrichment of composting material help to minimize environment pollution and increase soil fertility.

However, integrated use of organic manures with optimum level of NPK fertilizers not only improves the nutrient status and soil health but also stabilizes the crop yield at higher level (Yadav and Vijayakumari, 2003) [32]. Som *et al*. (1992) [25] reported that from the organic manure also amend the soil structure, correct the adverse soil condition and improve the soil productivity. Therefore, present study conducted on impact of integrated nitrogen management and intercrop on soil properties under Teak (*Tectona grandis* L. f.) based agroforestry system.

Methods and Materials

Site location and climatic condition: A field experiment was conducted during *summer* season of 2019 and 2020, at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India. Geographically it's located at 20.95° N latitude and 72.93° E longitude with an elevation of 10 m MSL. This area is typically characterized by humid and warm monsoon with rainfall of about 1500 mm, moderately cold winter, and fairly hot and humid summer. The average annual temperature is 27.1 °C.

FYM, Vermicompost and Neem cake

For experiment required quantity of FYM and Vermicompost were procured from Livestock production management, NAU, Navsari and Neem cake procured from the Horticulture Mandali, Navsari. Before the application of fertilizer the FYM, Vermicompost and Neem cake were analyzed to know the N content by using Wet digestion (Chromic acid) method (Trivedi *et al.*, 1999) [30]. On the basis of N content of Vermicompost (2.15%) and Neem cake (4.49%) different treatments were formulated.

Treatment applications: Experiment was designed in Randomized Block Design (RBD) in three replications with twelve treatment combinations *viz*., Under Teak T_1: 100% RDF through Chemical Fertilizer (150:50:50 @ NPK kg ha-1), T_2: 75% RDN through Neem coated urea + 25% RDN through Neem cake, T_3: 50% RDN through Neem coated urea + 50% RDN through Neem cake, T_4: 25% RDN through Neem coated urea + 75% RDN through Neem cake, T_5: 75% RDN through Neem coated urea + 25% RDN through Vermicompost, T_6: 50% RDN through Neem coated urea + 50% RDN through Vermicompost, T_7: 25% RDN through Neem coated urea + 75% RDN through Vermicompost, T_8: 100% RDN through Vermicompost, T_9: 100% RDN through Neem cake, T_{10}: Sole teak tree, In open condition T_{11}: 100% RDF through Chemical Fertilizer and T_{12}: 75% RDN through Neem coated urea + 25% RDN through Neem cake,

The recommended dose of nitrogen, phosphorus and potassium @ 150-50-50 kg ha^{-1} for okra crop under Teak and open condition trial was applied in the form of Vermicompost, Neem Cake, Urea, Single Super Phosphate and Muriate of Potash. Nitrogen from organic fertilizer applied full does initially while from chemical Recommended dose of N was applied at 30 days interval in three split doses (*i.e*. 50-50-50 N kg ha^{-1}) in aqueous form of urea. Phosphorus and potassium applied as basal dose.

Soil Analysis: For soil analysis samples collected from 15 cm depth of all treated plot initial and after harvest of crop of each treatment of replications and analysed by using different standard methods given by different scientist for electrical conductivity (Jackson, 1967) [10]; soil pH and organic carbon (Jackson, 1967) [10]; available N (Subbiah and Asija, 1956) [27]; available P_2O_5 (Singh *et al*., 2005) [24] and available K_2O (Jackson, 1967) [10]. Initial soil properties of experiment site described in below Table - 1.

Table 1: Initial soil properties of experiment site

	Soil Properties	Open	Under Teak
1.	pH	7.78	7.54
2.	EC (dSm^{-1})	0.89	0.67
3.	N (kg ha^{-1})	262.27	312.06
4.	P_2O_5 (kg ha^{-1})	66.99	77.93
5.	K_2O (kg ha^{-1})	732.5	542
6.	OC (%)	0.47	0.78

Statistical analysis: The recorded data were statistically analyzed and treatment means were compared by using critical difference tests at 5% of probability and analysis of variance (Panse and Sukhatme, 1985) [16].

Results

The data of soil chemical properties for both the years and pooled analysis are presented in the Table - 2, it confirmed that soil chemical properties *viz*., pH, electrical conductivity (EC), organic carbon (OC), available nitrogen (N), phosphorous (P_2O_5) and potassium (K_2O) assessed at the time of okra sowing and at final harvest varied significantly among different nitrogen management treatments under agroforestry system and in open condition. The interaction effect of years over treatments was found non-significant in pooled analysis for soil properties under teak based agroforestry system. The detailed description of results obtained is as follows:

The data with respect to soil pH are presenting in Table - 2. It is evident from the data presented in pooled analysis that at harvest of okra crop, the soil pH (7.76) and EC (0.921) was registered maximum in T_{11}: 100% RDF through chemical fertilizer in open condition which was at par with only T_{12}: 75% RDN through Neem coated urea + 25% RDN through Vermicompost (7.74) in open condition. Moreover, in the case of teak based agroforestry system, the maximum soil pH (7.52) and EC (0.697) recorded in T_{10}: Sole tree crop. Minimum soil pH (7.46) and EC (0.652) were recorded in T_8: 100% RDN through Vermicompost under teak based agroforestry system.

Available nitrogen, phosphorus, potassium and SOC content (%) are presented in Table - 2. Result of both years and pooled analysis showed that available N, P, K and SOC content significantly influenced by different INM treatments at the time of okra harvest under agroforestry system and in open condition. From the pooled analysis results, it is evident that available nitrogen (333.05 kg ha^{-1}) registered maximum in T_8: 100% RDN through Vermicompost under teak based agroforestry system which was at par with T_9, T_4, T_7, T_3, T_6, T_2, T_1, T_5 and T_{10}. Maximum organic carbon content in soil (0.860%) was recorded in T_8: 100% RDN through Vermicompost under teak based agroforestry system which was at par with T_7: 25% RDN through Neem coated urea + 25% RDN through Vermicompost (0.839%). Maximum available phosphorous (92.90 kg ha^{-1}) in soil was recorded in T_9: 100% RDN through Neem cake which was on same bar with T_8, T_7, T_4, T_3, T_6 and T_2. Whereas, lowest available Nitrogen (265.22 kg ha^{-1}), organic carbon content (0.477%) and phosphorous (69.46 kg ha^{-1}) was reported in T_{11}: 100% RDF from chemical fertilizer in open condition. Available potassium in soil (734.04 kg ha^{-1}) was registered maximum in T_{12}: 75% RDN from Neem coated urea + 25% RDN through

Vermicompost in open condition which was at par with T_{11}: 100% RDF through Chemical fertilizer (731.55 kg ha^{-1}). However, in case of different nitrogen management treatments under teak based agroforestry system, T_8: 100% RDN though Vermicompost recorded maximum available potassium content in soil (549.14 kg ha^{-1}) while, lowest (537.30 kg ha^{-1}) was recorded in T_{10}: Sole tree crop.

From Table – 2, it can be revealed that during first and second year of investigation it showed the same trend as per the results of pooled analysis.

Table 2: Effect of different INM treatments on available N (kg ha^{-1}) content in soil at harvest of crop under teak based agroforestry systems and in open condition

Treatments	Soil pH			Soil EC (dS m^{-1})			Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})			Soil OC (%)		
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
Under Teak																		
T_1	7.51	7.51	7.51	0.677	0.687	0.682	317.36	319.22	318.29	80.27	82.36	81.32	540.50	542.22	541.36	0.787	0.795	0.791
T_2	7.51	7.49	7.50	0.667	0.690	0.678	320.45	321.36	320.90	82.18	85.04	83.61	542.08	543.16	542.62	0.800	0.814	0.807
T_3	7.49	7.48	7.49	0.666	0.677	0.671	324.49	326.66	325.58	85.20	87.29	86.24	545.24	545.55	545.40	0.803	0.823	0.813
T_4	7.48	7.47	7.47	0.657	0.667	0.662	328.58	330.05	329.32	87.43	90.23	88.83	547.64	549.17	548.40	0.813	0.831	0.822
T_5	7.51	7.50	7.51	0.693	0.680	0.687	315.83	319.12	317.47	82.27	83.15	82.71	542.34	544.51	543.43	0.800	0.817	0.808
T_6	7.50	7.48	7.49	0.675	0.667	0.671	320.63	322.26	321.45	85.21	87.15	86.18	545.62	545.18	545.40	0.810	0.836	0.823
T_7	7.48	7.47	7.48	0.680	0.650	0.665	324.25	328.27	326.26	87.21	91.08	89.15	548.14	549.31	548.72	0.832	0.846	0.839
T_8	7.46	7.45	7.46	0.648	0.657	0.652	329.57	336.54	333.05	91.36	93.35	92.36	547.13	551.15	549.14	0.847	0.873	0.860
T_9	7.47	7.47	7.47	0.667	0.654	0.660	331.05	334.21	332.63	90.61	95.18	92.90	545.17	544.59	544.88	0.820	0.827	0.823
T_{10}	7.52	7.51	7.52	0.691	0.703	0.697	312.45	315.38	313.91	78.14	79.12	78.63	538.30	536.30	537.30	0.780	0.797	0.788
In open condition																		
T_{11}	7.77	7.76	7.76	0.908	0.933	0.921	264.05	266.39	265.22	68.27	70.65	69.46	730.02	733.08	731.55	0.477	0.477	0.477
T_{12}	7.75	7.73	7.74	0.900	0.907	0.903	267.25	270.54	268.89	71.56	74.13	72.85	733.04	735.03	734.04	0.493	0.497	0.495
S.Em (±)	0.07	0.06	0.04	0.016	0.014	0.010	12.08	12.99	7.94	5.19	6.05	3.57	41.23	39.43	25.52	0.013	0.014	0.009
CD @ 5%	0.20	0.18	0.12	0.047	0.042	0.029	35.44	38.11	22.52	NS	NS	10.13	120.94	115.65	72.34	0.037	0.040	0.024
S.Em (±) (Y×T)			0.06			0.015			12.55			5.64			40.34			0.013
CD @ 5% (Y×T)			NS			NS			NS			NS			NS			NS
CV (%)	1.57	1.39	1.48	3.87	3.54	3.71	6.69	7.13	6.91	10.90	12.34	11.67	12.41	11.84	12.13	2.91	3.11	3.01

T_1:-100% RDF through Chemical fertilizer (150:50:50 @NPK kg ha^{-1}), T_2:-75% RDN through Neem coated urea + 25% RDN through Neem cake, T_3:-50% RDN through Neem coated urea + 50% RDN through Neem cake, T_4:-25% RDN through Neem coated urea + 75% RDN through Neem cake, T_5:-75% RDN through Neem coated urea + 25% RDN through Vermicompost, T_6:-50% RDN through Neem coated urea + 50% RDN through Vermicompost, T_7:-25% RDN through Neem coated urea + 75% RDN through Vermicompost, T_8:-100% RDN through Vermicompost, T_9:-100% RDN through Neem cake, T10: Sole Teak tree T_{11}:-100% RDF through Chemical fertilizer, T_{12}:-75% RDN through Neem coated urea + 25% RDN through Vermicompost

Discussion

The various chemical properties of soil were improved under integrated nitrogen management in teak based agroforestry system as compared to open condition (Table – 2). The result showed the trend increasing the amount of inorganic fertilizer which increased the soil pH and EC in both years after the harvest of crop. Increased in EC values over the control could be attributed to quality of irrigation water (EC: 2.1 dS m^{-1}). However, among the treatments, the EC was found decreased numerically as the amount of addition of organic matter increased. Among the organic sources, Vermicompost had reported more beneficial effect over Neem cake when applied at equal N rates. In both years at the time of crop harvest available nitrogen, phosphorus and soil organic carbon content in soil were registered significantly increased with application of T_8: 100% RDN through Vermicompost and followed by T_9: 100% RDN through Neem cake under teak based agroforestry system as compared to other treatments while available potassium maximum reported in open filed it might be due to already availability high amount of K in soil of open field. Agroforestry system improved the various properties of soil might be due to high addition of organic matter as a result of leaf litter and root residues under tree cover. Secondly, it may be due to addition of leaf litter and its decomposition due to higher microbial activities and encouraging physical condition *i.e.* soil moisture and temperature of soil under tree cover which ultimately released soil nutrients. Third reason behind high nutrients in soil under tree cover may be recycling of these nutrients from deeper layer of the soil added to the upper layer in the form of leaf litter. The enrichment of soil by tree cover may result by a) reduction in nutrient loss through erosion b) reduction of nitrogen loss through evaporation c) mulching effect of leaf litter d) keeping soil warmer in winter and colder in summer. Composts work as a 'slow release fertilizer' whereas chemical fertilizers release their nutrients rather quickly in soil and soon get depleted. From the result significant amount of 'chemical nitrogen' is lost from soil due to oxidation in sunlight. However, with application of vermicompost the 'organic nitrogen' tends to be released much faster from the excreted 'humus' by worms and those mineralized by them and the net overall efficiency of nitrogen (N) is considerably greater than that of chemical fertilizers and also availability of phosphorus (P) is sometimes much greater found by Suhane (2007) [28]. These results are in conformity with the earlier findings of Sathesh (1998) [21], Badole and More (2000) [6], Anitha and Prema (2003) [4], Mahmoud *et al.* (2009) [12], Das *et al.* (2010) [7], Saravaiya *et al.* (2010) [20], Sharma *et al.* (2011) [22], Urmalia and Bansal (2014) [31], Sharma *et al.* (2015) [23], Kumar *et al.* (2016) [11], Reddy *et al.* (2017) [18], Patel (2018) and Sondarva (2018) [26].

Among different integrated nitrogen management treatments under teak based agroforestry system and in open condition, the soil properties were improved with the application of 100% organic fertilizer then other treatments. Whereas, soil properties declined by application of 100% chemical fertilizer. Similar results are also reported by Anand and Yaduvanshi (2000) [3], Renuka and Sankar (2001) [19], Anitha and Prema (2003) [4], Marathe *et al.* (2007) [13] in sweet potato,

Anwer *et al.* (2005) [5], Islam *et al.* (2017) [9], Amiry *et al.* (2018) [2], Tripathi (2019) [29] and Mng'omba *et al.* (2020) [14].

Conclusion

From the investigation it may be inferred that among the different integrated nitrogen management treatments, application of 100% RDN through Vermicompost significantly improved the soil properties as compared to other treatments. In comparison of open and under teak based agroforestry. Soil properties under teak based agroforestry systems improved soil fertility status as compared to open condition. Moreover, an application of 100% RDN from vermicompost improved various soil properties which might be very useful in long run.

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