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Effect of maize intercropping on light interception and productivity of the system

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Abstract
A field experiment was carried out at Zonal Agricultural Research Station, GKVK, Bengaluru, Karnataka during *kharif* season of 2014 and 2016 to study the effect of crop geometry in maize based intercropping system. The experiment was laid out in Randomized Complete Block Design with three replications. There were ten treatments consisting of sole maize (60 cm x 30 cm); sole maize (paired row system-30/90 cm); maize (60 cm x 30 cm) + guar; maize (60 cm x 30 cm) + frenchbean; maize (paired row system-30/90 cm) + guar; maize (paired row system-30/90 cm) + frenchbean; maize (paired row system-30/90 cm) + frenchbean + second intercrop-horsegram along with sole crops of guar, frenchbean and horsegram. The results revealed that significantly higher kernel yield of maize (5484 kg ha^{-1}) was obtained in maize (paired row system-30/90 cm) + frenchbean than maize (60 x 30 cm) + guar / frenchbean additive intercropping and it was on par with the sole maize with 30/90 cm paired row system. Significantly higher light absorption ratio (68.98) was observed in frenchbean and lower light absorption ratio (65.20) was received with paired row planting (30/90 cm) of maize + guar intercropping system. LER, maize equivalent yield, net returns and B:C ratio were also higher in maize (paired row system-30/90 cm) + frenchbean additive intercroppong (1.43, 13419 kg ha^{-1}, ₹ 142048 ha^{-1} and 3.61, respectively) than in maize (60 x 30 cm) + guar/frenchbean additive intercropping. Maize + frenchbean in paired row system (30/90 cm) was superior over all other treatment combinations.

Keywords: Maize, light interception, crop geometry, additive intercropping and productivity

Introduction
Maize (*Zea mays,* L.) is one of the important crop among cereals and it occupies third position in production next to wheat and rice in the world. Maize is known as "Miracle crop" and "Queen of Cereals", because of its high production potential and wider adaptability. Currently, nearly 1147.7 m t of maize is being produced together by over 170 countries from an area of 193.7 m ha with average productivity of 5.75 t ha^{-1}. Among the maize growing countries, India rank fourth in area and seventh in production, representing around 4 per cent of the world maize area and 2 per cent of total production. In India, the maize area has reached to 9.57 m ha with a production of 28.7 m t and productivity of 3006 kg ha^{-1} indicating the increased maize area over the decades. Although the productivity of maize in India is almost half of the world average, per day productivity of Indian maize is at par with many lead maize producing countries. In Karnataka, it occupies an area of 1.68 m ha with a production of 5.18 m t and productivity of 3092 kg ha^{-1} which is greater than the national average.

The extent of cultivable land is gradually decreasing, mainly because of rapid urbanization and industrialization due to the global population explosion resulting in ever increasing pressure on cultivated land for food and commercial crops. Food supply is one of the most important problems the world is enduring nowadays; intercropping is used in many parts of the world for the production of food and feed crops (Carruthers *et al.,* 2000) [5]. The main objective of intercropping is to augment total productivity per unit area and time, besides judicious and equitable utilization of land resources and farming inputs without reducing base crop yield (Marer *et al.,* 2007 and Zhang *et al.,* 2007) [12, 15].

Maize provides an opportunity for inclusion of intercrops because of its wider row spacing and plasticity of the crop to row spacing. Maize and legume intercropping was found to be more productive and remunerative compared to sole cropping (Kumar *et al.,* 2008 and Kamanga *et al.,* 2010) [10, 9]. Guar is a hardy legume containing gelling agent (guar gum) in seeds. Demand is rising rapidly due to industrial use of guar gum. The guar is being introduced into new areas because of higher commercial value and greater demand. It is an imperative to introduce guar crop in new areas, one way of introducing this crop is intercropping with cereals like maize.

Light interception by crops directly determines dry matter accumulation and yield formation, depending on canopy traits such as the distribution and photosynthetic capacity of the leaves (Gao *et al.*, 2010) [7]. Higher light interception can result in greater productivity. Many studies reported that yield advantage in intercropping was mainly due to greater light interception and use efficiency.

Material and Methods

A field experiment was carried out during *kharif,* 2014 and 2016 in Zonal Agricultural Research Station, GKVK, Benagluru, Karnataka which is situated in the Eastern Dry Zone (Zone–5) at 12° 58’ N latitude, 77° 35’ E longitude and an altitude of 930 m above mean sea level. The soil of experimental site was red sandy clay loam, neutral in soil reaction (pH 6.78), low in organic carbon content (0.32%), medium in available nitrogen (286.15 kg ha^{-1}), low in available P_2O_5 (21.69 kg ha^{-1}) and medium in available K_2O (243.48 kg ha^{-1}). The experiment was laid out in a randomized complete block design with three replications. The treatments comprised of T_1: Sole maize (60 x 30 cm); T_2: Sole maize (Paired row system - 30/90 cm); T_3: Sole guar; T_4: Sole frenchbean; T_5: Sole horsegram; T_6: Maize (60 x 30 cm) + guar additive interropping; T_7: Maize (60 x 30 cm) + frenchbean additive interropping; T_8: Maize (Paired row system - 30/90 cm) + guar additive interropping; T_9: Maize Paired row system - 30/90 cm) + frenchbean additive interropping; T_{10}: Maize Paired row system - 30/90 cm) + frenchbean + horsegram additive interropping. Horsegram was sown as second intercrop after the harvest of frenchbean in maize (paired row system of 30/90 cm) + frenchbean intercropping. Farm yard manure was applied uniformly to all the plots at the rate of 7.5 t ha^{-1} two weeks before sowing. The recommended dose of fertilizer for maize (100 kg N, 50 kg P_2O_5 and 25 kg K_2O ha^{-1}), guar (25 kg N, 75 kg P_2O_5 and 60 kg K_2O ha^{-1}) and frenchbean (62.5 kg N, 100 kg P_2O_5 and 75 kg K_2O ha^{-1}) was applied in the form of urea, single super phosphate and muriate of potash. In case of maize, 50 per cent N was applied as basal and remaining dose of nitrogen (50 kg ha^{-1}) was applied in two equal splits as top dressing at 30 and 45 DAS. In intercropping treatments, recommended dose of fertilizer for maize plus fertilizer for intercrops based on their population was applied. The other management operations were done as per recommended package of practices for both main and intercrops. Growth and yield parameters were recorded as per standard procedures. The light transmission by the canopies of sole maize, sole intercrops and intercropping system was measured by Lux meter. The light intensity above canopy (I_0) and at the ground level (I) was recorded between 12:30 and 1:00 pm and LTR was averaged for the system based on row proportions. B:C ratio was calculated by dividing the gross returns from the cost of cultivation and maize equivalent yield (MEY) was calculated on the basis of prevailing market prices of both maize and intercrops.

Results and Discussion

Significantly higher (34.81) light transmission ratio (LTR) was recorded in the paired row planting (30/90 cm) of maize + guar intercropping system and significantly lower (31.03) LTR was noticed in paired row planting (30/90 cm) of maize + frenchbean. Significantly higher (68.98) light absorption ratio (LAR) was observed in paired row planting (30/90 cm) of maize + frenchbean and lower LAR (65.20) (Table 1) was received with paired row planting (30/90 cm) of maize + guar intercropping system. Intercropping system of maize + french bean in paired row system able to intercept more light compared to sole maize. Trenbath (1989) [14] was also of the opinion that intercropping system have greater potentialities for interception of more light and judicious use of limited resources compared to sole crop. Higher crop growth rate may be ascribed for higher dry matter production and leaf area because of greater light interception which in turn resulted in better exploitation of solar radiation, higher dry matter accumulation and noticed better translocation of photosynthates from source to sink. These results are in conformity with the findings of Aravinda Kumar *et al.* (2004) [2], Asmat Ullah *et al.* (2007) [4] and Roy *et al.* (2015) [13].

The kernel yield of maize in sole cropping was not significantly influenced by crop geometry (60 x 30 cm and paired row system of 30/90 cm). There was no significant differences in yield parameters *viz.*, cob length, rows cob^{-1}, kernel weight $plant^{-1}$ and 100-kernel weight (Table 2) and growth parameters *viz.*, plant height, leaf area and dry matter $plant^{-1}$ (Table 1) between 60 x 30 cm spacing and paired row system (30/90 cm) of sole maize crop. These results are in conformity with the findings of Ashoka (2011) [3].

Table 1: Light interception and growth components of maize as influenced by crop geometry in additive intercropping system

Treatments	LTR (%)	LAR (%)	Plant height (cm)	Leaf area $plant^{-1}$ (cm^2)	Dry matter $plant^{-1}$ (g)
T_1	35.50	64.51	165.23	7247	229.08
T_2	36.46	63.54	173.11	7461	240.65
T_6	34.08	65.93	154.20	6843	213.92
T_7	30.20	69.81	160.14	7042	225.58
T_8	34.81	65.20	169.05	7267	233.21
T_9	31.03	68.98	172.13	7392	236.48
T_{10}	31.65	68.36	170.16	7333	233.34
S.Em±	1.28	1.03	2.14	83.21	1.25
C.D. (P=0.05)	3.76	3.04	6.30	245.46	3.68

Table 2: Yield and yield components of maize as influenced by crop geometry in additive intercropping system

Treatments	Cob length (cm)	Rows cob^{-1}	Kernel weight $plant^{-1}$ (g)	100 kernel weight (g)	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1	17.38	16.50	110.70	23.05	5389	6991
T_2	18.26	17.53	122.63	23.87	5680	7355
T_6	16.11	15.60	95.49	22.13	5234	6793
T_7	16.70	16.07	102.13	22.60	5248	6983
T_8	17.53	16.76	108.67	22.73	5404	7116
T_9	18.02	17.10	120.75	23.28	5484	7193
T_{10}	17.95	16.99	116.19	23.03	5481	7104
S.Em±	0.34	0.26	3.04	0.18	73.24	67.42
C.D. (P=0.05)	1.01	0.75	8.98	0.54	216.06	198.89

For intercropping systems, paired row system of 30/90 cm was better for maize crop. In intercropping systems, significantly higher kernel yield of maize (5484 kg ha^{-1}) was obtained in maize (paired row system of 30/90 cm) + frenchbean additive intercropping than with maize (60 x 30 cm) + guar/frenchbean intercropping and it was on par with the sole maize in 30/90 cm paired row system. Higher kernel yield of maize in paired row maize + frenchbean/guar intercropping was due to marginally higher kernel weight $plant^{-1}$ which was further due to significantly higher plant height and leaf area and marginally higher dry matter $plant^{-1}$ (Table 1). Similar results were also reported by Gollar and Patil (1997) [8] and Asoka (2011) [3]. Stover yield of maize did not differ significantly due to crop geometry and intercropping with frenchbean or guar.

All intercropping treatments recorded higher maize equivalent yield (MEY) and LER than sole maize crop (Table 4). Significantly higher MEY (13419 kg ha^{-1}) and higher LER (1.53) were observed in maize (paired row system of 30/90 cm) + frenchbean + horsegram additive intercropping and it was closely followed by maize (paired row system of 30/90 cm) + frenchbean intercropping (13102 kg ha^{-1} and 1.43 respectively). Similar results were also reported by Mandal *et al.* (2014) [11]. Higher maize equivalent yield in maize (paired row system of 30/90 cm) + frenhbean intercropping system was attributed to higher green bean yield of frenchbean in paired row system of intercropping than in normal planting of maize + frenchbean and its higher market price. Performance of frenchbean was better in maize (paired row system-30/90 cm) + frenchbean additive intercropping system compare to that in maize (60 x 30 cm) + frenchbean additive intercropping. This was due to higher growth and yield parameters of frenchbean in paired row system (Table 3). These results are in conformity with the findings of Ashoka (2011) [3] and Ganajaxi (2008) [6].

Table 3: Growth and yield parameters of intercrops as influenced by intercropping in maize at different crop geometry

Treatments	Plant height (cm)	Branches $plant^{-1}$	Dry matter $plant^{-1}$ (g)	Pods $plant^{-1}$	Pod/seed yield $plant^{-1}$	Pod/seed yield ha^{-1}	Haulm yield (kg ha^{-1})
T_3	42.27	3.25	8.82	21.04	5.02	408.83	1839.75
T_4	38.35	9.07	33.72	48.19	69.36	13416.00	2749.55
T_5	45.45	5.59	14.58	18.65	3.92	652.67	2800.99
T_6	31.00	2.50	3.60	8.84	1.57	96.78	565.21
T_7	27.29	4.64	22.96	32.63	36.95	3464.50	1804.15
T_8	37.05	2.05	5.80	15.37	2.67	121.67	684.00
T_9	34.68	7.93	28.85	41.67	62.65	6290.33	1721.08
T_{10}	34.25	7.63	27.15	39.06	60.03	6231.83	1656.71
	21.66*	3.20*	3.64*	7.31*	0.78*	61.67*	304.75*

Table 4: Maize equivalent yield (MEY) and LER as influenced by crop geometry in additive intercropping system

Treatments	Yield (kg ha^{-1})		MEY (kg ha^{-1})	LER
	Maize	Intercrop		
T_1	5389	-	5248	1
T_2	5680	-	5476	1
T_3	-	409	1295	1
T_4	-	13416	16505	1
T_5	-	653	1566	1
T_6	5234	97	5434	1.16
T_7	5248	3465	9471	1.23
T_8	5404	122	5733	1.25
T_9	5484	6290	13102	1.43
T_{10}	5481	6232	13419	1.53
S.Em±	73.24	-	169.31	-
C.D. (P=0.05)	216.06	-	503.05	-

Lesser growth and yield parameters of maize were observed in maize (60 x 30 cm) + frenchbean/guar intercropping as compared to paired row system. This might be attributed to availability of more space for maize at 30/90 cm paired row in intercropping than at 60 x 30 cm spacing, which might have helped maize plant in exploitation of natural resources more efficiently resulting in higher dry matter accumulation (Aravindkumar *et al.* 2004) [2].

Among intercropping systems, maize (paired row system-30/90 cm) + frenchbean additive intercropping and maize (paired row system-30/90 cm) + frenchbean + horsegram additive intercropping had given more net returns (₹ 1,42,048 ha^{-1} and ₹ 143443 ha^{-1}, respectively) and B:C ratio (3.61 and 3.48) (Table 5) than maize (60 x 30 cm) + frenchbean/guar intercropping and maize (paired row system-30/90 cm) + guar intercropping system and sole maize crop. This was due to higher frenchbean green pod yield and its higher market price. These results are in conformity with the findings of Ganajaxi (2008) [6].

Table 5: Cost of cultivation, gross returns, net returns and B:C ratio as influenced by crop geometry in maize based intercropping system

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1	35,015	78,720	43,706	2.25
T_2	35,015	82,144	47,130	2.35
T_3	14,962	19,426	4,465	1.30
T_4	47,593	2,47,575	1,99,983	5.20
T_5	14,673	23,488	8,816	1.60
T_6	39,017	81,517	42,501	2.09
T_7	54,480	1,42,066	87,586	2.61
T_8	39,017	85,999	46,982	2.21
T_9	54,480	1,96,527	1,42,048	3.61
T_{10}	57,847	2,01,289	1,43,443	3.48

Conclusion

Among crop geometry the paired row system of 30/90 cm is performed better in maize. The light absorption ratio is also good in maize (paired row system of 30/90cm) + frenchbean intercropping and it is highly productive and economical intercropping system as indicated by higher LER, net returns and B:C ratio under dryland condition.

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