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Influence of drumstick intercropping and fertilizer application on turmeric growth and yield

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Abstract
The present investigation was carried out during 2024 at college of Horticulture, VNMKV, Parbhani to envisage the optimizing effect of drumstick intercropping and fertilizer levels on growth and yield of turmeric The experiment was laid out in split plot design (SPD) with two factor i.e., intercropping system as main factor and fertilizer levels as sub factor with twelve treatment combinations which were replicated three times. In intercropping system, plantation of turmeric + drumstick (2:1) was found to be beneficial for higher growth, yield attributes along with higher equivalent yield, benefit cost ratio. Among the different fertilizer levels, the application of 125% RDF- 250:125:125 NPK kg ha^{-1} exhibited higher growth and yield attributes with more equivalent yield, benefit cost ratio. Among interaction effect, (I_1F_3) turmeric + drumstick (2:1) and 125% RDF- 250:125:125 NPK kg ha^{-1} found to be beneficial for higher growth, yield attributes with higher system turmeric equivalent yield.

Keywords: Turmeric intercropping, drumstick intercropping, fertilizer levels, split plot design (SPD), growth attributes

Introduction
Turmeric (*Curcuma longa* L.), a shade-loving crop belonging to the Zingiberaceae family, is a valuable spice with a long history of cultivation in India (Harish *et al*. 2022) [8]. Originating to tropical Southeast Asia, this ancient spice is primarily grown for its underground rhizome and is widely used as a condiment and in cosmetics in smaller quantities.

Turmeric cultivation in rainfed conditions comes with significant uncertainty, given that its production is heavily affected by moisture, a critical environmental element posing a considerable impact. To gain insights into appropriate cultivation techniques, examine how a plant species' growth and development react to the unique combination of local climate and soil factors (Ishimine *et al*. 2004; Hossain and Ishimine 2005) [11, 10]. The farmers usually grow turmeric as a sole crop in the open sunny place. Joyachandran *et al*. (1991) [12] reported from India that higher fresh turmeric yield was obtained in intercropping situation than sole crop due to shady condition than those in open sunlight. It can be cultivated in shady places as they are partially shade loving crops (Haque and Hossain, 1985) [7].

India is the largest producer, consumer and exporter of turmeric in the world. In the year 2022-23, an area of 3.24 lakh ha was under turmeric cultivation in India with a production of 11.61 lakh tonnes (over 75% of global turmeric production). More than 30 varieties of Turmeric are grown in India and it is grown in over 20 states in the country. The largest producing states of Turmeric are Maharashtra, Telangana, Karnataka and Tamil Nadu. India has more than 62% share of world trade in turmeric.

Moringa oleifera, commonly known as drumstick, is a sturdy tree species belonging to the Moringaceae family, Originating from the tropical regions of South Asia, it's notable that Drumstick is an unique vegetable crop, provides leafy and pod vegetables under rainfed conditions. Drumstick is highly adaptable to various type of soil and climate and also requires less care and water supply resulting into more area under cultivation. India is the prime producer of Moringa (Drumstick) with an annual production of 2.20 to 2.40 million tonnes of tender fruits from an area of 38,000 ha leading to the productivity of around 63 tonnes per ha. (Sekhar *et al* 2017) [17] Among the different states, Andhra Pradesh leads in both area and production (15,665 ha) followed by Karnataka (10,280 ha) and Tamil Nadu (13250 ha).

Intercropping, a practice wherein two or more different crops are cultivated simultaneously within the same field, has gained widespread adoption in regions across Asia, Africa, and Latin America (Bedoussac *et al.*, 2015; He *et al.*, 2013) [3, 9]. This agricultural technique has been increasingly recognized for its ability to boost yields and foster plant growth. According to Vandermeer (1989) [19], intercropping offers solutions to critical issues such as low crop productivity, pest and disease infestations, soil degradation, and environmental contamination. Moreover, studies conducted by Ehrmann and Ritz (2014) [6] have highlighted the significant benefits of intercropping, including enhanced soil nutrient absorption and improved efficiency in utilizing soil resources.

Material and Methods

The treatments involved in the study consist of two main factors: the intercropping system and fertilizer levels. For intercropping, treatments include: sole turmeric (I_1), sole drumstick ($_{I2}$), turmeric + drumstick in a 2:1 ratio (I_3), and turmeric + drumstick in a 1:1 ratio (I_4). Fertilizer levels are categorized by RDF (recommended dose of fertilizer) percentages: 75% RDF (150:75:75 NPK kg ha^{-1}, F_1), 100% RDF (200:100:100 NPK kg ha^{-1}, F_2), and 125% RDF (250:125:125 NPK kg ha^{-1}, F_3). Treatment combinations for each intercropping system and fertilizer level are represented as I_1F_1, I_1F_2, I_1F_3, etc., denoting specific intercropping and fertilizer applications for each setup. The study on turmeric cultivation involved several key stages. First, seed beds were prepared with proper drainage, and high-quality rhizomes were selected, fungicide-treated, and planted with precise depth and spacing. Fertilizers were applied according to soil tests, enhancing growth. Inter-cultivation practices, including hand weeding and earthing up, supported rhizome development, while pest and disease control ensured plant health. Harvesting occurred after maturity, when leaves dried; rhizomes were dug up, cleaned, and weighed to calculate yield per hectare. Biometric observations from selected plants included measurements of pseudostem height, tiller count, and rhizome characteristics. Yield metrics-such as rhizome count, weight, length, girth, and dry weight per plant-provided comprehensive insights into the productivity and quality of the turmeric crop.

Result and Discussion

Effect of intercropping on growth observations of turmeric

The data presented in table no. 1, revealed that the growth of turmeric were significantly influenced by different intercropping systems. Significantly maximum number of tillers plant^{-1} (3.76), pseudostem height at 60 120 and 180 DAP (18.04 cm, 46.57 cm and 73.56 cm), number of leaves plant^{-1} at 60, 120 and 180 DAP (6.95, 16.96 and 37.45), leaf area plant^{-1} at 60. 120 and 180 DAP (178.49 cm^2, 195.72 cm^2 and 208.15 cm^2) were recorded in treatment I_3 *i.e.*, turmeric + drumstick (2:1). This might be due to shade loving nature of species and higher nutrients availability in the soil at wider spacing. The growth in shade loving plant performance was always found to be positively correlated to soil moisture content in a significant manner. Lahiri (1972) [13] reported that due to partial shading effect of forest plants turmeric produced more number of tillers. Banerjee and Dhara (2009) [2], Vanlalngurzauva *et al.* (2010) [20], resulted higher pseudostem height under 50 percent shade of bamboo plantation; Das *et al.* (2011) [5] cultivated turmeric under the 6 year old *Emblica officinalis* orchard with better performance of the turmeric. Chandra (2014) [4] reported that turmeric produced more number of leaves when grown as inter crop in guava plantation as compared to sole crop.

Effect of fertilizers on growth observations of turmeric

The data presented in table no. 1, revealed that the growth of turmeric were significantly influenced by different fertilizer levels. Significantly maximum number of tillers plant^{-1} (3.65), pseudostem height at 60 120 and 180 DAP (17.40 cm, 45.91 cm and 72.99 cm), number of leaves plant^{-1} at 60, 120 and 180 DAP (6.65, 16.15 and 35.32), leaf area plant^{-1} at 60. 120 and 180 DAP (173.02.49 cm^2, 194.66 cm^2 and 205.50 cm^2) were recorded in treatment F_3 *i.e.*, 125% RDF – 250:125:125. Pseudostem height increased significantly with each successive rise in NPK levels. Higher fertilizer levels likely led to taller pseudo stems by boosting the production and distribution of photosynthates to the stems, which in turn promoted turmeric's pseudo stem growth. Earlier researchers have also reported increase in number of tillers with increasing doses of fertilizer Tiwari *et al.* (2014) [14]. These results are in conformity with the results reported by Satyareddi and Angadi (2014) [16]. Similar results with higher values of leaf area index were also recorded by Tiwari *et al.* (2014) [14] observed that additional fertilizer levels imparted significant effect on growth parameters. Due to availability of more nutrients as compared to low fertilizer levels, which might have enhanced the overall growth of leaves clump^{-1} and thereby leaf area clump-^{1}.

Interaction effect on growth observations of turmeric

The data presented in table no. 1, revealed that the growth of turmeric were significantly influenced by interaction effect of intercropping and fertilizer levels. Significantly maximum number of tillers plant^{-1} (4.40), pseudostem height at 60 120 and 180 DAP (19.49 cm, 49.66 cm and 76.69 cm), number of leaves plant^{-1} at 60, 120 and 180 DAP (7.82, 18.79 and 46.13), leaf area plant^{-1} at 60. 120 and 180 DAP (188.50 cm^2, 201.43 cm^2 and 210.53 cm^2) were recorded in treatment combination I_3F_3 *i.e.*, I_3 turmeric + drumstick (2:1) and F_3 125% RDF – 250:125:125.This might be deu to, when crops are compatible, they may support each other's growth by reducing competition and allowing for more effective nutrient uptake, resulting in better overall plant development and growth.

Effect of intercropping on yield observations of turmeric

The data presented in table no. 2, revealed that the growth of turmeric were significantly influenced by different intercropping systems. Significantly maximum number of mother rhizomes (3.17), weight of mother rhizome (56.44 g), length of mother rhizome (6.86 cm), Girth of mother rhizome (4.82 cm), number of fingers (6.33), number of secondary fingers (19.77), length of primary finger (11.79 cm), girth of primary finger (2.27 cm), fresh weight of rhizome plant^{-1} (491.12 g), fresh rhizome yield (39.14 t ha^{-1}), dry rhizome yield (8.95 t ha^{-1}) were recorded in treatment I_3 *i.e.*, turmeric + drumstick (2:1). Fresh rhizome weight directly influenced the yield this increase in yield of main crop turmeric with different intercrops at different planting ratio may be due to the differential influence of shade regimes caused by intercrops at different planting ratio on the rate of synthesis and accumulation of biomass and other

components of the rhizomes. Bai (1981) [1] and Philip *et al.* (1981) [15] also reported that yield of turmeric was increased gradually with the decrease of light levels and maximum yield was obtained under partial shade.

Table 1: Effect of different fertilizer levels and intercropping on growth observations of turmeric

Treatments	Number of tillers plant^{-1}	Pseudostem height (cm)			Number of leaves plant^{-1}			Leaf area plant^{-1} (cm^2)		
		60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
	Intercropping (I)									
I_1 Sole Turmeric	2.99	14.37	40.51	68.09	5.75	13.4	28.54	156.53	184	196.66
I_2 Sole Drumstick	-	-	-	-	-	-	-	-	-	-
I_3 Turmeric + Drumstick (2 :1)	3.76	18.04	46.57	73.56	6.95	16.96	37.45	178.49	195.72	208.15
I_4 Turmeric + Drumstick (1: 1)	2.306	12.31	36.17	57.7	4.71	11.88	25.71	141.17	175.09	186.37
SE (m)±	0.1	0.09	0.3	0.75	0.07	0.08	0.7	1.61	0.15	0.47
CD (P=0.05)	0.43	0.35	1.16	2.94	0.28	0.3	2.76	6.32	0.58	1.86
	Fertility levels (F)									
F_1 75% RDF -150:75:75	2.42	13.3	37.08	61.44	4.93	12.2	27.02	146.21	175.55	189.27
F_2 100% RDF – 200:100:100	3	14.02	40.26	64.91	5.83	13.89	29.37	156.96	184.59	196.41
F_3 125% RDF – 250:125:125	3.65	17.4	45.91	72.99	6.65	16.15	35.32	173.02	194.66	205.5
SE (m)±	0.1	0.18	0.38	0.58	0.11	0.15	0.63	1.68	0.09	0.4
CD (P=0.05)	0.31	0.57	1.17	1.79	0.34	0.47	1.93	5.16	0.27	1.22
	Interaction (I X F)									
I_1F_1	2.5	12.68	35.98	62.59	5.2	11.58	26.79	145.95	174	185.84
I_1F_2	3.1	12.88	39.11	66.14	5.65	13.43	27.11	146.29	181.72	197.58
I_1F_3	3.4	17.56	46.42	75.54	6.4	15.18	31.72	177.36	196.28	206.58
I_3F_1	3.2	16.4	42.64	68.2	6.36	14.49	31.03	164.05	187.27	204.44
I_3F_2	3.7	18.23	47.43	75.8	6.66	17.59	35.21	182.92	198.45	209.47
I_3F_3	4.4	19.49	49.66	76.69	7.82	18.79	46.13	188.5	201.43	210.53
I_4F_1	2	10.83	32.62	53.54	3.22	10.54	23.23	128.63	165.39	177.53
I_4F_2	2.2	10.96	34.24	52.8	5.18	10.63	25.8	141.68	173.6	182.19
I_4F_3	3.18	15.14	41.64	66.75	5.73	14.47	28.1	153.2	186.27	199.39
SE (m)±	0.17	0.324	0.66	1.01	0.19	0.26	1.08	2.9	0.15	0.69
CD (P=0.05)	NS	0.998	2.03	3.1	0.59	0.81	3.34	8.94	0.47	2.11

Effect of fertilizers on yield observations of turmeric

The data presented in table no. 2, revealed that the growth of turmeric were significantly influenced by fertilizer levels. Significantly maximum number of mother rhizomes (2.97), weight of mother rhizome (54.39 g), length of mother rhizome (6.58 cm), Girth of mother rhizome (4.52 cm), number of fingers (6.24), number of secondary fingers (18.88), length of primary finger (11.52 cm), girth of primary finger (2.13 cm), fresh weight of rhizome plant^{-1} (435.57 g), fresh rhizome yield (38.17 t ha^{-1}), dry rhizome yield (8.46 t ha^{-1}) were recorded in treatment F_3 *i.e.*, 125% RDF – 250:125:125. The higher yield at higher NPK levels may be due to better stem size and higher number of rhizomes plant^{-1} which may result from increase in number of leaf plant^{-1} and number of fingers with increase in fertilizer levels which results into higher photosynthesis. These findings are correlated with the findings reported by Tiwari *et al.* (2014) [14] and Ojikpong (2018) [14] in turmeric.

Interaction effect on yield observations of turmeric

The data presented in table no. 2, revealed that the growth of turmeric were significantly influenced by interaction effect of intercropping and fertilizer levels. Significantly maximum number of mother rhizomes (3.42), weight of mother rhizome (59.04 g), length of mother rhizome (7.54 cm), Girth of mother rhizome (5.09 cm), number of fingers (6.70), number of secondary fingers (21.06), length of primary finger (12.63 cm), girth of primary finger (2.82 cm), fresh weight of rhizome plant^{-1} (553.56 g), fresh rhizome yield (40.19 t ha^{-1}), dry rhizome yield (9.97 t ha^{-1}) were recorded in treatment combination I_3F_3 *i.e.*, I_3 turmeric + drumstick (2:1) and F_3 125% RDF – 250:125:125 This might be deu to, when crops are compatible, they may support each other's growth by reducing competition and allowing for more effective nutrient uptake, resulting in better overall plant development and yield

Table 2: Effect of different fertilizer levels and intercropping on yield observations of Turmeric

Treatments	Number of mother rhizomes	Weight of mother rhizomes (g)	Length of mother rhizomes (cm)	Girth of mother rhizome (cm)	Number of fingers plant^{-1}	Number of secondary fingers plant^{-1}	Length of primary finger at harvest (cm)	Girth of primary finger at harvest (cm)	fresh weight of rhizome plant^{-1} (g)	fresh rhizome yield t ha^{-1}	dry rhizome yield t ha^{-1}
Intercropping (I)											
I_1 Sole Turmeric	2.55	46.25	5.57	3.91	5.36	16.34	10.32	1.63	360.96	31.72	6.98
I_2 Sole Drumstick	-	-	-	-	-	-	-	-	-	-	-
I_3 Turmeric + Drumstick (2 :1)	3.17	56.44	6.86	4.82	6.33	19.77	11.79	2.27	491.12	39.14	8.95
I_4 Turmeric + Drumstick (1: 1)	2.33	44.91	4.3	3.37	4.57	13.89	9.17	1.51	332.66	25.11	5.06
SE (m)±	0.05	0.14	0.08	0.1	0.1	0.17	0.13	0.09	5.8	0.14	0.06
CD (P=0.05)	0.21	0.55	0.32	0.4	0.38	0.68	0.52	0.36	22.75	0.57	0.24
Fertility levels (F)											
F_1 75% RDF - 150:75:75	2.43	44.94	4.7	3.65	4.63	14.79	9.5	1.56	340.57	26.24	5.69
F_2 100% RDF – 200:100:100	2.65	48.26	5.45	3.94	5.4	16.33	10.26	1.7	408.59	31.56	6.84
F_3 125% RDF – 250:125:125	2.97	54.39	6.58	4.52	6.24	18.88	11.52	2.13	435.57	38.17	8.46
SE (m)±	0.06	0.08	0.11	0.13	0.06	0.23	0.1	0.07	5.53	0.16	0.09
CD (P=0.05)	0.18	0.23	0.35	0.41	0.19	0.71	0.3	0.22	17.03	0.51	0.27
Interaction (I X F)											
I_1F_1	2.32	44.46	4.51	3.37	4.6	14.56	9.62	1.47	337.31	22.54	5.59
I_1F_2	2.43	46.62	5.46	3.54	5.18	15.84	9.77	1.56	343.3	34.28	6.68
I_1F_3	2.9	47.68	6.73	4.83	6.31	18.63	11.59	1.87	402.25	38.33	8.68
I_3F_1	2.89	52.89	6.47	4.4	5.8	18.55	10.48	1.86	367.09	37.49	7.65
I_3F_2	3.2	57.38	6.58	4.97	6.49	19.69	12.26	2.12	552.72	39.75	9.21
I_3F_3	3.42	59.04	7.54	5.09	6.7	21.06	12.63	2.82	553.56	40.19	9.97
I_4F_1	2.08	37.48	3.1	3.16	3.5	11.28	8.4	1.37	317.32	18.68	3.84
I_4F_2	2.31	40.79	4.32	3.31	4.53	13.45	8.77	1.43	329.75	20.65	4.62
I_4F_3	2.58	56.46	5.47	3.63	5.7	16.94	10.33	1.72	350.91	36.01	6.73
SE (m)±	0.1	0.13	0.2	0.23	0.11	0.4	0.17	0.12	9.57	0.28	0.15
CD (P=0.05)	0.3	0.4	0.6	NS	0.33	1.23	0.52	NS	29.49	0.88	0.47

Conclusions

In the intercropping system, the combination of turmeric and drumstick in a 2:1 ratio proved beneficial for growth and yield attributes. Among the fertilizer levels, the application of 125% RDF (250:125:125 NPK kg ha^{-1}) enhanced growth and yield. Furthermore, the interaction of the turmeric + drumstick (2:1) intercropping system with 125% RDF (I_1F_3) was especially effective, resulting in the highest growth and productivity metrics. In nutshell, it is concluded that for higher yield and vigorous plant growth planting of turmeric + drumstick in 2:1 proportion along with application of 125% RDF 250:125:125 NPK kg ha^{-1} should be given. As above results are based on one year few more trials should be carried out to draw valid conclusion.

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Conflict of Interest

The authors declare no conflicts of interest. They bear sole responsibility for the content and composition of the paper.

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