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Crop Diversification for Enhanced Productivity in the Southern Laterites of Kerala

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ABSTRACT

Background: The key focus of crop diversification is the selection of compatible crops for increasing biodiversity, efficient use of resources and enhancing system productivity. Monocropped coconut gardens provide ample scope for crop diversification through the inclusion of several crops as intercrops. The present study was conducted to assess the feasibility of intercropping maize, finger millet, black gram and green gram in coconut garden.

Methods: Field experiments were conducted during two consecutive summer seasons to assess the suitability of maize, finger millet, black gram and green gram as intercrops in coconut garden.

Result: The present investigation revealed that maize (cereal) and finger millet (millet) were suitable as intercrops in coconut garden. The adaptability of the tested crops and system productivity were assessed and discussed. On the whole, the nutrient balance sheet revealed the importance of soil test based nutrient management for intercropping in coconut garden.

Key words: Black gram, Finger millet, Green gram, Intercropping, Maize, Nutrient balance sheet.

INTRODUCTION

Kerala is characterized by extreme diversity in its physical resources and agro-climatic conditions and, high cropping intensity of 127.66 per cent with 96.7 per cent of the operational holdings of less than one hectare (FIB, 2022). Hence increasing the productivity per unit area and time is of paramount importance. Diversifying the existing cropping systems in accordance with the prevailing agro-climatic conditions is an important consideration. About 38 per cent of the net area sown is under coconut, the prominent perennial crop covering an area of 760776 ha in 2019-'20 (FIB, 2022).

Kerala has been delineated into 23 agro-ecological units (Nair *et al*., 2013). Since the agro-ecological unit (AEU) wise studies show distinct intra unit variation with respect to crop yield, specific packages mitigating the yield barriers need to be developed for enhancing the productivity of the AEU. Considering the recommended spacing of coconut as 7.6 m × 7.6 m with a basin radius of 1.8 m (KAU, 2016), about 75 per cent of the area remains unoccupied under monocropping (Thomas *et al*., 2018), resulting in reduced resource use efficiency (Kumar, 2005). The growth pattern of coconut is such that in an even-aged plantation, comprising adult palms of more than 25 years, permits considerable amount of light to infiltrate through the canopy (Nelliat *et al*., 1974; Kumar and Kunhamu, 2022), which can be utilized effectively for raising intercrops, both annuals and perennials. Thus intercropping involving mixed species of crops capable of enhancing resource use efficiency and economic returns, in spatial and/or temporal dimensions has become a unique feature of coconut plantations. According to the "Niche-complementarity hypothesis of Harper (1977), inclusion of more number of crop species in intercropping could result in improved partitioning and utilisation of resources, creating a more productive system, than with lesser number of crop species. In this background the present study was undertaken to assess the effect of intercropping maize, finger millet, black gram and green gram in coconut garden, in terms of system productivity and soil nutrient balance.

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MATERIALS AND METHODS

The experiments were conducted at the Coconut Research Station (CRS), Balaramapuram, during two consecutive summer seasons in 2020 and 2021. The experimental site was geographically located at 8°22′52.881″N latitude and 77°1′47.303″E longitude, at an altitude of 26 m above mean sea level. The coconut garden chosen comprised uniformly aged (more than 60 years) palms of the West Coast Tall variety. The soil of the experimental site was red, sandy laom in texture, very strongly acidic in reaction (pH 4.65), medium in organic carbon (1.01%), low in available nitrogen (218.15 kg ha^{-1}), available phosphorus (17.02 kg ha^{-1}) and potassium (100.11 kg ha^{-1}) status. The experiment was laid out in randomized block design with eight treatments replicated five times. The treatments were sole crop of maize (T_1), sole crop of finger millet (T_2), sole crop of black gram (T_3), sole crop of green gram (T_4), maize + black gram (T_5), maize + green gram (T_6), finger millet + black gram (T_7) and finger millet + green gram (T_8).

The varieties used for the experiment were CO 6 (maize), PPR 2700 (finger millet), CO 8 (green gram) and DU 1 (black gram). The spacing followed was: maize (60 cm × 25 cm), finger millet (25 cm x 15 cm) and pulses (25 cm × 15 cm). The crops were managed adopting the nutrient recommendations as per the KAU Package of Practices (KAU, 2016) Pulses were intercropped in maize following the additive series (Kheroar and Patra, 2014), with one row of the pulse crop between two rows of maize. Finger millet was intercropped with pulses following the replacment series at 4:1 ratio (Nigade *et al*., 2012). While the seeds of maize and pulses were dibbled, solid row planting was followed for finger millet maintaining an inter row spacing of 25 cm. Thinning was done 15 days after sowing (DAS) to maintain an intra-row spacing of 15 cm.

Biometric observations, *viz*., total dry matter production and yield of crops were recorded following standard procedures. Biological efficiency of intercropping was assessed in terms of land equivalent ratio (Willey, 1979), aggressivity (McGilchrist, 1965) and percentage yield difference (Afe and Atanda, 2015). The system productivity was determined as the coconut equivalent yield (CEY), based on the crop equivalent yield (Lal and Ray, 1976; Verma and Modgal, 1983). Nutrient balance sheet (N, P and K) was computed following the procedure suggested by Palaniappan (1985). A positive balance indicated soil storage and negative balance depletion. The computed parameters were not analysed statistically. The data are presented as the mean (pooled) over the two years.

RESULTS AND DISCUSSION

Total dry matter production

Intercropping with pulses had significant effect on the total dry matter production (TDMP) of maize and finger millet, intercropped in coconut garden (Table 1). Between the sole crops, maize recorded higher total dry matter production (12626 kg ha^{-1}) than finger millet (4942 kg ha^{-1}). The robust nature of maize as evidenced by taller plants and larger leaves, compared to finger millet might have contributed to the higher dry matter production. Intercropping maize with black gram resulted in 16.91 per cent higher TDMP of maize (11234 kg ha^{-1}), than intercropping with green gram (10747 kg ha^{-1}). Intercropping with black gram was observed to increase the TDMP of finger millet (3984 kg ha^{-1}) by 5.17 per cent than green gram. (3788 kg ha^{-1}).

Sole crops of black gram and green gram recorded significantly higher TDMP (1916 kg ha^{-1} and 2300 kg ha^{-1}) compared to intercropping. In general, cereals and millets possess greater rooting densities (Anil *et al*., 1998). Thus, when pulses were intercropped with maize and finger millet, a competition might have emerged affecting the growth of pulses when intercropped, as reported by Reddy *et al*. (2021). Both black gram and green gram resulted in statistically comparable TDMP, when intercropped. However, the TDMP of green gram was observed to be higher (1441 kg ha^{-1}) than black gram (1204 kg ha^{-1}) under intercropping.

Table 1: TDMP and yield (pooled mean) of maize, finger millet, black gram and green gram as influenced by intercropping in coconut garden, kg ha^{-1}.

Treatment (as intercrop in coconut garden)	Maize, finger millet			Black gram, green gram		
	TDMP	Grain yield	Haulm yield	TDMP	Seed yield	Bhusa yield
T_1 - Maize	12626	6880	9211	-	-	-
T_2 - Finger millet	4942	1760	4053	-	-	-
T_3 - Black gram	-	-	-	1916	888	1499
T_4 - Green gram	-	-	-	2300	891	2496
T_5 - Maize + black gram	11234	5354	8898	1192	495	988
T_6 - Maize + green gram	10747	4999	8751	1532	357	1623
T_7 - Finger millet + black gram	3984	1407	3280	1215	501	1005
T_8 – Finger millet + green gram	3788	1337	3120	1349	457	1736
SE m (±)*	75	82	37	-	-	-
SE m (±)**	81	30	66	-	-	-
SE m (±)***	-	-	-	30	30	11
SE m (±)****	-	-	-	61	10	105
CD (0.05)*	301.8	331.1	149.5	-	-	-
CD (0.05)**	326.2	120.1	267.2	-	-	-
CD (0.05)***	-	-	-	120.4	121.1	44.9
CD (0.05)****	-	-	-	246.0	40.8	423.3

*Maize, ** Finger millet, *** Black gram, **** Green gram.

Yield

Sole crops of maize and finger millet intercropped in coconut garden recorded significantly higher grain yields (6880 kg ha^{-1} and 1760 kg ha^{-1} respectively) (Table 1), than when intercropped with pulses (5177 kg ha^{-1} and 1372 kg ha^{-1}). While difference between the sole crop and intercrop yields was 32.9 per cent for maize, it was 28.3 per cent for finger millet. Plant population is a key factor that decides yield. Thus it is logical to reason out that the higher plant population of maize and finger millet under sole cropping might have contributed to the higher yields. The reduction in the yields under intercropping could also be attributed to the competition with the pulses along with a reduced plant population. Maize + black gram resulted in 7.10 per cent higher grain yield of maize (5354 kg ha^{-1}) than maize + green gram, (4999 kg ha^{-1}). The yield of finger millet was statistically comparable between the two intercrops, *viz*., black gram and green gram.

There were significant variations in the haulm yields of maize and finger millet intercropped in coconut garden (Table 1). Haulm yield was also significantly superior for the sole crops of maize and finger millet (9211 kg ha^{-1} and 4053 kg ha^{-1}). Haulm yield of both maize and finger millet were superior when intercropped with black gram (8898 kg ha^{-1} and 3280 kg ha^{-1}).

Intercropping had significant effect on the seed yield of black gram and green gram (Table 1), with higher yields under sole cropping. Sole crop yields of black gram and green gram were almost equal. However, under intercropping, black gram yielded higher than green gram. The seed yield of black gram under finger millet + black gram (501 kg ha^{-1}) was comparable with maize + black gram (495 kg ha^{-1}). Green gram also behaved in a similar manner with higher seed yield under finger millet + green gram (457 kg ha^{-1}) followed by maize + green gram (357 kg ha^{-1}). The higher seed yield of black gram might be due to the higher test weight of black gram compared to green gram. Similar observations have been made by Sarma *et al*. (2016) in studies conducted with intercropping black gram and green gram in sesame.

The bhusa yields were also superior for the sole crops of black gram (1499 kg ha^{-1}) and green gram (2496 kg ha^{-1}). Bhusa yield of black gram was statistically comparable when intercropped with finger millet (1005 kg ha^{-1}) and maize (988 kg ha^{-1}). Bhusa yield of green gram was also comparable when intercropped with finger millet (1736 kg ha^{-1}) and maize (1623 kg ha^{-1}).

Under intercropping, the mean seed yield of black gram was 498 kg ha^{-1} and that of green gram was 407 kg ha^{-1}. The seed yield of black gram was 22.4 per cent higher than green gram under intercropping. Although the TDMP of green gram was 19.7 per cent higher than black gram, this was not reflected in the seed yield of the green gram. This is possibly because of a better source to sink translocation in black gram than in green gram.

Land equivalent ratio

The land equivalent ratio (LER) indicates the advantage of an intercropping system with efficient resource utilization compared to pure stands of the respective crops. LER values greater than unity denotes yield advantage. The data on the effect of intercropping on LER are presented in Table 2. The LER was higher for maize + black gram, closely followed by finger millet + black gram. The inclusion of black gram as an intercrop in maize or finger millet resulted in on an average 35 per cent yield advantage. According to Vandermeer (1989), intercrops that result in LER values greater than unity are considered to over yield, gaining their advantage through the 'competitive production principle' and/or the 'facilitative production principle'. The higher LER in intercropping than sole cropping could be attributed to the better utilization of both natural and supplemented resources.

Aggressivity

Aggressivity (A) is a focal competitive function used to assess the competitive ability of a crop when grown along with another crop. Aggressivity values with positive (+) sign denotes the dominant species and negative (-) sign denotes the dominated species. When the numerical values are greater, it indicates greater difference in the competitive abilities of the component crops. The data presented in Table 2 showed that the competitive ability of the component crops varied widely. Maize was more competitive than finger millet against pulses, as indicated by the positive (+) sign. The C_4 nature of maize might have contributed to its competitive behavior (Kheroar and Patra, 2014).

Table 2: Effect of intercropping on land equivalent ratio (LER), aggressivity (A) and percentage yield difference (PYD).

Treatment (as intercrop in coconut garden)	LER	Aggressivity		PYD
		A_{mp}/A_{fp}	A_{pm}/A_{pf}	
Maize + black gram	1.36	+0.16	-0.16	33.56
Maize + green gram	1.13	+0.22	-0.22	23.95
Finger millet + black gram	1.34	-0.33	+0.33	36.36
Finger millet + green gram	1.27	-0.24	+0.24	27.26

A_{mp}- Aggressivity of maize in combination with pulses.

A_{fp}- Aggressivity of finger millet in combination with pulses.

A_{pm}- Aggressivity of pulses in combination with maize.

A_{pf}- Aggressivity of pulses in combination with finger millet.

The competitive ability of maize and black gram was observed to be closer as indicated by lower values than maize + green gram. Maize tended to be more competitive than green gram. On the contrary, pulses exhibited more competitiveness with finger millet. Black gram showed greater competition with finger millet than green gram.

Percentage yield difference

Percentage yield difference (PYD) is an index of the yield compensation capacity of the component crops in an intercropping system. Irrespective of the proportion of crops, planting time and planting geometry, the reduction in yield of one crop gets compensated with increase in yield of the other. The PYD was the highest (36.36%) for finger millet + black gram, followed by maize + black gram (33.56%) (Table 2). This pointed towards the fact that the yield reduction of maize and finger millet under intercropping was compensated by increase in yield of black gram in a better manner than green gram. The superiority of black gram as intercrop with maize and finger millet has been reported previously by Kheroar and Patra (2014) and Kumar and Ray (2020), respectively.

Table 3: Effect of intercropping on coconut equivalent yield, kg ha^{-1}.

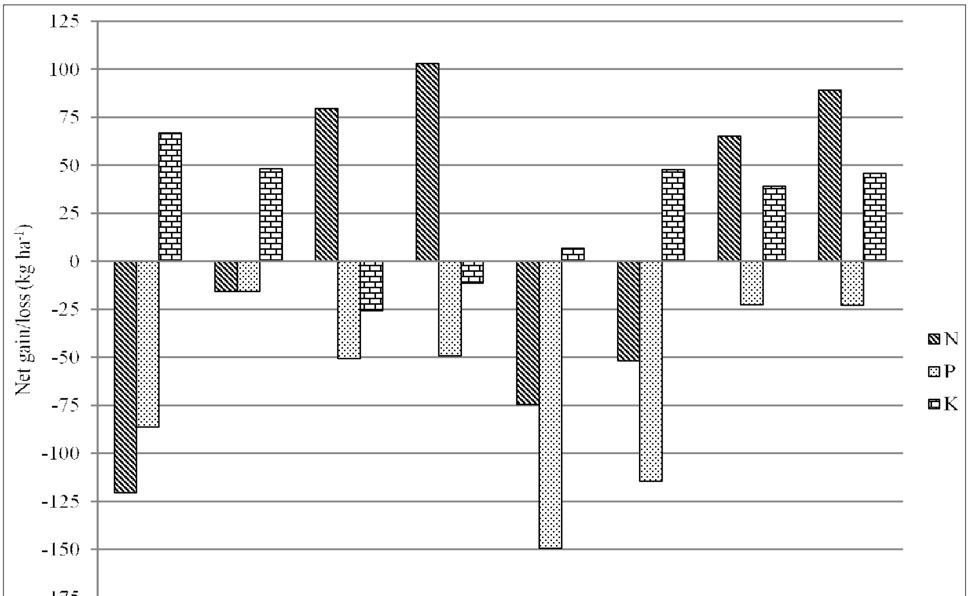
Treatment (as intercrop in coconut garden)	Coconut equivalent yield
T_1 - Maize	4609
T_2 - Finger millet	4261
T_3 - Black gram	4787
T_4 - Green gram	4287
T_5 - Maize + black gram	5500
T_6 - Maize + green gram	4780
T_7 - Finger millet + black gram	5290
T_8 - Finger millet + green gram	4822
SE m (±)	52
CD (0.05)	159.4

Coconut equivalent yield

Crop equivalent yield has been identified as one among the efficient indices capable of assessing the overall production potential of intercropping systems. Coconut equivalent yield (CEY) was higher for intercropping than sole cropping. Among the coconut based intercropping systems, CEY was significantly the highest (5500 kg ha^{-1}) for intercropping coconut with maize + black gram, followed by finger millet + black gram (5289 kg ha^{-1}) (Table 3). With respect to intercropping with green gram, the coconut equivalent yield was higher (4823 kg ha^{-1}) when green gram was intercropped with finger millet, than with maize (4780 kg ha^{-1}). When the sole crops were compared, it was observed that the production potential of coconut garden (2250 kg ha^{-1}) could be increased significantly when black gram was intercropped in coconut garden as indicated by significantly higher CEY (4787 kg ha^{-1}), followed by maize (4609 kg ha^{-1}).

Nitrogen balance sheet

The balance sheet of available nitrogen (N) was observed to be negative following the sole crops of maize and finger millet and maize + pulses (Fig 1). The depletion of N was



	T1 (C+M)	T2 (C+FM)	T3 (C + BG)	T4 (C+GG)	T5 (C+M+BG	T6 (C+M+GG)	T7 (C+FM+BG)	T8 (C+FM+GG)
N	-120.38	-15.74	79.5	103	-74.56	-51.73	65.27	88.98
P	-86.29	-15.61	-50.68	-49.26	-149.34	-114.43	-22.7	-22.94
K	66.79	48.09	-25.78	-11.46	6.9	47.72	39.1	45.79

Fig 1: Balance sheet of available N, P and K as influenced by intercropping, kg ha^{-1}.
C- Coconut; M- Maize; FM- Finger millet; BG- Black gram; GG- Green gram.

observed to be more for maize. The depletion in N following maize could be attributed to the higher uptake of N due to its exhaustive nature. However, when maize was intercropped with pulses, there was a lessening in the depletion of N as indicated by lesser negative values. Several studies have shown that maize is a crop that places major demand for resources at different times of system duration. When legumes or pulses are intercropped with maize, the longer duration maize could recover its resource needs after the harvest of the pulses. A positive balance was observed for available N after the sole crops of black gram and green gram. Finger millet + pulses also resulted in positive balance for available N in soil. Legumes derive 5 per cent to 83 per cent of their N requirement by fixing atmospheric nitrogen under field conditions and remaining from the soil N pool (Dudeja and Duhan, 2005). Thus the demand placed by legumes on soil N is less compared to the non-nitrogen fixing crops like maize and finger millet. This together with the legume effect might have resulted in the positive balance for available N in the soil. Between the two pulses, green gram left the soil more enriched in terms of N, both under sole crop and as intercrop.

Phosphorus balance sheet

The data on the balance sheet of available phosphorus (P) are presented in Fig 1. Balance sheet of available (P) was observed to be negative in all the treatments, including sole crops and intercrops. The magnitude of depletion was higher for sole crop of maize and in intercropping systems involving maize. Studies have shown rhizosphere acidification and increase of DTPA - extractable Fe and concomitant decrease in rhizosphere phosphorus in maize. Further, the soil of the experimental site was acidic in reaction. The negative balance of P observed might be due to P fixation under acidic pH. Similar cases P fixation as iron and aluminium phosphate was reported by Huck *et al*. (2014).

Potassium balance sheet

The balance sheet of available potassium (K) was observed to be positive in all the treatments, except black gram and green gram raised as sole crops in coconut garden (Fig 1). The initial status of available K was rated as low. Potassium may be lost from soil through leaching. Both these factors might have contributed to a negative balance for available K after pulses. In the case of maize and finger millet and the respective intercropping systems with pulses, the computed balance was lower than the actual balance, leading to net gain. Maize and finger millet, being members of the Poaceae family require larger quantity of K for their growth and development. Thus their higher values of K uptake led to lower computed balance for potassium than its actual balance.

On the whole, the nutrient balance sheet revealed the importance of soil test based nutrient management in coconut garden. Though maize proved to be an exhaustive crop as hypothesized, intercropping maize with pulses was observed to compensate for the exhaustive behavior of maize. Pulses were observed to improve the fertility status of the soil.

CONCLUSION

The present study showed that maize (cereal) and finger millet (millet) were suitable as intercrops in coconut garden. Further, out of the two pulse crops tested, black gram showed better adaptability and productivity as intercrop with maize and finger millet in coconut garden. Compared to green gram, black gram yielded 38.7 per cent and 9.62 per cent more when intercropped with maize and finger millet, respectively. The system productivity assessed in terms of coconut equivalent yield was observed to be the highest for intercropping coconut with maize + black gram, followed by finger millet + black gram. Intercropping coconut with maize + black gram was 144 per cent more productive in terms of CEY as compared to sole crop of coconut. Maize proved to be an exhaustive crop based on the amount of nutrients absorbed by the crop from the soil. However, intercropping maize + black gram in coconut garden was observed to reduce the soil depleting effect of maize. On the whole, the nutrient balance sheet studies revealed the importance of soil test based nutrient management for intercropping in coconut garden.

Conflict of interest: None.

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