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Productive and profitable black pepper based mixed cropping systems involving tuber crops

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Abstract

An experiment on pepper based mixed cropping systems involving tuber intercrops was carried out at Pepper Research Station (Kerala Agricultural University), Panniyur, Kannur during 2013-14 to 2022-23. Five different black pepper based mixed cropping systems which accommodated five different tropical tuber crops were experimented. The data pertaining to 2020-21, 2021-22 and 2022-23 were separately recorded and the pooled mean worked out for individual crop yields as well as equivalent yields and economics of cultivation of the different systems. The pooled equivalent yield for black pepper + greater yam and black pepper + elephant foot yam mixed cropping systems were recorded in terms of base crop black pepper as 1239.28 and 1214.25 kg ha^{-1} respectively, significantly superior to all other mixed cropping systems. The equivalent yield recorded for black pepper sole cropping was 561.73 kg ha^{-1} only. The pooled data revealed higher profitability for black pepper + greater yam mixed cropping system with gross returns, net returns and B:C ratio of Rs. 619637 ha^{-1}, Rs.440043 ha^{-1} and 3.45 respectively. For black pepper + elephant foot yam system, the respective values were Rs. 607126 ha^{-1}, Rs. 440043 ha^{-1} and 3.57. The soil properties were also favourably maintained under mixed cropping as that in sole cropping of black pepper as indicated by soil nutrient analysis conducted at the end of the field experiment.

Keywords: Black pepper, mixed cropping systems, tuber crops, intercrops, yield economics

Introduction

In Kerala, land is a scarce resource. The Tenth Agricultural Census of Kerala reported the average size of an operational holding in Kerala as 0.18 ha in 2015-16. During 2010 - 2011 and 2000-2001, the respective figures for this were 0.22 and 0.24 ha, which clearly reveals the decline in the size of operational holdings (Department of Economics and Statistics, 2021). The situation is sure to worsen in the coming years with further fragmentation of holdings. This necessitates intensification of farming activities and best use of available land area for ensuring food and economic security. In this context, mixed cropping, which refers to the simultaneous growing of two or more crops in the same piece of land gain much significance.

Another challenge that Kerala agriculture faces is the change in climatic pattern. Long spells of drought, considerable increase in air temperature during summer, changes in the rainfall pattern with sudden and heavy downpours leading to floods *etc.* have become quite common in the last few years and has hit hard the agricultural sector (George *et al.,* 2017). This necessitates inclusion of climate resilient crops in the existing cropping systems.

Pepper is a widely spaced crop amenable to intercropping. Intercrops can help suppression of weeds and control soil erosion in pepper gardens (Thankamani *et al*., 2012). Tuber crops are regarded as climate resilient crops (Anju *et al.,* 2014) and are reported to be profitable intercrops in pepper gardens. Based on the idea, five different mixed cropping systems involving tropical tuber crops were evaluated in the present experiment, along with sole cropping of black pepper with the objective to analyse the production and profit from these systems and to study the changes in soil properties.

Materials and methods

The experiment on tuber intercropping in pepper gardens was carried out at Pepper Research Station, Panniyur, functioning under Kerala Agricultural University at Kannur district of Kerala. The different tuber intercrops selected were colocasia (*Colocasia esculenta*), arrow root (*Maranta arundinacea*), elephant foot yam (*Amorphophallus paeoniifolius*), cassava (*Manihot esculenta*) and greater yam (*Dioscorea alata*) and the respective mixed farming systems were designated as T_1 to T_5. Sole cropping of pepper was also evaluated as T_6 cropping system.

The experimental site was located at 12.0764^0N latitude and 75.4053^0E at an altitude of 95 m above mean sea level. Tropical climate prevailed in the area. The total annual rainfall of the region ranges between 3000 to 3150 mm. The mean daily maximum temperature was recorded as 34^oC and the mean daily minimum temperature as 24^oC for the cropping season. The soil type of the experimental site was laterite with loamy texture. Regarding the soil characters at the start of the experiment, the soil was acidic (pH 5.5), EC normal (0.12 dS m^{-1}), organic carbon high (1.60%); the available nitrogen status was medium (360 kg ha^{-1}), available P high (120 kg ha^{-1}) and available K high (290 kg ha^{-1})

The black pepper variety selected was Panniyur -1, a prominent variety released from Kerala Agricultural University. The variety is the world's first hybrid in pepper and is a cross between Uthirankotta and Cheriyakaniakkadan local varieties of black pepper in Kerala. The potential yield of the variety is reported as upto 8800 kg *dry pepper ha*$^{-1}$ and the average yield is *3850 kg dry pepper ha*$^{-1}$. For intercropping, Gajendra (elephant foot yam), Sree Vijaya (cassava), Sree Keerthi (greater yam) varieties released from the ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Thiruvananthapuram were selected. Local varieties were planted for colocasia and arrowroot and the same varieties were raised for all these years under study. *Glyricidia* sp. was used as the standard tree for trailing pepper. Greater yam was trailed on to glyricidia stems obtained from the field itself.

Gajendra is a selection of elephant foot yam from local collections of Kovvur, West Godavari district, Andhra Pradesh, released from Vegetable Research Station, Rajendra Nagar, under the aegis of ICAR-All India Co-ordinated Research Project (ICAR-AICRP) on Tuber Crops. It is an improved variety with an average yield of 42.00 t ha^{-1} and potential yield of 55.00 t ha^{-1} that matures by 180-210 days (Sahoo *et al*., 2015). The tubers are non-acrid, well-shaped and generally devoid of cormels or propagules (Kamal Kant *et al*., 2020). Cassava variety Sree Vijaya is an early maturing variety of 6-7 months duration with an average yield of 25-28 t ha^{-1}, starch content of 27-30% and the tuber has yellow flesh colour. Sree Keerthi is a high yielding variety of greater yam (*Dioscorea alata*) with a starch content 20-22 per cent on fresh weight basis. This variety has good cooking quality and excellent taste with an average yield in the range of 25-30 t ha^{-1}. Local varieties were selected for other intercrops, arrowroot and colocasia.

The spacing adopted was 4x2 m between pepper vines. Intercrops were raised in the interspace area of 8 m^2 between two vines. Colocasia was spaced at 60x45 cm, arrow root at 15x15 cm, elephant foot yam at 90x90 cm, cassava at 90x90 cm and greater yam at 1x1 m. Both under sole and intercropped conditions, 1250 pepper vines were maintained per hectare. Plant population of arrowroot was 66667 plants per ha and that of colocasia, elephant foot yam, cassava and greater yam were 2500 per hectare. Basal dose of organic manures and top dressings using chemical fertilizers both for main crop and intercrops were carried out as per the recommendations of Kerala Agricultural University (KAU, 2016).

The experiment was initiated during 2013-14 and after yield stabilisation of pepper, the production and economics of the different cropping systems were worked out for the years 2020-21, 2021-22 and 2022-23, *i.e.* seventh, eighth and ninth year of planting of pepper. Pepper yield in terms of green and dry berry yields, intercrop yields and the equivalent yield of all the mixed cropping systems with respect to the base crop pepper were worked out for the three years under study and the pooled data generated. The yield of main and intercrops were recorded and based on the prevailing market price for these crops, the gross income from each treatment was worked

out. Further, the yield of the base crop that could contribute to the same gross income was worked out and expressed as equivalent yield. The economics of the study in terms of gross and net returns and B:C ratios were also worked out for individual years and the pooled mean data are presented. The statistical analysis was carried out using the software OPSTAT developed at the Department of Statistics, Haryana Agricultural University. The analysis of variance was conducted and critical differences at 5 % significance level was worked out.

Results and discussion

Yield of pepper

The green berry yield of pepper per vine ranged between 3.30 and 4.75 kg vine^{-1} (4125 to 5937.5 kg ha^{-1}). The yield of dry berry yield per vine is presented in Table 1. The different treatments had no significant influence on the yield of dry berry yield vine^{-1} for all the three years of study. As per the pooled data, the dry black pepper yield ranged between 1.15 and 1.66 kg vine^{-1} (1437.5 to 2075 kg ha^{-1}).

Comparable yield recorded under sole and mixed cropped stands of pepper could be justified based on the fact that main and intercrops did not face competition as separate and adequate manuring and irrigation were provided and there were no antagonistic effects among crops.

Table 1. Year wise and pooled data on dry berry yield of black pepper (kg vine^{-1})

Treatment	Year			Pooled mean yield (kg vine^{-1})	Pooled mean yield (kg ha^{-1})
	2020-21	2021-22	2022-23		
T_1 Colocasia + Black pepper	0.86	1.09	1.80	1.25	1562.5
T_2 Arrowroot + Black pepper	0.82	0.93	1.71	1.15	1441.2
T_3 EFY + Black pepper	0.58	1.48	1.82	1.29	1616.2
T_4 Cassava + Black pepper	1.16	1.32	1.85	1.44	1803.7
T_5 Greater yam + Black pepper	1.98	1.20	1.81	1.66	2078.7
T_6 Black pepper alone	0.86	1.46	1.83	1.38	1728.7
CD (0.05)	NS	NS	NS	NS	NS

Yield of intercrops

Year wise and pooled data on the yield of tuber intercrops in pepper garden is presented in Table 2. From an intercrop area of 8 m^2, pooled mean yield in the range of 2.48 to 8.11 kg was obtained from different tuber intercrops. The different treatments had a significant influence on intercrop yields. For the years 2020-21 and 2022-23, significantly higher and comparable intercrop yields were recorded by T_3 (Elephant foot yam + black pepper) and T_5 (Greater yam + black pepper) whereas during 2021-22, significantly higher yield was recorded by T5 (Greater yam + black pepper).

Table 2. Year wise and pooled data on yield of tuber intercrops in pepper garden

Treatment	Year			Pooled mean yield (kg/8 m² interspace)
	2020-21	2021-22	2022-23	
T_1 Colocasia + Black pepper	3.03	2.97	3.47	3.16
T_2 Arrowroot + Black pepper	2.43	2.43	2.57	2.48
T_3 EFY + Black pepper	5.33	8.00	8.20	7.18
T_4 Cassava + Black pepper	3.20	3.52	5.43	4.05
T_5 Greater yam + Black pepper	6.09	10.71	7.53	8.11
T_6 Black pepper alone	No intercrops			
CD (0.05)		1.71	1.46	2.36

Equivalent yield of the different mixed cropping systems

Equivalent yields of the different pepper based cropping systems worked out in terms of base crop (kg ha^{-1} of black pepper) are presented in Table 3. Greater yam + black pepper system resulted in an equivalent yield of 1239.28 kg ha^{-1} whereas elephant foot yam + black pepper system yielded 1214.25 kg ha^{-1} of black pepper. These were statistically comparable and significantly higher than other treatments. Similar to this research result, Thankamani *et al.* (2011) reported a black pepper equivalent yield of 1147 kg ha^{-1} from a mixed cropping system of elephant foot yam and black pepper. Diversified cropping systems in black pepper has an advantage over pepper monocropping with regard to enhanced system productivity as reported by Degri and Ayuba (2016).

Table 3. Equivalent yield (pooled data) of the different pepper based cropping systems worked out in terms of base crop black pepper (kg ha^{-1} of pepper).

Treatment	Year			Equivalent yield (kg ha^{-1})
	2020-21	2021-22	2022-23	
T_1 Colocasia + Black pepper	748.3	825.8	956.8	843.6
T_2 Arrowroot + Black pepper	764.1	812.6	866.8	814.5
T_3 EFY + Black pepper	793.3	1419.2	1430.2	1214.2
T_4 Cassava + Black pepper	555.8	635.0	1153.5	781.4
T_5 Greater yam + Black pepper	1131.6	1222.6	1363.5	1239.2
T_6 Black pepper alone	564.1	510.8	610.2	561.7
CD (0.05)	352.01	43.83	104.06	296.55

Economics of cultivation

The cost of cultivation (Rs. ha^{-1}) of different systems were worked out as 174468 (T_1), 155975 (T_2), 167083 (T_3), 186448 (T_4), 179234 (T_5) and 132369 (T_6). Gross returns were the highest (Rs. 619637 ha^{-1}) for T_5 (Greater yam + black pepper) closely followed by Rs. 607126 ha^{-1} in T_3 (Elephant foot yam + black pepper) (Table 4). The net returns from both the above cropping systems were Rs. 440043 ha^{-1} (T3) and Rs 440403 ha^{-1} (T5) respectively (Table 5). T_3 and T_5 recorded higher B:C ratios of 3.57 and 3.45 respectively (Table 5). This could be attributed to the higher productivity from these tuber intercrops and less incidence of pests.

Table 4. Gross returns (pooled data) from the different mixed cropping systems (Rs. ha^{-1})

Treatment	Year			Gross returns* (Rs. ha^{-1})
	2020-21	2021-22	2022-23	
T_1 Colocasia + Black pepper	374166	412900	478445	421837
T_2 Arrowroot + Black pepper	382083	406300	433445	407276
T_3 EFY + Black pepper	396666	709600	715112	607126
T_4 Cassava + Black pepper	277916	317500	576779	390731
T_5 Greater yam + Black pepper	565833	611300	681779	619637
T_6 Black pepper alone	282083	255400	305112	280865

*Price of black pepper was calculated as Rs. 500kg, Colocasia Rs. 60 kg^{-1}, Arrowroot Rs. 80 kg^{-1}, Elephant Foot yam Rs. 45 kg^{-1}, Cassava Rs. 20 kg^{-1} and Greater yam as Rs. 30 kg^{-1}, to arrive at gross returns by multiplying with production (kg) in each treatment.

Table 5. Net returns and B:C ratio (pooled data) from different mixed cropping systems (Rs. ha^{-1})

Treatment	Year			Net returns (Rs. ha^{-1})	B:C ratio
	2020-21	2021-22	2022-23		
T_1 Colocasia + Black pepper	207870	246408	287829	247369	2.41
T_2 Arrowroot + Black pepper	228636	253556	271712	251301	2.61
T_3 EFY + Black pepper	260821	524326	534983	440043	3.57
T_4 Cassava + Black pepper	91395	144946	376509	204283	2.07
T_5 Greater yam + Black pepper	389561	435639	496008	440403	3.45
T_6 Black pepper alone	153278	127058	165152	148496	2.12

Thankamani *et al*. (2011) reported enhancement in the gross and net returns and B:C ratio from pepper gardens with tuber intercropping. The maximum net returns obtained from elephant foot yam + black pepper mixed cropping system was Rs. 270230 ha^{-1} with a B: C ratio of 3.4. Advantages of yield increase and hence higher income generation were recorded with pepper based mixed cropping systems by Subramanian *et al.* (2016).

Soil nutrient status after cropping

The soil nutrient status under intercropping and that with sole cropping of pepper recorded non-significant differences as evident from Table 6. After the cropping phase, the available soil N was in the medium range, available P in higher range and available K was in medium to high range. The pH of the soil remained acidic as in the start; organic carbon level maintained as high and electrical conductivity was normal. A very slight decline noticed with soil K after cropping, in comparison to that at start could be attributed to the enhanced K uptake by tuber crops, which could be replenished by nutrient supply for the upcoming crop. Byju and Nedunchezhiyan (2004) reported that potassium is a key nutrient for higher productivity of tropical tuber crops and hence the medium range of soil K in certain treatments could be justified based on crop use. There are many research works citing the importance of potassium for tuber crops. White (2013) and Van *et al.* (2016) reported that K executes carbon mobilization and accumulation and is thus essential for the later phase of tuber development. K uptake by tubers is high. Tubers remove 1.5 times more potassium than nitrogen and 4 or 5 times the amount of phosphate (Laszlo, 2010). Separate and adequate fertilizer application for main and intercrops could maintain the soil nutrient levels after crop harvest.

Table 6. Soil properties after the cropping period

Treatment	Available plant nutrients kg ha^{-1}			pH	EC dS m^{-1}	OC (%)
	N	P_2O_5	K_2O			
T_1 Colocasia + Black pepper	348.27	110.87	277.27	5.53	0.112	1.60
T_2 Arrowroot + Black pepper	343.20	113.42	283.00	5.50	0.111	1.60
T_3 EFY + Black pepper	350.13	112.50	285.20	5.37	0.104	1.64
T_4 Cassava + Black pepper	355.20	114.10	278.17	5.27	0.108	1.58
T_5 Greater yam + Black pepper	346.67	115.00	282.83	5.43	0.106	1.55
T_6 Black pepper alone	358.00	115.00	285.27	5.53	0.106	1.57
CD (0.05)	NS	NS	NS	NS	NS	NS

Conclusion

The study suggests that mixed cropping systems in pepper including greater yam and elephant foot yam are especially productive and profitable and are highly appreciable in the context of ensuring food security and economic prospects. As evident from the equivalent yield data, yield increase to the tune of 121 per cent and 116 per cent respectively were obtained from T_5 (Greater yam + black pepper) and T_3 (Elephant foot yam + black pepper) mixed cropping systems compared to sole cropping of pepper. These systems recorded maximum profits also. The soil fertility was also maintained in mixed cropping systems with separate and adequate manuring for both the main crop and intercrops.

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