Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(3): 4051-4056
Received: 28-03-2019
Accepted: 30-04-2019

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Evaluation of maize based intercropping systems in Thamirabarani basin of Tamil Nadu

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Abstract
An experiment was conducted at Agricultural College and Research Institute, Killikulam, Tuticorin, Tamil Nadu, during the rabi season of 2018-19 to evolve the most profitable maize based intercropping systems in additive series with 1:1 and 2:2 row proportion. Maize with five intercrops viz., black gram (*Vigna mungo* L.), green gram (*Vigna radiata* L.), vegetable cowpea (*Vigna unguiculata* L.), sesame (*Sesamum indicum* L.) and groundnut (*Arachis hypogaea* L.) were tested in both row ratios. The results indicated during at intercropping enhanced the returns to farmers compared to sole crop. The highest maize grain yield (6830 kg ha^{-1}) and maize equivalent yield (9688 kg ha^{-1}) were recorded in maize + vegetable cowpea (2:2) intercropping system during rabi 2018-19. It was followed by maize + black gram (2:2). The values of all the competition functions were higher in maize + vegetable cowpea in 2:2 row ratio. This intercropping system recorded higher LER, LEC, IA, ATER and SPI of 1.53, 0.52, +13.86, 1.23 and 10.25 respectively. The highest gross return (₹.1,35,330), net return (₹.94,842) and B:C (3.34) ratio were recorded in maize + vegetable cowpea (2:2) intercropping system adopted in Thamirabarani basin of Tamil Nadu.

Keywords: Intercropping, maize (*Zea mays* L.), benefit-cost ratio

1. Introduction
Maize (*Zea mays* L.) is the third most important food grain crop in India next to rice and wheat. It is the main source of cereal for food, forage and processed industrial products and it has the highest yield potential among the cereals hence it is called "Queen of Cereals". Maize is an efficient converter of absorbed nutrient into food because it is a C_4 plant. Intercropping of maize with legumes is one of the ways to improve and stabilize the productivity of maize. Practice of cultivating two or more crops at the same time, in same land is called intercropping. Intercropping in maize with short duration legumes or oilseeds offers the potential to obtain high productivity and profitability at low water use without reducing its own yield (Sharma *et al.*, 2013) [18]. Intercropping provides insurance against crop failure or unstable market prices for a given commodity. Inclusion of legumes as intercrop, not only provides nitrogen to the base crop but also increases the amount of humus in the soil due to decaying crop remains (Shyamal Kheroar *et al.*, 2013) [20].
Black gram *(Vigna mungo* L.) is one of the most important pulse crops in India because of its adaptation to short growth duration. It has ability to fix atmospheric nitrogen through symbiotic nitrogen fixation. This characteristic of black gram makes compatible intercrop with maize. Green gram (*Vigna radiata* L.) is a short duration pulse crop. It is grown as low fertile soil because it fixes atmospheric nitrogen in soil. Inclusion of green gram as an intercrop in maize improved the soil focalizations of N, mineral composition of soil culture and soil fertility (Mehdi Dahmardeh *et al.*, 2013) [1]. Cowpea (*Vigna unguiculata* L.) is one of the important food legumes and a valuable component of traditional cropping systems in semi-arid tropics. Cowpea used as tender pods as vegetables and dry bean as pulse. Shade tolerance is important characteristic of cowpea, it makes compatible intercrop with maize, sorghum as well as with several plantation crops (Singh *et al.*, 2003) [19].
Groundnut (*Arachis hypogaea* L.) is a pea and bean family. It creates micro climate where it is intercropped. Peanut plants can tolerate the shade produced by maize plants when grown as an intercrop. Maize + peanut intercropping would help to increase production through the efficient utilization of solar energy (M.A. Awal *et al.*, 2006) [2]. Sesame (*Sesamum indicum* L.) is one of the most important oil seed crops. To increase the production of maize and oil seed production, it is intercropped with maize. Maize, Black gram, Green gram, Vegetable Cowpea, Groundnut, Sesame are grown in sole as well as mixed stands because of their diverse morphology, growth rhythm and similar climatic requirements, yet the suitable combination of intercropping pattern and planting density needs to be optimized.

The objectives of the present study were to evaluate the various intercrops with maize and to identify the most profitable maize based intercropping system in Thamirabarani basin of Tamil Nadu.

2. Materials and Methods

2.1. Experimental site

The experiment was conducted at Agricultural College and Research Institute, Killikulam, Tuticorin, Tamil Nadu, during the rabi season of 2018-19. The experiment site was situated at southern agro-climatic zone of Tamil Nadu at 8°45'N latitude and 77°42'E longitude at an altitude of 40 m above mean sea level. The soil was sandy clay loam texture having the available N, P and K of 238 kg ha^{-1}, 19 kg ha^{-1} and 292 kg ha^{-1} respectively.

2.2. Experimental Design

The experiment was laid out in randomized block design with three replications. The experiment consisted of 11 treatments viz., T_1: maize + black gram (1:1), T_2: maize + green gram (1:1), T_3: maize + vegetable cowpea (1:1), T_4: maize + sesame (1:1), T_5: maize + groundnut (1:1), T_6: paired row maize intercropped with black gram at 30/90 cm spacing (2:2), T_7: paired row maize intercropped with green gram at 30/90 cm spacing (2:2), T_8: paired row maize intercropped with vegetable cowpea at 30/90 cm spacing (2:2), T_9: paired row maize intercropped with sesame at 30/90 cm spacing (2:2), T_{10}: paired row maize intercropped with groundnut at 30/90 cm spacing (2:2), T_{11}: sole maize. Sole crops of intercrops raised outside the experimental field for calculating intercropping indices.

2.3. Trial Management

The crops were sown during the first week of October 2018. The plot size of 5 m x 4.2 m was adopted. Maize - COH(M)8 (duration 90 days), Black gram – VBN 6 (duration 65 days), Green gram – VBN (Gg) 3 (duration 70 days), Vegetable cowpea – Pusa Komal (duration 60 days), Sesame – TMV 7 (duration 80 days), Groundnut – TMV Gn 13 (duration 90 days) were selected for testing. Recommended dose of fertilizers for hybrid maize is 250:75:75 kg NPK ha^{-1} for sole maize and intercropping situation.

2.4. Assessment of Intercropping Efficiency

Evaluation of the cropping systems was carried out by using the following indices.

1. Land equivalent ratio (LER) is the unit to measure the production efficiency of different intercropping systems by converting the production in terms of land acreage (Balasubramaniyan and Palaniappan, 2009).

$$LER = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb})$$

where, Y_{aa} and Y_{bb} : pure crop yield of maize and intercrops respectively, Y_{ab} and Y_{ba} : yield of main crop and intercrops in mixture.

2. Land equivalent coefficient (LEC) was developed for to assess the interaction and production potential of crop mixture (Adetiloye *et al.*, 1983)

$$LEC = (Y_{ab}/Y_{aa}) \times (Y_{ba}/Y_{bb})$$

where, Y_{aa} and Y_{bb} : pure crop yield of maize and intercrops respectively, Y_{ab} and Y_{ba} : yield of main crop and intercrops in mixture.

3. Intercropping advantage is an indicator of economic feasibility of the intercropping system used (Banik *et al.*, 2000).

$$IA_{maize} = AYL_{maize} \times P_{maize}$$

$$IA_{intercrops} = AYL_{intercrops} \times P_{intercrops}$$

where, P_{maize} and $P_{intercrops}$: commercial value of maize and intercrops.

4. Area time equivalent ratio provides more realistic comparison of the yield advantage of intercropping over monocropping in terms of time taken by component crops in the intercropping system (Heibsch, 1980).

$$ATER = [(RY_a \times t_a) + (RY_b \times t_b)]/T$$

where, RY: Relative yield of main crop or intercrop, RY_a: Intercrop yield of maize with associated crop / Pure stand yield of maize, RY_b: Intercrop yield of associated crop / Pure stand yield of associated crop, t: duration for main crop or intercrop, T: duration of intercropping system.

5. System productivity index was used to identify the intercrop have higher productivity and stability (Odo, 1991).

$$SPI = [(SA/LB) \times Lb] + Sa$$

where, SA and LB: yield of maize and intercrops in sole cropping, Sa and Lb: yield of maize & intercrops in intercropping.

6. Maize equivalent yield (MEY) was arrived by equating grain cost of intercrop to that of maize grain cost.

MEY= (Grain yield of intercrop/market price of maize) x market price of intercrop

2.5. Economic analysis

The prices of the inputs, seeds (maize-₹.150/kg, black gram-₹.100/kg, green gram- ₹.150/kg, vegetable cowpea-₹.500/kg, sesame-₹.130/kg, groundnut-₹.90/kg), fertilizers (urea-₹.5.96/kg, DAP-₹.10.86/kg, MOP-₹.11.55/kg), labours (women-₹.250/day, men-₹.300/day) that prevailed during experimentation were considered for working out of the cost of cultivation. Gross returns (₹./ha) was calculate on the basis of market price of the produce (maize grain- ₹.13/kg, black gram- ₹.50/kg, green gram-₹.50/kg , vegetable cowpea-₹.20/kg, sesame-₹.40/kg, groundnut ₹.25/kg) during harvest period. The net return (₹./ha) were computed by subtracting the cost of cultivation from gross returns. B:C ratio was worked out by dividing the gross returns (₹.ha^{-1}) with total cost of cultivation (₹.ha^{-1}).

The data were analyzed using AGRES software.

3. Results and Discussion

3.1. Effect of maize based intercropping system on yield parameters of maize

Paired row maize with vegetable cowpea in 2:2 row ratio (T_8) recorded higher yield parameters of maize viz., number of cobs $plant^{-1}$ (1.13), cob length (21.2 cm), cob girth (16.3 cm), number of rows cob^{-1} (15.8), number of grains row^{-1} (35.8) and test weight (42.3 g). Number of grains row^{-1}, number of rows cob^{-1} and cob length of maize was significantly influenced by various intercropping system (Table 1). Patra *et al.*, (1999) reported that number of grains cob^{-1} increased

during maize intercropped with legumes. Hamd Alla *et al.*, (2014) reported that yield parameters of maize will be higher in maize + cowpea intercropping system. Rajashekhar *et al.*, (2004) reported the number of grains per cob in paired row planting of sole and intercropped maize was higher compared to 60 cm x 30 cm spacing.

Table 1: Yield parameters of maize influenced by various intercropping system

Treatments	No. of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	No. of rows cob^{-1}	No. of grains row^{-1}	Test weight (g)
T_1 - Maize + Black gram (1:1)	1.07	18.7	15.0	14.6	33.7	40.8
T_2 - Maize + Green gram (1:1)	1.06	18.4	14.8	14.5	33.5	40.4
T_3 - Maize + Vegetable cowpea (1:1)	1.07	19.0	15.1	14.7	33.9	40.9
T_4 - Maize + Sesame (1:1)	1.05	17.3	14.4	14.2	32.7	39.9
T_5 - Maize + Groundnut (1:1)	1.06	18.1	14.7	14.4	33.2	40.2
T_6 - Maize + Black gram (2:2)	1.12	20.6	16.1	15.7	35.7	42.1
T_7 - Maize + Green gram (2:2)	1.08	19.8	15.4	15.0	34.6	41.6
T_8 - Maize + Vegetable cowpea (2:2)	1.13	21.2	16.3	15.8	35.8	42.3
T_9 - Maize + Sesame (2:2)	1.05	17.5	14.5	14.0	32.8	39.6
T_{10} -Maize + Groundnut (2:2)	1.08	19.2	15.2	14.7	34.4	41.2
T_{11} -Sole Maize	1.10	20.4	15.9	15.2	35.1	41.8
SEd	0.03	1.39	0.77	0.61	0.94	0.88
CD (P=0.05)	NS	2.89	NS	1.27	1.97	NS

*NS-Not significant

3.2. Effect of maize based intercropping system on grain yield, stover yield and harvest index of maize

The highest grain yield (6830 kg ha^{-1}), stover yield (9640 kg ha^{-1}) and HI (0.415) of maize was recorded in paired row maize intercropped with vegetable cowpea (T_8) in 2:2 row ratio. It was on par with T_6, T_{11} and T_7. Legumes have ability to fix atmospheric nitrogen to the soil so the grain yield of maize was increased by intercropped legumes. Paired row maize intercropped with legumes gave better yield compared to normal plant spacing of maize (Table 2). Similar result was found by Banik *et al.*, (2000). Maize yield was increased due to intercropped with vegetable cowpea compared to other intercrops. Muoneke *et al.*, (2012) reported maize intercropped with vegetable cowpea, the grain yield of maize was increased. Choudhary, (2014) reported highest stover yield of maize was obtained in maize intercropped with cowpea. Increase in grain yield of maize was also reported by Ndakidemi and Dakora, (2005) due to intercropping with cowpea.

3.3. Effect of maize based intercropping system on Maize Equivalent Yield

Among the various intercrops tested, higher intercrop yield (1845 kg ha^{-1}) was obtained in paired row maize intercropped with vegetable cowpea in 2:2 row proportion (T_8). Cowpea can tolerate shade produced from maize and it fix atmospheric nitrogen to the soil. Nutrient competition between maize and vegetable cowpea will be less compared to other intercrops so yield will be increased both the crops. Maize equivalent yield of all the intercropping treatments are higher than sole maize. Highest maize equivalent yield (9668 kg ha^{-1}) was obtained in maize + vegetable cowpea (2:2) in paired rows (Table 3). MEY was higher in paired row planting pattern compared to normal plant spacing. Similar results are reported by Rana *et al.*, 2006.

Table 2: Grain yield, Stover yield, Harvest Index of maize as influenced by different intercropping system

Treatments	Grain Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})	Harvest Index
T_1 - Maize + Black gram (1:1)	5280	7770	0.406
T_2 - Maize + Green gram (1:1)	5240	7740	0.402
T_3 - Maize + Vegetable cowpea (1:1)	5310	7860	0.402
T_4 - Maize + Sesame (1:1)	4750	7060	0.401
T_5 - Maize + Groundnut (1:1)	5060	7550	0.402
T_6 - Maize + Black gram (2:2)	6620	9350	0.414
T_7 - Maize + Green gram (2:2)	6010	9020	0.401
T_8 - Maize + Vegetable cowpea (2:2)	6830	9640	0.415
T_9 - Maize + Sesame (2:2)	4980	7300	0.402
T_{10} -Maize + Groundnut (2:2)	5380	8080	0.401
T_{11} -Sole Maize	6590	9320	0.415
SEd	599.25	642.45	NA
CD (P=0.05)	1250.02	1340.12	

*NA-Not Analyzed.

3.4. Land equivalent ratio, Land equivalent coefficient, Intercropping advantage, Area time equivalent ratio and System productivity index of various intercropping systems

All the intercropping systems showed land equivalent ratio greater than unity in 1:1 and 2:2 row proportions indicating higher land use efficiency of intercropping over the monoculture. Maize + vegetable cowpea (2:2) in paired rows recorded the highest LER of 1.53 (T_8). To produce same yield from sole crop, 1.53 ha area would be required. It recorded 53% more land use efficiency. It was followed by maize + black gram (2:2) in paired rows (1.49) (T_6) (Table 4). Maximum land equivalent ratio was obtained in 2:2 row ratio compared to 1:1. Similar results found by Liang *et al.*, 2017.

Paired row maize with vegetable cowpea in 2:2 row ratio (T_8) recorded higher land equivalent coefficient of 0.52. It was

followed by paired row maize with black gram in 2:2 row ratio (T_6) (0.49). LEC values greater than 0.25 indicated yield advantages of intercropping systems (Table 4). All the intercropping systems are yield advantages compared to sole crop.

The maximum intercropping advantage (+13.86) was recorded in maize + vegetable cowpea (2:2) (T_8) intercropping system. It was followed by maize + black gram (2:2) (T_6) (13.19), maize + green gram (2:2) (T_7) (10.69). The positive value of LEC indicates the intercropping system had the highest economic advantages whereas all the other treatments, which had negative values, showed an economic disadvantage. The positive values of LEC obtained in T8, T_6, T_7, T_{10}, T_3 and T_5 (Table 4).

Maize + vegetable cowpea (2:2) in paired rows (T_8) recorded the highest area time equivalent ratio of 1.23. It was followed by maize + black gram (2:2) in paired rows (T_6) (1.22) and maize + groundnut (2:2) in paired rows (T_{10}) (1.19) (Table 4). Higher per day yield obtained from these treatments.

System productivity index (10.25) was higher in paired row maize intercropped with vegetable cowpea in 2:2 row ratio (T_8). It was followed by maize + black gram (2:2) (T_6) (9.84) and maize + green gram (2:2) (T_7) (9.35). Maize + vegetable cowpea (2:2) (T_8) intercropping system showed greater yield stability than other mixtures (Table 4). Similar results found by Odo, 1991 in sorghum-cowpea (1:3) mixture.

Table 3: Effect of maize based intercropping system on maize equivalent yield

Treatments	Maize grain yield (kg ha^{-1})	Intercrop Yield (kg ha^{-1})	MEY (kg ha^{-1})
T_1 - Maize + Black gram (1:1)	5280	385	6761
T_2 - Maize + Green gram (1:1)	5240	352	6594
T_3 - Maize + Vegetable cowpea (1:1)	5310	1620	7802
T_4 - Maize + Sesame (1:1)	4750	256	5538
T_5 - Maize + Groundnut (1:1)	5060	1060	7098
T_6 - Maize + Black gram (2:2)	6620	450	8351
T_7 - Maize + Green gram (2:2)	6010	430	7664
T_8 - Maize + Vegetable cowpea (2:2)	6830	1845	9668
T_9 - Maize + Sesame (2:2)	4980	315	5949
T_{10} -Maize + Groundnut (2:2)	5380	1250	7784
T_{11} -Sole Maize	6590	-	6590
SEd	599.25	NA	596.38
CD (P=0.05)	1250.02		1244.04

*NA-Not Analyzed

3.5. Effect of maize based intercropping system on the economics of maize

Gross and net returns were increased due to intercropping of legumes as compared to sole crop. Maize + vegetable cowpea (2:2) (T_8) combination recorded higher gross returns and net returns (₹.1,35,330 and ₹.97,842). It was followed by maize + black gram (2:2) (T_6) (₹.1,17,910 and ₹.81,422)**.** Returns are increased when maize intercropped with legumes. Intercropping was always beneficial and recorded higher B:C with respect to monoculture of maize. Among the intercropping system maize + vegetable cowpea (2:2) recorded the highest B:C ratio of 3.34. It was followed by maize + black gram (2:2) (3.23) (Table 5). Similarly, higher net returns and B:C ratio was obtained by Marer *et al.,* 2007 in maize based intercropping systems.

Table 4: Competition functions of various intercropping systems

Treatments	LER	LEC	IA			ATER	SPI
			Maize	IC	Total		
T_1 - Maize + Black gram (1:1)	1.21	0.33	7.82	-8.60	-0.78	0.99	8.01
T_2 - Maize + Green gram (1:1)	1.21	0.32	7.73	-8.59	-0.86	1.01	8.45
T_3 - Maize + Vegetable cowpea (1:1)	1.25	0.36	8.03	-3.11	4.92	0.99	8.19
T_4 - Maize + Sesame (1:1)	1.06	0.25	5.71	-13.05	-7.35	0.92	6.98
T_5 - Maize + Groundnut (1:1)	1.20	0.33	6.98	-3.63	3.35	1.08	7.88
T_6 - Maize + Black gram (2:2)	1.49	0.49	13.19	-1.61	11.57	1.22	9.84
T_7 - Maize + Green gram (2:2)	1.42	0.46	10.69	0.59	11.28	1.17	9.35
T_8 - Maize + Vegetable cowpea (2:2)	1.53	0.52	13.92	-0.07	13.86	1.23	10.25
T_9 - Maize + Sesame (2:2)	1.17	0.31	6.58	-6.84	-0.26	1.01	7.70
T_{10} -Maize + Groundnut (2:2)	1.32	0.41	8.22	0.20	8.42	1.19	8.70
T_{11} -Sole Maize	1.00	-	-	-	-	-	-
SEd	0.09	0.05	2.37	4.00	4.22	0.08	NA
CD (P=0.05)	0.20	0.10	4.95	8.34	8.81	0.17	

*NA-Not Analyzed

Table 5: Cost of cultivation, gross returns, net returns and B:C ratio as influenced by different intercropping systems

Treatments	Cost of cultivation (₹ . ha^{-1})	Gross returns (₹ . ha^{-1})	Net returns (₹ . ha^{-1})	B:C ratio
T_1 - Maize + Black gram (1:1)	36488	96010	59522	2.63
T_2 - Maize + Green gram (1:1)	36988	93460	56472	2.53
T_3 - Maize + Vegetable cowpea (1:1)	40488	110120	69632	2.72
T_4 - Maize + Sesame (1:1)	35813	79050	43237	2.21
T_5 - Maize + Groundnut (1:1)	41788	99980	58192	2.39
T_6 - Maize + Black gram (2:2)	36488	117910	81422	3.23
T_7 - Maize + Green gram (2:2)	36988	108780	71792	2.94
T_8 - Maize + Vegetable cowpea (2:2)	40488	135330	94842	3.34
T_9 - Maize + Sesame (2:2)	35813	84640	48827	2.36
T_{10} -Maize + Groundnut (2:2)	41788	110320	68532	2.64
T_{11} -Sole Maize	35488	94990	59502	2.68

4. Conclusion

This study concludes that paired row maize intercropped with vegetable cowpea (2:2) and paired row maize intercropped with black gram (2:2), these two intercropping system was beneficial compared to other intercropping systems. Paired row planting gave more yield compared to normal plant spacing. Cowpea acts as cover crop thereby reduced weed growth in intercropping system ultimately resulting in increasing the yield of maize. Intercropping is the ecofriendly method to control weed problems. Land equivalent ratio of all the intercropping systems with maize as the base crop was greater than 1 indicating that all the intercropping systems tested were beneficial than sole cropping. Intercropping is the one of the ways to increase returns of the farmers. According to various intercropping indices like LER, LEC, IA, ATER and SPI, maize + vegetable cowpea (2:2) and maize + black gram (2:2) intercropping system was advantageous and more remunerative intercropping system. Hence, based on the study, it is concluded that maize intercropped with vegetable cowpea (2:2) would be the most profitable intercropping system for the Thamirabarani basin of Tamil Nadu.

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