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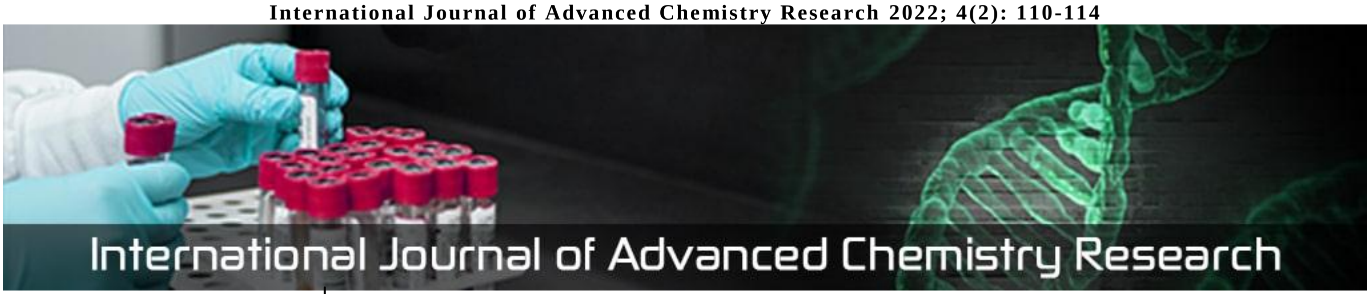

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Effect of different intercropping and mulching on yield and quality of turmeric (*Curcuma longa* L.)

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Abstract
The field experiment entitled "Effect of different intercropping and mulching on yield and quality of turmeric (*Curcuma longa* L.)" was conducted at students' research farm, Khalsa College, Amritsar during *kharif* season of 2020-21. The soil of the experimental field was categorized as sandy loam. The soil reaction pH ranged from 7.7 to 8.4. The maximum pH (8.4) was observed in open condition followed by soil under sugarcane plantation and least were observed in peach. The value of OC (%), available N, P and K were higher under peach as compared to sugarcane plantation and open conditions. The field experiment was laid out in Factorial split-plot design with three intercropping system *viz.* T_3 (turmeric + peach), T_2 (turmeric + sugarcane) along with T_1 (turmeric sole) in main plots while the three different mulching rates *viz.* M_8 (Mulching @8t ha^{-1}), M_4 (Mulching @4t ha^{-1}) and M_0 (Mulching @0t ha^{-1}) in sub plots with four replications. Results indicated that growth parameters such as plant height (90.1 cm), number of leaves (12.9), LAI (4.2) were highest in intercropping as compared to control, whereas yield parameters such as number of tillers (2.9), Fresh (189.5 g) and dry weight (34.9) of rhizomes, fresh (174.2 q ha^{-1}), dry (38.2 q ha^{-1}) and processed yield (36.5 q ha^{-1}) were recorded higher in T_1 as compared to T_2 and least were found in T_3. The oil (8.23 %) and curcumin content (1.8%) increased with intercropping. On the other hand, it was observed that application of paddy straw mulch resulted in significantly higher emergence count (81.9 %), plant height (89.8 cm), number of leaves (12.7), LAI (4.1) number of tillers (2.8), number of rhizomes (15.1), Fresh (193.4g) and dry rhizome weight (35.2g) and Fresh yield (174.2 q ha^{-1}), Dry yield (38.2 q ha^{-1}) and processed rhizome yield (36.4 q ha^{-1}) of turmeric. These parameters were significantly higher in M_8 over M_4 and M_0. Application of straw mulch resulted in higher curcumin (1.85 %) and oil content (8.15 %). So it was concluded that paddy straw mulch application @ 8t ha^{-1} is resulted higher rhizome yield and growth parameters and thus improved performance of turmeric.

Keywords: Turmeric, intercrops, mulching, yield

Introduction

Turmeric (*Curcuma longa* L.), an annual herbaceous plant belongs to order *Zingiberale*, family *Zingiberacea* and genus *Curcuma* commonly known as Haldi. *Curcuma* has 42 species, out of which *Curcuma longa* L. is commercially cultivated because of its economic importance. Cultivated turmeric is triploid (2n=63). It is also known as the "golden spice" as well as "spice of life". In India turmeric cultivation covers an area of 2.48 lakh hectare, with an annual production of 5.32 lakh tonnes (dry crop) (Anonymous 2019a). In Punjab it covers an area of 1030 hectare and annual production of 3730 mts in terms of powder (Anonymous 2019b). The thick underground stem (Rhizome) is the major produce of turmeric crop. Turmeric is grown for its rhizomes, which have many uses. Turmeric powder is a biologically active component with functional properties like antifungal, antioxidant, anti-inflammatory, anti-diabetic, anti-cancer, anti-bacterial and considered cure for AIDS (Singh and Jain, 2012). The yellow colour of turmeric is due to the presence of a crystalline substance called curcumin i.e. diferuloyl methanol. The rhizome has 1.8-5.4% curcumin and 2.5-7.2% essential oil (termerol). In Punjab, planting of turmeric is done in the month of April after the harvesting of wheat. This crop takes long time to emerge and its growth rate is also slow in initial stages, so it does not cover the soil very fast and the solar energy remains unutilized. Further, this crop can be grown under partial shade so it can offers good scope of growing as intercrop in agro- horti systems which helps in utilizing the solar radiation during period of slow growth rate in the initial growth stage of turmeric and increase remuneration of the farmers by harvesting the maximum benefits of natural resources. Intercropping can help the farmers by providing alternate source income from same piece of land.

Intercropping being a unique practice of tropical and sub-tropical areas is being more among small scale farmers as it offers the yield advantage relative to sole cropping through yield stability and improved yield. Weeds are a big constraint in crop production and they are responsible for heavy yield losses in almost all the crops grown in this region of the country. Use of straw and tree leaves as mulch in turmeric is another approach adopted by farmers that conserve soil moisture and modifies soil temperature for the benefit of crop (Manhas *et al*. 2011) [8], beside controlling weeds (Hossain and Ishimine, 2005) [3]. The application of straw mulch, conserve soil moisture by decreasing evaporation losses, reduces weeds menace, regulate soil temperature and helps protect the germinating rhizomes from dessication especially during early growth period of hot and dry months (May and June).

Materials and Methods

The study was carried out at Student's Research farm of P.G. Department of Agriculture, Khalsa College Amritsar, during *kharif* season 2020-2021. The soil of the experimental field was categorized as sandy loam. The soil reaction pH ranged from 7.7 to 8.4. The maximum pH was observed in open condition followed by soil under sugarcane plantation and least were observed in peach. The value of OC (%), available N, P and K were higher under peach followed by sugarcane plantation and least values in open conditions. The field experiment was laid out in Factorial split-plot design with three intercropping system *viz.* T_3 (turmeric + peach), T_2 (turmeric + sugarcane) along with T_1 (turmeric sole) in main plots while the three different mulching rates *viz.* M_8 (Mulching @8t ha^{-1}), M_4 (Mulching @4t ha^{-1}) and M_0 (Mulching @0t ha^{-1}) in sub plots with four replications. Recommended dose of fertilizers (137 kg urea ha^{-1}) were applied to the crop in two equal split at 75 and 100 days after planting. Irrigations were as per requirement (when there is rainfall). Harvesting was done manually with spade. All data on growth, yield and yield component were measured from the central areas of each plot. Statistical analysis of the data recorded was done as per Factorial split plot design using CPCS-1 software developed by PAU, Ludhiana. The comparisons were made at five per cent level of significance.

Results and Discussion

Yield contributing characters

Number of tillers per plant at harvest

Data on number of tillers per plant of turmeric are presented in table 1. Number of tillers per plant is an index of growth and adaptability of the plant in soil and climatic conditions. It is one of the most important parameter which has direct bearing on development of rhizome and rhizome yield. The plants with T_1 treatment observed significantly higher number of tillers per plant than T_2 and T_3 treatment at all periodic intervals. The number of tillers per plant with T_2 treatment recorded significantly lower than T_1 treatment, but produced significantly higher tillers over T_3 treatment. The maximum tillers were observed with T_1 treatment i.e. 2.9 which was 13.79 and 27.58 per cent more than T_2 and T_3 treatment. This might be due to increased synthesis of growth promoting hormones like gibberlic acid which would have induced the apical dominance thereby reducing the tiller production in shaded conditions. Mulched plots produced higher number of tillers per plant as compared to plots where mulch was not applied. Number of tillers remained significantly superior under M_4 treatment (i.e. with 4 t ha^{-1}) over M_0 treatment (i.e. 0 t ha^{-1}), but remained significantly inferior to M_8 treatment (i.e. with the application of 8 t ha^{-1}). Moreover the M_8 treatment was significantly superior to both M_4 and M_0 treatments at all growth stages. This might be due to mulch was applied to the plots produced better growth and development of the plant. Verma and Sarnaik (2006) [12] has also been reported that application of mulch increase the number of tiller per plant.

The interaction effect between intercropping and mulching level on number of tillers per plant was non- significant.

Number of rhizomes per plant

Data presented in table 1 showed that intercropping and mulching had significant effect on number of rhizomes per plant. However, Maximum number of rhizomes per plant (15.2) was recorded in T_1 which was followed by T_2 (13.8) and least were found in T_3 (12.2). Similar result was found by Gill *et al.* (2004). The effect of mulching had significant effect on number of rhizomes. It was revealed that highest number of rhizomes per plant was recorded in M_8 which was followed by M_4 and M_0 treatment. The lowest rhizomes per plant was observed in M_0 treatment. The general trend of number of rhizomes per plant observed was $M_8 > M_4 > M_0$. The percent increase in number of rhizomes per plant was 29.1 and 23.1 in M_4 over M_0 treatment, respectively over M_0 treatment. Increase in number of rhizomes could be due to beneficial effect of mulching. Similar observations was also made by Sanyal and Dhar (2008) [9].

Fresh and dry weight of rhizomes per plant

Data on fresh and dry weight of rhizomes per plant are presented in table 1. The weight of rhizome per plant is an important characteristics of turmeric which ultimately effects the yield of turmeric. The result showed that the fresh weight of rhizome as well as dry rhizome weight per plant was significantly affected by intercropping at different periodic intervals. The fresh as well as dry weight of rhizome per plant of T_1 was significantly more than T_2 and T_3 treatments at all intervals. Further, although the fresh and dry weight of rhizome per plant with T_2 treatment recorded significantly less than T_1 but shows higher over T_3 treatment. The T_1 treatment recorded higher fresh and dry weight than T_2 and T_3. The more weight of rhizome per plant in turmeric sole may be due to proper availability of light which increased the photosynthetic activities which resulted in better growth and yield contributing characters such as total number of rhizome per plant. Vikram and Hedge (2014) [11] observed significantly higher fresh and dry weight of rhizome per plant under sole cropping compared to cashew based intercropping. All the mulch treatments had perceptible influence on fresh weight and dry weight of rhizome per plant. The maximum weight of rhizome per plant was recorded with M_8 treatment, which was 5.11 and 11.08 per cent more than M_4 and M_0 treatment. Kumar *et al.* (2008) [5] also reported higher dry rhizome weight of turmeric with mulching, which might be due to higher vegetative growth and more accumulation of photosynthates in mulched plots.

The interaction effect between intercropping and mulching level on fresh and dry rhizome weight was non- significant.

Table 1: Yield attributes of turmeric in relation to intercropping and mulching

Treatments	Yield contributing characters			
	Number of tillers plant^{-1}	Number of rhizomes per plant	Fresh rhizome weight (g)	Dry rhizome weight (g)
Intercropping				
T_1 (turmeric sole)	2.9	15.2	189.5	34.9
T_2 (turmeric + sugarcane)	2.5	13.8	174.4	33.6
T_3 (turmeric + peach)	2.1	12.2	158.4	31.4
CD(p=0.05)	0.27	0.68	12.14	1.56
Mulches level				
M_0 (0 t ha^{-1})	2.2	11.7	149.4	31.3
M_4 (4 t ha^{-1})	2.5	14.4	179.5	33.4
M_8 (8 t ha^{-1})	2.8	15.1	193.4	35.2
CD(p=0.05)	0.27	0.68	12.14	1.56

Fresh rhizome yield

The data presented in table 2 revealed that the fresh rhizome yield was significantly influenced by intercropping and mulching. The plants with T_1 treatment observed significantly higher fresh rhizome yield than T_2 and T_3 treatment. Further, although yield with T_2 treatment recorded significantly lower than T_1 treatment, but produced significantly higher fresh yield over T_3 treatment. The maximum fresh rhizome yield were observed with T_1 treatment i.e 174.2 which was 8.66 and 14.98 per cent more than T_2 and T_3 treatment. This was due to the higher plant population under sole turmeric as compared to intercropping treatments. Chauhan *et al.* (2013) also recorded decrease in yield of agronomic crops *viz,* turmeric *(Curcuma longa* L.*)* and mung *(Vigna radiate* L.*)* under poplar canopy with advancement in age or canopy spread. Effect of different mulch treatment on fresh rhizome yield was also significant. Maximum fresh rhizome yield (173.1 q ha^{-1}) was found under M_8 treatment which remained 5.43 and 16.46 per cent higher over M_4 and M_0 treatment. Kumar *et al*. 2017 also reported that paddy straw mulch enhanced the growth, rhizome yield and quality. The interaction effect between intercropping and mulching level on fresh rhizome yield of turmeric was non- significant.

Dry rhizome yield

The data presented in table 2 signify that dry rhizome yield was significantly affected by intercropping and the maximum dry rhizome yield (38.2 q ha^{-1}) was obtained in T_1 which was followed by T_2 (34.1 q ha^{-1}) and lowest was observed in T_3 (30.6 q ha^{-1}). The lowest dry rhizome yield was obtained in T_1 due to reduced availability of light which greatly reduced fresh yield and ultimately the dry yield. These results are in close proximity with the earlier findings of Gill *et al.* (2004). Data revealed that different mulching treatment had significant effect on dry rhizome yield. The highest dry rhizome yield was recorded in M_8 at all observational periods which was followed by M_4 and M_0 treatment. The lowest dry rhizome yield was observed in M_0 treatment. The general trend of dry rhizome yield observed was $M_8 > M_4 > M_0$. The percent increase in dry rhizome yield were 15.9 and 10.8 in M_8 and M_4 treatment, respectively over M_0 treatment. This might be due to beneficial effect of mulch which resulted in early emergence, having taller plants with higher number of leaves, more number of tiller and greater number and weight of rhizome as compared to those of pure turmeric and intercropping treatments. Verma and Sarnaik (2006) [12] have also been recorded higher dry yield of turmeric with mulching.

The interaction effect between intercropping and mulching level on dry rhizome yield of turmeric was non- significant.

Processed rhizome yield

Data on processed rhizome yield are presented in table 2. It is the ultimate processed yield which is rewarding as compared to the fresh and dry yield for the cultivator. The plants with T_1 treatment (i.e. Turmeric sole) observed significantly higher processed rhizome yield than T_2 and T_3 treatment. Further, although the processed yield with T_2 treatment recorded significantly lower than T_1 treatment, but produced significantly higher yield over T_3 treatment. Bijakal *et al.* (2019) have also been recorded higher processed rhizome yield in open conditions as compared to under poplar. Further, the data revealed that different mulching levels from 0 to 8 t ha^{-1} showed a significant effect on processed rhizome yield. Maximum processed rhizome yield was observed when the crop was applied with M_8 treatment which was significantly more than M_4 and M_0 treatment. Moreover processed yield with M_4 treatment was also significantly more than M_0 treatment. The higher leaf area index realization in mulched plots resulted from quick emergence because of favourable moisture and temperature conditions, which ultimately resulted in higher processed rhizome yield. This is in accordance with Kaur *et al.* (2019) [7] that application of straw mulch produced more turmeric yield than that of no mulch and favourable effect of mulch on the yield might be due to early emergence, quick establishment of the crop and higher interception of light.

The interaction effect between intercropping and mulching level on processed rhizome yield of turmeric was non-significant.

Table 2: Fresh, dry and processed rhizome yield in relation to intercropping and mulching

Treatments	Fresh rhizome yield (q ha^{-1})	Dry rhizome yield (q ha^{-1})	Processed rhizome yield (q ha^{-1})
Intercropping			
T_1 (turmeric sole)	174.2	38.2	36.5
T_2 (turmeric + sugarcane)	159.1	34.1	32.4
T_3 (turmeric + peach)	148.0	30.6	27.1
CD(p=0.05)	7.85	2.09	3.94
Mulching Mulches level			
M_0 (0 t ha^{-1})	144.5	34.8	27.9

M_4 (4 t ha^{-1})	163.7	37.0	31.7
M_8 (8 t ha^{-1})	173.1	2.09	36.4
CD(p=0.05)	7.85	1.56	3.94

5.2 Economics

5.2.1 Total cost of cultivation

Data on total cost of cultivation are presented in table 3. Total cost of cultivation is the sum of common cost of cultivation and variable cost of cultivation. The data on total cost of cultivation of all treatments was calculated. Total cost of cultivation was highest in T_1 treatment followed by T_2 and T_3. Kikon *et al.* (2017) [4] also reported higher mean total cost of production in sole cropping of turmeric as compared to turmeric + bamboo based agroforestry system.

Among the different mulching treatments total cost of cultivation was highest in M_0 followed by M_4 and M_8.

5.2.2 Gross return

Data on gross return are presented in table 3. Gross returns include the cost of cultivation and net returns obtained from the crop. In other words, the combination of input and output in monetary form is known as gross returns. The gross returns were highest in T_1 followed by T_2 and T_3 Treatments. Kikon *et al.* (2017) [4] also reported higher mean total cost of production in sole cropping of turmeric as compared to turmeric + bamboo based agroforestry system.

Among the different mulching rates higher gross returns were recorded in M_8 followed by M_4 and M_0. Sidhu *et al.* (2016) [10] also reported higher gross return in turmeric sole with mulching as compared to turmeric sole without mulching.

5.2.3 Net Returns

The net returns are the important monetary parameter for the feasibility and adoption of the crop in agriculture. The net returns were highest in T_1 followed by T_2 and T_3. Kikon *et al.* (2017) [4] observed higher mean net return under sole cropping.

Among the different mulching rates higher net returns were recorded in M_8 followed by M_4 and M_0. Kikon *et al.* (2017) [4] also reported that mulching enhance the fertility status and return from turmeric cultivation under bamboo based agroforestry system.

5.2.4 Benefit cost ratio

Benefit cost ratio can be obtained by dividing gross returns with total cost of cultivation of particular system. Benefit cost ratio was found maximum in T_1 followed by T_2 and T_3. Brar *et al.* (2020) [1] also reported higher B: C ratio when turmeric grown as sole crop as compared to other agri-horti-silviculture system. Data on B: C ratio are presented in table 2.

Among the mulching higher benefit cost ratio were recorded in M_8 followed by M_4 and M_0. The present results are in accordance with the findings of Sidhu *et al.* (2016) [10], who reported higher B:C ratio in turmeric sole with mulching as compared to turmeric sole without mulching.

Table 3: Effect of intercrops and mulching on economics of turmeric.

Treatments / **Main plot treatments**	**Gross return (Rs ha^{-1})**	**Total cost (Rs ha^{-1})**	**Net return (Rs ha^{-1})**	**B:C**
T_1 (turmeric sole)	348400	136169	201231	1.47
T_2(turmeric + sugarcane)	318200	133242	184958	1.38
T_3 (turmeric + peach)	296200	129177	167023	1.29
Sub plot treatments				
M_0 (0 t ha^{-1})	289200	138372	150828	1.09
M_4 (4 t ha^{-1})	327400	133843	193557	1.44
M_8 (8 t ha^{-1})	346200	132243	213957	1.61

6. Conclusion

From the experiment, it may be concluded that;

The better results were observed with turmeric sole as compared to turmeric + sugarcane and turmeric + peach intercropping system. Among the cropping systems, peach + turmeric was recorded significantly higher curcumin content, essential oil (%) and LER, when compared to sole crop of turmeric. Higher turmeric equivalent yield were observed in T_2 treatment and lowest were observed in T_3. Regarding mulching, turmeric yield increased significantly with mulching and highest yield were observed with straw mulching @8 t ha^{-1} proved significantly beneficial in turmeric cultivation as compared to mulching @4 t ha^{-1} and no mulch. Moreover, the highest benefit –cost ratio (1.61) was recorded in M_8, while lowest in M_0.

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