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Growth and Yield of Maize (*Zea mays* L.) as Influenced by Planting Geometry and Nutrient Management in Maize Based Intercropping

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Abstract

A field experiment was conducted at Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK Bangalore during *kharif*- 2016 to develop suitable planting geometry and nutrient management practices for maize based intercropping system. The results revealed that between the planting geometry, paired row planting of maize (30/90×30 cm) has recorded significantly higher kernel yield (7286 kg ha^{-1}), stover yield (8748 kg ha^{-1}), maize equivalent yield (11039 kg ha^{-1}), LER (1.29) and ATER (1.14). Among the intercrops, kernel and stover yield were found to be non-significant. However, significantly higher maize equivalent yield (13309 kg ha^{-1}), LER (1.39) and ATER (1.20) were recorded in maize + french bean intercropping system. Among the nutrient management practices, base crop RDF + proportionate RDF for intercrops has recorded significantly higher kernel yield (7452 kg ha^{-1}), stover yield (8950 kg ha^{-1}), maize equivalent yield (11279 kg ha^{-1}), LER (1.33) and ATER (1.17).

Keywords: Planting geometry, intercrops, nutrient management, LER, ATER

Maize (*Zea mays* L.) globally an important cereal crop next to wheat and rice is called as Queen of Cereals due to its higher genetic yield potential. It is the most versatile emerging crop having wider adaptability under varied agro-climatic conditions. Maize is being used as food, fodder and also for industrial purpose. In India, about 25 per cent of the maize produced is used for human consumption, 49 per cent in poultry, 12 per cent as cattle feed and 12 per cent in food processing industries mainly as starch and one per cent each in brewery and seed industry (Jat *et al.*, 2009). In India, maize is cultivated in an area of 9.4 m ha with production of 22.27 m t. However, its productivity is 2.5 t ha^{-1} which is much lower than the global average. Karnataka being major maize producing state contributes 16.5 per cent of the Indian maize production with an area of 1.3 m ha with production of 4.0 m t and productivity of 2.88 t ha^{-1} (Anon., 2017). Although, the state productivity is greater than the national average, but it is still lower than global average. Its special features like higher dry matter production, ability to suppress weeds and high adaptability to both rainfed and irrigated situations have favoured expansion of its area.

Planting geometry is one of the practice that made significant change in productivity of maize (Jiang *et al.*, 2013). It is well known fact that maize is much flexible to row spacing and nutrients management, because of its C4 nature. It is very efficient in converting solar energy into dry matter. Maize being a widely spaced crop, can accommodate intercrops within the available inter space. In this regard, legumes are considered to be profitable because of additional yield and maintaining soil sustainability. However, the benefits accrued from an intercrop vary according to the nature of crops and their adoptability in the local condition. Further, yield gap in maize based cropping system is due to inadequate and imbalanced fertilization and lack of distinct fertilizer recommendations. Research information is meagre on planting geometry, intercrops and nutrient management in maize based intercropping system. Such information will help the farmer to enhance the total productivity of maize based intercropping and may increase the total income of the farmer. Keeping these things in view the present study on growth and yield of maize as influenced by planting geometry and nutrient management in maize based intercropping was undertaken.

MATERIAL AND METHODS

A field experiment was conducted during *kharif*-2016 at Zonal Agricultural Research Station, University of Agricultural Sciences, Bangalore, which is situated in the Eastern Dry Zone (Zone-5) of Karnataka. The experimental site is located between 13º 05' 2'' N latitude and 77º 34' 02'' E longitude at an altitude of 930 m above mean sea level (MSL). The soil was sandy loam in texture with low organic carbon content and soil pH of 5.98 and EC of 0.35 dSm^{-1}. Initial nitrogen, phosphorus and potassium status of the soil was medium (325.6, 29.23 and 281.87 kg ha^{-1}, respectively). The field experiment was laid out in Randomized Complete Block Design with factorial concept and replicated thrice. There were 16 treatment combinations involving 2 planting geometry (P_1: Normal planting (60×30 cm), P_2: Paired row planting (30/90×30 cm), 4 intercrops (I_1: French bean (*Phaseolus vulgaris*), I_2: Cowpea (*Vigna unguiculata*), I_3: Field bean (*Dolichos lablab*), I_4: Polebean (*Phaseolus vulgaris*) and two nutrient management practices (N_1: Base crop RDF, N_2: Base crop RDF + proportionate RDF for intercrops). The pure crops of the respective intercrops and sole crops were raised separately for computation of LER and ATER. Land was ploughed twice and levelled. The field was laid out as per plan of layout and the plots were marked. Furrows were opened at 60 cm apart and two seeds per spot were dibbled at 30 cm within a row as per treatment details. Inpaired row configuration at spacing of 30 / 90 × 30 cm. The furrows were opened in between two pairs of maize rows and two rows of intercrops were sown as per treatment details following recommended intra-row spacing as in the package of practices for respective crops under pure stand treatments. Fertilizers were applied to the both main and intercrop as per the treatment details (RDF for maize-150:75:40, french bean-63:100:75, cowpea-10:30:24, field bean-10:20:10, pole bean-63:100:75 kg N, P_2O_5 and K_2O ha^{-1}). Growth and yield observations of the crops were recorded at 30, 60, 90 days after sowing and at harvest and subjected to statistical analysis. For comparison with sole crop separate RCBD design was used.

RESULTS AND DISCUSSION

Growth parameters of maize

The growth parameters of maize (Table I) were significantly influenced by planting geometry, intercrops and nutrient management practices. Between the planting geometry, the paired row planting (30/90×30 cm) of maize has recorded significantly higher plant height (213.63 cm), number of leaves (11.00), leaf area (7001 cm^2 $plant^{-1}$) and total dry matter production (283.19 g $plant^{-1}$) as compared to normal planting (60×30 cm) of maize (203.81 cm, 10.49, 6679 and 270.17 g, respectively). The higher growth parameters under paired row system was mainly attributed to the better exploitation of natural resources more efficiently and resulted in higher dry matter accumulation. Similar findings were also reported by Yamuna *et al.* (2015).

Among the intercropped maize, the growth parameters were found to be non-significant. However, numerically higher plant height (217.19 cm), number of leaves (11.18), leaf area (7118 cm^2 $plant^{-1}$) and total dry matter production (287.90 g $plant^{-1}$) was recorded with maize + french bean intercropping system (Table I). This could be assigned to the synergistic effect of maize and french bean in association which helps for efficient utilization of solar energy and annidation effect of french bean like enhancement of soil fertility by nitrogen fixation, leaf shedding nature and deep root growth habit are well known. French bean reached flowering by 38 days after sowing and pod initiation by 45 days after sowing. In contrast vegetables reached flowering and pod initiation prior to peak flowering and harvest of maize. The results are in accordance with the findings of Ashok (2011).

Between nutrient management practices significantly higher plant height (218.49 cm), number of leaves (11.25), leaf area (7160 cm^2 $plant^{-1}$) and total dry matter production (289.63 g $plant^{-1}$) were recorded in base crop RDF with proportionate RDF for intercrops (Table II). Application of respective recommended dose of nutrients to both main crop and component crops resulted in higher nutrient uptake by main crop of maize. Further, substantial role of well fertilized legume component with respect to transfer of nutrients towards the maize crop also was a reality. Similar findings were reported by Mohan Kumar *et al.* (2013).

TABLE 1

Growth parameters of maize at 90 DAS as influenced by planting geometry and nutrient management in maize based intercropping system

Treatments	Plant height (cm)	Number of leaves	Leaf area (cm^2 plant^{-1})	Total dry matter (g plant^{-1})
Planting Geometry (P)				
P_1: Normal planting (60 × 30 cm)	203.81	10.49	6679	270.17
P_2: Paired row planting (30/90 × 30 cm)	213.63	11.00	7001	283.19
S.Em.±	3.30	0.17	108.20	4.38
CD (p=0.05)	9.54	0.49	312.51	12.64
Intercrops (I)				
I_1: French bean	217.19	11.18	7118	287.90
I_2: Cowpea	202.46	10.42	6635	268.38
I_3: Field bean	204.73	10.54	6709	271.38
I_4: Pole bean	210.52	10.83	6899	279.05
S.Em.±	4.67	0.24	153.02	6.19
CD (p=0.05)	NS	NS	NS	NS
Nutrient management (N)				
N_1: Base crop RDF	198.95	10.24	6520	263.73
N_2 : Base crop RDF + Proportionate RDF for intercrops	218.49	11.25	7160	289.63
S.Em.±	3.30	0.17	108.20	4.38
CD (p=0.05)	9.54	0.49	312.51	12.64
Interaction (P×I×N)				
$P_1 \times I_1 \times N_1$	203.07	10.45	6655	269.18
$P_1 \times I_1 \times N_2$	219.83	11.31	7204	291.40
$P_1 \times I_2 \times N_1$	184.58	9.50	6049	244.68
$P_1 \times I_2 \times N_2$	214.43	11.04	7027	284.24
$P_1 \times I_3 \times N_1$	184.68	9.50	6052	244.81
$P_1 \times I_3 \times N_2$	213.28	10.98	6990	282.72
$P_1 \times I_4 \times N_1$	194.27	10.00	6367	257.52
$P_1 \times I_4 \times N_2$	216.34	11.13	7090	286.78
$P_2 \times I_1 \times N_1$	218.53	11.25	7162	289.68
$P_2 \times I_1 \times N_2$	227.32	11.70	7450	301.33
$P_2 \times I_2 \times N_1$	197.77	10.18	6481	262.16
$P_2 \times I_2 \times N_2$	213.07	10.97	6983	282.44
$P_2 \times I_3 \times N_1$	201.15	10.35	6592	266.64
$P_2 \times I_3 \times N_2$	219.79	11.31	7203	291.35
$P_2 \times I_4 \times N_1$	207.57	10.68	6803	275.15
$P_2 \times I_4 \times N_2$	223.87	11.52	7337	296.76
S.Em.±	9.34	0.48	306.04	12.38
CD (p=0.05)	NS	NS	NS	NS
Sole Maize				
P_1: Normal planting (60 × 30 cm)	227.96	11.73	7470.84	302.18
P_2: Paired row planting (30/90 × 30 cm)	232.62	11.97	7623.30	308.35
S.Em.±	8.93	0.46	292.68	11.84
CD (p=0.05)	25.67	1.32	841.18	34.02

TABLE II

Yield parameters and yield of maize as influenced by planting geometry and nutrient management in maize based intercropping system

Treatments	Number of kernel rows cob^{-1}	Number of kernels row^{-1}	Kernel weight cob^{-1} (g)	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
			Planting Geometry (P)			
P_1: Normal planting (60 × 30 cm)	16.23	28.70	126.79	6951	8347	0.45
P_2: Paired row planting (30/90 × 30 cm)	17.01	30.09	132.90	7286	8748	0.45
S.Em.±	0.26	0.46	2.05	112.61	135.51	-
CD (p=0.05)	0.76	1.34	5.93	325.23	391.37	-
			Intercrops (I)			
I_1: French bean	17.30	30.59	135.11	7407	8649	0.46
I_2: Cowpea	16.12	28.51	125.95	6905	8487	0.45
I_3: Field bean	16.30	28.83	127.36	6983	8582	0.45
I_4: Pole bean	16.77	29.65	130.96	7180	8472	0.46
S.Em.±	0.37	0.66	2.90	159.25	191.64	-
CD (p=0.05)	NS	NS	NS	NS	NS	-
			Nutrient management (N)			
N_1: Base crop RDF	15.84	28.02	123.77	6786	8145	0.45
N_2 : Base crop RDF + Proportionate RDF for intercrops	17.40	30.77	135.92	7452	8950	0.45
S.Em.±	0.26	0.46	2.05	112.61	135.51	-
CD (p=0.05)	0.76	1.34	5.93	325.23	391.37	-
			Interaction (P×I×N)			
P_1×I_1× N_1	16.17	28.60	126.33	6926	8087	0.46
P_1×I_1× N_2	17.51	30.96	136.75	7497	8754	0.46
P_1×I_2× N_1	14.70	25.99	114.83	6295	7737	0.45
P_1×I_2× N_2	17.08	30.20	133.40	7313	8989	0.45
P_1×I_3× N_1	14.71	26.01	114.89	6299	7742	0.45
P_1×I_3× N_2	16.99	30.03	132.68	7274	8940	0.45
P_1×I_4× N_1	15.47	27.36	120.86	6626	7818	0.46
P_1×I_4× N_2	17.23	30.47	134.59	7379	8706	0.46
P_2×I_1× N_1	17.40	30.77	135.95	7453	8703	0.46
P_2×I_1× N_2	18.10	32.01	141.41	7753	9052	0.46
P_2×I_2× N_1	15.75	27.85	123.03	6745	8290	0.45
P_2×I_2× N_2	16.97	30.01	132.55	7267	8932	0.45
P_2×I_3× N_1	16.02	28.33	125.14	6861	8432	0.45
P_2×I_3× N_2	17.50	30.95	136.73	7496	9214	0.45
P_2×I_4× N_1	16.53	29.23	129.13	7080	8353	0.46
P_2×I_4× N_2	17.83	31.53	139.27	7636	9009	0.46
S.Em.±	0.74	1.32	5.81	318.50	383.27	-
CD (p=0.05)	NS	NS	NS	NS	NS	-
			Sole Maize			
P_1: Normal planting (60 × 30 cm)	18.15	32.10	141.82	7775	9427	0.45
P_2: Paired row planting (30/90 × 30 cm)	18.53	32.76	144.71	7934	9628	0.45
S.Em.±	0.71	1.26	5.56	304.60	374.87	-
CD (p=0.05)	2.04	3.61	15.97	875.40	1077.39	-

The interaction between planting geometry × intercrops (P × I), planting geometry × nutrient management (P × N), intercrops × nutrient management (I × N) and planting geometry × intercrops × nutrient management (P × I × N) were found to be non-significant. However, significantly higher growth parameters were recorded in sole cropping of maize at 60×30 cm (normal planting) and 30/90×30 cm (paired row planting) when compared to intercropping system. All the growth parameters of maize decreased significantly in intercropping system depending on nature of intercrop and their arrangements, which may be due to the partial competition exerted by the component crops for the growth recourses during various stages of the crop growth. These results are in line with the findings of Ummed Singh *et al.* (2008).

Yield and yield parameters of maize

The yield and yield parameters of maize (Table II) were significantly influenced by planting geometry, intercrops and nutrient management practices. Between the planting geometry, the paired row planting (30/90×30 cm) of maize has recorded significantly higher kernel (7286 kg ha^{-1}) and stover yield (8748 kg ha^{-1}) as compared to normal planting (60×30 cm) of maize (6951 & 8347 kg ha^{-1}, respectively). The higher yield was mainly attributed to significantly higher number of kernel rows cob^{-1} (17.01), number of kernels row^{-1} (30.09), kernel weight cob^{-1} (132.90 g) as compared to normal planting of maize *i.e.*, 60×30 cm (16.23, 28.70, 126.79g, respectively). But the harvest index was found to be non-significant. The higher yield attributes which might be due to better utilization of solar energy and nutrients,resulted in increased photosynthesis in paired row planting system. Similar findings were reported by Choudhary *et al.* (2014).

Among the intercropped maize, the yield and yield parameters were found to be non-significant. However, numerically higher number of kernel rows cob^{-1} (17.30), number of kernels row^{-1} (30.59), kernel weight cob^{-1} (135.11 g), kernel yield (7407 kg ha^{-1}) and stover yield (8649 kg ha^{-1}) were recorded under maize + french bean intercropping system (Table II).

Among nutrient management practices, significantly higher kernel (7452 kg ha^{-1}) and stover yield (8950 kg ha^{-1}) were recorded in base crop RDF with proportionate RDF for intercrops as compared to base crop RDF alone (6786 & 8145 kg ha^{-1}, respectively).The higher yield in this treatment was mainly attributed to significantly higher number of kernel rows cob^{-1}(17.40), number of kernels row^{-1} (30.77) and kernel weight cob^{-1} (135.92 g), as compared to base crop RDF alone (15.84, 28.02 and 123.77 g, respectively). Because of the higher dose of nutrients significantly improved the growth parameters *viz.,* plant height, number of leaves, leaf area and total dry matter production which has resulted in higher yield and yield attributes.

The interaction between planting geometry × intercrops (P×I), planting geometry × nutrient management (P×N), intercrops × nutrient management (I×N) and planting geometry × intercrops × nutrient management (P×I×N) were found to be non-significant. However significantly higher yield and yield parameters were recorded in sole cropping of maize at 60×30 cm (normal planting) and 30/90×30 cm (paired row planting) as compared to intercropping system. When two or more crops are grown together as intercrops, their growth and yield are generally reduced in intercropping system as compared to yields obtained under sole cropping, although combined yield may be higher than sole crops. Hence, higher total productivity and returns is possible if the crops are compatible with suitable crop geometry.The reduction in maize yield under intercrop treatments may be due to crowding effect as a result of higher plant density per unit area resulting in higher inter-row competition under intercropping of legumes.

Maize equivalent yield (MEY)

To express yield advantage, the yield of individual crops are converted in to equivalent yield of any one crop based on their economic value. Though yield of maize was reduced due to intercropping, the maize equivalent yield recorded was higher in the intercropping systems. Between planting geometry significantly higher maize equivalent yield (11039 kg ha^{-1}) was noticed in paired row planting of maize 30/90×30cm as compared to normal planting of maize at 60×30 cm (10430 kg ha^{-1}). The higher maize equivalent yield under paired row planting might be due to better utilization of growth resources as reflected by higher plant height, number of leaves, leaf area and higher total dry matter production.

Among the intercropped maize, significantly higher maize equivalent yield (Table III) was recorded in maize + french bean intercropping system (13309 kg ha^{-1}) followed by maize + pole bean (12165 kg ha^{-1}), maize + field bean (8869 kg ha^{-1}) and maize + cowpea (8595 kg ha^{-1}) intercropping system, which was attributed to higher yield and market price of french bean. This could also be assigned to the synergistic effect of maize and french bean in association which helps for efficient utilization of solar energy and annidation effect of french bean like enhancement of soil fertility by nitrogen fixation, leaf shedding nature and deep root growth habit are well known. French bean reached flowering by 38 days after sowing and pod initiation by 45 days after sowing. In contrast vegetables reached flowering and pod initiation prior to peak flowering and harvest of maize. When two crops of widely varying duration are planted, their peak demand for light, moisture and nutrients are likely to occur at different periods. Further, when crop is harvested early, conditions become favourable for the late maturing crops to recoup and improve growth at later stage.

TABLE III

Maize equivalent yield (MEY), Land equivalent ratio (LER) and Area time equivalent ratio (ATER) as influenced by planting geometry and nutrient management in maize based intercropping system

Treatments	MEY (kg ha^{-1})	LER	ATER
Planting Geometry (P)			
P_1: Normal planting (60 × 30 cm)	10430	1.23	1.09
P_2: Paired row planting (30/90 × 30 cm)	11039	1.29	1.14
S.Em.±	129.48	0.01	0.01
CD (p=0.05)	373.97	0.04	0.04
Intercrops (I)			
I_1: French bean	13309	1.39	1.20
I_2: Cowpea	8595	1.17	1.05
I_3: Field bean	8869	1.19	1.06
I_4: Pole bean	12165	1.30	1.14
S.Em.±	183.11	0.02	0.02
CD (p=0.05)	528.87	0.06	0.05
Nutrient management (N)			
N_1: Base crop RDF	10190	1.20	1.06
N_2: Base crop RDF + Proportionate RDF for intercrops	11279	1.33	1.17
S.Em.±	129.48	0.01	0.01
CD (p=0.05)	373.97	0.04	0.04
Interaction (P×I×N)			
$P_1 \times I_1 \times N_1$	12446	1.31	1.13
$P_1 \times I_1 \times N_2$	13762	1.44	1.24
$P_1 \times I_2 \times N_1$	7747	1.05	0.95
$P_1 \times I_2 \times N_2$	8935	1.22	1.10
$P_1 \times I_3 \times N_1$	7885	1.06	0.96
$P_1 \times I_3 \times N_2$	9119	1.23	1.11
$P_1 \times I_4 \times N_1$	11196	1.21	1.06
$P_1 \times I_4 \times N_2$	12351	1.34	1.18
$P_2 \times I_1 \times N_1$	13057	1.36	1.19
$P_2 \times I_1 \times N_2$	13971	1.45	1.25
$P_2 \times I_2 \times N_1$	8487	1.14	1.02
$P_2 \times I_2 \times N_2$	9213	1.25	1.11
$P_2 \times I_3 \times N_1$	8764	1.17	1.04
$P_2 \times I_3 \times N_2$	9710	1.30	1.15
$P_2 \times I_4 \times N_1$	11940	1.27	1.11
$P_2 \times I_4 \times N_2$	13172	1.40	1.22
S.Em.±	366.20	0.04	0.03
CD (p=0.05)	NS	NS	NS
Sole Crops			
P_1: Normal planting (60 × 30 cm)	7775	-	-
P_2: Paired row planting (30/90 × 30 cm)	7934	-	-
I_1: French bean	8040	-	-
I_2: Cowpea	3896	-	-
I_3: Field bean	4529	-	-
I_4: Pole bean	7738	-	-
S.Em.±	326.12	-	-
CD (p=0.05)	930.70	-	-

Between nutrient management practices, significantly higher maize equivalent yield (11279 kg ha^{-1}) was noticed in base crop RDF + proportionate RDF for intercrops as compared to base crop RDF alone (10190 kg ha^{-1}).

The interaction between planting geometry × intercrops (P×I), planting geometry × nutrient management (P×N), intercrops × nutrient management (I×N) and planting geometry × intercrops × nutrient management (P×I×N) were found to be non-significant.

Land equivalent ratio (LER) and Area time equivalent ratio (ATER)

Land equivalent ratio (LER) implies the relative land area under sole crop that is required to produce the yields achieved in intercropping under same level of management. Intercropping advantages estimated by land equivalent ratio method sometimes misleading because the conceptual basis in which the monoculture versus intercrop comparison. Area time equivalent ratio will correct this conceptual inadequacy in LER and enable to assess land use efficiency along with time use efficiency in crop mixture.

Between planting geometry, paired row planting of maize at 30/90×30 cm has noticed significantly higher LER (1.29) and ATER (1.14) as compared to normal planting of maize at 60×30 cm (1.23 & 1.09, respectively).

Among the intercropping system, LER and ATER were significantly higher in maize + French bean (1.39 & 1.20) system which were followed by maize + pole bean (1.30 & 1.14), maize + field bean (1.19 & 1.06) and maize + cowpea (1.17 & 1.05). The land utilization efficiency increased with intercropping system. Lower LER and ATER values with other intercropping combinations might be due to lower efficiency of these intercropping systems probably due to competitive factors. These results are in accordance with the findings of Yamuna *et al.* (2015).

Between nutrient management practices, significantly higher LER (1.33) and ATER (1.17) were obtained in base crop RDF + proportionate RDF for intercrops as compared to base crop RDF alone (1.20 & 1.06, respectively). Because of the application of recommended dose of fertilizers to the both main and component crop has resulted in higher LER and ATER (Table III).

The interaction effects were found to non-significant. However, compared to sole cropping, all intercropping treatments recorded LER more than unity, whereas, ATER ranged from 0.95 to 1.25. (Table III).

It can be concluded that intercropping of french bean in paired row planted maize with application of base crop RDF + proportionate RDF for intercrops has realized higher grain yield, stover yield, maize equivalent yield, LER and ATER under Eastern Dry Zone of Karnataka.

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