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Growth and Yield of Pulses as Influenced by Intercropping with Finger Millet [*Eleusine coracana* (L.) Gaertn.] in the Southern Laterites of Kerala

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ABSTRACT

Background: In the recent years, the yield plateau of the major cereals together with the climate change concerns, the potential of millets and pulses have been identified as pivotal for addressing the agrarian and nutritional challenges. The present study was conducted to assess the feasibility of intercropping green gram, black gram and cowpea in finger millet.

Methods: A field experiment was conducted during summer 2019-2020 (February to May, 2020) to assess the variation in the growth and yield of pulses, *viz*., green gram, black gram and cowpea on intercropping with finger millet, along with and without AMF inoculation.

Result: Pulses were observed to be significantly taller when intercropped with finger millet in the presence of AMF. Leaf area index (LAI), dry matter production, seed yield and haulm yield were higher for sole crops. Between the intercropping treatments, with and without AMF, LAI, dry matter production and seed yield were superior when pulses where intercropped in finger millet inoculated with AMF. Intercropping finger millet with cowpea recorded the highest finger millet equivalent yield (FMEY) followed by black gram and green gram. The treatment, T_6 (finger millet with AMF + cowpea) registered the highest FMEY (3388 kg ha^{-1}) followed by T_5 (3234 kg ha^{-1}). Intercropping finger millet (with AMF) with black gram (T_4) and green gram (T_2) recorded FMEY of 2708 kg ha^{-1} and 2497 kg ha^{-1} respectively.

Key words: AMF, Black gram, Cowpea, Finger millet equivalent yield, Green gram.

INTRODUCTION

Pulses are considered as principal sources of dietary protein, especially for the vegetarians. They also help in the maintenance of soil fertility by virtue of their ability to fix atmospheric nitrogen. Pulses have been reported to fix 72 to 350 kg N ha^{-1} year^{-1} (Tiwari and Shivhare, 2016). Thus pulses play a pivotal role in sustainable agriculture. India is the largest producer (25% of world's production) and consumes 27 per cent of total pulses produced. However, the share of pulses to total food grain production is only 6 to 7 per cent. The per capita availability of pulses is 42 g per day as against the recommended dietary allowance of 60 g per day and 55 g per day for adult man and woman respectively (Tiwari and Shivhare, 2016). The morphology and physiology of pulses are such that they can be raised under rainfed conditions with minimal irrigation and can fit into intercropping, mixed cropping and crop rotation systems. Utilisation of fallow lands have been identified as a viable option to increase the production of pulses, especially when lands are left fallow during summer season due to shortage of water for irrigation. Millets are yet another group of crops which thrive well under water shortage. Among millets, finger millet [*Eleusine coracana* (L.) Gaertn.] is noted for its ability to survive with 28 per cent of paddy's water requirement (Rurinda *et al*., 2014).

Crop diversification through intercropping not only increases the cropping intensity, but is also a form of biological insurance against risks and abnormal rainfall in rainfed areas. In Kerala, the low per capita land availability (approximately 26 cents) clubbed together with the risk involved in raising sole crops, has made farmers to venture into intercropping. Intercropping helps in optimising resource utilization, both in spatial and temporal dimensions. Kumar and Ray (2020) observed the highest productivity in sole crop of finger millet. Among the intercropping treatments, yield of finger millet was the maximum for finger millet + black gram. Grain however, the compatibility and complimentarity of crops need to be assessed for successful intercropping. Further, to enhance crop productivity and soil

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fertility in a sustainable manner, biofertilization may be combined with intercropping (Wezel *et al*., 2014). Linking cereal - legume intercropping through common mycorrhizal network improves the productivity of crops (Hauggaard-Nielsen and Jensen, 2005). Specific interactions between root and microbes have also been reported to affect nutrient mobilization and result in efficient acquisition of nutrients (Li *et al*., 2014). The present study was undertaken to assess the growth and yield of pulses, *viz*., green gram (*Vigna radiata*), black gram (*Vigna mungo*) and cowpea (*Vigna unguiculata*) raised as intercrops in finger millet.

MATERIALS AND METHODS

The experiment was conducted in the rice fallows of Integrated Farming System Research Station, Karamana, Thiruvananthapuram, Kerala, during summer 2019-20 (February to May 2020). The experimental field was geographically located at 8°28'25" N latitude and 76°57'32" E longitude, at an altitude of 5 m above mean sea level. The soil of the experimental site was sandy clay loam in texture, strongly acidic in reaction (pH 5.03), high in organic carbon (1.58%), low in available nitrogen (248.74 kg ha^{-1}) and medium in available phosphorus (22.42 kg ha^{-1}) and potassium (142.82 kg ha^{-1}) status. The experiment was laid out in randomized block design with nine treatments and seven replications. The treatments were finger millet without AMF inoculation + green gram (T_1), finger millet with AMF inoculation + green gram (T_2), finger millet without AMF inoculation + black gram (T_3), finger millet with AMF inoculation + black gram (T_4), finger millet without AMF inoculation + cowpea (T_5), finger millet with AMF inoculation + cowpea (T_6), sole crop of green gram (T_7), sole crop of black gram (T_8), sole crop of cowpea (T_9). The varieties used for the study were PPR 2700 (finger millet), CO 8 (green gram), DU 1 (black gram) and Kanakamony (cowpea). Finger millet and pulses were intercropped in the ratio 4:1, following the results of Nigade *et al*. (2012).

Seeds of finger millet were soaked overnight in water and sown on the next day at 5 kg ha^{-1} (sole crop) and 3 kg ha^{-1} (intercrop). Solid row planting was adopted with a row to row spacing of 25 cm. Thinning was done at 15 days after sowing (DAS) so as maintain a plant to plant spacing of 15 cm within a row. Seeds of pulses were dibbled at a spacing of 25 cm x 15 cm. Green gram and black gram were sown at the rate of 20 kg ha^{-1} for sole crop and 6 kg ha^{-1} for intercrop. Cowpea was sown at the rate of 50 kg ha^{-1} for sole crop and 14 kg ha^{-1} for intercrop. Arbuscular mycorrhizal fungi (AMF) were applied to finger millet at the time of sowing at the rate of 10 kg ha^{-1} (NIPHM, 2015). Both finger millet and pulses were supplied with manures and fertilizers as per the package of practices recommendations of Kerala Agricultural University (KAU, 2016).

Biometric observations on plant height (cm), primary branches plant^{-1} (nos), leaf area index (LAI) (Puttasamy *et al*., 1976; Olal, 2015) were recorded from six sample plants, at 30 and 60 DAS and at harvest and total dry matter production (kg ha^{-1}) was recorded at harvest. Yield and yield attributes were recorded at harvest. The overall production potential of intercropping pulses in finger millet was assessed in terms of finger millet equivalent yield (FMEY). Finger millet equivalent yield (kg ha^{-1}) was computed based on the seed yield (kg ha^{-1}) of the intercropped pulses and prevailing market price (Rs. kg^{-1}) of finger millet and pulses, based on the crop equivalent yield concept suggested by Lal and Ray (1976) and Verma and Modgal (1983). Being a computed parameter, FMEY was not analysed statistically.

RESULTS AND DISCUSSION

Growth and Growth Attributes

Green gram plants were observed to be significantly taller under sole cropping (T_7) at 60 DAS (34.31 cm) and at harvest (43 cm) (Table 1). At harvest, plant height recorded by T_2 (finger millet with AMF + green gram) was comparable with that of the sole crop of green gram. Plant height was significantly more (31.12 cm) for sole crop of black gram (T_8) at 60 DAS. Between the two intercropping treatments, black gram was observed to be taller in T_4 (finger millet with AMF + black gram). Cowpea was observed to register significantly taller plants at 60 DAS (38.62 cm) when intercropped with finger millet (with AMF) (T_6). It was at par with sole crop of cowpea (T_9).

The number of primary branches per plant did not exhibit any significant variation between intercropping treatments and between intercrop and sole crop of green gram, at 30 and 60 DAS and at harvest (Table 1). Black gram was observed to elicit significant response to intercropping at 60 DAS and at harvest. Primary branches were noted to be considerably more in sole crop of black gram (T_8) at 60 DAS (5.40 per plant) and at harvest (7.38 per plant). However, it was comparable with the count of primary branches per plant recorded in T_4, wherein black gram was intercropped with finger millet (with AMF). Cowpea failed to exhibit response to intercropping in terms of number of primary branches per plant at 30 and 60 DAS and at harvest.

Sole crop of green gram (T_7) recorded significantly higher leaf area index (LAI) at 30 DAS (0.74) and at harvest (2.14) (Table 1). Between the two intercropping treatments, LAI of green intercropped in finger millet (with AMF) (T_2) was observed to be higher than T_1. Black gram raised as sole crop (T_8) was observed to be substantially greater at 60 DAS (2.55) and at harvest (1.38). At 60 DAS, LAI was observed to be higher in T_4 (finger millet with AMF + black gram) than T_3. As in the case of black gram, LAI was significantly higher for sole cropped cowpea (T_9), at 60 DAS (2.81) and at harvest (1.47). Further, LAI recorded at 60 DAS was superior for T_6 (cowpea intercropped in finger millet with AMF) than T_5 (cowpea intercropped in finger millet with AMF).

Dry matter production of green gram (Table 2) was significantly higher (3484 kg ha^{-1}) for the sole crop (T_9) compared to intercropping. Dry matter production was recorded in T_1 (finger millet without AMF + green gram) remained at par with T_2. Sole crop of black gram (T_{10}) recorded significantly higher dry matter production at harvest (3300 kg ha^{-1}). Further, the dry matter production of black gram intercropped with finger millet, both with and without AMF (T_1 and T_2) was at par. Dry matter production recorded by T_9 (sole crop of cowpea) was observed to be significantly higher (3202 kg ha^{-1}). Between the two intercropping treatments, T_6 (finger millet with AMF + cowpea) registered higher dry matter production (2674 kg ha^{-1}) than T_5 (2586 kg ha^{-1}).

Geren *et al*. (2008) and Refay *et al*. (2013) have reported that LAI, crop growth rate and net assimilation rate of component crops decreased in intercropping compared to sole cropping. Finger millet, being taller might have also had a shading effect on the intercropped pulses, resulting in reduction in the growth of pulses under intercropped condition. The better performance of sole cropped pulses could also be attributed to the belowground interactions reported in millet - legume intercropping systems. In general, cereals and millets possess greater rooting densities (Anil *et al*., 1998). Thus, when pulses were intercropped with finger millet, a competition might have emerged affecting the growth of pulses under intercropped condition. However, the presence of mycorrhiza has been observed to assist the intercropped legumes to subvert this competition and

Table 1: Effect of intercropping on plant height, number of primary branches per plant and leaf area index of pulses.

Treatment	Plant height (cm)			Primary branches per plant (nos)			Leaf area index		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1: Finger millet (without AMF) + green gram	15.21	32.90	40.57	3.82	4.87	6.91	0.53	2.62	1.84
T_2: Finger millet (with AMF) + green gram	15.65	32.99	41.51	3.75	4.64	6.78	0.62	2.73	1.94
T_3: Finger millet (without AMF) + black gram	15.53	28.23	36.27	3.51	4.84	6.38	0.62	1.99	1.05
T_4: Finger millet (with AMF) + black gram	15.88	29.03	36.43	3.80	5.14	6.87	0.64	2.14	1.04
T_5: Finger millet (without AMF) + cowpea	20.15	36.95	61.93	4.04	8.20	11.71	0.84	1.92	1.11
T_6: Finger millet (with AMF) + cowpea	19.60	38.62	61.77	3.92	8.61	12.33	0.82	2.45	1.10
T_7: Green gram as sole crop	15.82	34.31	43.00	3.61	4.69	7.19	0.74	2.96	2.14
T_8: Black gram as sole crop	16.19	31.12	37.68	4.00	5.40	7.38	0.69	2.55	1.38
T_9: Cowpea as sole crop	20.32	37.96	61.38	4.05	8.84	12.38	0.84	2.81	1.47
SE m (±)*	0.23	0.32	0.50	0.15	0.13	0.28	0.03	0.10	0.04
SE m (±)**	0.30	0.60	0.44	0.14	0.12	0.17	0.02	0.12	0.05
SE m (±)***	0.44	0.30	0.78	0.17	0.27	0.26	0.04	0.11	0.10
CD (0.05)*	NS	1.010	1.608	NS	NS	NS	0.106	NS	0.133
CD (0.05)**	NS	1.904	NS	NS	0.407	0.556	NS	0.388	0.170
CD (0.05)***	NS	0.955	NS	NS	NS	NS	NS	0.347	0.316

* Green gram ** Black gram *** Cowpea NS – Not significant

Table 2: Effect of intercropping of dry matter production of pulses and finger millet equivalent yield.

Treatment	Dry matter production (kg ha^{-1})	Finger millet equivalent yield (kg ha^{-1})
T_1: Finger millet (without AMF) + green gram	1957	2315
T_2 : Finger millet (with AMF) + green gram	1850	2497
T_3: Finger millet (without AMF) + black gram	1350	2365
T_4: Finger millet (with AMF) + black gram	1353	2708
T_5: Finger millet (without AMF) + cowpea	2586	3234
T_6: Finger millet (with AMF) + cowpea	2674	3388
T_7: Green gram as sole crop	3484	1568
T_8: Black gram as sole crop	3300	1764
T_9: Cowpea as sole crop	3202	2349
SE m (±)*	43	-
SE m (±)**	49	-
SE m (±)***	68	-
CD (0.05)*	137.9	-
CD (0.05)**	156.5	-
CD (0.05)***	217.0	-

* Green gram ** Black gram *** Cowpea

Table 3: Effect of intercropping on yield attributes, yield and harvest index of pulses.

Treatment	Pods per plant (nos)	Seeds per pod (nos)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
T_3: Finger millet (without AMF) + green gram	30.93	10.10	454	1712	0.21
T_4: Finger millet (with AMF) + green gram	31.57	11.27	460	1503	0.23
T_5: Finger millet (without AMF) + black gram	29.20	8.07	457	994	0.32
T_6: Finger millet (with AMF) + black gram	27.20	8.78	510	978	0.34
T_7: Finger millet (without AMF) + cowpea	23.93	10.07	1008	1852	0.35
T_8: Finger millet (with AMF) + cowpea	24.90	11.80	1001	1866	0.35
T_9: Green gram as sole crop	36.88	13.44	784	2299	0.26
T_{10}: Black gram as sole crop	31.23	9.53	891	1498	0.36
T_{11}: Cowpea as sole crop	23.80	10.93	1342	2135	0.39
SE m (±)*	0.97	0.05	8	36	0.01
SE m (±)**	0.56	0.39	6	27	0.01
SE m (±)***	0.68	0.74	22	49	0.01
CD (0.05)*	3.105	0.151	24.0	115.3	0.007
CD (0.05)**	1.791	NS	18.1	87.3	0.014
CD (0.05)***	NS	0.526	71.0	155.5	0.011

* Green gram   ** Black gram   *** Cowpea

result in better growth and development as suggested by Bethlenfalvay (1992).

Yield Attributes and Yield

The number of pods per plant was significantly higher in sole crop of green gram and black gram (Table 3). It was observed that the percentage variation in the number of pods between sole crop and intercrop was 19.23 per cent (without AMF) and 14.40 percent (without AMF) for green gram intercropped in finger millet. While the number of seeds per pods was higher for sole crop in green gram, it was noted to be higher in cowpea when intercropped with finger millet (with AMF). Hundred seed weight remained unaffected by the treatments. Seed yield and harvest index of green gram, black gram and cowpea was significantly more in the sole crop. Between the two intercropping systems (*i.e*., along with finger millet with and without AMF), black gram recorded superior seed yield (10.39% higher) when intercropped in finger millet (with AMF). In the case of green gram and cowpea, seed yield in the two intercropping systems were comparable. Haulm yield of all the three pulses were higher for the sole crop. Inoculating finger millet with AMF did not elicit a specific response in haulm yield of pulses.

The results of higher yields of sole crops compared to intercropping were in agreement with those of Ndakidemi and Dakora (2007). The yield advantage of sole crops could be due to higher plant density and also due to absence of competition with the main crop of finger millet. Sole crop of pulses had higher LAI and dry matter production. Tajul *et al*. (2013) observed that yield and dry matter production is a function of the photosynthetic surface, which increases with population density. Similar results were reported by Lucus and Remison (1984). Makoi *et al*. (2009) have opined that the shading effects of the main crop could lead to a reduction in the photosynthetic efficiency of the intercropped pulses, resulting in low productivity. The higher harvest index recorded by green gram and black gram intercropped with finger millet inoculated with AMF might be due to enhanced photosynthesis and better translocation of accumulates towards the sink. The capacity of AMF to regulate the production of osmoregulatory substances and maintain photosynthesis and translocation of photosynthates has been reported by Bearden and Petersen (2000) and Asghari *et al*. (2005).

Finger Millet Equivalent Yield

Among the three pulses tested, intercropping finger millet with cowpea recorded the highest finger millet equivalent yield (FMEY) followed by black gram and green gram (Table 2). The treatment, T_6 (finger millet with AMF + cowpea) registered the highest FMEY (3388 kg ha^{-1}) followed by T_5 (3234 kg ha^{-1}). Intercropping finger millet (with AMF) with black gram (T_4) and green gram (T_2) recorded FMEY of 2708 kg ha^{-1} and 2497 kg ha^{-1} respectively. It was observed that irrespective of the pulse intercropped, application of AMF to finger millet enhanced the FMEY of the respective intercropping system.

Crop equivalent yield has been identified as one among the efficient indices capable of assessing the overall production potential of intercropping systems. Irrespective of the pulse intercropped, AMF inoculation in finger millet enhanced the FMEY of the intercropping systems. In spite of higher market price of green gram and black gram, the higher FMEY recorded with cowpea might be due to higher yield realized in the finger millet + cowpea intercropping system, through better utilization of the available resources. Higher FMEY in intercropping revealed the fact that the overall productivity was higher for intercropping than sole cropping of finger millet.

CONCLUSION

Increasing pulse production assumes paramount importance considering the need to bridge the gap between production and demand. Intercropping pulses in the existing cropping systems is a viable option in the light shrinking arable land in states like Kerala. Green gram, black gram and cowpea have been recommended for the summer season. Among these three pulses, cowpea was observed to perform better in terms of growth and yield when intercropped with finger millet in the summer rice fallows. The overall productivity of intercropping assessed in terms of crop equivalent yield was also observed to be superior with intercropping cowpea in finger millet inoculated with AMF. It could be concluded that intercropping cowpea in finger millet (inoculated with AMF @ 10 kg ha^{-1}) in the ratio 4 :1, was a feasible option for increasing the overall productivity of the system in the southern laterites of Kerala.

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