

Production Potential of Turmeric under Different Cultural Practices in Guava based Agrihorticulture Practice of Agroforestry

THESIS

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In

**FORESTRY
(AGROFORESTRY)**

By

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2013

CERTIFICATE – I

This is to certify that the thesis entitled “**Production Potential of Turmeric under Different Cultural Practices in Guava based Agrihorticulture Practice of Agroforestry**” submitted in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE IN FORESTRY (AGROFORESTRY)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Jayashree Hembram** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been fully acknowledged by her.

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CERTIFICATE – II

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ABBREVIATIONS

@	:	At the rate of
<i>et al.</i> ,	:	And others
BCR	:	Benefit cost ratio
cm	:	Centimetre
CD	:	Critical difference
DAS	:	Days after sowing
⁰ C	:	Degree centigrade
DF	:	Degree of freedom
db- 0.30m	:	Diameter at base
dbh-1.37	:	Diameter at breast height
LAI	:	Leaf Area Index
GMR	:	Gross monetary return
ha	:	Hectare
max	:	Maximum
m	:	Metre
viz.	:	Namely
NMR	:	Net monetary return
N	:	Nitrogen
ha ⁻¹	:	Per hectare
%	:	Percentage
P	:	Phosphorus
K	:	Potassium
Q	:	Quintal
Rs.	:	Rupees
SEm±	:	Standard error of means
i.e.	:	That is

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INTRODUCTION

Agroforestry is a collective term for all land use systems and practices in which woody plants (tree/shrubs) are deliberately combined with herbaceous crops and/or animals on the same land management unit with some form of spatial arrangement or in sequence. Agroforestry provides more opportunity for efficient use of natural resources as compared to monocropping of trees or crops (Venkatrao, 2005). Agroforestry enables returns from land even in extreme droughts or other natural calamities when pure agriculture fails and also allows diversified land use and reduces the risk associated with monoculture. It generates high income and minimizes risk in cropping enterprises (Rahangdale, 2011).

Under agroforestry system, fruits owe special significance on account of short juvenile phase than timber trees and assure regular production for long period (up to 40 years). This is the most common management system. This system is highly profitable for the farmers having small holdings which cannot afford the investment required to make their holdings more productive. Under certain circumstances available solution in the agrihorticulture system which combines fruit trees with agricultural crops. The horticultural trees provide cash returns to the growers. The farmers can continue to harvest arable crops until the trees develop a dense canopy or bear fruits. Experiences have indicated that agrihorticulture, obviously due to assured returns and national security is preferred by the farmers than agrisilviculture. It provides higher economic return under stressed conditions.

Guava (*Psidium guajava*), the "poor man's fruit" or "apple of the tropics" is a popular tree fruit of the tropical and subtropical climate and is native to the tropical America stretching from Mexico to Peru. It excels most other fruit trees in productivity, hardiness, adaptability and vitamin-C content. Besides its high nutritive value, it bears heavy crop

every year and gives good economic returns involving very little input. This has prompted several farmers to take up guava cultivation on a commercial scale is the fourth most important fruit after mango, banana and citrus which is native to tropical America. It tolerates high temperatures and drought conditions prevalent in India. Major guava producing states include Uttar Pradesh, Bihar, West Bengal, Maharashtra, Chhattisgarh, Tamil Nadu, Karnataka, Madhya Pradesh, Gujarat and Andhra Pradesh. The cultivated area of guava in M.P. is 2763 ha. and production is 55260 tonnes ha⁻¹ (Agricultural Statistics, 2004-05). The fruit is a good source of vitamin C, pectin, calcium and phosphorus and is used for the preparation of processed products like jams, jellies and nectar. The leaves are used for toothache treatment. Its wood is moderately strong and durable and useful for making handles, in carpentry and turnery. In addition, the wood is excellent as fuel wood and a valuable resource for charcoal. However, overall performance of the different cultivars that Allahabad Safeda, Lucknow-49, Rewa-72, Dharidar, Apple Colour and Gwalior-27 are promising for cultivation in Malwa Plateau conditions of Madhya Pradesh (Mahour *et al.*, 2012).

Turmeric (*Curcuma longa* L.), belonging to the family Zingiberaceae is a native of South Asia particularly India (Parthasarthy *et al.*, 2006). It thrives well under shade and can be grown on different soil types from sea level to 1500m elevation. Turmeric is valued for its underground orange coloured rhizome which is used as natural colouring agent for food, cosmetics and dye. Curcuminoids the active principles in turmeric rhizomes is known to have some medicinal properties and has been used efficiently in the treatment of circulatory problems, liver diseases, dermatological disorders and blood purification. India is the largest producer, consumer and exporter of turmeric in the world (Parthasarthy *et al.*, 2006). The global production of turmeric is around 11 lakh tonnes per annum. India dominates the world production scenario contributing 78 % followed by China (8%),

Myanmar (4%) and Nigeria and Bangladesh together contributing to 6% of the global production. Indian turmeric is considered to be the best in the world market because of its high curcumin content (3.14% by weight). India exported 5150 tonnes of turmeric valued at Rs.164.80 crores during 2006-07. The cultivated area under turmeric in M.P. is 664 ha and the production is 637.44 tonnes and the productivity is 0.96 tonnes ha⁻¹ (Agricultural Statistics, 2004 – 05).

Earthing is an important cultural practice in cultivation of turmeric for good harvest, which is beneficial for proper growth, development and yield of this crop. Earthing up provides sufficient soil volume for root proliferation, promotes better soil aeration and provides a sound anchorage or support to the crop and thus preventing lodging and helps to control weeds. The root development starts after 30 days and so the operation is carried out in different stages i.e., 30, 45, and 60 days after planting etc.

On the basis of experiment conducted in JNKVV it was reported that crops like turmeric and ginger etc. can be taken successfully, but the suitable packages of practices to grow these crops under shaded conditions are not developed hence, the present investigation was conducted to study the effect of planting method and time of earthing on the growth and yield of turmeric under guava based agrihorticulture practice.

It is time that greater attention be devoted to economically and ecologically sustainable agricultural production system, to design more efficient and ecologically sustainable agroforestry systems to overcome physiological, biological, ecological and economic constraints and should aim to achieve the highest possible output per unit of land, water, time and labour (Venkatrao, 2005).

Keeping above facts in view, the present investigation entitled **“Production potential of turmeric under different cultural practices in guava based Agrihorticulture practice of Agroforestry”** is undertaken with the following objectives:-

1. Find out the suitable method of planting and time of earthing on the growth and yield of turmeric under guava trees.
2. Find out the interaction effect between methods of planting and time earthing on the yield attributes of turmeric under open and shaded conditions.
3. Find out the economics of the treatments.

REVIEW OF LITERATURE

The present investigation deals with the growing of field crops under well established tree plantation in agrihorticulture system.

I. Effects of methods of planting on the growth and yield of turmeric under shaded conditions of orchards

Baghel *et al.*, (2004a) reported that turmeric cv. Suroma grown under the shade of mango trees showed the tallest plants (52.85 cm) with more number of leaves (10.25) and number of tillers/clump (7.02). They also reported that variety Suroma led to record the highest fresh marketable yield (234.26 q/ha) and took more days (255) to reach maturity than other varieties.

Baghel *et al.*, (2004b) found that cultivation of turmeric as an intercrop in the vacant places of mango orchards gave maximum productivity (232.19 q/ha) followed by cultivation of turmeric in the aonla orchard (228.57 q/ha), whereas, minimum productivity (172.86 q/ha) of turmeric was recorded in mix orchard of mango+aonla.

Baghel *et al.*, (2004c) reported that ridge method of planting of turmeric significantly gave higher yield per plant per unit area basis than those obtained with furrow and flat method of planting. They further added that furrow and flat method of planting were at par for yield.

Bisht *et al.*, (2004) emphasized that turmeric being a shade loving crop did better under the shade of fodder trees than obtained under open condition.

Sharma and Rai (2004) reported that the planting of turmeric cv. Ranga produced the highest yield (143.2 q/ha) of fresh rhizomes under the shade of mango.

Pandey *et al.*, (2004) revealed that the intercropping of turmeric in between mango and aonla orchards proved feasible as well as productive. The planting of turmeric gave 232.2 and 228.6 q/ha fresh yield of rhizomes under mango and aonla orchards which might be due to the fact that these orchards pass more sunlight as mango is taller and aonla has thin canopy when compared to citrus and guava orchards.

Venkatrao (2005) observed that the pod yield of groundnut was higher when teak alley was in east-west direction as compared to teak alleys in north-south direction and it was higher in 4-5 m distance from teak row as compared to 0-1 m from teak row in all the agroforestry systems. The pod yield of groundnut was higher (1318.62 kg/ha) when grown in agroforestry system.

Parthasarthy *et al.*, (2006) reported that India has 149,410 ha area under turmeric cultivation with a total annual production of 527,960 tonnes the compound growth of turmeric area is 6.30 and production is 3.37 when comparing 2000 levels over those of 1970. It was found that site suitability is an important factor to determine the productivity of the crop. A highly suitable location may not result in larger yields than suitable or marginally suitable areas. Suitability maps are useful to determine areas which will have the greatest success for growing a particular crop in a region.

Leve (2008) reported that growing of turmeric with guava trees produced higher monetary return (Rs. 201950 /ha.) under raised bed method of planting than growing of turmeric alone (Rs. 195550 /ha.) and guava (Rs. 6400 /ha.) under Agrihorticulture practice of agroforestry.

Padmapriya and Cheziyan (2009) reported that the quality parameters of turmeric were found to be higher under shade compared to open conditions.

Olojede *et al.*, (2009) worked on the effect of variety, rhizome, and seed bed types on yield of turmeric (*Curcuma longa* L.) under a humid tropical agro-ecology and found that planting either on the flat bed or ridge bed using the mother rhizome will ensure optimum yield and rhizome yield. However, optimum yield to be obtained when planting on the flat bed, the land has to be ploughed and harrowed for the formation of good rhizome.

Ahirwar (2009) reported that the application of nitrogen up to 200 kg/ha along with potassium up to 200 kg/ha proved most suitable fertilizer dose for growing turmeric variety PCT – 8 under the existing agroclimatic conditions of Vindhya region of Madhya Pradesh. The fertility ($N_{200} \times K_{200}$) brought about maximum rhizomes yield up to 103.50 q/ha, net income up to Rs.316488/ha and benefit : cost ratio up to 3.24.

Gill *et al.*, (2008) worked out on the effect of planting dates and methods of planting of turmeric (*Curcuma longa* L.) intercropped in Poplar (*Populus deltoids*) plantation and found out that the ridge method of planting produced 8%, 11%, and 9.8% more yield which was significantly higher than flat method of planting during 2004-05, 2005-06, 2006-07, respectively.

Kumar and Gill (2010) carried out at Ludhiana (Punjab) to evaluate the effect of planting method, plant density and planting material on growth, yield and quality of turmeric and found out that fresh rhizome yield of 164.8 and 160.3 q ha⁻¹ (pooled data) was produced in flat and ridge method of planting but the differences were non-significant. Closer plant spacing or higher plant density produced highest fresh, dry and processed turmeric yield and it decreased with decrease in plant density; whereas, number and weight of rhizomes increased with decrease in plant density. Planting of mother rhizomes produced highest fresh (207.7 q ha⁻¹), dry (46 q ha⁻¹) and processed

(44.1 q ha⁻¹) turmeric yield and it decreased significantly with decrease in seed size.

Bhadoria (2010) carried out an experiment in JNKVV and reported that the ridge bed method of planting performed significant extent in case of plant height and number of leaves per plant breadth of leaf and number of clumps per plant in turmeric.

Rahangdale (2011) carried out an experiment at JNKVV reported that growing of turmeric with guava produced higher monetary returns i.e., 103600/ha under raised bed method of planting than growing of turmeric alone i.e., 17300/ha under Agrihorticulture practice.

II. Effect of time of earthing on the growth and yield of turmeric under shaded conditions

Newaz *et al.*, (2001) reported that the tree species in association with crops in agroforestry compete strongly with crops for light, nutrients, space and moisture which have an adverse effect on the intercrop yield mainly with the advancement in growth period of trees.

Koshta and Khare (2003) emphasized that growing of paddy with guava in agroforestry system led to record higher monetary return (Rs.7626/ha) than growing of paddy alone (Rs. 6235/ha) due to reduced investment in weed control.

Koshta *et al.*, (2004) observed that earthing twice at 60 and 90 days growth stages of turmeric produced maximum yield (7.0 q/ha) which was 36.1% and 19% higher than no earthing (5.14 q/ha), and earthing once at 60 days growth stage (5.88 q/ha), respectively. Two earthing proved to be the best to produce superior yield attributes like plant height number of leaves/plant, number of rhizomes/plant, except to number of fingers/plant over no earthing and one earthing.

Dhillon *et al.*, (2007) studied the effect of 2 years old poplar trees on inter crops of turmeric and soybean. They reported that turmeric

under shaded condition showed a yield reduction of 14% while in soybean; yield reduction was 17.6% as compared to sole crop.

III. Effect of methods of planting and time of earthing on the growth and yield of turmeric under open condition

Prajapati *et al.*, (2012) carried out at Navsari (Gujarat) during Kharif season 2005. In all total eight treatment combinations involving 16 year old forest tree species viz., *Terminalia arjuna* Bedd. (T1), *Casuarina equisetifolia*. (T2) and *Mitragyna parvifolia* Korth. (T3) and open field (T0) as main plot treatments and two varieties of *Cucurma longa* L. namely Sugundham (C1) and Kesar (C2) were tried as an intercrop in FRBD with the four replications. Significantly the maximum plant height, number of leaves, number of shoots, leaf length, leaf breadth, rhizome length, rhizome breadth, highest yield per plant and per plot were recorded when crops grown under T3 (Kalam) as compared to T0 (open condition). Among the tree species significantly the maximum light intensity was observed under Kalam followed by Arjun and Casuarina. The variety Sugundham was found compatible when grown as an intercrop with Kalam and resulted in better growth and yield. From economic point of view *Curcuma longa* (var.-Sugundham) grown under Kalam was found more profitable (BCR: 2.34) than other treatments and variety.

Islam *et al.*, (2002) conducted the research work to find out the optimum plant spacing for maximizing the yield of turmeric. Four plant spacing i.e., 45 x 10, 45 x 20, 45 x 30, and 60 x 30 were considered in the study. The highest average yield of 17.87 t/ha was obtained at 45 x 10 plant spacing but economically 45 x 20 plant spacing was viable for turmeric production.

Angles and Hosamani (2002) studied the performance of turmeric in terms of area, production and productivity in states of South India. Evolving location-specific cultivars, adoption of modern cultural

practices and intensive cultivation were some of the suggestions for enhancing the productivity of turmeric.

Singh *et al.*, (2003) studied on ginger sown in flat beds, ridges and in flat beds followed by earthing up and found out that plant height, number of leaves per clump, number of tillers per clump, leaf length, fresh and dry yield, crude protein and fibre, and volatile oil content were highest when ginger was sown in flat beds followed by earthing up and with the application of 50 kg P/ha.

Yadav *et al.*, (2006) studied on the phenotypic and genotypic correlation of 12 quantitative characters namely plant height number of clumps/plant; number of leaves/plant, number of primary and secondary rhizomes, length of mother, primary and secondary rhizomes, weight of mother, primary and secondary rhizomes and yield/plant. All the characters, under study showed positive correlation with yield both at phenotypic and genotypic levels.

Shaikh *et al.*, (2006) studied the effect of different planting methods (flat bed, furrow bed and raised bed) and 3 times of earthing up (3, 4 and 5 months after planting) on ginger. Earthing up at 4 months after planting gave significantly higher green rhizome yield (19.10 t/ha) compared to earthing up at 3 and 5 months after planting (14.33 and 15.94 t/ha respectively).

Kandiannan and Chandragiri (2008) conducted a field experiment with split plot design to study the effect of monetary and non monetary input on growth, nutrient uptake, yield and economics of turmeric. Non monetary input viz; two varieties (BSR 1 and BSR 2) and three planting time (15 May, 15 June and 15 July); monetary input viz. three spacing 30cm x 15cm, 45cm x 15cm, and 60cm x 15cm and three N levels (125, 150, 175 kg/ha). Turmeric variety BSR 2 out yielded BSR 1 in terms of growth, nutrient uptake and yield. Planting the turmeric during middle of May (15 May) was superior compared to 15 June and 15 July planting.

Dey and Datta (2009) carried out a field experiment during the Rabi season of 2005-06 and 2006-07 to select the suitable Chilli (*Capsicum annum* L.) genotypes under open and Mahogany (*Swietenia mahagani* L.) based Agroforestry system. The maximum light intensity was recorded under open field than the Agroforestry system. It was observed that vegetative characters such as plant height and stem girth were promoted in Agroforestry, while branches per plant and reproductive characters like fruit length, fruit diameter and yield were higher in open field CA-5 recorded higher yield (10.23 t/ha).

Chattha *et al.*, (2010) studied the three earthing up treatments i.e., no earthing up, earthing up 90 days after planting (DAP) and earthing up at 120 DAP. Maximum number of tillers (14.34/m²) were obtained with no earthing up followed by earthing up at 120 DAP (14.28 tillers/m²).

Manhas *et al.*, (2011a) conducted a field experiment at Ludhiana to study the effect of different planting material, planting dates and harvesting time on the growth, yield and quality of turmeric. Use of mother rhizomes as planting material resulted in significantly higher growth parameters viz. Number of leaves/plant, plant height and dry matter accumulation/plant as compared to primary and secondary finger planting material during both the year.

Manhas *et al.*, (2011b) studied the effect of different cultural practices on yield and economy of turmeric (*Curcuma longa* L.). Oil and curcumin content in turmeric was not significantly affected by the planting materials, mulch or FYM application.

Getachew *et al.*, (2012) studied the effect of intra row spacing and four times of earthing up: at 15, 30, 45 days after plant emergence and no earthing on growth and yield of potato (var. Jalene). The effect of time of earthing up was found highly significant on all growth parameters: days to 50% flowering and maturity, plant height and spread, stem diameter, leaf area and main stem number and all yield

parameters studied. Earthing up at 15 days after plant emergence showed superior performance in most and yield parameters. .

IV. Effect of methods of planting and time of earthing on the growth and yield of turmeric under shaded condition

Singh and Singh (2001) investigated the effect of three tree species (4.5 years old) namely eucalyptus (*Eucalyptus tereticornis*), deshi babul (*Acacia nilotica*) and poplar (*Populus deltoids*) on the performance of turmeric (*C. longa*). The mean germination count of turmeric was maximum in control i.e. in open condition (4 plants m-1 row length).

Sharma and Rai (2004) demonstrated that the uniform mother rhizomes of 5 turmeric cultivars (Rashme, Ranga, Suroma, Rooma and Sonali) were planted in third week of June in all years at 60 x 20 cm under shade of 35 to 40 year old mango trees. The recommended practices for turmeric cultivation were adopted. The crop was harvested in the month of April in all years. Ranga produced the highest rhizome yield of 143.2 q/ha, whereas Sonali gave the lowest yield of 122.5 q/ha. Ranga, followed by Rashme, is recommended for shaded cultivation in mango orchards of Madhya Pradesh.

Dey *et al.*, (2006) investigated the growth and productivity of turmeric as a shade-tolerant, with subabul (*Leucaena leucocephala*), resulted in the mean yield of turmeric (139 q/ha) which was not influenced due to growing of subabul. This agroforestry system was found to be an effective and economic form of land management and is expected to provide a considerable income 8-10 years after planting.

Sarangi *et al.*, (2007) reported that turmeric was grown under the shade of 25 trees during 2003-05. The highest curcumin, oil and oleoresin contents in rhizomes were obtained under the shade of *Cinnamomum camphora*, *Cunninghamia lanceolata* and *M. ferrea*, respectively.

Dhillon *et al.*, (2009) conducted an experiment to explore the performance of turmeric (*Curcuma domestica* [C. longa]) under three and four year old poplar (*Populus deltoids*) canopy. Results showed maximum LAI of 0.52 and 0.44 under the three and four year old poplar trees, respectively. Net photosynthesis, stomatal conductance, and transpiration in turmeric were higher in open areas than in shaded areas.

Hossain *et al.*, (2009) examined the effects of relative light intensity (RLI) on the growth, yield and curcumin content of turmeric and the study indicated that turmeric is a partial shade-tolerant plant that could be cultivated at around 59-73% RLI for higher yield and curcumin content.

V. Correlation regression

Jain and Sharma (2011a) studied the association of growth and yield attributing characters of paddy under guava based agrihorticulture practices of agroforestry in 15 years old guava plantation. The regression analysis revealed that weight of grains per panicle was the most important character towards the seed yield per hectare. The increase in weight of grains per panicle by one gram may result an increase in seed yield by 161.115 kg/ha.

Jain and Sharma (2011b) studied the growth characters of turmeric under guava based agrihorticulture practice of agroforestry. The correlation coefficient amongst different growth characters of turmeric on fresh rhizome yield revealed that fresh yield of turmeric had significant highest positive correlation width of finger/plant (0.7954) rhizome yield/plant (0.9390) number of fingers/rhizome (0.9322) and length of fingers/plant (0.7954). The regression analysis revealed that with the increase of 1 cm in plant height the increase in fresh yield of turmeric could be obtained by 2.056 kg/ha. Similarly the increase of 3.77, 1.09, 23.76, 14.81 and 85.92 kg./ha can be predicted with increase of 1 cm in stem girth, 1 gm in yield per plant, 1 finger/rhizome, 1 cm length and width of finger/plant respectively.

MATERIALS AND METHODS

The materials used and methods adopted during the course of present investigation are concisely described in this chapter. The edaphic and climatic conditions of the locality influenced the growth and the yield of the crops, besides the treatment tested hence these parameters are also described here :

Experimental site

The field experiment was conducted on a well established 16 year old orchard of guava cv. Lucknow-49 at Forestry Research Farm, Imalia, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). The present investigation was carried out during Kharif season of 2012-13. The facilities required for conducting this experiment were available at the research farm.

Climate

Jabalpur lies between 22° 49' to 24° 8' North Latitude and 78° 21' to 80° 58' East Longitude with an average altitude of 411.78 metres above the mean sea level. Jabalpur belongs to Kymore Plateau and Satpura Hills Agro-climatic Zone as per classification of National Agricultural Research Project.

Jabalpur enjoys a typical subtropical climate with hot dry summer and cool dry winter. Temperature extremes varies between minimum temperature of 2°C in the months of December - January to maximum temperature of 46°C in the months of May-June. According to the 20 years of the mean meteorological data, the average annual rainfall for the locality is 1315 mm, which are mostly received in the months of mid June till the end of September with an occasional winter showers in the month of December-January (Figure 1).

Table 1. Weekly meteorological data during Crop Season (Kharif 2012 – 13)

Month	Met. week	Temperature (°C)		Relative Humidity (%)		S.S. (hrs.)	Rainfall (mm)	No. of Rainy days	Wind Velocity (Km/hr)
		Max	Min	Morn.	Even.				
June	23	40	27.4	45	23	8.1	0	0	8.5
	24	40.2	26.7	64	30	4.9	58.2	2	8.5
	25	33.2	23.2	78	53	3.3	63.4	2	9
	26	37.7	27	64	42	6.4	0	0	8.8
July	27	34.5	24.4	85	62	5.6	296.8	3	6.9
	28	31.3	23.9	88	77	4.7	116	4	6.3
	29	32.3	24.1	90	76	3.1	117.5	3	6.6
	30	28.2	22.8	95	88	3	119.9	5	6.9
	31	26.3	22	94	81	0	32.4	4	7.6
Aug.	32	27.7	22.7	96	77	1.2	145.8	5	6
	33	28.2	23	89	69	0.8	101.8	5	5.9
	34	30.2	22.9	92	79	4.9	84.4	4	6.3
	35	31.9	24.2	92	69	4.8	3	0	3
Sept.	36	30.8	23.9	93	79	2.8	52.2	3	5.4
	37	30.7	23.4	91	79	2.8	87.4	2	5.1
	38	30.8	23.1	89	69	4.6	11	1	3.9
	39	31.9	22.6	88	51	8.7	0	0	3.1
Oct.	40	33.4	21.9	91	44	7.3	2.3	0	3.3
	41	32.4	18.5	83	35	9	0	0	2.9
	42	32.5	18.6	79	32	9.4	0	0	2.4
	43	31.6	15.2	82	35	8.4	0	0	1.9
	44	27.9	15.6	91	51	6.7	0	0	3.6
Nov.	45	28.2	14.6	88	30	7.7	0	0	3
	46	28.6	10	85	28	8.4	0	0	2.7
	47	27.9	10.6	88	29	7.6	0	0	2.2
	48	28.4	11.5	83	33	8.4	0	0	2.1
Dec.	49	28.7	10.6	85	26	9	0	0	2.1
	50	29	14	92	41	7.2	3.2	1	2.2
	51	25.3	7.1	88	29	8.6	0	0	2.3
	52	23.8	5	90	30	9.1	0	0	2.2
Jan.	1	23.3	7.2	87	42	5.9	0	0	3.6
	2	23	5.2	87	32	9.2	0	0	2.6
	3	26.7	10.1	84	36	8.1	0	0	4
	4	21.4	5	86	36	7.6	0	0	2.9
Feb.	5	24.6	7.4	91	36	7.4	0	0	2.3
	6	25.9	11.3	88	49	6.2	0	0	4.4
	7	25.2	13	91	60	4.1	55.4	3	4.4
	8	25	11	93	49	9.3	4.8	1	3.2
	9	28	9.2	87	37	9.8	0	0	3.1
March	10	30.7	9.9	83	28	9.6	0	0	2.6
	11	31.6	14.7	84	39	7.4	26.1	2	4.6
	12	33.4	16.2	77	28	8.2	0	0	3.6
	13	33.8	16.2	76	30	7.8	7.2	1	3.7

Weather conditions during the Crop Season

Seasonal variations prevailing during the growth period plays an important role on the growth and development of Turmeric crop as well as the Guava trees, which ultimately influenced the final yield of crops. The weekly meteorological data during the course of investigation recorded at Meteorological Observatory, Agricultural Engineering College, JNKVV, Jabalpur are presented in Table 1 and illustrated in Figure 1a.

It is evident from the data that weather conditions were almost favourable for the growth and development of turmeric as well as the guava tree. The monsoon was commenced in the third week of June and terminated in the last week of September (Table 1). During the growing season (June 2012 to March 2013) maximum temperature (44.1°C) was recorded in the month of June and minimum (23.0°C) was recorded in the month of January. The average relative humidity was 45 to 96 per cent in the morning and 23 to 88 per cent in the evening. The rainfall during the crop season was 1388.8 mm and was received in 51 rainy days which had a beneficial effect on growth and development of turmeric crop as well as for the guava tree.

Soil

As earlier mentioned the present investigation was the third consecutive year of experimentation at the same site. Hence, data pertaining to initial soil status of various physio-chemical properties were recorded from the soil sample taken at the time of turmeric sowing from 10 places up to a depth of 0-30 cm with the help of screw type soil auger. The soil samples were well mixed together for making representative samples. The composite samples were analyzed for physio-chemical properties of the soil in the laboratory, Department of Soil Science and Agricultural Chemistry as per standard methods. The analytical values are presented in Table 2. To know the changes in

chemical properties of the soil after three years of experimentation, soil samples from each plot were also taken and analysed separately.

Table 2. Physio-Chemical properties of the soil in experimental area

Sl. No.	Particular	Analytical Values	Category	Method used
A. Mechanical composition				
1.	Sand %	24.65	Silt	International pipette method (Piper, 1967)
2.	Silt %	18.96	Clay	
3.	Clay %	56.39	Loam	
B. Chemical composition				
1.	Organic carbon %	0.46	Medium	Walkely and Black method (Black, 1965)
2.	Available N (Kg/ha)	207.00	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
3.	Available P (Kg/ha)	16.26	Medium	Olsen method (Olsen <i>et al.</i> , 1954)
4.	Available K (Kg/ha)	172.00	Low	Flame photometer method (Chapman and Pratt, 1961)
5.	Soil pH	7.21	Neutral	pH meter (Piper, 1967)
6.	Electrical conductivity (ds/m ² at 25 ⁰)	0.26	Low	Conductivity meter Solubridge method (Black, 1965)

It is obvious from the results that the soil of the experimental field was sandy clay loam in texture, neutral in reaction (pH 7.21) with medium organic carbon content and having low electrical conductivity and medium in available Nitrogen (N) and Phosphorus (P) and low in available Potash (K) content.

Cropping history of the experimental field

The following crop was grown during the past six years under shaded condition of guava orchard.

Table 3. Previous crop grown as intercropping in the experimental field

Year	Kharif		Rabi	
	Crop	Fertilizer N:P:K (Kg/ha)	Crop	Fertilizer N:P:K (Kg/ha)
2006	Turmeric	Nil	Fallow	Nil
2007	Paddy	Nil	Fallow	Nil
2008	Paddy	Nil	Fallow	Nil
2009	Turmeric	Nil	Mustard	Nil
2010	Fallow	Nil	Mustard	Nil
2011	Turmeric	Nil	Mustard	Nil

It is obvious from the above information that in the past Turmeric and paddy crops were grown in the field without using any fertilizers and manures because the soil was having lot of organic matter content due to the addition of leaf litter. Thus, it could be said that the fertility status of the field was homogenous under all treatments.

Experimental Techniques

A field experiment was conducted on Turmeric under guava in shaded condition. It involved 12 treatments which consisted of 3 methods of planting, 2 times of earthing and 2 environmental conditions in RCBD Asymmetrical Factorial with 3 replications. The layout plan of the experiment is depicted through the Figure 2 and other details of the treatments and layout plan are given below :

Treatments – (12)

	Under shaded conditions		Under open conditions
T ₁	Flat bed + earthing at 30 DAP	T ₇	Flat bed + earthing at 30 DAP
T ₂	Flat bed + earthing at 45 DAP	T ₈	Flat bed + earthing at 45 DAP
T ₃	Raised bed + earthing at 30 DAP	T ₉	Raised bed + earthing at 30 DAP
T ₄	Raised bed + earthing at 45 DAP	T ₁₀	Raised bed + earthing at 45 DAP
T ₅	Furrow bed + earthing at 30 DAP	T ₁₁	Furrow bed + earthing at 30 DAP
T ₆	Furrow bed + earthing at 45 DAP	T ₁₂	Furrow bed + earthing at 45 DAP

Experimental detail

Design	:	RCBD Asymmetrical Factorial
Replication	:	3
Treatment	:	12
Total number of plots	:	36
Number of Guava tree per plot	:	1
Planting geometry for guava	:	5 m x 5 m
Gross plot size	:	5 m x 5 m
Distance between row to row of Turmeric	:	50 cm
Distance between plant to plant of Turmeric	:	15 cm
Variety of Turmeric	:	Suroma
Variety of Guava	:	Lucknow-49
Seed rate of Turmeric	:	2000 Kg/ha

Characteristics of the Variety

The Suroma variety of Turmeric has been evolved by the selection from the progenies of 'Sunder' (PT 5-25) during the year 1989. It is a high yielding variety and is recommended for cultivation in all parts of Madhya Pradesh.

It is long duration variety, and matures in about 240-250 days. It gives an average yield of 20 tonnes fresh rhizomes/ha. This variety has a recovery of about 26%, on the basis of dry weight. It contains 3.14% curcumin, 13.0% oleoresin and 4.4% volatile oil.

Field preparation

The experimental field was prepared by tilling it with a tractor drawn cultivator followed by two harrowings for obtaining a fine tilth. The field was finally, levelled by using tractor operated leveller, then the treatments were laid out. Thereafter, flat beds, raised beds, and furrow beds were made manually as per the treatments.

Sowing

The rhizomes were treated with 1% Bordeaux mixture ($\text{CuSO}_4 + \text{CaCO}_3$) for planting, to prevent the possible damages by the seed borne diseases. Planting was done on 10- June 2012. Furrows of 15 cm deep were placed as per treatments. The open furrows were properly covered with the help of manual labourers for proper germination and to prevent the damages from birds and pests subsequently, the field was irrigated to ensure the proper germination and crop stand.

Gap filling

Four weeks after completion of the germination, the dead and damaged seedling were replaced by planting of the seedlings obtained through the thinning of crowded seedlings from the same plot to maintain the homogenous plant population in the plots.

Inter culture

The weeds were removed from all the plots at 25 and 35 days after planting (DAP) by manual weeding to keep the plots free from weed infestation. Earthing was done manually at 30 and 45 DAP under different planting methods as per the treatments by loosening the soil from both the sides of each row with the help of a spade.

Irrigation

Immediately after the planting of crop, it was irrigated by using dairy waste water for ensuring proper emergence and then subsequent irrigation were given, as and when the crop faced moisture stress. In all ten irrigations were given during the crop span period.

Plant protection measures

No plant protection measures were applied on the crop because it did not face any incidence of insect – pests and diseases.

Harvesting

The crop became ready for harvesting in about 9 months after planting. The harvesting was done by digging of turmeric rhizomes manually with the help of spade and kodali. Then the rhizomes were collected manually by hands. The collected rhizomes were transported to store. These rhizomes were cleaned before storage.

Observations on Turmeric

Phenological studies

1. Days taken to start emergence
2. Days taken to start 50% emergence
3. Days taken to full emergence

Plant height

Heights of all tagged plants from each plot were measured with the help of meter scale from ground level to the top of newly emerged leaf of each treatment at 30 DAP and at the interval of 30 days during the entire growth period of crop. Then mean was computed for the observation.

Leaf area

The length and width of five randomly selected leaves from the marked plants of each plot were measured in cm from the base to the tip of the leaf with the help of a plastic scale and then the leaf area was determined as per the formula. After this, mean leaf area was determined.

Number of shoot/hill

The number of shoots/hill were recorded by counting the shoots of five selected plant from each plot.

Number of leaves/shoot

The numbers of leaves/shoot were recorded from five tagged plants from each plot from each treatment.

Stem diameter

The diameter of all tagged plants of each plot was recorded with the help of a digital vernier calliper at the same time when plant height was recorded and the mean was determined for all observations.

Length and Width of leaves

The length and width of five leaves from the marked plants of each plot were measured in centimetre from the base to the tip of the

leaf with the help of a plastic scale and then mean values of both the parameters were determined for all the observation.

Post harvest observations

Yield per plot

Rhizome yield from all five tagged plant from each plot was recorded on a pan balance and then the mean yield per plant was determined.

Number of fingers per rhizome

The number of developed fingers in rhizomes of all five marked plants was counted from each plot after removing the rhizomes and then the mean was worked out.

Length of the fingers

The length of all the fingers were measured in centimetre with the help of a plastic scale from the middle point of the fingers and then the average of fingers was determined

Width of fingers

The width of fingers was measured in centimetre with the help of a thread by wrapping it around the middle point of each finger and then the average of the width of fingers was determined.

Fresh yield ha⁻¹

After harvesting the rhizomes of net plot area from each plot are weighed, then the weight of clean rhizomes was recorded treatment wise on double pan balance and then the values were converted in to yield per hectare by multiplying it with an appropriate factor.

Leaf Area Index

The leaf area per plant was calculated by the following formula as suggested by Sestak *et al.*, (1971).

$$LA/plant = L \times W \times K \times \text{Number of leaves/plant}$$

Where,

K = constant (0.654)

L = length

W = width

The leaf area index was calculated by using the following formula (Watson, 1952).

$$LAI = \frac{A}{P}$$

Where,

A = leaf area

P = ground area

Observation on Guava tree

The following growth characters on Guava tree were recorded as suggested by Chaturvedi and Khanna (1994).

Diameter at Base (db-0.3m)

The girth at base was measured at 30 cm from the ground level with the help of a measuring tape.

$$\text{Diameter at base} = \frac{\text{Girth at base}}{\pi}$$

It is denoted as db 0.3 meter.

Diameter at breast height (dbh-1.37 m)

The girth at the breast height was also measured with the help of measuring tape at 1.37 m height from the ground level.

$$\text{Diameter at breast height} = \frac{\text{Girth at breast height}}{\pi}$$

Dbh is denoted as dbh – 1.37 m.

Basal area (m²)

It is the square of dbh and multiplied by a factor = 0.00007854.

$$\text{Basal area} = (\text{dbh})^2 \times 0.00007854$$

Tree height (m)

The height of the tree is measured from the tip of the leading shoot (from the highest point of the crown where there is no leader) from the ground level. The height of the tree measured with the help of a measuring tape.

Crown spread

The crown spread per tree was recorded from North – South and East – West direction with the help of a measuring tape in metres.

Fruit yield (Kg ha⁻¹)

The weight of the fruit was recorded per tree on a balance and the values were converted in to yield per hectare.

Correlation and Regression study

1. Correlation studies of different yield and the yield attributes of Turmeric with fresh rhizome yield.
2. Regression studies of the yield attributes of Turmeric with the unit change on fresh rhizome yield.

Economics of the treatments

The economics of the treatment have much importance from practical point of view to farmers. Therefore, the economics of different treatment were worked out in terms of cost of cultivation, gross monetary returns (GMR), net monetary returns (NMR) and Benefit : Cost ratio (B:C ratio) to assess the economic viability of the treatments.

Cost of cultivation

The cost of cultivation for each treatment was determined on the basis of inputs used in different operations performed for raising the crop in one hectare area under different treatments.

Gross monetary returns (GMR)

The values could be realized from the produce so obtained under each treatment was computed on the basis of existing market price of the produced (Appendix-II). Total values of the produce (rhizomes) will be the GMR per hectare under different treatments.

Net monetary returns (NMR)

After this, NMR per hectare under each treatment was determined by subtracting the cost of cultivation of a particular from the GMR of the same treatment.

Benefit : Cost ratio (B : C ratio)

To estimate the benefits obtained from different treatment for each rupee of expenditure incurred. B : C ratio of each treatment was calculated as below :

$$\text{B : C ratio} = \frac{\text{GMR per hectare}}{\text{Cost of cultivation per hectare}}$$

Statistical analysis

The statistical analysis of the data was done as per Randomised Block Design (Factorial) as suggested by Panse and Sukhatme, (1967). The significance of the treatment was tested by 'F' test. The critical difference at 5 % level of significance was computed for comparison of the difference of mean.

The data obtained on various growth characters under study were analysed by the method of analysis of variance appropriate for the Randomized Block Design. The skeleton of analysis of variance is as follows :

Table 4. Skeleton of analysis of variance

Sl. No.	Source of variance	d.f.	SS	MSS	F calculated	F table value (5%)
1.	Replication	2				
2.	M	2				3.44
3.	E	1				4.30
4.	C	1				
5.	M x E	2				
6.	E x C	1				
7.	M x C	2				
8.	M x E x C	2				
9.	Error	22				
10.	Total	35				

T value for 22 d.f. = 2.074

The data are summarized in the form of two-way Table mean with appropriate error and critical difference for obtaining statistical interferences.

Standard error of difference between two treatment mean

$$SE_m = \sqrt{\frac{V_E}{r}}$$

$$SE_d = \sqrt{\frac{2 \cdot V_E}{r}}$$

$$C.D. (P = 0.05) = (S. E.) \text{ difference} \times t_{5\%} (22 \text{ d.f.})$$

Correlation and Regression Studies

The correlation matrix amongst different growth characters of turmeric with fresh rhizome yield was calculated as suggested by Sendecor and Cochran (1967) for the following formula.

$$\text{Correlation coefficient (r)} = \frac{\sum xy - \frac{(\sum x) \times (\sum y)}{n}}{\sqrt{\frac{\sum y^2 \times (\sum y)^2}{n} \cdot \frac{\sum x^2 \times (\sum x)^2}{n}}}$$

In order to predict the effects of different variables on fresh rhizome yield of Turmeric, regression model was used and regression coefficient was used to interpret quantitative change in rhizome yield. The following regression equation was used

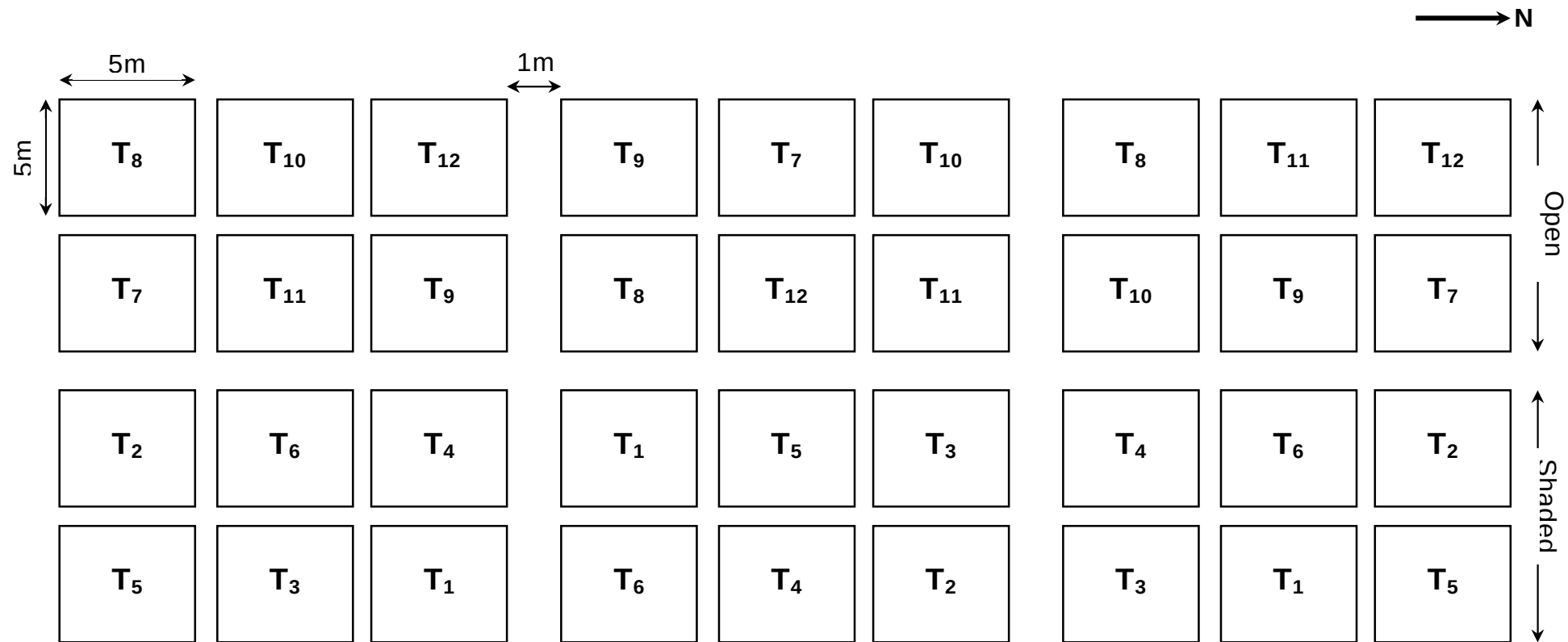
$$\hat{Y} = a + b X$$

where,

$\hat{Y}$ = fresh rhizome yield

a and b are constant and regression coefficient, respectively

X = variables (growth characters of Turmeric)



Treatment – 12 (3 methods of planting, 2 time of earthing, 2 Environmental condition)
 Replication – 3
 Plot size – 5 m x 5m

Figure 2. Plan of layout of experimental area (tree + crop)

RESULTS

Data recorded on various observations during the course of investigation were properly tabulated and statistically analysed to find out the effect of different treatments. The results are furnished in this chapter along with tables under appropriate heading. The most significant results are illustrated through the figures also. The details of statistical analysis are given in appendices for reference.

Observation on turmeric

Germination

The germination has started after 8 days of planting in all treatments except the treatments consisted with raised bed method of planting in which the germination was delayed by 3 days. However the 50 % germination was observed in all treatment at 16 days after planting except the plots under raised beds which was delayed by a week. The full germination was noted at 4th week after planting under all treatments.

Table 5. Effect of methods of planting on emergence of turmeric

Treatment	Days taken to start germination	Days taken to 50 % germination	Days taken to full germination
Methods of planting			
Raised bed	11	23	4 th week
Flat bed	8	16	4 th week
Furrow bed	8	16	4 th week

Table 6. Effect of different treatments on Plant Height (cm) at different intervals of plant growth under Agrihorticulture practice of agroforestry

Treatment	Interval (DAP)						
Methods of planting	30	60	90	120	150	180	At harvest
Raised bed	23.6	67.5	84.5	94.6	109.3	110.1	102.6
Flat bed	22.9	50.4	74.0	76.2	77.3	79.8	77.9
Furrow bed	21.4	47.0	65.3	73.6	75.7	76.6	74.1
SEm±	0.82	2.64	2.17	2.37	2.19	1.85	1.84
CD(p=0.05)	2.40	NS	NS	6.94	6.43	5.44	NS
Time of earthing (DAP)							
30	23.3	55.5	74.9	82.0	93.3	94.9	87.3
45	22.0	54.5	74.3	81.0	81.6	82.7	82.5
SEm±	0.67	2.15	1.77	1.93	1.79	1.51	1.50
CD(p=0.05)	1.96	NS	NS	5.66	NS	NS	4.40
Environmental condition							
Shaded	25.7	55.2	75.5	83.0	93.9	94.4	86.8
Open	19.6	54.8	73.7	80.0	81.0	83.2	83.0
SEm±	0.67	2.15	1.77	1.93	1.79	1.51	1.50
CD(p=0.05)	1.96	NS	NS	5.66	NS	NS	4.40
Interaction							
Method x Earthing	**	NS	NS	**	NS	NS	NS
Earthing x Condition	*	NS	NS	**	**	**	*
Method x Condition	**	*	**	*	**	**	**
Method x Earthing x Condition	**	NS	NS	NS	NS	**	NS

Note: * Significant
 ** Highly Significant
 NS Non Significant

Plant height

Data pertaining to plant height as affected by different treatments at successive growth intervals are given in Table 6 and illustrated through Figure 3.

It is obvious that plant heights gradually increased at a steady rate up to 180 DAP under all treatment and then slightly reduced as the crop reaches towards maturity.

Methods of planting

Results revealed that the plant under raised bed method of planting were significantly taller than that of flat and furrow method of planting at all the growth intervals. However, the maximum plant height was noted under raised bed method of planting followed by flat bed method of planting whereas, the lowest plant height was recorded under furrow method at different intervals of plant growth.

Time of earthing

Significantly maximum plant height was observed when earthing was done at 30 DAP (94.9 cm) as compared to earthing done at 45 DAP (82.7 cm) at different intervals of growth.

Environmental condition

The effect of different environmental condition on plant height was significant at 30 DAP, 120 DAP and at harvest and was found to be 25.7 cm, 83.0 cm and 86.8 cm, respectively under shaded condition whereas, for open condition it was, 19.6 cm, 80.0 cm and 83.0 cm respectively. However, at 180 DAP growth intervals the maximum plant height was noted in shaded condition (94.4 cm) as compared to open condition (83.2 cm).

Table 6.1. Interaction between method of planting and time of earthing on the plant height at harvest

Treatment	Earthing		
Method of Planting	30	45	Mean
Raised bed	102.43	102.73	102.60
Flat bed	79.83	76.01	77.90
Furrow bed	79.55	68.60	74.10
Mean	87.30	82.50	

	Method of planting	Time of earthing
SEm±	1.84	1.50
CD(p=0.05)	NS	4.40

The result revealed that the maximum plant height was recorded under raised bed method of planting when earthing was done at 45 DAP (102.73 cm) as compared to other interaction whereas, the lowest plant height of (68.60 cm) was noted under furrow bed method of planting when earthing was done at 45 DAP (Table 6.1).

Table 6.2. Interaction between time of earthing and environmental condition on the plant height at harvest

Treatment	Earthing DAP		
Condition	30	45	Mean
Shaded	137.1	124.73	130.91
Open	124.03	123.23	123.63

	Time of earthing	Environmental condition
SEm±	1.50	1.50
CD (p=0.05)	4.40	4.40

It also noted, that the maximum plant height was recorded under shaded condition, when earthing was done at 30 DAP (137.1 cm) and minimum was under open condition when earthing was done at 45 DAP (123.23 cm).

Table 6.3. Interaction between methods of planting and environmental condition on the plant height at harvest

Treatment	Method of planting			
Environmental condition	Raised bed	Flat bed	Furrow bed	Mean
Shaded	112.63	79.38	68.31	86.8
Open	92.53	76.48	79.85	83.0

	Method of planting	Environmental condition
SEm±	1.84	1.50
CD (p=0.05)	NS	4.40

It was also noted, that the maximum plant height was in raised bed method under shaded condition (112.63 cm) and minimum was in furrow bed method under shaded condition (68.31 cm).

Stem diameter

The stem diameter of turmeric as affected by different treatments at successive growth interval of the crop are presented in Table 7 and depicted the Figure 10.

It is evident that diameter of stem gradually increased at a steady rate up to 180 days after planting (DAP) under all treatments and then slightly reduced as the crop reaches towards maturity.

Methods of planting

The significant increase in stem diameter was recorded under raised bed method of planting (23.8 mm) followed by flat (20.4 mm) and furrow (18.2 mm) method of planting. However, the effect of planting method on the diameter of stem did not differ significantly in early growth stages of the crop (30 and 45 DAP).

Table 7. Effect of different treatments on Stem diameter (mm) at different intervals of plant growth under Agrihorticulture practice of agroforestry

Treatment	Interval (DAP)						
Methods of planting	30	60	90	120	150	180	At harvest
Raised bed	4.6	9.4	18.6	23.5	23.7	23.8	22.5
Flat bed	4.3	8.6	17.6	19.3	20.1	20.4	19.4
Furrow bed	3.9	7.6	15.8	17.2	18.1	18.2	17.7
SEm±	0.15	0.24	0.83	0.46	0.46	0.47	0.43
CD(p=0.05)	0.46	0.70	2.44	1.36	1.36	1.38	1.28
Time of earthing (DAS)							
30	4.3	8.6	18.0	20.1	21.3	21.7	20.4
45	4.2	8.5	16.7	19.8	20.0	20.0	19.3
SEm±	0.12	0.19	0.68	0.38	0.38	0.38	0.35
CD(p=0.05)	0.37	0.57	1.99	1.11	1.11	1.11	1.04
Environmental condition							
Shaded	4.4	8.6	17.5	20.1	21.0	21.4	20.0
Open	4.1	8.5	17.2	19.9	20.3	20.3	19.8
SEm±	0.12	0.19	0.68	0.38	0.38	0.38	0.35
CD(p=0.05)	0.37	0.57	1.99	1.11	1.11	1.11	1.04
Interaction							
Method x Earthing	NS	NS	NS	NS	NS	NS	*
Earthing x Condition	NS	NS	NS	NS	NS	*	NS
Method x Condition	NS	NS	NS	NS	NS	NS	*
Method x Earthing x Condition	NS	NS	NS	NS	NS	NS	NS

Note: * Significant

** Highly Significant

NS Non Significant

Time of earthing

Effect of time of earthing on stem diameter at different growth stages was found to be maximum at 30 DAP (21.7 mm) and was minimum at 45 DAP (20.0 mm).

Environmental condition

Effect of different environmental conditions and the interaction between the methods of planting and time of earthing was found to be maximum under shaded condition (21.4 mm) and was minimum under open condition (20.3 mm).

Table 7.1. Interaction between methods of planting and time of earthing on the stem diameter at harvest

Treatment	Earthing DAP		
Method	30	45	Mean
Raised bed	22.2	22.78	22.5
Flat bed	20.96	17.88	19.4
Furrow bed	18.1	17.38	17.7
Mean	20.4	19.3	

	Methods of planting	Time of earthing
SEm±	0.43	0.35
CD (p=0.05)	1.28	1.04

The result revealed that the maximum stem diameter was recorded under raised bed method of planting when earthing was done at 45 DAP (22.78 mm) as compared to other interaction whereas, the lowest stem diameter of (17.38 mm) was noted under furrow bed method of planting when earthing was done at 45 DAP.

Table 7.2. Interaction between methods of planting and environmental condition on the stem diameter at harvest

Treatment	Method of planting			
Environmental condition	Raised bed	Flat bed	Furrow bed	Mean
Shaded	21.85	20.45	17.75	20.4
Open	23.13	18.4	17.73	19.8

Methods of planting Environmental condition

SEm±	0.43	0.35
CD (p=0.05)	1.29	1.04

It also noted that the maximum stem diameter was in raised bed method under open condition (23.13 mm) and minimum was in furrow bed method under open condition (17.73 mm).

Leaf Area Index

Leaf area index as affected by different treatments at successive growth intervals of the crop is presented in Table 8 and Figure 17.

The results revealed that the leaf area index is gradually increased at a steady rate up to 180 days after planting (DAP) (5.0) under all treatments and then slightly reduced as the crop reaches towards maturity (4.1). There was significant effect of methods of planting at 30 and 45 days after planting due to lesser number of leaves and also lesser length and width. It also exhibited significant effect at other intervals of plant growth (i.e. 30, 60, 90, 120, 150, 180 and at harvest).

Method of planting

The significant increase in leaf area index was recorded under raised bed method of planting followed by flat and furrow method of planting.

Table 8. Effect of different treatments on LAI at different intervals of plant growth under Agrihorticulture practice of agroforestry

Treatment	Interval (DAP)						
Methods of planting	30	60	90	120	150	180	At harvest
Raised bed	0.7	1.7	3.1	3.4	4.1	5.0	4.1
Flat bed	0.6	1.2	2.0	2.4	2.7	3.8	3.8
Furrow bed	0.5	1.1	1.8	1.6	2.3	3.3	2.9
SEm±	0.04	0.15	0.18	0.12	0.15	0.09	0.09
CD(p=0.05)	0.12	0.46	0.53	0.37	0.46	0.26	0.26
Time of earthing (DAS)							
30	0.6	1.5	2.2	2.5	3.3	4.4	3.8
45	0.5	1.2	2.4	2.5	2.7	3.6	3.3
SEm±	0.01	0.12	0.14	0.10	0.12	0.07	0.07
CD(p=0.05)	0.03	0.37	0.43	0.30	0.37	0.21	0.21
Environmental condition							
Shaded	0.6	1.3	2.4	2.5	3.1	4.0	3.7
Open	0.5	1.4	2.2	2.4	3.0	4.0	3.4
SEm±	0.01	0.12	0.14	0.10	0.12	0.07	0.07
CD(p=0.05)	0.03	0.37	0.43	0.30	0.37	0.21	0.21
Interaction							
Method x Earthing	NS	NS	NS	NS	NS	**	**
Earthing x Condition	NS	NS	NS	NS	NS	NS	**
Method x Condition	NS	NS	NS	NS	NS	NS	**
Method x Earthing x Condition	NS	NS	NS	NS	*	NS	NS

Note: * Significant

** Highly Significant

NS Non Significant

The maximum leaf area index was produced at 180 days growth stage (5.0) of the crop in plot under raised bed method of planting followed by flat bed method (3.8) and furrow bed method of planting (3.3).

Time of earthing

The effect of time of earthing at 30 DAP on the leaf area index at different intervals of crop growth such as 30, 60, 90, 120, 150, 180 and at harvest was found to be 0.6, 1.5, 2.2, 2.5, 3.3, 4.4, and 3.8 respectively and at 45 DAP it was 0.5, 1.2, 2.4, 2.5, 2.7, 3.6, and 3.3 respectively showing an increase towards maturity but reduces after maturity stage is reached.

Environmental condition

Effect of different environmental condition was found to be similar under shaded condition (4.0) as well as under open condition (4.0) at 180 days interval and reduces after reaching the maturity stages.

Table 8.1. Interaction between methods of planting and time of earthing on the leaf area index at harvest

Treatment	Earthing DAP		
	30	45	Mean
Methods of planting			
Raised bed	4.01	4.15	4.10
Flat bed	4.16	3.33	3.80
Furrow bed	3.33	2.40	2.90
Mean	3.80	3.30	

	Methods of planting	Time of earthing
SEm±	0.09	0.07
CD (p=0.05)	0.26	0.21

The result revealed that the maximum LAI was recorded under raised bed method of planting when earthing was done at 30 DAP (4.16) as compared to other interaction whereas, the lowest LAI of (2.40) was noted under furrow bed method of planting when earthing was done at 45 DAP.

Table 8.2. Interaction between time of earthing and environmental conditions on the leaf area index at harvest

Treatment	Earthing DAP		
	30	45	Mean
Shaded	5.70	5.50	5.60
Open	5.81	4.38	5.09

	Time of earthing	Environmental conditions
SEm±	0.07	0.07
CD (p=0.05)	0.21	0.21

It is also noted, that the maximum LAI was under open condition, when earthing was done at 30 DAP (5.81) and minimum was under open condition when earthing was done at 45 DAP (4.38).

Table 8.3. Interaction between method of planting, time of earthing and environmental condition on the leaf area index at harvest

	Earthing DAP			Condition	
	30	45	Mean	Shaded	Open
Method of planting					
Raised bed	4.01	4.15	4.10	4.46	3.68
Flat bed	4.16	3.33	3.80	3.83	3.68
Furrow bed	3.33	2.40	2.90	2.91	2.83
Mean	3.80	3.30	Mean	3.73	3.40
Condition					
Shaded	5.70	5.50	3.70		
Open	5.81	4.38	3.40		

	Method of planting	Time of earthing	Condition
SEm±	0.09	0.07	0.07
CD (p=0.05)	0.26	0.21	0.21

The result revealed that the maximum LAI was recorded under flat bed method of planting when earthing was done at 30 DAP (4.16) in comparison with other interaction whereas, the lowest LAI of (2.40) was

noted under furrow bed method of planting when earthing was done at 45 DAP.

It was also noted, that the maximum LAI was under open condition, when earthing was done at 30 DAP (5.81) and minimum was also observed under open condition when earthing was done at 45 DAP (4.38). It was noted that the maximum LAI was in raised bed method under shaded condition (4.46) and minimum was in furrow bed method under open condition (2.83).

Number of fingers per rhizome

Data pertaining to number of fingers per rhizome as affected by different treatments revealed that the effect of different methods of planting was recorded maximum under raised bed method of planting (7.1) followed by flat bed (6.1) and minimum was recorded under furrow bed method of planting (5.2). The number of fingers were recorded maximum under 30 DAP (6.8) and minimum under 45 DAP (6.4) (Table 9 and Figure 24).

Length of fingers

Method of planting

The effect of different methods of planting on finger was found significant. The maximum length of fingers (5.8 cm) was recorded under raised bed method of planting followed by flat bed method of planting (4.4 cm) whereas, the lowest length of fingers was recorded under furrow method of planting (4.2 cm).

Time of earthing

The effect of time of earthing on the length of fingers was found significant. The maximum length of fingers (4.9 cm) was recorded when earthing was done at 30 days after planting and the minimum (4.7 cm) was when earthing was done at 45 days after planting.

Table 9. Effect of different treatments on Yield attributes of Turmeric under Agrihorticulture practice of agroforestry

Methods of planting	Number of fingers per rhizomes	Length of fingers (cm)	Width of finger (cm)	Fresh turmeric yield (Kg ha ⁻¹)
Raised bed	7.1	5.8	6.6	9279.4
Flat bed	6.1	4.4	6.4	8260.3
Furrow bed	5.2	4.2	6.7	7434.9
SEm±	0.41	0.18	0.20	124.37
CD(p=0.05)	1.22	0.53	0.6	NS
Time of earthing (DAP)				
30	6.8	4.9	6.7	8430.9
45	6.4	4.7	6.5	8218.8
SEm±	0.34	0.14	0.16	101.54
CD(p=0.05)	0.99	0.43	0.48	NS
Environmental condition				
Shaded	6.4	4.9	7.0	8491.2
Open	6.1	4.7	6.1	8158.5
SEm±	0.34	0.14	0.16	101.54
CD (p=0.05)	0.99	0.43	0.48	NS
Interaction				
Method x Earthing	NS	*	NS	**
Earthing x Condition	NS	NS	NS	*
Method x Condition	NS	*	NS	NS
Method x Earthing x Condition	NS	NS	NS	NS

Note: * Significant

** Highly Significant

NS Non Significant

Environmental condition

The effect of different environmental condition was found significant. The maximum length of fingers (4.9 cm) was recorded under shaded condition. The lowest length of finger was recorded under open condition (4.7 cm).

Table 9.1. Interaction between method of planting, time of earthing and environmental condition on the length of fingers (cm)

	Earthing DAP			Condition	
Method of planting	30	45	Mean	Shaded	Open
Raised bed	6.31	5.28	5.80	6.48	5.11
Flat bed	4.26	4.48	4.40	4.31	4.43
Furrow bed	4.03	4.43	4.20	4.30	4.18
Mean	4.90	4.70	Mean	4.90	4.70
Condition					
Shaded	7.90	7.20	7.30		
Open	6.71	7.00	7.10		

	Methods of planting	Time of earthing	Condition
SEm±	0.18	0.14	0.14
CD (p=0.05)	0.53	0.43	0.43

The result revealed that the maximum length was recorded under raised bed method of planting when earthing was done at 30 DAP (6.31cm) as compared to other interaction whereas the lowest length of (4.03) was noted under furrow bed method of planting when earthing was done at 30 DAP.

It was also noted that the maximum length (7.90 cm) was under shaded condition, when earthing was done at 30 DAP and minimum was (6.71 cm) under open condition when earthing was done at 30 DAP.

It was again noted that the maximum length was in raised bed method under shaded condition (6.48 cm) and minimum was in furrow bed method under open condition (4.18 cm).

Width of fingers

Data pertaining to width of fingers per rhizomes as affected by different treatment revealed that the effect of different method of planting and time of earthing was found significant. The maximum width of fingers was recorded under raised bed method of planting (6.6 cm) followed by furrow bed method of planting (6.7 cm) and was recorded minimum under flat bed method of planting (6.4 cm).

The effect of different time of earthing was noted and was found to be maximum under 30 DAP (6.7 cm) and was minimum under 45 DAP (6.5 cm).

The effect of different environmental condition on width of fingers was found to be significant and was recorded to be maximum under shaded condition (7.0 cm) and was minimum under open condition (6.1 cm).

Fresh turmeric yield (kg ha⁻¹)

The ultimate produce i.e., yield is the final assessment of different treatment under any investigation.

Data pertaining to fresh yield (kg ha⁻¹) were obtained from the data of fresh yield (kg plot⁻¹) as influenced by different methods of planting, time of earthing and different environmental condition and their interaction are presented in Table 9.

Methods of planting

The effect of different methods of planting on fresh yield was found significant. The maximum fresh yield of rhizomes (9279.4 kg ha⁻¹) was recorded under raised bed method of planting followed by flat bed

method (8260.3 kg ha⁻¹) whereas, the lowest fresh yield of rhizomes (7434.9 kg ha⁻¹) was recorded under furrow bed method of planting.

Time of earthing

The effect of different timings of earthing i.e., 30 and 45 days after planting was found non-significant.

Environmental condition

The effect of different environmental condition on fresh turmeric yield was found non-significant.

Table 9.2. Interaction between method of planting and time of earthing on the yield of turmeric

Treatment	Earthing DAP		
	30	45	Mean
Method of planting			
Raised bed	9464.5	9094.3	9279.4
Flat bed	8084.41	8436.16	8260.28
Furrow bed	7743.83	7125.8	7434.81
Mean	8430.91	8218.8	

	Method of planting	Time of earthing
SEm±	124.37	101.54
CD (p=0.05)	364.09	304.62

The result revealed that the maximum yield was recorded under raised bed method of planting when earthing was done at 30 DAP (9464.5 kg ha⁻¹) as compared to other interaction whereas the lowest yield (7125.8 kg ha⁻¹) was noted under furrow bed method of planting when earthing was done at 45 DAP.

Table 9.3. Interaction between methods of planting and condition on the yield of turmeric

Treatment	Method of planting			
Condition	Raised bed	Flat bed	Furrow bed	Mean
Shaded	9365.03	8308.85	7799.65	8491.20
Open	9193.78	8211.66	7070.08	8158.50

	Method of planting	Condition
SEm±	124.37	101.54
CD (p=0.05)	364.09	297.27

It is noted, that the maximum yield was in raised bed method under shaded condition (9365.03kg ha⁻¹) and minimum was in furrow bed method under open condition (7070.08 kg ha⁻¹).

Correlation and Regression studies under shaded condition

Table 10. Zero order correlation matrix of fresh turmeric yield (kg ha⁻¹) with different growth parameters under shaded condition

Character	Stem diameter (mm)	LAI	Number of fingers	Length of fingers (cm)	Width of fingers (cm)	Fresh turmeric yield (kg ha ⁻¹)
	(X2)	(X3)	(X4)	(X5)	(X6)	(Y)
(X1) Plant height (cm)	0.8799**	0.9383**	0.5288	0.8772**	-0.3443	0.9485**
(X2) Stem diameter (mm)	-	0.9607**	0.7882 **	0.9154**	-0.2311	0.9605**
(X3) LAI	-	-	0.7749*	0.8569**	-0.2830	0.9352**
(X4) Number of fingers	-	-	-	0.5747	-0.3197	0.5969*
(X5) Length of fingers (cm)	-	-	-	-	-0.2535	0.9579**
(X6) Width of fingers (cm)	-	-	-	-	-	-0.2115

*significant at 0.05 level of probability

**significant at 0.01 level of probability

Correlation

The correlation coefficient amongst different growth characters on fresh yield of turmeric under shaded condition has significant positive association with stem diameter (0.9605) followed by length of fingers (0.9579). The width of fingers had negative correlation (-0.2115), but it was non-significant (Table 10). Different growth characters viz., plant height, stem diameter, LAI, number of fingers and Length of fingers had positive and significant association except number of fingers. Width of fingers had negative and non-significant correlation with plant height (-0.3443), stem diameter (-0.2311), LAI (-0.2830), number of fingers (-0.3197) and length of fingers (-0.2535).

Table 11. Linear regression equation of fresh turmeric yield on different growth parameters under shaded condition

Variable	$\hat{Y} = a + bx$	R^2
Plant height (cm)	$16.06 + 0.04 x_1$	0.89**
Stem diameter (mm)	$6.42 + 0.39 x_2$	0.92**
LAI	$16.67 + 1.16 x_3$	0.87**
Number of fingers	$16.38 + 0.49 x_4$	0.35
Length of fingers (cm)	$3.86 + 1.57 x_5$	0.91**
Width of fingers(cm)	$38.50 - 0.70 x_6$	0.04

Regression

The regression analysis revealed that, the linear increase in fresh turmeric yield was predicted with plant height, stem diameter, LAI, number of fingers, length of fingers and the increase in yield of turmeric could be predicted by 0.04, 0.39, 1.16, 0.49 and 1.57, kg ha⁻¹, respectively with the increase of one unit of each parameter (Table 11). The decline in fresh turmeric yield could be predicted by 0.70 kg ha⁻¹ with increase in width of fingers by one unit under shaded condition in guava based agrihorticulture practice of agroforestry.

Stem diameter followed by length of fingers, plant height and LAI are the most important character towards the prediction of yield. The value of coefficient of determination (R^2) for stem diameter is 0.92 followed by length of fingers is 0.91, plant height is 0.89 and for LAI is 0.87 which approaches to 1 and is found to be highly significant so it may be called as best predictor towards the contribution of fresh turmeric yield.

Correlation and Regression studies under open condition

Table 12. Zero order correlation matrix of fresh turmeric yield (kg ha⁻¹) with different growth parameters under open condition

Character	Stem diameter (mm)	LAI	Number of fingers	Length of fingers (cm)	Width of fingers (cm)	Fresh turmeric yield (kg ha ⁻¹)
	(X2)	(X3)	(X4)	(X5)	(X6)	(Y)
(X1) Plant height (cm)	0.9160**	0.9194**	0.8601**	0.8540**	0.0494	0.9314**
(X2) Stem diameter (mm)	-	0.9855**	0.6976*	0.7526**	0.1281	0.7937**
(X3) LAI	-	-	0.6404*	0.6772*	0.1591	0.8551**
(X4) Number of fingers	-	-	-	0.6404*	0.6772*	0.7129**
(X5) Length of fingers (cm)	-	-	-	-	-0.1396	0.6364*
(X6) Width of fingers (cm)	-	-	-	-	-	0.0930

*significant at 0.05 level of probability

**significant at 0.01 level of probability

Correlation

The correlation coefficients amongst different growth characters on fresh yield of turmeric under open condition had significant positive association with plant height (0.9314), stem diameter (0.7937), LAI (0.8551), and number of fingers (0.7129). The length of fingers (0.6364)

whereas, the width of fingers (0.0930) was found to have positive association but it was non-significant (Table 12).

The width of fingers has negative association with length of fingers (-0.1396) but it was non-significant.

Table 13. Linear regression equation of fresh turmeric yield (kg ha⁻¹) on different growth parameters under open conditions

Variable	$\hat{Y} = a + bx$	R^2
Plant height (cm)	$-9.65 + 0.16 x_1$	0.86**
Stem diameter (mm)	$3.83 + 0.43 x_2$	0.62
LAI	$13.05 + 1.57 x_3$	0.73*
Number of fingers	$13.33 + 0.60 x_4$	0.50
Length of fingers (cm)	$17.04 + 0.49 x_5$	0.40
Width of fingers (cm)	$19.92 + 0.21 x_6$	0.008

Regression

The regression analysis revealed that the linear increase in fresh turmeric yield was predicted with plant height, stem diameter, LAI, number of fingers, length of fingers, and width of fingers/rhizome, the increase in yield of turmeric could be predicted by 0.16, 0.43, 1.57, 0.60, 0.49, 0.21 kg ha⁻¹, respectively with the increase of one unit of each parameter (Table 13) under open condition in guava based agrihorticulture practice of agroforestry.

Plant height is the most important character towards the production of yield. The value coefficient of determination (R^2) for plant height is 0.86 which approaches to 1 and is found to be highly significant here so it may be called as the best predictor towards the contribution in fresh turmeric yield. Merely the 14% variation in the

turmeric yield can be explained by other independent characters towards the fresh turmeric yield.

On the basis of above going finding it may be concluded that the increase in yield of turmeric could be predicted more under shaded condition as compared to open condition. Hence, more productivity of turmeric may be achieved if grown under shaded condition of agroforestry compared with open condition.

Growth characters of Guava tree

Basal diameter (db-0.3 m)

The basal diameter was recorded at 30 cm from the ground level. Amongst the different guava tree, the lowest basal diameter was recorded 11.78 cm while the highest was 21.33 cm. The diameter of plant ranges in between 11.78 to 21.33 cm. The average value of basal diameter was 15.19 cm.

Diameter at breast height (dbh-1.37 m)

This is important growth character which was noted at 1.37 m height. The maximum value of dbh was 18.15. The dbh of other trees ranged in between 7.64 to 18.15 cm. The average value of diameter at breast height was 11.38 cm.

Crown spread

The crown spread controls shading effect on the underneath crop growth. The crown spread was recorded in North-South and East-West direction. In North-South direction the maximum crown spread was observed 6.70 m and the minimum was 3.20 m while in East-West direction the maximum crown spread was 6.90 m and lowest 3.30 m was observed as these values were low hence, there was minimum

shading effect on the crop which could be grown successfully. The average value of crown spread was 5.25 m in North-South direction and on 5.23 m in East-West direction.

Tree height (m)

The maximum tree height was 6.80 m and the minimum was 4.20 m. The height of other guava plant ranged in between 4.20 m to 6.80 m. The average of tree height was 5.35 m.

Economic analysis of treatments

The economic analysis was determined on per hectare area basis, which includes cost of cultivation, gross monetary return, net monetary return and benefit cost ratio (profitability per rupees investment under different treatments). Data pertaining to economic analysis as affected by different treatments are given in Table 14.

Table 14. Economics and benefit cost ratio (B:C ratio) of different treatments under different condition Agrihorticulture practice of agroforestry

Treatments	Net profit (Rs/ha)	B:C ratio
Method of planting		
Raised bed	448934	5.15
Flat bed	385794	4.78
Furrow bed	331734	4.26
Earthing		
30 DAP	396994	4.90
45 DAP	382774	4.73

Net monetary return (net profit)

The net monetary return (NMR) of each treatment was determined by subtracting the cost of cultivation from (GMR) of a particular treatment.

The net monetary return (NMR) also varied due to different method of planting and time of earthing. The NMR for guava alone was RS 33600 per ha obtained under all method of planting and times of earthing whereas, for turmeric alone the minimum net profit of Rs 303634 ha⁻¹ was obtained under furrow methods of planting which increased to Rs 353194 and Rs 414334 ha⁻¹ under flat and raised bed method of planting respectively.

The combined net profit from guava and turmeric was the highest (Rs 448934 ha⁻¹) under raised bed method of planting followed by flat bed method of planting (Rs 385794 ha⁻¹) whereas, the lowest net profit was obtained when planting was done in furrow bed (Rs 331734 ha⁻¹).

The combined net profit from guava and turmeric was the minimum Rs 382774 ha⁻¹ when earthing was done at 45 DAP against Rs 396994 ha⁻¹ at 30 DAP.

Benefit cost ratio

It refers to the net monetary gain under a particular treatment with each rupees of investment. The benefit cost ratio indicates as affected by different treatment. The benefit cost ratio differs due to different method of planting and time of earthing. In case of guava the benefit cost ratio was 6.40 under raised bed method of planting followed by flat bed method of planting (6.09) and furrow bed method of planting (5.39) respectively. It indicated that with each rupee investment the B:C ratio was 6.40, 6.09 and 5.39.

The B:C ratio for turmeric under different method of planting revealed that the highest benefit cost ratio was obtained under raised bed planting (3.90) followed by flat method (3.48). Whereas, the minimum cost benefit ratio was obtained under furrow method of planting (3.13).

The combined benefit cost ratio from guava and turmeric was the maximum Rs 5.15 under raised bed method of planting followed by flat bed method of planting Rs. 4.78 whereas, the minimum benefit cost ratio was observed when planting was done in furrow bed Rs 4.26.

The time of earthing have also influenced the benefit cost ratio from turmeric. The minimum benefit cost ratio Rs. 3.46 ha⁻¹ was obtained when earthing was done at 45 days after planting. The B : C ratio was recorded to Rs 3.55 h⁻¹a when earthing was done at 30 DAP.

The combined benefit cost ratio from turmeric and guava was the minimum Rs 4.73 ha⁻¹ when earthing was done at 45 DAP and was maximum of Rs 4.90 ha⁻¹.

DISCUSSION

The agroforestry based research are mainly aimed to increase the productivity of the crop and tree under available agro-climatic conditions and agro-resources including production technologies. The production or yield is an end result of the plant which depends on genetic constitution of the plant and the edaphic, biotic and environmental factors. In agrihorticulture practice of agroforestry system where crop is grown with fruit trees, as the trees grow, their canopy will also increase which may cause shading effect on crop. Due to shading of tree, growth and yield of underneath crop may be affected.

Keeping this in view, the present investigation was carried out to optimize the productivity of turmeric under guava based agrihorticulture practice in relation to different methods of planting and time of earthing under agro-climatic conditions of Jabalpur region. The results obtained have been discussed critically in the light of research findings of other workers. Relevant explanations have also been given to understand the cause-effect relationship.

Edaphic variations

The present study was undertaken on the field where continuously turmeric cropping system was followed with guava from the last five years. Data on physio-chemical properties showed that fertility status of the soil in the experimental area was fairly homogenous and treatment exhibited their own effects during the investigation. This shows that variation on yield under experimental plots was mainly due to the effect of treatments tested and not by the heterogeneity of soil during the investigation.

Weather variations

The weekly meteorological observations during the period of investigation recorded at the Meteorological Observatory, Agriculture

Engineering College, JNKVV, Jabalpur are presented in Table 1 and graphically illustrated in Figure 1 and 1a. Weather has a significant influence in every sphere or agricultural activity from sowing to harvesting and storage. Weather elements like temperature (maximum and minimum), Rainfall (amount and rainy days), relative humidity and sunshine hours were recorded, which play an important role in crop production. The data revealed that the maximum rainfall was recorded in July (682.6 mm) followed by August (335 mm) making a total of 1017.6 mm. The maximum and minimum temperature and relative humidity were almost identical to their average condition of the locality.

Effect of methods of planting

Growth parameters

In flat bed and furrow bed method of planting rhizomes were emerged out at 8 days after planting whereas, the germination was delayed by 3 days under raised bed method of planting. This might be due to delay in availability of moisture for its germination.

The plants under raised bed method of planting were significantly taller than that of flat bed method of planting while the lowest plant height was observed in furrow methods at all the intervals of plant growth (Table 6). This might be due to greater meristematic activities of the cell. The stem diameter was also higher in case of raised bed method which was significant as compared to flat bed and furrow bed. The results are in confirmity with the findings of Gill et al., (2008), Bhadoria (2010) and Rahangdale (2011).

Physiological parameters

Leaf being the source of photosynthesis to economic sinks exhibited a greater dependence on LAI. In the present experiment the leaf area index was gradually increased at a steady rate up to 180 days and then slightly reduced as the crop reaches towards maturity. The

increased LAI is due to increase in number of leaves/plant. The reduction in LAI towards maturity was due to top reduction in number of leaves/plant, hence there was a decrease in total leaf area with ageing of plants. The plants grown on raised bed exhibited higher LAI than flat bed and furrow method of planting (Table 8). The visual observations on leaves revealed that in raised bed leaves were more in green colour and greater size of the leaves reflecting the effects of planting methods. The increased LAI on the tuber crop is also reported by Dhillon *et al.*, (2009).

Yield parameters

The number of fingers per rhizome was found significant. The length of fingers per rhizome was higher under raised bed method of planting (5.8 cm) followed by flat (4.4 cm) and minimum was in furrow (4.2 cm) method of planting. The width was found to be maximum under raised bed method of planting (6.6 cm) followed by furrow bed method of planting (6.7 cm) and minimum was in flat bed (6.4 cm) method of planting. This might be due to the favourable environment conditions viz., aeration, light interception, drainage and nutrient uptake were favourable. The raised bed method of planting resulted in better growth and yield of turmeric crop.

Fresh rhizome yield (kg ha⁻¹)

The fresh turmeric yield (kg ha⁻¹) was significantly influenced by different methods of planting. The maximum fresh yield was recorded under raised bed method of planting (9279.4 kg ha⁻¹) followed by flat (8260.3 kg ha⁻¹) while the lowest was noted under furrow bed (7434.9 kg ha⁻¹).

The increased in yield under raised bed method of planting was due to more favourable environmental condition viz., aeration, root proliferation, light interception, drainage, better nutrient uptake and availability of better soil condition which has helped in increasing the

growth and yield attributing characters viz., plant height, number of leaves per plant, number of fingers per rhizome. The findings were similar with the findings of Bisht *et al.*, (2004), Olojede *et al.*, (2009), Gill *et al.*, (2008), Kumar and Gill (2010).

Effect of time of earthing

Growth parameters

Plant height was significantly influenced due to different time of earthing. Earthing at 30 DAP exhibited maximum plant height up to 180 DAP after that the plant height reduced as the crop reaches towards maturity. While the lowest plant height was recorded when earthing was done at 45 DAP (Table 6). It might be attributed to favourable physical condition provided for penetration, proliferation and ramification of root resulted in better growth and height of plant. The results are in conformity with the findings of Koshta *et al.*, (2004) and Shaikh *et al.*, (2006).

Physiological parameters

The LAI is the most important parameter which determines the crop growth. The effect of time of earthing on the leaf area index at different interval of the crop growth was found significant.

The maximum leaf area index was recorded at 180 days growth period (4.4) when earthing was done at 30 DAP followed by earthing done at 45 DAP (3.6). It was observed that the LAI decreased towards the maturity stage of the crop.

The increased photosynthetic productivity per unit area increased with increasing in assimilatory area in the canopy architecture developed and favourable conditions for proper vegetative growth when earthing was done at 30 days after planting (Table 8).

Yield parameters

Effect of different time of earthing on yield per plant was found to be maximum under 30 DAP (8430.9 kg ha⁻¹) and minimum under 45 DAP (8218.8 kg ha⁻¹) (Table 9). The effect of different time of earthing on the number of fingers per rhizomes was found to be maximum under 30 DAP (6.8) and was minimum under 45 DAP (6.4). The effect of time of earthing on the length of finger was observed significant and the maximum length of fingers (4.9 cm) was noted when earthing was done at 30 DAP. However, minimum length was observed under 45 DAP (4.7 cm). The effect of time of earthing on the width of fingers was more under 30 DAP (6.7 cm) than 45 DAP (6.5 cm). The increased length of fingers was due to more favourable conditions for the development of fingers under sufficient moisture availability and better soil aeration. The similar findings were also observed by Yadav *et al.*, (2006) and Getachew *et al.*, (2012).

Effect of environmental condition

Growth parameters

Plant height was significantly influenced due to different condition. The shaded condition exhibited maximum plant heights up to 180 DAP. While the lowest plant height was recorded under open condition. The results are in conformity with the findings of Bisht *et al.*, (2004), Sharma and Rai (2004), Padmapriya and Cheziyan (2009), Bhadoria (2010).

Physiological parameters

The LAI is the most important parameter which determined the crop growth. The effect of different environmental condition on the leaf area index at different interval of the crop growth was found non-significant.

Yield parameters

The effect of different environmental condition on the number of fingers per rhizome was found significant and it was observed that the length of fingers (4.9 cm) under shaded condition was more when compared with length of fingers under open condition (4.7 cm). Therefore, the increase in length of fingers attributes to more moisture availability and favourable temperature due to the shading effect of guava canopy.

Fresh rhizome yield (kg ha⁻¹)

The fresh turmeric yield (kg ha⁻¹) in case of different environmental condition was found to be maximum under shaded condition (8491.2 kg ha⁻¹) and was minimum under open condition (8158.5 kg ha⁻¹).

Correlation and regression studies under shaded condition

Correlation

The correlation coefficient amongst different growth character on fresh yield of turmeric under shaded condition had significant positive association with stem diameter (0.9605) followed by length of fingers/plant (0.9579). Other growth characters viz., plant height, LAI, number of fingers, had positive and significant association except number of fingers which is non-significant. The width of fingers/plant had negative association (-0.2115) and was non-significant. Amongst the different growth characters width of fingers had negative association with stem height (-0.3443), stem diameter (-0.2311), LAI (-0.2830), number of fingers (-0.3197), and length of fingers (-0.2535).

Regression

The regression analysis revealed that, the linear increase in fresh turmeric yield was predicted with plant height, stem diameter, LAI, number of fingers, length of fingers the increase in yield of turmeric could be predicted by 0.04, 0.39, 1.16, 0.49 and 1.57, kg ha⁻¹, respectively with the increase of one unit of each parameter (Table 11). The decline in fresh turmeric yield could be predicted by 0.70 kg ha⁻¹ with increase in width of fingers by one unit under shaded condition of guava based agrihorticulture practice of agroforestry.

Stem diameter followed by length of fingers, plant height and LAI are the most important character towards the prediction of yield. The value of coefficient of determination (R^2) for stem diameter is 0.92 followed by length of fingers is 0.91, plant height is 0.89 and for LAI is 0.87 which approaches to 1 and is found to be highly significant so it may be called as best predictor towards the contribution of fresh turmeric yield.

Correlation and regression studies under open condition

Correlation

The correlation coefficients amongst different growth characters on fresh yield of turmeric under open condition had significant positive association with plant height (0.9314), stem diameter (0.7937), LAI (0.8551), and number of fingers (0.7129). The length of fingers (0.6364) and width of fingers (0.0930) were found to have positive and significant association except the width of fingers and length of fingers (Table 12).

The width of fingers had negative but non-significant association with number of fingers (-0.1893) and length of fingers (-0.1396).

Regression

The regression analysis revealed that the linear increase in fresh turmeric yield was predicted with plant height, stem diameter, LAI number of fingers, length of fingers, and width of fingers/rhizome, the increase in yield of turmeric could be predicted by 0.16, 0.43, 1.57, 0.60, 0.49, 0.21 kg ha⁻¹, respectively with the increase of one unit of each parameter (Table 13) under open condition of guava based agrihorticulture practice of agroforestry.

Plant height is the most important character towards the production of yield. The value coefficient of determination (R^2) for plant height is 0.86 which approaches to 1 and is found to be highly significant here so it may be called as the best predictor towards the contribution in fresh turmeric yield. Merely the 14% variation in the turmeric yield can be explained by other independent characters towards the fresh turmeric yield.

Growth character of guava

The basal diameter was recorded at 30 cm from the ground level. Amongst the different guava tree, the lowest basal diameter was recorded 11.78 cm while the highest was 21.33 cm. The diameter of plant ranges in between 11.78 to 21.33 cm. The average value of basal diameter was 15.19 cm.

The diameter at breast height which is an important growth character noted at 1.37 m height. The maximum value of dbh was 18.15. The dbh of other trees ranged in between 7.64 to 18.15 cm. The average value of diameter at breast height was 11.38 cm.

The crown spread controls shading effect on the underneath crop growth. The crown spread was recorded in North-South and East-West direction. In North-South direction the maximum crown spread

was observed 6.70 m and the minimum was 3.20 m while in East-West direction the maximum crown spread was 6.90 m and lowest 3.30 m was observed as these values were low hence, there was minimum shading effect on the crop which could be grown successfully. The average value of crown spread was 5.25 m in North-South direction and on 5.23 m in East-West direction.

The maximum tree height was 6.80 m and the minimum was 4.20 m. the height of other guava plant ranged in between 4.20 m to 6.80 m. The average of tree height was 5.35 m.

Economics of the treatments

The determination of economic factors like cost of cultivation, gross monetary return, net monetary return and benefit cost ratio are the most important to evaluate the effect of treatment for practical value in relation to farmers as well as planners point of view. The farmers are mainly interested to earn more profit per unit area, time and investment while for planner's, policies are mainly concerned with high productivity.

Therefore, economic analysis of the treatment gives valuable information to both planners and growers too. These economic analysis are discussed here by considering the cost of inputs and value of produce on prevailing rates in the local market as per hectare area basis. Although market rate of inputs and outputs to Jabalpur locality may be used on other places and time on the basis of the procedures followed for determining the analysis cost of cultivation was determined treatment wise on the basis of market price of various common and variable agro-inputs (Appendix II).

Net monetary return (net profit)

The net monetary return (NMR) of each treatment was determined by subtracting the cost of cultivation from (GMR) of a particular treatment.

The net monetary return (NMR) also varied due to different method of planting and time of earthing. The NMR for guava alone was RS 33600 per ha obtained under all method of planting and times of earthing whereas, for turmeric alone the minimum net profit of Rs 303634 ha⁻¹ was obtained under furrow methods of planting which increased to Rs 353194 and Rs 414334 ha⁻¹ under flat and raised bed method of planting respectively.

The combined net profit from guava and turmeric was the highest (Rs 448934 ha⁻¹) under raised bed method of planting followed by flat bed method of planting (Rs 385794 ha⁻¹) whereas, the lowest net profit was obtained when planting was done in furrow bed (Rs 331734 ha⁻¹).

The combined net profit from guava and turmeric was the minimum Rs 382774 ha⁻¹ when earthing was done at 45 DAP against Rs 396994 ha⁻¹ at 30 DAP.

B : C ratio

It refers to the net monetary gain under a particular treatment with each rupees of investment. The benefit cost ratio indicates as affected by different treatment. The benefit cost ratio differs due to different method of planting and time of earthing. In case of guava the benefit cost ratio was 6.40 under raised bed method of planting followed by flat bed method of planting (6.09) and furrow bed method of planting (5.39) respectively. It indicated that with each rupee investment the B:C ratio was 6.40, 6.09 and 5.39.

The B:C ratio for turmeric under different method of planting revealed that the highest benefit cost ratio was obtained under raised bed planting (3.90) followed by flat method (3.48). Whereas, the minimum cost benefit ratio was obtained under furrow method of planting (3.13).

The combined benefit cost ratio from guava and turmeric was the maximum Rs 5.15 under raised bed method of planting followed by flat bed method of planting Rs. 4.78 whereas, the minimum benefit cost ratio was observed when planting was done in furrow bed Rs 4.26.

The time of earthing have also influenced the benefit cost ratio from turmeric. The minimum benefit cost ratio Rs. 3.46 ha⁻¹ was obtained when earthing was done at 45 days after planting. The B : C ratio was recorded to Rs 3.55 h⁻¹a when earthing was done at 30 DAP.

The combined benefit cost ratio from turmeric and guava was the minimum Rs 4.73 ha⁻¹ when earthing was done at 45 DAP and was maximum of Rs 4.90 ha⁻¹.



Plate 1. Germination after four weeks



2a



2b



2c

Plate 2a, 2b,2c. Raised bed, Flat bed and Furrow bed methods of planting



3a



3b

Plate 3a and 3b. Turmeric under open condition and under shaded condition

SUMMARY, CONCLUSIONS, AND SUGGESTIONS FOR FURTHER WORK

The endeavour details with “Production potential of turmeric under different cultural practices in guava based agrihorticulture practice of agroforestry”. The field experiment conducted at the Forestry Research Farm, Imalia, JNKVV, Jabalpur (MP) in Kharif of 2012-13.

The 12 treatment combinations consisting of methods of planting viz., raised bed, flat bed, furrow bed and time of earthing (30 and 45 DAP) under open and shaded condition in all possible combinations were tested in RBD (factorial) with three replications.

It is needless to emphasize the importance of agroforestry, at the present time when the country is facing a great shortage of fodder, fuelwood, timber etc. In addition, there is also a need for environmental and nutritional security through planting fruits. In this situation, agroforestry system will bring about sustained production and risk minimization due to failure of agriculture crop. In agrihorticulture practice of Agroforestry, yield of field crop reduced gradually with increase in tree age. This is because of spreading in tree canopy resulting into reduced crop yield grown underneath the tree. Yield of crop can be increased by manipulation of agronomical practices like selection of appropriate variety, increasing seed rate and fertilizer dose. Thus, the development of agro-techniques for underneath growing crop like turmeric is urgently needed to increase the production under agroforestry systems. A proper understanding of the crop character, plant height, stem diameter, length and width of fingers per rhizome is important.

The present experiment was carried out on clay loam soil which was medium in organic carbon and available nitrogen was low, while available phosphorus and potash content was medium and the soil was neutral in reaction. The experiment was comprised of a treatment

combinations resulting from 3 methods of planting, 2 time of earthing and 2 environmental conditions. The seed rate of turmeric was 2500 Rs ha⁻¹ as per recommendation. The sowing of turmeric cv. Suroma in the field was done on June 10th 2012 as per treatment given in plan of layout.

The various observations on growth characters viz. plant height (cm), stem diameter (mm) were made at successive growth intervals including maturity. The physiological parameter was calculated as leaf area index only. The yield attributing traits i.e., number of fingers per rhizomes, length and width of fingers and fresh rhizome yield/plant were recorded at harvest. Finally the fresh rhizome yield was recorded. The economic viability of treatments was also determined on per hectare area basis. Tabulation and statistical analysis of data were done for interpretation of result which are summarized as under.

Effect of method of planting

The maximum plant height (23.6 cm) and stem diameter (4.6 cm) were noted under raised bed method of planting followed by flat bed where the plant height is 22.9 cm and the stem diameter is 4.3 cm, while the lowest plant height (21.4 cm) and stem diameter (3.9 cm) was recorded under furrow bed method of planting at different intervals of plant growth.

The length of fingers per rhizome was maximum under raised bed method of planting (5.8 cm) followed by flat bed method of planting (4.4 cm), while the lowest length was recorded under furrow method of planting (4.2 cm).

The number of fingers per rhizome (7.1) and the width of fingers (6.6 cm) were maximum under raised bed method of planting followed by flat bed where the number of fingers is 6.1 and width is 6.4 cm, while the lowest number of fingers (5.2) and width of fingers (6.7 cm) was recorded under furrow bed method of planting.

The LAI gradually increased at steady rate up to 180 days after planting under all treatment then decreased as crop reaches maturity.

The maximum fresh yield of rhizomes was recorded under raised bed method of planting ($9279.4 \text{ kg ha}^{-1}$) followed by flat bed method ($8260.3 \text{ kg ha}^{-1}$) while the furrow bed method ($7434.9 \text{ kg ha}^{-1}$) resulted the lowest.

Effect of time of earthing

Significantly maximum plant height was observed when earthing was done at 30 DAP as compared to earthing done at 45 DAP at different growth intervals.

The effect of time of earthing on the leaf area index at different intervals of crop growth was found significant at different growth stages. However, the maximum leaf area was recorded at 180 days growth stage period when earthing was done at 30 days after planting (4.4) followed by earthing done at 45 days (3.6).

Effect of environmental condition

The maximum plant height was noted under shaded condition (94.4 cm) and minimum was under open condition (83.2 cm). The effect of environmental condition on stem diameter was also maximum under shaded condition (21.4 cm) as compared to the open condition (20.3 cm) but the LAI was similar under shaded condition as well as under the open condition (4.0).

The length of fingers per rhizome was maximum under shaded condition (4.9 cm) as compared to open condition (4.7 cm).

Effect of environmental condition on number of fingers, width of fingers and fresh yield was found to be 6.4, 7.0 cm, $8491.2 \text{ kg ha}^{-1}$ respectively under shaded condition and it was 6.1, 6.1 cm, $8158.5 \text{ kg ha}^{-1}$ respectively under open condition.

Morphological growth characters of guava tree

The growth characters on guava tree viz., tree height, dbh, canopy spread in North-South and East–West were recorded.

The lowest basal diameter was 11.78 cm while the highest was 21.33 cm and the average value of basal diameter was 15.19 cm.

The maximum value of dbh was 18.15 cm. and the average value of diameter at breast height was 11.38 cm.

In North–South direction the maximum crown spread was observed 6.70 m and the minimum was 3.20 m while in East–West direction the highest crown spread was observed 6.90 m and the lowest was 3.30 m. The average value of crown spread was 5.25 m in North–South direction and 5.23 m in East–West direction.

The maximum tree height was 6.80 m and the minimum was 4.20 m the average tree height was 5.35m.

Conclusions

Based on the above results following conclusions could be drawn:-

Planting of turmeric cv. Suroma with raised bed method of planting gave maximum fresh rhizome yield (9279.4 kg ha⁻¹) under agrihorticulture practices of agroforestry.

- The time of earthing at 30 DAP increased the yield attributing characters and fresh rhizome yield to 8430.9 kg ha⁻¹ of turmeric under agrihorticulture practices.
- The shaded environmental condition produced maximum fresh rhizome yield (8491.2 kg ha⁻¹).

- The net monetary returns and profitable cost benefit ratio was maximum in raised bed method of planting turmeric under agrihorticulture practice.
- Growing of turmeric with guava i.e., Agroforestry system produced higher net returns (Rs 596740/ha) under raised bed method of planting than growing of turmeric alone (Rs 556740/ha) and guava (Rs 41000/ha) under agrihorticulture practice.
- On the basis of above findings it may be concluded that the increase in yield of turmeric could be predicted more under shaded condition as compared to open condition. Hence, more productivity of turmeric may be achieved if grown under shaded condition of agroforestry compared with open condition.

Suggestions for further work

Based on the results of present investigation following are the suggestions :

- Every year turmeric crop is being cultivated in the field and other shade loving crop like ginger may also be tested.
- These treatments need to be tested on other variety and at different location also.
- Other tree species should be intercropped with turmeric cv. Suroma.

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APPENDICES

Appendix I: Rates of different items considered for calculating the cost of cultivation during the present investigation

Sl. No.	Particulars	Inputs (ha ⁻¹)	Rate (Rs ha ⁻¹)	Cost (Rs.)
(A) Cost of cultivation for Turmeric				
1.	Tractor for cultivation (for ploughing, harrowing and levelling)	1	1500	1500
2.	Preparation of beds	5 mandays (5x150)	150	750
3.	Cost of rhizome	2000 kg (2000x60)	60	120000
4.	Cost of material required for making Bordeaux mixture			
	i) CuSO ₄	1 kg	150	150
	ii) Lime	1 kg	6	6
5.	Handweeding	20 mandays for 2 days (20x2x150)	150	6000
6.	Irrigation	2 mandays for 10 days @Rs 500 per irrigation (2x10x150)+(500x10)	150	8000
7.	Harvesting and removing rootlets	10 mandays for 4 days (10x4x150)	150	6000
(B) Cost of cultivation for Guava				
1.	Picking + marketing	2 mandays for 8 days (2x8x150)	150	2400
2.	Watchmen	-	-	2000
3.	Transport	-	-	1000
4.	Miscellaneous	-	-	1000
	Grand Total =			148806

Appendix II. Economics of different treatment under agrihorticulture practice of agroforestry

Treatments	Yield (q/ha)		Gross return (Rs/ha)			Cost of cultivation (Rs/ha)			Net profit (Rs/ha)			B : C ratio		
Method of planting	Turmeric	Guava	Turmeric	Guava	Total	Turmeric	Guava	Total	Turmeric	Guava	Total	Turmeric	Guava	Mean
Raised bed	92.79	41	556740	41000	596740	142406	6400	148806	414334	34600	448934	3.90	6.40	5.15
Flat bed	82.60	39	495600	39000	535600	142406	6400	148806	353194	32600	385794	3.48	6.09	4.78
Furrow bed	74.34	34.5	446040	34500	486040	142406	6400	148806	303634	28100	331734	3.13	5.39	4.26
Earthing (DAP)														
One at 30 DAP	84.30	40	505800	40000	545800	142406	6400	148806	363394	33600	396994	3.55	6.25	4.90
One at 45 DAP	82.18	38.5	493080	38500	533080	142406	6400	148806	350674	32100	382774	3.46	6.01	4.73

Sales rate of turmeric and guava was Rs 3500 and 1000 q/ha, respectively.

Appendix III: Observation on Guava tree

No. of tree	Diameter at base (0.3m)	dbh (1.37m)	Crown spread (m)		Tree height (m)
			N - S	E - W	
1.	14.22	11.88	6.50	5.30	6.20
2.	13.16	10.50	5.80	4.90	4.80
3.	19.74	10.08	6.63	6.90**	5.20
4.	13.53	11.30	5.10	4.50	6.30
5.	20.06	18.15**	4.84	6.70	4.25
6.	21.33**	11.25	5.50	6.46	4.60
7.	12.26	10.50	4.90	3.85	4.72
8.	13.37	10.82	3.40	3.40	4.60
9.	17.19	12.10	5.61	4.40	6.50
10.	16.56	11.62	4.50	5.50	5.76
11.	16.87	13.37	5.10	5.20	5.20
12.	12.42	7.64*	5.80	5.71	5.82
13.	12.73	11.46	5.50	4.30	4.70
14.	11.78*	12.10	3.20*	5.70	4.20*
15.	13.37	10.50	4.80	4.70	6.80**
16.	16.87	10.19	6.70**	6.65	5.40
17.	15.92	11.78	4.80	3.30*	5.30
18.	12.10	9.71	5.90	6.80	6.00

** Maximum

* Minimum

ANOVA TABLE

Plant height at 30 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	5.3	2.7	0.3	
Methods	2	28.3	14.1	1.8	
Earthing	1	16.9	16.9	2.1	
Condition	1	340.5	340.5	42.3	
Method x Earthing	2	68.5	34.2	4.2	**
Earthing x Condition	1	70.3	70.3	16.0	**
Method x Condition	2	257.9	129.0	8.7	**
Method x Earthing x Condition	2	93.2	46.6	5.8	**
Error	22	177.3	8.1		
Total	35	1933.9			

Plant height at 60 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	576.5	288.2	3.4	
Methods	2	2888.5	1444.3	17.3	
Earthing	1	9.5	9.5	0.1	
Condition	1	1.8	1.8	0.0	
Method x Earthing	2	104.1	52.0	0.6	
Earthing x Condition	1	68.0	409.2	4.9	**
Method x Condition	2	818.4	68	0.8	
Method x Earthing x Condition	2	15.0	7.5	0.1	
Error	22	1841.8	83.7		
Total	35	10228.7			

Plant height at 90 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	177.9	88.9	1.6	
Method	2	2207.8	1103.9	19.4	**
Earthing	1	2.9	2.9	0.1	
Condition	1	27.9	27.9	0.5	
Method x Earthing	2	266.8	133.4	2.3	
Earthing x Condition	1	0.1	0.1	0.0	
Method x Condition	2	64.9	320.4	5.6	**
Method x Earthing x Condition	2	16.6	8.3	0.1	
Error	22	1249.0	56.8		
Total	35				

Plant height at 120 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	540.2	270.1	4.0	
Method	2	3135.4	1567.7	23.2	**
Earthing	1	9.5	9.5	0.1	
Condition	1	82.9	82.9	1.2	
Method x Earthing	2	1076.8	538.4	8.0	**
Earthing x Condition	1	354.5	354.5	5.2	**
Method x Condition	2	1287.1	643.6	9.5	**
Method x Earthing x Condition	2	170.2	85.1	1.3	
Error	22	1485.8	67.5		
Total	35	14258.7			

Plant height at 150 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	12.6	6.3	0.1	
Method	2	8593.9	4296.9	74.2	**
Earthing	1	1234.2	1234.2	21.3	**
Condition	1	1505.0	1505.0	26.0	**
Method x Earthing	2	191.3	95.7	1.7	
Earthing x Condition	1	481.6	481.6	8.3	**
Method x Condition	2	2233.3	1116.6	19.3	**
Method x Earthing x Condition	2	157.1	78.5	1.4	
Error	22	1274.7	57.9		
Total	35	30080.0			

Plant height at 180 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	9.1	4.6	0.1	
Method	2	8209.7	4104.9	98.9	**
Earthing	1	1354.1	1354.1	32.6	**
Condition	1	1142.1	1142.1	27.5	**
Method x Earthing	2	170.7	85.3	2.1	
Earthing x Condition	1	1365.0	1365.0	32.9	**
Method x Condition	2	2763.9	1381.9	33.3	**
Method x Earthing x Condition	2	421.2	210.6	5.1	**
Error	22	912.8	41.5		
Total	35				

Plant height at harvest

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	8.6	4.3	0.1	
Method	2	5741.9	2870.9	70.4	**
Earthing	1	209.2	209.2	5.1	**
Condition	1	131.4	131.4	3.2	
Method x Earthing	2	194.5	97.2	2.4	
Earthing x Condition	1	176.3	176.3	4.3	**
Method x Condition	2	1504.9	752.5	18.5	**
Method x Earthing x Condition	2	96.1	48.1	1.2	
Error	22	897.2	40.8		
Total	35	17014.4			

Stem diameter at 30 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.1	0.1	0.2	
Method	2	3.2	1.6	4.6	**
Earthing	1	0.1	0.1	0.4	
Condition	1	0.7	0.7	1.9	
Method x Earthing	2	0.0	0.0	0.0	
Earthing x Condition	1	0.4	0.4	1.2	
Method x Condition	2	0.5	0.3	0.8	
Method x Earthing x Condition	2	0.2	0.1	0.4	
Error	22	7.6	0.3		
Total	35	18.1			

Stem diameter at 60 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	1.3	0.7	1.0	
Method	2	18.0	9.0	13.2	**
Earthing	1	0.0	0.0	0.0	
Condition	1	0.3	0.3	0.4	
Method x Earthing	2	1.7	0.8	1.2	
Earthing x Condition	1	0.1	0.1	0.1	
Method x Condition	2	0.1	0.1	0.1	
Method x Earthing x Condition	2	1.3	0.6	0.9	
Error	22	15.0	0.7		
Total	35	59.1			

Stem diameter at 90 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	51.2	25.6	3.0	
Method	2	48.7	24.3	2.9	
Earthing	1	13.5	13.5	1.6	
Condition	1	0.7	0.7	0.1	
Method x Earthing	2	24.4	12.2	1.4	
Earthing x Condition	1	2.2	2.2	0.3	
Method x Condition	2	6.3	3.2	0.4	
Method x Earthing x Condition	2	2.2	5.9	0.7	
Error	22	11.9	8.4		
Total	35	451.9			

Stem diameter at 120 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	10.3	5.2	2.0	
Method	2	244.8	122.4	47.6	**
Earthing	1	0.8	0.8	0.3	
Condition	1	0.2	0.2	0.1	
Method x Earthing	2	0.2	0.1	0.0	
Earthing x Condition	1	1.0	1.0	0.4	
Method x Condition	2	8.4	4.2	1.6	
Method x Earthing x Condition	2	0.5	0.3	0.1	
Error	22	56.6	2.6		
Total	35	579.0			

Stem diameter at 150 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	3.6	1.8	0.7	
Method	2	203.7	101.9	38.6	**
Earthing	1	15.3	15.3	5.8	**
Condition	1	4.5	4.5	1.7	
Method x Earthing	2	3.4	1.7	0.6	
Earthing x Condition	1	4.0	4.0	1.5	
Method x Condition	2	0.5	0.3	0.1	
Method x Earthing x Condition	2	4.7	2.3	0.9	
Error	22	58.0	2.6		
Total	35	533.9			

Stem diameter at 180 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	3.3	1.7	0.6	
Method	2	190.6	95.3	35.2	**
Earthing	1	27.4	27.4	10.1	**
Condition	1	11.9	11.9	4.4	**
Method x Earthing	2	6.0	3.0	1.1	
Earthing x Condition	1	11.1	11.1	4.1	**
Method x Condition	2	1.6	0.8	0.3	
Method x Earthing x Condition	2	3.9	2.0	0.7	
Error	22	59.6	2.7		
Total	35	567.9			

Stem diameter at harvest DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	6.1	3.0	1.3	
Method	2	139.7	69.8	30.8	**
Earthing	1	10.5	10.5	4.6	**
Condition	1	0.6	0.6	0.3	
Method x Earthing	2	20.8	10.4	4.6	**
Earthing x Condition	1	0.1	0.1	0.0	
Method x Condition	2	16.9	8.4	3.7	*
Method x Earthing x Condition	2	10.8	5.4	2.4	
Error	22	49.8	2.3		
Total	35	454.5			

LAI at 30 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.0	0.0	0.4	
Method	2	0.2	0.1	2.6	
Earthing	1	0.0	0.0	0.6	
Condition	1	0.2	0.2	3.7	
Method x Earthing	2	0.2	0.1	2.8	
Earthing x Condition	1	0.0	0.0	0.0	
Method x Condition	2	0.1	0.1	1.4	
Method x Earthing x Condition	2	0.2	0.1	2.4	
Error	22	1.0	0.01		
Total	35	3.0			

LAI at 60 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.5	0.2	0.7	
Method	2	1.9	0.9	2.8	
Earthing	1	0.5	0.5	1.4	
Condition	1	0.3	0.3	0.8	
Method x Earthing	2	2.0	1.0	3.0	
Earthing x Condition	1	0.0	0.0	0.0	
Method x Condition	2	0.2	0.1	0.3	
Method x Earthing x Condition	2	0.9	0.4	1.3	
Error	22	7.2	0.3		
Total	35	18.8			

LAI at 90 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.9	0.5	1.2	
Method	2	12.1	6.0	15.4	**
Earthing	1	0.5	0.5	1.3	
Condition	1	0.4	0.4	1.0	
Method x Earthing	2	1.3	0.6	1.6	
Earthing x Condition	1	0.7	0.7	1.7	
Method x Condition	2	0.4	0.2	0.5	
Method x Earthing x Condition	2	1.9	1.0	2.4	
Error	22	8.7	0.4		
Total	35	44.0			

LAI at 120 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.1	0.0	0.2	
Method	2	18.8	9.4	43.9	**
Earthing	1	0.0	0.0	0.0	
Condition	1	0.2	0.2	1.1	
Method x Earthing	2	0.5	0.3	1.3	
Earthing x Condition	1	0.9	0.9	4.2	
Method x Condition	2	0.4	0.2	0.9	
Method x Earthing x Condition	2	0.4	0.2	0.9	
Error	22	4.7	0.2		
Total	35	47.3			

LAI at 150 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	1.1	0.5	1.7	
Method	2	23.1	11.6	36.3	**
Earthing	1	3.4	3.4	10.7	**
Condition	1	0.2	0.2	0.6	
Method x Earthing	2	0.6	0.3	1.0	
Earthing x Condition	1	0.0	0.0	0.1	
Method x Condition	2	0.4	0.2	0.6	
Method x Earthing x Condition	2	3.1	1.5	4.8	**
Error	22	7.0	0.3		
Total	35	69.7			

LAI at 180 DAP

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.4	0.2	3.1	
Method	2	18.5	9.2	132.4	**
Earthing	1	5.4	5.4	76.9	**
Condition	1	0.0	0.0	0.4	
Method x Earthing	2	1.2	0.6	8.4	**
Earthing x Condition	1	0.1	0.1	1.4	
Method x Condition	2	0.0	0.0	0.1	
Method x Earthing x Condition	2	0.2	0.1	1.2	
Error	22	1.5	0.1		
Total	35	52.6			

LAI at harvest

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.4	0.2	3.6	
Method	2	9.4	4.7	84.3	**
Earthing	1	2.6	2.6	47.2	**
Condition	1	1.0	1.0	17.8	**
Method x Earthing	2	2.1	1.0	18.4	**
Earthing x Condition	1	1.5	1.5	7.9	**
Method x Condition	2	0.9	0.4	26.6	**
Method x Earthing x Condition	2	0.3	0.2	3.0	
Error	22	1.2	0.1		
Total	35	37.2			

Number of fingers

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.5	0.3	0.1	
Method	2	22.1	11.0	5.4	**
Earthing	1	2.6	2.6	1.2	
Condition	1	0.0	0.0	0.0	
Method x Earthing	2	4.9	2.4	1.2	
Earthing x Condition	1	1.4	1.4	0.7	
Method x Condition	2	2.3	1.1	0.6	
Method x Earthing x Condition	2	1.3	0.6	0.3	
Error	22	45.2	2.1		
Total	35	114.8			

Length of fingers

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	0.4	0.2	0.5	
Method	2	17.9	8.9	20.8	**
Earthing	1	0.2	0.2	0.4	
Condition	1	1.9	1.9	4.4	*
Method x Earthing	2	3.6	1.8	4.2	**
Earthing x Earthing	1	1.0	1.0	4.4	**
Method x Condition	2	3.8	1.9	2.3	
Method x Earthing x Condition	2	2.2	1.1	2.6	
Error	22	9.5	0.4		
Total	35	71.1			

Width of fingers

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	1.2	0.6	1.2	
Method	2	0.5	0.2	0.5	
Earthing	1	0.3	0.3	0.6	
Condition	1	6.7	6.7	13.4	**
Method x Earthing	2	0.5	0.3	0.5	
Earthing x Condition	1	0.2	0.2	0.3	
Method x Condition	2	0.8	0.4	0.8	
Method x Earthing x Condition	2	1.4	0.7	1.4	
Error	22	10.9	0.5		
Total	35	32.9			

Fresh yield of turmeric (kg ha⁻¹)

Source of variation	D.F.	S.S.	M.S.	F value	Significant
Replication	2	36485.4	18242.7	0.1	
Method	2	25466764.7	10244469.8	55.2	**
Earthing	1	20488939.6	405235.7	2.2	
Condition	1	405235.7	995875.1	5.4	**
Method x Earthing	2	995875.1	761675.5	4.1	**
Earthing x Condition	1	1523351.1	969794.1	5.2	**
Method x Condition	2	969794.1	358585.8	1.9	
Method x Earthing x Condition	2	717171.7	183198.7	1.0	
Error	22	4083702.4	185622.88		
Total	35	55053717.1			

GUAVA

Botanical name : (*Psidium guajava*)

Family : Myrtaceae



Guava Tree



Fruit



Flower



Leaves

Guava is a very popular fruit. It is available throughout the year except during the summer season. Being very hardy, it gives an assured crop even with very little care.

Climate and soil

Guava is successfully grown under tropical and subtropical climate. The quality of the fruits is better in areas having distinct winters therefore guava grown near Allahabad is famous for the best quality fruits. Although guava tolerates drought, protective irrigation facilities are required. It grows best with an annual rainfall around 1000 mm restricted between June and September.

The importance of guava is due to the fact that it is a hardy plant, which can be grown on wide varieties of soils including shallow, medium black and alkaline soil. However, it grows successfully on well-drained soils with atleast 0.5 to 1m in depth. The soils should not be very deep, marshy, low lying, having hard pan or water table in the root zones. The pH should be between 5.5 to 7.5.

Variety

Lucknow-49 : It is also known as Sardar is actually the selection from Allahabad safeda. The tree is dwarf, height 6-7 mts., growth upright, spreading, somewhat flattened top, dense foliage, branching is heavily with medium to large sized fruit and quality is excellent with 10-12% TSS.

Cultivation

Planting

The field should be deeply ploughed, cross ploughed, harrowed and levelled before digging pits. The pits of about 0.6 m x 0.6m x0.6 m dimension should be dug before the monsoon. After 15-20 days, each pit should be filled with soil mixed with 20 kg of organic manure and 500

g of super phosphate. In very poor soils, the pit size may be bigger, about 1m x 1m x 1m and more of organic manures may be necessary. Onset of monsoon is the time to start planting.

Manuring and fertilization

Guava is very responsive to the application of inorganic fertilisers along with organic manures. Soil type, nutrient status and leaf analysis can give better indication for requirement of nutrients. A thumb rule recommendation is considered in this model. NPK may be applied @100, 40 and 40 g per plant year of age, with stabilisation in the 6th year. They may be applied in two equally split doses in January and August.

Spraying the trees with 0.45 kg zinc sulphate and 0.34 kg slaked lime dissolved in 72.74 l (16 gallons) of water cures Zn deficiency. The number of sprays depend on the severity and extent of the deficiency. Pre-flowering sprays with 0.4% Boric Acid and 0.3% Zinc Sulphate increase the yield and fruit size. Spraying of copper sulphate at 0.2 to 0.4% also increases the growth and yield of guava.

Irrigation

Normally irrigation is not required in guava plantation. However, in the early stage, young guava plants require 8 to 10 irrigations a year. Life saving hand watering is necessary in summer season in dry areas and on light soils. Full grown bearing trees require watering during May-July at weekly intervals. Irrigations during winter reduce fruit drop and improve fruit size of winter crop. In order to conserve soil moisture from pre-monsoon showers, V shaped or half moon shaped bunds or saucer shaped basins may be made. Drip irrigation has been proved to be very beneficial for guava. Besides saving 60 % of water, it results in substantial increase in size and number of fruits.

Flowering and fruiting

Two important seasons of blooming are observed, one in April-May (Monsoon Crop) and the other in September - October (Winter Crop). Growth regulators like NAA, NAD, and 2,4-D are very effective in thinning of flowers and manipulating the cropping season.

Fruit drop in guava is as severe as 45-65% due to different physiological and environmental factors. Spraying of GA is highly effective in reducing the drop.

Harvesting and post harvest management

Grafted, budded or layered guava trees start bearing at the age of 2 to 3 years. Seedling trees require 4 to 5 years to bear. The guava fruit can not be retained on the tree in ripe stage. So, it should be picked immediately when it is mature. Guava is ready for harvest as soon as the deep green colour turns light and a yellowish green patch appears. Individual hand picking at regular intervals will avoid all possible damage.

Guava is highly perishable in nature. Shelf life under ambient conditions is 2 to 3 days on an average. Therefore, it should be marketed immediately after harvest. However, it may be stored for a few days to adjust the market demand. After careful harvest, the fruits should be brought to packhouse. For packing, corrugated fibre board with adequate perforation may be used. However, fruits are reported to keep 3 to 5 weeks in cold store at a temperature of 8 to 10 degree Celsius with 85 -90 % RH.

TURMERIC

Botanical name : *Curcuma longa*

Family : Zingiberaceae



Turmeric plant



Flower



Fresh rhizome



Dried rhizome

Turmeric (*Curcuma longa* L.) is an important condiment and a useful dye, with varied uses in drug and cosmetic industries. It is used medicinally for external application and taken internally as a stimulant. 'Kum-kum', popular with every house wife, is also a by product of turmeric. It finds a place in offerings on religious and ceremonial occasions. A type of starch can also be extracted from a particular type of turmeric. India is one of the leading growers, with about 79,300 ha under this crop, producing 1,43,900 tonnes per annum.

Climate and soil

Turmeric can be grown in diverse tropical conditions from sea level to 1500 m above sea level, at a temperature range of 20-35°C with an annual rainfall of 1500 mm or more, under rain fed or irrigated conditions. Though it can be grown on different types of soils, it thrives best in well-drained sandy or clay loam soils with a pH range of 4.5-7.5 with good organic status.

Varieties

A number of cultivars are available in the country and are known mostly by the name of locality where they are cultivated. Some of the popular cultivars are Duggirala, Tekurpeta, Sugandham, Amalapuram, Erode local, Alleppey, Moovattupuzha, and Lakadong. The improved varieties of turmeric are- Suvarna, Suguna, Sudarsana, Prabha, Prathibha, Krishna, Sugandham, Roma, Suroma, Ranga, Rasmi, Rajendra, Sonia, Alleppey, Supreme, Kedaram.

Cultivation

Preparation of land

The land is prepared with the receipt of early monsoon showers. The soil is brought to a fine tilth by giving about four deep ploughing. Hydrated lime @ 500 kg/ha has to be applied for laterite soils and

thoroughly ploughed. Immediately with the receipt of pre-monsoon showers, beds of 1.0 m width, 15 cm height and of convenient length are prepared with spacing of 50 cm between beds. Planting is also done by forming ridges and furrows.

Seed material

Whole or split mother and finger rhizomes are used for planting and well developed healthy and disease free rhizomes are to be selected. Small pits are made with a hand hoe on the beds with a spacing of 25 cm x 30 cm. Pits are filled with well decomposed cattle manure or compost, seed rhizomes are placed over it then covered with soil. The optimum spacing in furrows and ridges is 45-60 cm between the rows and 25 cm between the plants. A seed rate of 2,500 kg of rhizomes is required for planting one hectare of turmeric.

Manuring and fertilizer application

Farmyard manure (FYM) or compost @ 30-40 t/ha is applied by broadcasting and ploughed at the time of preparation of land or as basal dressing by spreading over the beds or in to the pits at the time of planting. Zinc @ 5 kg/ha may also be applied at the time of planting and organic manures like oil cakes can also be applied @ 2 t/ha. In such case, the dosage of FYM can be reduced. Integrated application of compost (@ 2.5 t/ha) combined with FYM, biofertilizer (*Azospirillum*) and half recommended dose of NPK is also recommended. Fertilizers @ 60 kg N, 50 kg P₂O₅ and 120 kg K₂O per hectare are to be applied in split doses.

Weeding and irrigation

Weeding has to be done thrice at 60, 90 and 120 days after planting depending upon weed intensity. In the case of irrigated crop, depending upon the weather and soil conditions, about 15 to 23

irrigation's are to be given in clayey soils and 40 irrigation's in sandy loams.

Harvesting

Depending upon the variety, the crop becomes ready for harvest in 7-9 months after planting during January-March. Early varieties mature in 7-8 months, medium varieties in 8-9 months and late varieties after 9 months. The land is ploughed and the rhizomes are gathered by hand picking or the clumps are carefully lifted with a spade. The harvested rhizomes are cleared of mud and other extraneous matter adhering to them.

Processing

Curing

Fresh turmeric is cured for obtaining dry turmeric. The fingers are separated from mother rhizomes. Mother rhizomes are usually kept as seed material. Curing involves boiling of fresh rhizomes in water and drying in the sun. In the traditional method of curing, the cleaned rhizomes are boiled in water just enough to immerse them. Boiling is stopped when froth comes out and white fumes appear giving out a typical odour. The boiling should last for 45-60 minutes when the rhizomes turn soft. The stage at which boiling is stopped largely influences the colour and aroma of the final product. Over cooking spoils the colour of the final product while under-cooking renders the dried product brittle.

In the improved scientific method of curing, the cleaned fingers (approximately 50 kg) are taken in a perforated trough of 0.9 m x 0.5 m x 0.4 m size made of GI or MS sheet with extended parallel handle. The perforated trough containing the fingers is then immersed in a pan; 100 litres of water is poured into the trough so as to immerse the turmeric fingers. The whole mass is boiled till the fingers become soft. The

cooked fingers are taken out of the pan by lifting the trough and draining the water into the pan. The water used for boiling turmeric rhizomes can be used for curing fresh samples. The processing of turmeric is to be done 2 or 3 days after harvesting. If there is delay in processing, the rhizomes should be stored under shade or covered with sawdust or coir dust.

Drying

The cooked fingers are dried in the sun by spreading them in 5-7 cm thick layers on bamboo mats or drying floor. A thinner layer is not desirable, as the colour of the dried product may be adversely affected. During night time, the rhizomes should be heaped or covered with material which provides aeration. It may take 10-15 days for the rhizomes to become completely dry.

Artificial drying, using cross-flow hot air at a maximum temperature of 60 degree centigrade also gives a satisfactory product. In the case of sliced turmeric, artificial drying has clear advantages in giving a brighter coloured product than sun drying which tends to undergo surface bleaching. The yield of the dry product varies from 10-30% depending upon the variety and the location where the crop is grown.

Polishing

Dried turmeric has a poor appearance and a rough dull outer surface with scales and root bits. The appearance is improved by smoothening and polishing the outer surface by manual or mechanical rubbing. Manual polishing consists of rubbing the dried turmeric fingers on a hard surface. The improved method is by using a hand operated barrel or drum mounted on a central axis, the sides of which are made of expanded metal mesh. When the drum filled with turmeric is rotated, polishing is effected by abrasion of the surface against the mesh as well as by mutual rubbing against each other as they roll inside the drum.

Turmeric is also polished in power operated drums. The yield of polished turmeric from the raw material varies from 15-25%.

Colouring

The colour of the processed turmeric influences the price of the produce. For an attractive product, turmeric powder (mixed with little water) may be sprinkled during the last phase of polishing.

Preservation of seed rhizomes

Rhizomes for seed purpose are generally stored by heaping in well ventilated rooms and covered with turmeric leaves. The seed rhizomes can also be stored in pits with saw dust, sand along with leaves of *Strychnos nuxvomica* (kanjiram). The pits are to be covered with wooden planks with one or two openings for aeration. The rhizomes are to be dipped in quinalphos 7.5ml in 10 litres of water solution for 15 minutes if scale infestations are observed and in mancozeb 35gm in 10 litres of water to avoid storage losses due to fungi.

ABSTRACT

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ABSTRACT

It is needless to emphasize the importance of agroforestry, at the present time when the country is facing a great shortage of fodder, fuelwood, timber etc. In addition, there is also a need for environmental and nutritional security through planting fruits. In this situation, agroforestry system will bring about sustained production and risk minimization due to failure of agriculture crop. In agrihorticulture system of Agroforestry, yield of field crop reduced gradually with increase in tree age. This is because of spreading in tree canopy resulting into reduced crop yield grown underneath the tree. Yield of crop can be increased by manipulation of agronomical practices like selection of appropriate variety, increasing seed rate and fertilizer dose. Thus, the development of agro-techniques for underneath growing crop like turmeric is urgently needed to increase the production under agroforestry systems. A proper understanding of the crop character, plant height, stem diameter, length and width of fingers per rhizome is important.

The study was carried out at Jabalpur (Madhya Pradesh) to evaluate the effect of planting method, time of earthing and environmental condition on the production of turmeric (*Curcuma longa*). The experiment consisted of 12 treatment combinations consisting of methods of planting viz., raised bed, flat bed, furrow bed and time of earthing (30 and 45 DAP) under open and shaded condition in all possible combinations were tested in RBD (factorial) with three replications.

Planting of turmeric cv. Suroma with raised bed method of planting gave maximum fresh rhizome yield ($9279.4 \text{ kg ha}^{-1}$) under agrihorticulture practices of agroforestry. The time of earthing at 30 DAP increased the yield attributing characters and fresh rhizome yield to $8430.9 \text{ kg ha}^{-1}$ of turmeric under agrihorticulture practices. The shaded

environmental condition produced maximum fresh rhizome yield (8491.2 kg ha⁻¹). The increased in yield under raised bed method of planting was due to more favourable environmental condition viz., aeration, root proliferation, light interception, drainage, better nutrient uptake and availability of better soil condition which has helped in increasing the growth and yield attributing characters viz., plant height, number of leaves per plant, number of fingers per rhizome. The net monetary returns and profitable cost benefit ratio was maximum in raised bed method of planting turmeric under agrihorticulture practice. Growing of turmeric with guava i.e., Agroforestry system produced higher net returns (Rs 596740/ha) under raised bed method of planting than growing of turmeric alone (Rs 556740/ha) and guava (Rs 41000/ha) under agrihorticulture practice. On the basis of above findings it may be concluded that the increase in yield of turmeric could be predicted more under shaded condition as compared to open condition. Hence, more productivity of turmeric may be achieved if grown under shaded condition of agroforestry compared with open condition.

Under shaded condition the correlation coefficient amongst different growth characters on fresh yield of turmeric has significant positive association with stem diameter (0.9605) followed by length of fingers (0.9579). The width of fingers had negative correlation (-0.2115), but it was non-significant. Different growth characters viz., plant height, stem diameter, LAI, number of fingers and Length of fingers had positive and significant association except number of fingers. Width of fingers had negative and non-significant correlation with plant height (-0.3443), stem diameter (-0.2311), LAI (-0.2830), number of fingers (-0.3197) and length of fingers (-0.2535).

The regression analysis revealed that, the linear increase in fresh turmeric yield was predicted with plant height, stem diameter, LAI, number of fingers, length of fingers and the increase in yield of turmeric could be predicted by 0.04, 0.39, 1.16, 0.49 and 1.57, kg ha⁻¹,

respectively with the increase of one unit of each parameter (Table 11). The decline in fresh turmeric yield could be predicted by 0.70 kg ha⁻¹ with increase in width of fingers by one unit under shaded condition in guava based agrihorticulture practice of agroforestry.

Stem diameter followed by length of fingers, plant height and LAI are the most important character towards the prediction of yield. The value of coefficient of determination (R^2) for stem diameter is 0.92 followed by length of fingers is 0.91, plant height is 0.89 and for LAI is 0.87 which approaches to 1 and is found to be highly significant so it may be called as best predictor towards the contribution of fresh turmeric yield.

Under open condition the correlation coefficients amongst different growth characters on fresh yield of turmeric had significant positive association with plant height (0.9314), stem diameter (0.7937), LAI (0.8551), and number of fingers (0.7129). The length of fingers (0.6364) whereas, the width of fingers (0.0930) was found to have positive association but it was non-significant. The width of fingers has negative association with length of fingers (-0.1396) but it was non-significant.

The regression analysis revealed that the linear increase in fresh turmeric yield was predicted with plant height, stem diameter, LAI, number of fingers, length of fingers, and width of fingers/rhizome, the increase in yield of turmeric could be predicted by 0.16, 0.43, 1.57, 0.60, 0.49, 0.21 kg ha⁻¹, respectively with the increase of one unit of each parameter under open condition in guava based agrihorticulture practice of agroforestry.

Plant height is the most important character towards the production of yield. The value coefficient of determination (R^2) for plant height is 0.86 which approaches to 1 and is found to be highly significant here so it may be called as the best predictor towards the

contribution in fresh turmeric yield. Merely the 14% variation in the turmeric yield can be explained by other independent characters towards the fresh turmeric yield.

On the basis of above going finding it may be concluded that the increase in yield of turmeric could be predicted more under shaded condition as compared to open condition. Hence, more productivity of turmeric may be achieved if grown under shaded condition of agroforestry compared with open condition.