Indian Journal of Agricultural Sciences **89** (12): 2020–4, December 2019/Article
https://doi.org/10.56093/ijas.v89i12.96266

Vertical cropping to enhance productivity and profitability of dry terraces in North Eastern Indian Himalayas

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Received: 16 February 2019; Accepted: 31 May 2019

ABSTRACT

Land terracing is a vital means to minimize soil erosion in steep slopes of north eastern region of India. Monocropping of turmeric is one of the main production systems in these terraces, resulting in poor land productivity and profitability. Hence, a fixed plot field experiment was undertaken during five consecutive years (2012–17) at ICAR Research Complex for NEH Region, Meghalaya by involving five vertical cropping combinations, viz. turmeric (*Curcuma longa*)+cucumber (*Cucumis sativus*), turmeric+bottlegourd (*Lagenaria siceraria*), turmeric+sponge gourd (*Luffa aegyptiaca*), turmeric+squash (*Sechium edule*) and turmeric sole (open cultivation) to find out the best cucurbits for vertical integration with turmeric for efficient utilization of natural resources and profit maximization. Results revealed that integration of bottle gourd with turmeric in vertical fashion recorded the maximum system productivity (33.94 t/ha), profitability (₹ 1308 ha/day) and B:C ratio (3.37). Over all, vertical integration of cucurbits increased 38.52% yield of turmeric over open cultivation. Maximum enhancement in soil organic carbon (SOC) (2.18%), available N (241 kg/ha), P (22.2 kg/ha) and K (194.7 kg/ha) were recorded when squash was integrated with turmeric followed by turmeric + bottlegourd vertical cropping system. Integration of cucurbits with turmeric improves soil microbial biomass carbon (SMBC) level by 9.85% over the open cultivation of turmeric in dry terraces. Hence, vertical integration of cucurbits with turmeric not only enhances the system productivity and monetary returns of dry terraces but also improves the soil fertility status over open cultivation of turmeric.

Key words: Cucurbits, Monocropping, Relative production efficiency, Vertical cropping

The total geographical area of north eastern hill region (NEHR) of India is 26.2 Mha. Majority of agricultural land (>80%) in the region is sloping and under rainfed monocropping systems. Region faces both excess and deficit moisture stresses, characterized by heavy rainfall during rainy season which very often causes serious soil losses and scanty rainfall during post rainy season forces farmers to leave their land fallow. Traditional farming practices (monocropping) cannot produce enough food to feed the population of the region. Further, hilly land is 3–4 times less efficient in terms of production as compared to fertile plain land (Babu *et al.* 2016). Hence, enhancement in land productivity is essential to meet the increasing food demand of population in hilly region (Chapagain and Raizada 2017). Famers of the NEH region constructed impressive terraces on the slopes for cultivation of crops. In terracing, hilly terrains are divided into narrow and graduated steps, typically 2–3 m wide across the slopes, to facilitate cultivation of various crops (Wymann von Dach *et al.* 2013). However, farmers of the region grow only one crop during rainy season and during rest of the period terraces remain fallow mainly due to moisture stress. Vertical cropping involves growing of crops in multilayer, with precise utilization of natural resources. Growing more number of crops having different growth behaviour at a time in the same piece of land, minimizes soil erosion (Hoshikawa 1991), maximizes water use efficiency, land productivity, profitability and maintains soil fertility (Singh *et al.* 2014,Trupti *et al.* 2018) besides reducing the input requirements (Chapagain *et al.* 2014). Selection of crop in vertical cropping depends upon type of soil, topography, landholdings, farmers' needs, availability of agricultural inputs and opportunities in local market. As vertical cropping allows farmers to produce more number of crops in same piece of land, it has the potential to achieve the goal of zero hunger and doubling farmers' income under changing production and climatic scenario of NEH

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region. In case of failures of one crop other can generate some income, thus, vertical cropping gives resilience to a production system and helps combat inherent risk associated with agriculture especially in rainfed production systems where it can act as "biological insurance". Vertical cropping offers various kinds of crops having different operational requirement hence, reduces seasonal work peaks and provides continuous employments. Turmeric is second most important spice crop of the north east region (NER) contributing about 12% share in India's national market. However, farmers of the region are not able to harvest full potential of turmeric as it is a partially shade loving crop and shade level influence the growth and tuber yield of turmeric (Srikrishnah and Sutharsan 2015). But the farmers of NER region generally grow turmeric in open condition as a rainfed monocrop.Turmeric grows well under partial shade, however, higher shades affected yield adversely (Singh and Edison 2003). Cultivation of cucurbitaceous crops namely cucumber, bottle gourd, sponge gourd, squash is an integral component of farming in NEHR of India, however, yield per unit area of these cucurbits is very low due to poor management practices. But these cucurbits have very good foliage.Due to high crop coverage there is minimal water run-off. Therefore, it was hypothesized that integration of turmeric with cucurbits in vertical fashion simultaneously on the same piece of land will enhance productivity, profitability, and resource use efficiency of sloping land. Hence, the present study was conducted at 25–32% slopes on dry terraces to find out the best cucurbit for vertical integration in turmeric for efficient utilization of natural resources and profit maximization.

MATERIALS AND METHODS

Fixed plot field experiment was undertaken during five consecutive years (2012–17) at Farming Systems Research Project, ICAR Research Complex for NEH Region, Umiam, Meghalaya situated at latitude 25°41'21"N and longitude 91°55'25"E, at an altitude of 980 amsl. Umiam has a tropical monsoon climate and 70% of the total rainfall is received from July to September. December to March is extremely dry period during which crop suffers from water scarcity. The experimental site received a total rainfall of 2087, 2011, 2344, 2551 and 2217 mm/annum during 2012–13, 2013–14, 2014–15, 2015–16 and 2016–17, respectively. Wide variation in rainfall distribution across the years was observed during experimentation. During 2012, 2014 and 2015 August was the wettest month while June and July received the maximum rainfall during 2013 and 2016, respectively. The variation in maximum temperature was also observed across the years, during 2012 maximum temperature was recorded in May (29.2°C). However, the maximum temperature during 2013, 2014 and 2015 was recorded in July and during 2016, June (28.6°C) was observed as the hottest month. Although minimum temperature remained constant and the lowest temperature in all the five years was recorded in the month of January. The experimental soil was acidic in nature, rich in organic matter and low in nitrogen and medium in phosphorus and potassium. The initial content of pH, organic carbon, available N, P, K and soil microbial biomass carbon (SMBC) was 4.92, 2.12%, 201.2 kg/ha, 15.9 kg/ha and 156.1 kg/ha, 149.3 g/kg soil, respectively. Five vertical cropping combinations, viz. turmeric (*Curcuma longa*) + cucumber (*Cucumis sativus*), turmeric + bottlegourd (*Lagenaria siceraria*), turmeric + spongegourd (*Luffa aegyptiaca*), turmeric + squash (*Sechium edule*) and turmeric in open condition were tested in Randomized Block Design (RBD) replicated four times.

The vertical structure commonly called as machan (raised platform about 1.5 to 2 m above ground) was made from locally available bamboos as per the treatment's requirement to provide climbing support to cucurbits. In order to avoid the mixing of soil in different plots, individual plots were prepared manually using a spade each year for planting turmeric crop. A nitrogen equivalent of 80 kg was applied through organic manures before sowing turmeric. Farmyard manure (FYM) @10 t/ha was also at the time of last spading. Disease free rhizomes (20–30 g each) of + RCT-1 (Megha turmeric-1) cultivar were planted in furrow at a spacing of 30 cm × 30 cm with the average seed rate of 2 t/ha between last week of April and first week of May during all the years.Vermicompost (VC) was appliedin two equal splits @2–5 t/ha at the time of first earthing (45–50 days after planting) and second earthing (85–90 days after planting). Mulching with locally available weed biomass @5 t/ha was done just after planting of turmeric. In order to minimize the incidence of insect and pests neem oil @0.75% was sprayed fortnightly. The crop was harvested in the month of November during all the years. At maturity, dry leaves of turmeric were cut close to the ground. After that the rhizomes were dried in shade for 4 to 6 days after removing the dirt and leaves. With regard to the cucurbitaceous crops, three to four seed of cucurbits were sown in the pit (30 cm × 30 cm × 30 cm) at 2.5 to 3 cm depth between last week of April and first week of June with a spacing of 2.5 m × 2.0 m during all the years of experimentation. Before sowing, the seed was treated with *Pseudomonas florescence* @10 g/kg of seed and *Trichoderma viride* @4 g/kg of seed. With regard to manuring, 5 kg FYM per pit (treated with consortia of Azospirillum, Phosphobacteria and Pseudomonas @5 g) one week before sowing and 0.5 kg vermicompost per pit at time of sowing as a basal dose were applied. In general most of the cucurbits under study were ready to harvest after 90 DAS (Days after sowing). Observations on yield of all the crops were recorded as per the standard procedures. Cost of cultivation of each crop was computed based on the prevailing local market price of the inputs and outputs during the respective crop season. System productivity, returns, B:C ratio, production efficiency (SPE), relative production efficiency (RPE), system profitability (SP), relative economic efficiency (REE) and relative employment generation efficiency (REGE) were calculated as per the formulae suggested by Babu *et al.* (2016). For soil analysis, s (Brassica oleracea var. italica) oil samples were collected from each plot (0–15 cm soil depth) before initiation and after five years of fixed plot experiment. Soil organic carbon (SOC) concentration was determined by Walkley and Black method (Nelson and Sommers 2005), available N by alkaline Potassium Permanganate method (Subbiah and Asajia 1956), available P by Bray's method (Bray and Kurtz 1945) and available K by Ammonium Acetate Extraction method (Jackson 1973). The SMBC was determined by the ethanol-free chloroform fumigation extraction method (Vance *et al.* 1987) using Kc value of 0.45 (Jenkinson and Ladd 1981).

Data obtained from various systems were averaged and statistically analyzed using the F-test as per the procedure given by Gomez and Gomez (1984). Critical difference (CD) values at P=0.05 were used to determine the significance of differences between means.

RESULTS AND DISCUSSION

System productivity and profitability: In general, vertical integration of cucurbits was more productive over the open cultivation of turmeric (farmers' practice). While comparing the total productivity of vertical integration of turmeric with cucurbits in terms of turmeric equivalent yield, significantly higher turmeric equivalent yield (TEY) was recorded with turmeric + bottle gourd (33.94 t/ha) followed by turmeric + sponge gourd and turmeric + cucumber system (Table 1), whereas open cultivation of turmeric resulted in the lowest TEY (20.71 t/ha). This enhanced productivity of turmeric under partial shade condition over the open cultivation resulted in higher cumulative amount of produce in vertical integration. Correspondingly, maximum system production efficiency (93 kg/ha/day) was recorded with turmeric + bottle gourd system followed by turmeric + sponge gourd system. Being partially shade loving in nature, turmeric performs well in vertical cropping system and gives more production and income over the open or traditional cultivation of turmeric. Turmeric under vertical cropping gave around 63% higher productivity as against growing of sole crop in open conditions. Yield improvement in turmeric due to shading was also reported by Behera *et al.* (2014). Crop yield, duration and sale price of the produce greatly influenced the overall return and PE (production efficiency) of various systems (Babu *et al.* 2016) and resulted in higher production efficiency. Similarly, relative production efficiency (RPE), i.e. the capacity of the system for production in relation to existing system was maximum (63.9%) with turmeric + bottle gourd followed by turmeric + sponge gourd system.

Economics and employment generation efficiency: Economic analysis showed that the highest cost was incurred in the cultivation of turmeric + sponge gourd combination (226.2 × 10^3₹/ha) followed by turmeric + cucumber (208.7 × 10^3₹/ha). The lowest cost was incurred in the open cultivation ofturmeric (160.3 × 10^3₹/ha). The net return (477.7 × 10^3₹/ha) and B:C ratio (3.37) were significantly higher with turmeric + bottle gourd system followed by turmeric + cucumber integration. This was due to higher system productivity of turmeric in vertical integration. Similar results were also reported by Srikrishnah and Sutharsan (2015). Relative economic efficiency (REE)is a comparative measure of economic gains over the existing system.Vertical integration of cucurbits had higher economic gain over the open cultivation of turmeric. Among the various combinations of cucurbits with turmeric, the vertical integration of turmeric with bottle gourd recorded highest economic gain (151.5%) followed by turmeric+cucumber system (Table 2). Similarly, the maximum system profitability (1308.0 ₹/ha/day) was recorded with turmeric +bottlegourd. On the contrary, minimum system profitability (695.8 ₹/ha/day) was recorded with open cultivation of turmeric. Employment generation is a key indicator to assess sustainability of any production system. It was evident from data (Table 2) that vertical integration of cucurbits with turmeric generated more employment as compared to monocropping of turmeric that generated only 637 mandays/ha to harvest the final produce. Among the vertical integration systems, turmeric + squash cropping system provided highest employment (724 mandays/ha) followed by turmeric+ bottlegourd cropping system. Cumulative synergetic effect of intercropping over monocropping was also reported by Wang *et al.* (2014). Data related to relative system employment generation efficiency (REGE), i.e. additional mandays required for an improved system in relation to the existing production system, showed that all the vertical combinations had higher economic generation

Table 1 Effect of vertical cropping on turmeric equivalent yield (TEY), system production efficiency (SPE), relative production efficiency (RPE) (Data pooled over 5 years)

Treatment	Average yield (t/ha)					TEY (t/ha)	SPE (kg/ ha/day)	RPE (%)
	Turmeric	Cucumber	Bottlegourd	Sponge gourd	Squash			
Turmeric + Cucumber	29.6	4.8	--	--	--	31.96	87.6	54.3
Turmeric + Bottlegourd	30.3	--	10.4	--	--	33.94	93.0	63.9
Turmeric + Sponge gourd	28.4	--	--	9.4	--	33.10	90.7	59.8
Turmeric + Squash	26.4	--	--	--	7.9	28.37	77.7	37.0
Turmeric (Monocropping)	20.7	--	--	--	--	20.71	56.7	0.0
SEm±	--	-	-	-	--	1.40	2.34	--
LSD (P=0.05)		-	-	-		9.47	5.77	--

Table 2 Effect of vertical cropping on system net returns, B:C ratio, profitability, relative economic efficiency (REE), employment generation and relative employment generation efficiency (REGE) (Data pooled over 5 years)

Treatment	Average cost of cultivation (₹ × 10^3 /ha)	Net returns (₹ × 10^3 /ha)	B:C ratio	Profitability (₹/ha/day)	REE (%)	Employment generation (Man-days)	REGE (%)
Turmeric + Cucumber	208.7	430.47	3.06	1179.4	69.49	703	10.20
Turmeric + Bottlegourd	201.4	477.41	3.37	1308.0	87.97	715	12.16
Turmeric + Spongegourd	226.2	435.82	2.93	1194.0	71.60	708	10.98
Turmeric + Squash	190.6	376.79	2.98	1032.3	48.36	724	13.50
Turmeric	160.3	253.98	2.58	695.8	0.0	637	0
SEm±	--	6.92	0.12	5.07	--	--	--
LSD (P=0.05)	--	13.66	7.90	27.43	--	--	--

Table 3 Effect of vertical cropping on soil fertility status and soil microbial biomass carbon (SMBC) after five years

Treatment	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	SMBC (g/kg soil)
Turmeric + Cucumber	2.15	220.8	18.2	177.2	152.9
Turmeric + Bottlegourd	2.18	231.2	21.5	185.8	155.4
Turmeric + Spongegourd	2.16	225.7	18.8	189.3	164.8
Turmeric + Squash	2.18	241.0	22.2	194.7	175.9
Turmeric	2.14	216.2	17.4	168.5	147.7
SEm±	0.014	27.6	0.71	2.59	4.09
LSD (P=0.05)	NS	85.12	2.20	7.99	12.62
Initial value	2.12	201.2	15.9	156.1	139.3

ability as compared to the prevailing system of the region. Among the vertical cropping sequences, integration of turmeric with squash resulted in maximum REGE (13.50%) followed by turmeric+ bottlegourd system.

Post-harvest soil fertility status: Soil organic carbon is less affected by vertical cropping over a period of five years but it was dependent on crop combinations. All vertical cropping systems did not change soil organic carbon significantly, but turmeric + squash and turmeric+bottle gourd recorded the highest organic carbon content among the various vertical crop combinations (Table 3). Positive effect of plant diversity on soil carbon storage was also reported by Beedy *et al.* (2010).

The crops with varying root depth, tap different layers of soil for plant nutrients and moisture. Among the available nutrients, maximum amount of nitrogen (241 kg/ha), phosphorus (22.2 kg/ha) and potassium (194.7 kg/ha) was recorded in turmeric + squash system followed by turmeric + bottle gourd. It was presumed that the nutrient removal would be more in vertical cropping over the open cultivation of turmeric and it is logically correct also. However, in the present study, fixed plots were maintained over five years and residue of both the crops were incorporated in same plot which might be the basic reason for fertility improvement in vertical integration over the open cultivation of turmeric. Improvement in available soil nutrients due to addition of crop residue was also reported by Kopke and Nemecek (2010), Yadav *et al.* (2019). With regards to the soil microbial biomass carbon (SMBC), vertical integration significantly improved the SMBC over the open cultivation of turmeric (monocropping). Improvement in selected soil biological activities in intercropping systems was also reported by Wang *et al.* (2014). Among the vertical combinations, the maximum value of SMBC (175.9g/kg) soil was recorded with turmeric + squash followed by turmeric+ sponge gourd. The soil biological activities are greatly influenced by the type of crops grown in the combinations, hence the results were in agreement with the finding of Gunes *et al.* (2007).

Thus, it can be concluded that the ecofriendly vertical cropping of turmeric with cucurbits is a viable alternative for sustaining the livelihood security of hill farmers. Combination of turmeric with bottle gourd is the best option for harvesting the maximum crop productivity from unit area in NEHR. Therefore, this can be recommended for proper utilization of sloping lands in NEHR to achieve higher productivity and income in the region.

ACKNOWLEDEMENTS

The authors are thankful to the ICAR-IIFSR, Modipuram, Meerut, Uttar Pradesh for providing financial support to conduct this research under AICRP-IFS.

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