RESEARCH ARTICLE

IMPACT OF DIFFERENT AGRO-FORESTRY SYSTEMS ON GROWTH AND YIELD OF TURMERIC AT TARAI REGION OF UTTARAKHAND, INDIA

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Abstract: An experiment was carried out to evaluate the effect of different agroforestry system on turmeric with reference to vegetative growth, rhizome yield and its attributes of turmeric (*Curcuma longa* L.). Turmeric showed positive response to the agroforestry system as compared to open system. Turmeric with (T2) *Diospyrus embryophytum* had the taller plant height, maximum number of leaves, maximum leaf area index (5.02), maximum curcumun per cent (4.12) and maximum curing per cent (27.41). Maximum number of tillers was showed by the turmeric grown under T9 *(Terminalia chebula)*, fresh yield (22.20 t ha^{-1}) and cured yield (6.08 t ha^{-1}) of rhizome was obtained under open condition however, among the different agroforestry system it was higher under T9. Moreover, the soil parameters such as SOC (0.99%), available N (304.51 kg ha^{-1}), P (18.23 kg ha^{-1}) and K (161.52 kg ha^{-1}) were also highly influenced by the T9 (*Terminalia chebula).*

Keywords: Agroforestry, *Curcuma longa* L., Rhizome yield, Curcumin

INTRODUCTION

The rising population pressure and urbanization, coupled with land degradation, soil salinization and global warming are the major causes for food insufficiency in developing world. Among different approaches to combat this problem, agroforestry is potential option. It not only arrest land degradation but also improve site productivity through interaction among trees, soil, crops and livestock. It is considered as a panacea for maladies of intensive agriculture **(**Pingali, 1999). It is a way to practice agriculture without deteriorating agro-ecosystem. Its role in the light of combating hunger, disease and environmental degradation is highly appreciable (Garrity, 2004). The microclimate under agroforestry system is somewhat modified due to presence of trees, under such conditions, the growth response of turmeric may be different from sole cropping system. Agroforestry is a sustainable land use system that maintains or increase total yield by combining food crops with perennial tree crops and/or live stock on the same unit of land either alternately or at the same time using management practices that suits the social and cultural characteristics of the local people and economic and ecological condition of the area. Turmeric (*Curcuma longa* L.), a herbaceous perennial medicinal plant, belonging to family Zingiberaceae, is one of the most valuable spice all over the world and is cultivated in the country since ancient times. India is the largest producer and exporter of this crop in the world. It occupies an area of about 1.65 lakh hectares with a production of 5.6 lakh tonnes per annum with average yield of 3.5t ha^{-1}. It has about 14 per cent share by quantity wise and 7 per cent by value in export among all the spices and 22 percent share of total world production (Peter *et al*., 2004). Uttarakhand produces about 3600 q of turmeric from an area of 45 ha with productivity of 80 q ha^{-1} which is quite low as compare to Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, West Bengal, Gujarat, Meghalaya, Maharashtra and Assam some of the important states which cultivate turmeric. Turmeric grows well under partial shade but thick shade condition affects yield of turmeric adversely (Singh and Edision, 2003). Ancient system of Indian medicine has fully documented the significance of turmeric in curing various diseases such as stomach disorders, leprosy, fever, dropsy, discharge from ear, ulcer, liver disorders, wounds, burns and as a blood purifier. The turmeric powder increases the mucus in gastric secretions and prevents the formation of the uretic stones (Divya Himachal, 1999). The root of turmeric is bactericidal and its paste is used to cure skin infections. The antibacterial effect of turmeric is due to three principal compounds viz. curcumin, curcuminoids and aromatic oil, out of which, curcumin is the most active therapeutic ingredient. It is a yellow, crystalline substance, which is a phenolic antioxidant, the scavenger of free radicals, which otherwise account for curing many diseases including cancer (Khanna, 1999). Besides medicinal value, it is used as condiment with curry-stuff and as a dye. As for its quality ramifications, sun dried finger rhizomes of turmeric contains 1.4 - 6.1 per cent curcumin, 3.9 -8.7 per cent starch, 5.2 - 7.0 per cent protein, 2.0 - 9.3 per cent essential oil, and curing percentage ranging from 16.0 - 37.4 per cent (Aiyadurai, 1966). Due to its increasing demand, not only for internal consumption but for export purpose also, the productivity and quality of crop needs to be upgraded (Medhi and Bora, 1993). Most of the soils are not so rich to supply all the nutrients for its optimum growth and development. Furthermore, it is difficult to sustain the yield of the crop and soil

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health for longer duration without integrated use of organics and inorganics . The removal of nitrogen, phosphorus and potassium by crops is much more than their replenishment through mineral fertilizers, thereby leading to nutrient mining but this problem can be overcome through the agroforestry. Because agroforestry improve the soil fertility status by the addition of continuous organic matter in the soil in the form of leaves, twig and branches etc. At present, the level of N, P and K removal in India is about 28 million tonnes against addition of only 18 million tonnes, thus resulting in a negative balance of about 10 million tonnes (Rao and Srivastava, 1998). The removal of nutrient from the soil can also be minimize by the agroforestry because the tree root works as a binding agent against the soil erosion and enhance the natural nutrient recycling into the soil. So the practices of agroforestry is the best solution to fulfill the demand of increasing population in the present world.

MATERIAL AND METHOD

The field experiment was conducted in the arboretum during 2016-17 at Experimental site of Agroforestry Research Centre near, Haldi, G. B. Pant University of Agriculture and Technology, Pantnagar, Distt. Udham Singh Nagar, Uttarakhand. The site was situated at 29^0 Latitude and 79^0.29' longitudes and at an altitude of 243.84 meters above the mean sea level in *Tarai* region. The climate and weather of Pantnagar is humid sub-tropical with cold winters and hot dry summers. The maximum daily temperature in summer may reach up to 42^0C and minimum temperature in winter may fall up to 0.5^0C. Generally, south-west monsoon sets in the second or third week of June and continues up to the end of September. The mean annual rainfall is about 1450 mm, of which 80-90 per cent is received during the wet season (July to September). The soils of *Tarai* region are developed from alluvial, medium to moderately coarse textures materials under predominant influence of tall vegetation and moderate to well drain conditions. The soils are weakly developed with mollic epipedons and horizons are classified as Mollisols. Turmeric were laid out on the Randomized Block Design (RBD) with single factor experiment. Eleven treatments were used in this study viz. T1-Open condition (Control), T2- *Diospyrus embryophytum* with turmeric, T3- *Delonix regia* with turmeric, T4- *Paulomia fortunii* with turmeric, T5- *Cassia fistula* with turmeric, T6- *Pongamia pinnata* with turmeric, T7- *Madhuca Indica* with turmeric, T8- *Tamarindus Indica* with turmeric, T9- *Terminalia chebula,* with turmeric T10- *Sapindus mukorossi* with turmeric and T11- *Melia azaderach* with turmeric.). The plantation was 12 year old with a spacing of 4×4 m planted during the year 2003-04. The seed rhizomes of the turmeric var. Pantpitabh were planted maintaining 60x20 cm spacing between and within the rows at a depth of 10 cm. Turmeric crop was planted on May 2016 and harvested on February 2017 after 280 days of planting when leaves turned yellow and started drying up. To evaluate vegetative growth parameters and yield influenced by the different agroforestry system, plant height, number of tiller, number of leaf, leaf area index and yield (Fresh rhizome yield and cured yield) were recorded on five randomly selected plants in each of the treatment or agroforestry system. Curcumin content was done following the procedure suggested by Donald (1962) and Manjunath et al., (1991), respectively. Curing percentage was computed by deducting dry weight of rhizomes after curing from fresh weight of rhizomes and divided by fresh weight then multiplied by percentage. Soil analysis like pH, SOC% available N, P & K was done by Beckman Glass Electrode pH meter(Jackson, 1973), Walkley–Black Modifiedmethod (Jackson, 1973), Alkaline$KMnO_4$ (Subbiah and Asija,1956), Olsen's extraction method(Olsen *et al.*,1954) and Flame emission spectrometrymethod (Jackson, 1973) methods respectively.

RESULT AND DISCUSSION

Turmeric Plant height: The data pertaining to plant height of turmeric under different agroforestry system at 90 and 180 DAS are summarized in the Table 1. At 90 DAS, the maximum plant height was found under T2 (91.85 cm) followed by T6 (90.65 cm), T8 (90.58 cm) and T11 (90.50 cm). The minimum plant height at 90 DAS was observed under T1 (83.23 cm) and T7 (84.35 cm). At 180 DAS the maximum plant height was recorded under T2 (104.75 cm) followed by T6 (102.20 cm), T4 (101.52 cm) and T5 (100.24 cm) whereas minimum in T1 (94.20 cm) and T7 (96.65 cm).

Number of leaves: Leaves of turmeric as affected by different agroforestry systems are presented in Table 1. The maximum no of leaves are recorded in T2 (7.24) followed by T6 (7.06) and T5 (6.95) whereas minimum in (T1) open condition (no tree) at 90 DAS. The similar trend was observed at 180 DAS.

Number of tillers: Data regarding number of tiller of turmeric under different agroforestry system are summarized in the Table 1. Treatment (T9) showed the maximum (5.26) no of tillers followed by T10 (5.24), T11 (5.04) and T8 (5.02) while treatment (T1) showed the minimum no of tillers. In the present study, maximum plant height, maximum no of leaves and maximum no of tillers were observed under different agroforestry system at all the growth stages. Increase in plant height, no of leaves and no of tillers in different agroforestry system as compared to open farming system might be due to competition for light with the tree crop and also less weed population under the trees. Similar finding were also reported by Padmapriya and Chezhiyan (2009) that height of turmeric crop under the shade was higher than open system.

Leaf Area Index: Data on leaf area index at 90 DAS under different agroforestry systems are presented in Table 1. The higher LAI was observed under T2 (5.02), T6 (5.00) and T10 (4.96) as compared to open condition (no tree). Green leaf area is the primary source of food production through the process of photosynthesis by the plants. Increased in leaf area index under agroforestry system as compared to open farming system might be due to availability of limited solar radiation under the soapnut tree which is required for photosynthesis. So, in order to capture more solar radiation the turmeric plant increased its leaf area leading to more leaf area index.

Table 1. Growth parameters of turmeric under different agroforestry system and open system.

Treatments	Plant Height at 90 DAS	Plant Height at 180 DAS	No of Leaves at 90 DAS	No of Leaves at 180 DAS	No of tillers	LAI
T1	84.35	96.85	6.09	8.33	3.98	4.28
T2	91.85	104.75	7.24	12.03	4.02	5.02
T3	86.52	99.01	6.79	9.63	4.31	4.88
T4	88.64	101.52	6.51	10.03	4.52	4.72
T5	84.65	100.24	6.95	10.32	4.63	4.65
T6	90.65	102.20	7.06	11.56	4.22	5.00
T7	83.23	94.20	6.44	10.22	4.85	4.35
T8	90.58	99.83	6.55	9.68	5.02	4.38
T9	89.13	98.81	6.88	9.65	5.26	4.87
T10	89.28	100.15	6.75	9.98	5.24	4.96
T11	90.5	99.91	6.56	10.24	5.04	4.98
SEm ±	1.22	1.56	0.13	0.12	0.08	0.10
CD (5%)	3.62	4.64	0.39	0.37	0.25	0.30

Size of mother rhizomes: At the time of sowing the average size of five rhizome recorded (Table 2) and it was found that the maximum size of mother rhizome showed by the T9 (21.80 cm^2) followed by T10 (21.32 cm^2), T8 (18.65 cm^2) and T11 (17.35 cm^2). The minimum size of mother rhizome was recorded under T1 (13.05 cm^2) followed by T4 (11.32 cm^2), T3 (13.81 cm^2) and T1 (13.85 cm^2).

Size of rhizomes: Five average rhizome were selected at the time of harvesting and their size was recorded (Table 2). The maximum rhizome size was recorded under T9 (415.34 cm^2) followed by T10 (411.81 cm^2), T8 (387.16 cm^2) and T1 (386.78 cm^2). The minimum size of mother rhizome was found under T5 (255.36 cm^2) followed by T7 (278.65 cm^2), T4 (302.58 cm^2) and T2 (308.20 cm^2).

Curcumin %: The yellow color of turmeric is due to the curcumin. The results (Table 2) of the present study reveals that the maximum per cent of curumin was found in the T2 treatment (4.12%) followed by T3 (4.06%), T6 (4.05) and T5 & T8 (3.89%). However the minimum per cent of curcumin was found under open (control) treatment T1 (3.11%) followed by T7 (3.69%) and T10 (3.81%). The results of curcumin content (%) in turmeric rhizome indicated the positive effect of shade on curcumin synthesis, translocation and assimilation in the rhizome.

Curing %: The data for curing per cent are presented in Table 2. The proportion of boiled and dried product of the fresh rhizome is Curing percentage, which is influenced by the nutrients. Though curing percentage is a varietal character, it is also influenced by other factors such as soil moisture, soil fertility, and bright sunshine. T2 treatment showed the maximum curing per cent (27.41%) followed by T6 & T8 (26.35%). The minimum curing per cent was recorded under the treatment T1 (23.25%) followed by T5 (23.98%) and T7 (24.32%).

Fresh yield of turmeric rhizome: The data defining the effect of different agroforestry system on the oil yield are summarized in Table 2. The results of this study reveals that the turmeric grown under the open condition (no tree) showed the maximum (22.20 t ha^{-1}) fresh rhizome yield followed by T10 (21.77 t ha^{-1}), T11 (21.19 t ha^{-1}), T9 (19.88 t ha^{-1}) and T7 (19.65 t ha^{-1}). The minimum yield of fresh turmeric rhizome was recorded in the T2 (17.36 t ha^{-1}) T6 (17.52 t ha^{-1}) and T3 (17.85 t ha^{-1}).

Cured yield: Data pertaining to cured yield as influenced by different agroforestry systems are tabulated in Table 2. It was observed that the maximum cured yield (t ha^{-1}) obtained in the T1 treatment (6.08 t ha^{-1}) followed by T10 (6.01 t ha^{-1}) T11 (5.98 t ha^{-1}) and T9 (5.94 t ha^{-1}). The minimum cured yield was obtained under the T2 (4.68 t ha^{-1}) T6 (4.81 t ha^{-1}) and T7 (4.83 t ha^{-1}). Under the open system (no tree) the fresh and cured yield was higher as compared to different agroforestry system, but it was non significant. It might be due to the reduced level of photosynthesis rate. Even though turmeric is a partially shade loving crop, higher level of shade had negative effect on yield. The similar results was obtained by Ridley (1912) who observed that turmeric grew luxuriantly in shade, but it produced higher and better rhizomes yield in the open ground which is exposed to full sunlight. Turmeric crop grows well under partial shade conditions, but thick shade affects the yield of rhizome adversely (Sundararaj and Thulasidas, 1976).

Table 2. Yield and yield attributes of turmeric under different agroforestry system and open system.

Treatments	Size of mother rhizome (cm^2)	Size of rhizome (cm^2)	Curcumin %	Curing %	Fresh yield (t ha^1)	Cured Yield (t ha^{-1})
T1	13.85	386.78	3.11	23.25	22.20	6.08
T2	14.52	308.20	4.12	27.41	17.36	4.68
T3	13.81	373.81	4.06	24.65	17.85	5.46
T4	11.32	302.58	3.65	24.74	18.22	5.49
T5	15.32	255.36	3.89	23.98	18.08	5.17
T6	16.35	366.31	4.05	26.35	17.52	4.81
T7	16.85	278.65	3.69	24.32	19.65	4.83
T8	18.65	387.16	3.89	26.35	19.45	5.53
T9	21.80	415.34	3.92	24.63	19.88	5.94
T10	21.32	411.81	3.81	24.49	21.77	6.01
T11	17.35	385.39	3.88	24.65	21.19	5.98
SEm ±	0.76	4.53	0.05	0.59	0.33	0.12
CD (5%)	1.08	13.47	0.17	1.75	1.00	0.37

Soil pH: The results pertaining to soil pH are presented in table 3 and showed that the values ranged from 6.85 to 7.51 under different agroforestry system and open system. Maximum (7.51) soil pH was recorded under open system as compared to different agroforestry system. Among the different agroforestry system the lowest soil pH was recorded under the T9 (6.85) followed by T10 (6.88) and T8 (7.01). however the maximum in T7 (7.48) followed by T2 (7.39), T4 (7.33) and T3 (7.25). Lower pH values were observed under different agroforestry system as compared to the open system. The reason may be due to an increase in organic matter content of soil through the addition of leaf litter, twigs, branches, pruning materials and other biomass on the surface soil that could have significant effects on soil pH. The results are in general agreement with those obtained by Kumar *et al*. (2008) who reported that due to the addition of organic matter to the surface soil and release of weak organic acid during litter decomposition had resulted in decrease of soil pH.

Soil Organic Carbon: The data presented in Table 3 on soil organic carbon (%) indicated variation and ranged from 0.64 to 0.99 per cent under open system and different agroforestry system. Soil organic carbon content was observed maximum (0.99%) in T8 which was at par with T9 (0.99) and T10 (0.98) and minimum in T1 (0.64) followed by T5 (0.88) which was at par with T7 (0.88). The soil enrichment in organic carbon content under the tree based systems could be reason of several factors such as addition of litter fall, fine root biomass recycled and root exudates and its reduced oxidation of organic matter under tree shades. The results obtained are in agreement with the finding of Bhardwaj *et al*. (2001) and Ghimire (2010).

Available Nitrogen: The results pertaining to status of available soil nitrogen presented in Table 3. It is evident from the data that available soil nitrogen ranged from 264.84 to 304.51 kg ha^{-1} under open system and different agroforestry system. Among the different agroforestry system maximum available nitrogen was estimated under T9 (304.51 kg ha^{-1}) followed by T10 (298.09 kg ha^{-1}) T11 (296.21 kg ha^{-1}) and T4 (294.74 kg ha^{-1}). The minimum available nitrogen was recorded under T6 (268.36 kg ha^{-1}) and T7 (274.65 kg ha^{-1}), but it was better than the open condition. Increase in available soil nitrogen under different agroforestry system as compared to open system was attributed to addition of organic matter in the form of leaf litter fall, twigs, small branches etc. to the soil. The mineralization of organic matter release nutrients to the soil (**Osman *et al*., 2001)**. Similar finding was reported by Chaudhry *et al*. (2007) under poplar based agroforestry system.

Available Phosphorus: The available phosphorus ranged from 15.36 to 18.68 kg ha^{-1} under open system and different agroforestry system,respectively (Table 3). The highest (18.68 kg ha^{-1}) available phosphorus content was found under treatment T9 which was at par with T10 (18.23 kg ha^{-1}) and T11 (18.01 kg ha^{-1}) and lowest (15.36 ha^{-1}) was found under open condition (no tree) treatment T1. The maximum available phosphorus was recorded under different agroforestry system than open system. This might be attributed to higher phosphatase activity under the trees, as the organic anion exudation and acid phosphatase activity of tree roots has resulted to increase mobilization of phosphorus in the rhizosphere. Not only this greater phosphorus content could be due to nutrient pumping from deeper layer of soil by the tree species and is deposited to the surface soil layer through litterfall, small branches and twigs. The increase in soil phosphorus under tree based land-use system and forest cover has been reported earlier by Kumar and Chaudhuri (1997).

Available Potassium: It is clear from the Table 3 that available potassium ranged from 134.23 to 161.52 kg ha^{-1} under open system and agroforestry system. Available potassium was observed significantly higher (161.52 kg ha^{-1}) under T9 followed by T8 (161.30 kg ha^{-1}) and T10 (160.03 kg ha^{-1}) agroforestry system as compared to open system (134.23 kg ha^{-1}). The possible reason could be due to the addition of higher amount of litter fall in the forms of leaves, bark, small branches and fine roots to the soil. Thereafter, the decomposition process started depending upon the intensity of climatic variable such as solar radiation, temperature and relative humidity. As a result, variable quantity of available soil potassium may produce in the soil as compared to open farming system. Similar results were also reported by Chijioke (1980) who stated that the bulk of the organic matter and nutrients that are added or contributed by inclusion of tree species are mostly located in the top soil layer.

Table 3. Soil properties under different agroforestry system and open system.

Treatments	pH	SOC %	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T1	7.51	0.64	264.84	15.36	134.23
T2	7.39	0.89	290.43	17.35	154.32
T3	7.25	0.96	293.71	17.68	156.32
T4	7.33	0.94	294.74	18.12	158.37
T5	7.11	0.88	289.35	18.07	153.23
T6	7.21	0.87	268.36	16.52	149.68
T7	7.48	0.88	274.65	16.97	159.36
T8	7.01	0.99	294.61	17.68	160.30
T9	6.85	0.99	304.51	18.68	161.52
T10	6.88	0.98	298.09	18.23	161.03
T11	7.05	0.88	296.21	18.01	158.43
SEm ±	0.07	0.018	3.24	0.19	1.71
CD (5%)	0.22	0.052	9.64	0.58	5.08

CONCLUSION

It is concluded that tree based system or agroforestry system have significant influence on growth and quality parameters of turmeric. In case of fresh yield and cured yield open condition (no tree) performed better than agroforestry system, but it was non significant. Therefore, the overall (Tree + crop) return by the agroforestry will be higher than the open condition. It is also concluded that the soil properties like SOC per cent, available N, P and K was greatly influenced by agroforestry system in comparasion to open system. So, agroforestry strategy that involves organic matter is crucial for nutrient exhaustive crops like turmeric for commercial cultivation.

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