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Yield, nutrient uptake and available soil nutrient status after harvest 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 Bengaluru during *kharif*- 2016 and summer 2017 to develop suitable planting geometry and nutrient management practices for maize based intercropping system. The experiment was laid out in a Randomized Complete Block Design with three replications using factorial concept involving different planting geometry, intercrops and nutrient management practices. The results revealed that between the planting geometry, paired row planting of maize (30/90×30 cm) has recorded significantly higher kernel yield (7686 kg ha^{-1}), stover yield (8748 kg ha^{-1}) and total nutrient uptake *viz.*, nitrogen (143.68 kg ha^{-1}), phosphorus (38.43 kg ha^{-1}) and potassium uptake (145.39 kg ha^{-1}). Among the intercrops, kernel yield, stover yield and nutrient uptake were found to be non-significant. Between 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}) and total nutrient uptake *viz.*, nitrogen (143.68 kg ha^{-1}), phosphorus (38.43 kg ha^{-1}) and potassium uptake (145.39 kg ha^{-1}).

Keywords: Planting geometry, intercrops, nutrient management, yield, nutrient uptake

Introduction

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) [9]. 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) [2]. 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.

The feasibility and economic viability of intercropping system largely depends on adoption of proper planting geometry, selection of compatible crops and nutrient management. Thus, the objectives of intercropping is now more towards augmenting the total productivity per unit area of the land per unit time through inclusion of more than one crop in the same field, although the prime objective being better utilization of environmental resources under rainfed and irrigated ecosystem. Maize is one such crop which provides opportunity for inclusion of intercrops because of its wider row spacing and plasticity of the crop to row spacing. Besides this, addition of organic matter through addition of litter by legume intercrops plays an important role in increasing the sustainable productivity of companion crop due to their ability to fix atmospheric nitrogen and build up soil fertility, improving aggregation of soil particles, porosity and water holding capacity of the soil. Since, 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 points in view the present study on yield nutrient uptake and available soil nutrient status after harvest 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 and summer 2017 at Zonal Agricultural Research Station, University of Agricultural Sciences, Bengaluru, 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: Pole bean (*Phaseolus vulgaris*) and two nutrient management practices (N_1: Base crop RDF, N_2: Base crop RDF + proportionate RDF for intercrops). 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. In paired 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}).

Nutrient uptake by crop

Digestion of plant samples

One gram plant samples were pre-digested with 5 ml nitric acid and digested with di-acid mixture of nitric acid and perchloric acid (9:4). The clean digested material was made up to 50 ml volume with 6 N HCl and was used for the analysis of all mineral elements.

Nitrogen Uptake

Nitrogen content was estimated by modified micro-kjeldhal's method as outlined by Jackson (1967) [8] and expressed in percentage. Nitrogen uptake (kg/ha) by crop was calculated for each treatment separately using the following formula.

$$\text{Nitrogen uptake (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1}\text{)}$$

Phosphorus Uptake

Phosphorus content in the digested plant sample was estimated by vanadomolybdo phosphoric yellow colour method in nitric acid medium and the colour intensity was measured at 460 nm wave length as outlined by Jackson (1973) [7]. It is calculated using the following formula.

$$\text{Phosphorus uptake (kg ha}^{-1}\text{)} = \frac{\text{Phosphorus concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1}\text{)}$$

Potassium uptake

Potassium in the plant and tuber samples digest were estimated by atomizing the diluted acid extract in a flame photometer as described by Jackson (1973) [7]. It is calculated using the following formula.

$$\text{Potassium uptake (kg ha}^{-1}\text{)} = \frac{\text{Potassium concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1}\text{)}$$

Chemical analysis of soil

Representative soil samples from the experimental plots were drawn from the top 45 cm depth before sowing of the crop. Similarly, the surface soil samples from 0 to 45 cm depth were also collected from each experimental plot after harvest of crop. Soil samples collected were air dried in shade, powdered with wooden mallet and passed through 2 mm sieve and chemically analyzed for organic carbon content (%), pH, EC (dsm^{-1}), available nitrogen, phosphorus and potassium content of the soil.

Available nitrogen (kg ha^{-1})

Available nitrogen was determined by alkaline permanganate method as outlined by Subbiah and Asija (1956) [14].

Available phosphorus (kg ha^{-1})

Available phosphorus was determined by Olsen's method as outlined by Jackson (1967) [8].

Available potassium (kg ha^{-1})

Available potassium was determined by Neutral normal ammonium acetate solution using flame photometer as outlined by Jackson (1967) [8].

Results and Discussion

Yield of Maize

The yield of maize (Table 1) was 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 (7156 kg ha^{-1}) and stover yield (8941 kg ha^{-1}) as compared to normal planting (60×30 cm) of maize (6617 & 8240 kg ha^{-1}, respectively). The higher yield was mainly attributed to significantly higher number of kernel rows cob^{-1}, number of kernels row^{-1} and kernel weight cob^{-1} as compared to normal planting of maize *i.e.* 60×30 cm. But the harvest index was found to be non-significant. The higher yield which might be due to better utilization of solar energy and nutrients, resulted in increased photosynthesis in paired row planting system (Choudhary *et al.*, 2014) [4].

Among the intercropped maize, the yield of maize was found to be non-significant. However, numerically higher kernel yield (7164 kg ha^{-1}) and stover yield (8818 kg ha^{-1}) were recorded under maize + french bean intercropping system (Table 1).

Between nutrient management practices, significantly higher kernel (7293 kg ha^{-1}) and stover yield (9050 kg ha^{-1}) were recorded in base crop RDF with proportionate RDF for intercrops as compared to base crop RDF alone (6481 & 8131 kg ha^{-1}, respectively). The higher yield in this treatment was mainly attributed to significantly higher number of kernel rows cob^{-1}, number of kernels row^{-1} and kernel weight cob^{-1} as compared to base crop RDF alone. 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 of maize was 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.

Nutrient uptake by maize

Nutrient uptake by crop is the manifestation of biomass production and available nutrient status of soil. In the present study, nitrogen, phosphorus and potassium uptake by maize followed similar trends as that of kernel and stover yields. Significantly higher total nitrogen (143.68 kg ha^{-1}), phosphorus (38.43 kg ha^{-1}) and potassium uptake (145.39 kg ha^{-1}) was recorded in the paired row planting (30/90×30 cm) of maize as compared to normal planting (60×30 cm) of maize (131.34, 36.00 & 132.89 kg ha^{-1}, respectively). The higher nitrogen, phosphorus and potassium uptake by maize might be due to higher biomass production coupled with higher availability of nitrogen, phosphorus and potassium. Similar results were also obtained by Hamid *et al*. (2011) [5].

Nutrient uptake by maize as influenced by intercrops was found to be non-significant. However, numerically higher total nitrogen (103.58 kg ha^{-1}), phosphorus (40.14 kg ha^{-1}) and potassium uptake (143.72 kg ha^{-1}) was recorded with maize + french bean intercropping system. Followed by maize + pole bean (101.15, 38.96, 140.11 kg ha^{-1}, respectively), maize + field bean (95.70, 37.73, 133.42 kg ha^{-1}, respectively) and maize + cowpea (95.28, 37.53, 132.81 kg ha^{-1}, respectively) intercropping system. The higher nitrogen, phosphorus and potassium uptake by maize could be attributed to higher biomass production coupled with higher availability of nitrogen, phosphorus and potassium (Whitehead, 1970; Hongal, 2001 and Nooli, 2001) [15, 6, 10].

Significantly higher total nitrogen (146.43 kg ha^{-1}), phosphorus (40.04 kg ha^{-1}) and potassium uptake (148.16 kg ha^{-1}) were recorded in base crop RDF + proportionate RDF for intercrops as compared to base crop RDF alone (128.60, 34.39 & 130.12 kg ha^{-1}, respectively). Higher nitrogen, phosphorus and potassium uptake by maize might be due to higher biomass production coupled with higher availability of nitrogen, phosphorus and potassium. The nutrient uptake is a function of yield and nutrient concentration in plant. Thus, significant improvement in uptake of nitrogen, phosphorus and potassium might be attributed to their increased concentration in plant under base crop RDF + proportionate RDF for intercrops. This might have enhanced the vegetative growth of maize which ultimately increased nutrient concentration in total biomass of plants. The results of present investigation are in close agreement with the findings of Parthipan and Premsekhar (2002) [12], Singh and Sarkar (2001) [13] and Parasuraman (2005) [11].

The interaction effect of 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 with respect to nitrogen, phosphorus and potassium uptake (Table 2, 3 & 4). However, these interactions were compared statistically with sole maize crop with different planting geometry (normal and paired row planting). Significantly higher nitrogen, phosphorus and potassium uptake were recorded in sole cropping of maize at 60×30 cm (113.16, 45.39, 158.55 kg ha^{-1}, respectively) and 30/90×30 cm (114.88, 46.27, 161.15 kg ha^{-1}, respectively) as compared to intercropping system.

Available Soil nutrient status after harvest of maize

Planting geometry had a significant influence on available nutrient status of soil after harvest of maize. Paired row planting (30/90×30 cm) of maize recorded significantly lower residual nitrogen, phosphorus and potassium status of soil after harvest of maize (306.43, 37.56 and 261.93 kg ha^{-1}, respectively). It could be due to higher biomass production per hectare of maize and higher amount of nutrient removal under paired row planting.

Cropping systems are known to influence the soil physical, chemical and biological properties. These properties in turn influence the soil fertility. Several studies consistently have shown the advantage of legume inclusion in non-legume cropping system in the present study, soil available nitrogen, phosphorus and potassium were improved with inclusion of leguminous intercrops as compared to sole maize.

Among the intercropping system, the available nutrient status of the soil after of the maize was found to be non-significant. However, Numerically higher available nitrogen (316.00 kg ha^{-1}), phosphorus (39.92 kg ha^{-1}) and potassium uptake (271.27 kg ha^{-1}) were recorded maize + cowpea intercropping system. Followed by maize + field bean (314.12, 39.16, 266.95 kg ha^{-1}, respectively), maize + pole bean (312.98, 38.86, 266.89 kg ha^{-1}, respectively) and maize + french bean (311.03, 37.27, 265.75 kg ha^{-1}, respectively) intercropping system. Presence of legumes in the mixture benefits the associated non-legumes as the legumes provide a portion of biologically fixed nitrogen to non-legume components. Further, legumes increase the soil nitrogen content and help to maintain soil fertility (Hongal, 2001 and Nooli, 2001) [6, 10].

Nutrient management practices had a significant influence on available nutrient status of soil after harvest of maize. Application of base crop RDF + proportionate RDF for intercrops has recorded significantly higher available nitrogen (320.26 kg ha^{-1}), phosphorus (45.68 kg ha^{-1}) and potassium (273.10 kg ha^{-1}) status of soil after harvest of maize as compared to the application of RDF alone (306.81, 31.92, 262.33 kg ha^{-1}, respectively). This might be due to application of RDF to maize and proportionate RDF for intercrops leads to higher availability of nutrients in soil. The results are in conformity with the findings of Ananthi *et al*. (2017) [1] and Ashish *et al*. (2015) [3].

With respect to available nutrient status of soil, 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 (Table 5). However significantly higher available nitrogen (298.40 to 332.92 kg ha^{-1}), phosphorus (28.51 to 49.35 kg ha^{-1}) and potassium (255.93 to 290.04) status soil after harvest maize were recorded intercropping system as compared to sole cropping of maize at 60×30 cm (284.67, 30.02 & 251.10 kg ha^{-1}, respectively) and 30/90×30 cm (287.30, 30.03 & 252.66 kg ha^{-1}, respectively). Presence of legumes in the mixture benefits the associated non-legumes as the legumes provide a portion of biologically fixed nitrogen to non-legume components. Further, legumes increase the soil nitrogen content and help to maintain soil fertility (Hongal, 2001 and Nooli, 2001) [6, 10].

Table 1: Grain yield (kg ha^{-1}), stover yield (kg ha^{-1}) and Harvest index of maize as influenced by planting geometry and nutrient management in maize based intercropping system

Treatments	Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})			Harvest index		
	2016	2017	pooled	2016	2017	pooled	2016	2017	pooled
Planting Geometry (P)									
P_1	6951	6283	6617	8347	8132	8240	0.45	0.44	0.45
P_2	7286	7025	7156	8748	9133	8941	0.45	0.44	0.45
S.Em.±	113	102	97	136	158	133	0.00	0.00	0.00
CD (p=0.05)	325	296	289	391	456	386	NS	NS	NS
Intercrops (I)									
I_1	7407	6921	7164	8649	8986	8818	0.46	0.44	0.45
I_2	6905	6454	6680	8487	8376	8432	0.45	0.44	0.45
I_3	6983	6529	6756	8582	8463	8523	0.45	0.44	0.45
I_4	7180	6711	6946	8472	8706	8589	0.46	0.44	0.45
S.Em.±	159	145	141	192	223	196	0.00	0.00	0.00
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1	6786	6175	6481	8145	8116	8131	0.45	0.43	0.44
N_2	7452	7133	7293	8950	9149	9050	0.45	0.44	0.45
S.Em.±	113	102	97	136	158	133	0.00	0.00	0.00
CD (p=0.05)	325	296	289	391	456	386	NS	0.00	0.00
Interaction (P×I×N)									
$P_1 \times I_1 \times N_1$	6926	6090	6508	8087	7988	8038	0.46	0.43	0.45
$P_1 \times I_1 \times N_2$	7497	6940	7219	8754	8894	8824	0.46	0.44	0.45
$P_1 \times I_2 \times N_1$	6295	5536	5916	7737	7260	7499	0.45	0.43	0.44
$P_1 \times I_2 \times N_2$	7313	6769	7041	8989	8670	8830	0.45	0.44	0.45
$P_1 \times I_3 \times N_1$	6299	5539	5919	7742	7256	7499	0.45	0.43	0.44
$P_1 \times I_3 \times N_2$	7274	6733	7004	8940	8610	8775	0.45	0.44	0.45
$P_1 \times I_4 \times N_1$	6626	5826	6226	7818	7641	7730	0.46	0.43	0.45
$P_1 \times I_4 \times N_2$	7379	6830	7105	8706	8740	8723	0.46	0.44	0.45
$P_2 \times I_1 \times N_1$	7453	6996	7225	8703	9221	8962	0.46	0.43	0.45
$P_2 \times I_1 \times N_2$	7753	7660	7707	9052	9840	9446	0.46	0.44	0.45
$P_2 \times I_2 \times N_1$	6745	6331	6538	8290	8336	8313	0.45	0.43	0.44
$P_2 \times I_2 \times N_2$	7267	7180	7224	8932	9237	9085	0.45	0.44	0.45
$P_2 \times I_3 \times N_1$	6861	6439	6650	8432	8478	8455	0.45	0.43	0.44
$P_2 \times I_3 \times N_2$	7496	7406	7451	9214	9508	9361	0.45	0.44	0.45
$P_2 \times I_4 \times N_1$	7080	6645	6863	8353	8748	8551	0.46	0.43	0.45
$P_2 \times I_4 \times N_2$	7636	7544	7590	9009	9697	9353	0.46	0.44	0.45
S.Em.±	318.	289	285	383	446	401	0.00	0.00	0.00
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sole Maize									
P_1	7775	7467	7621	9427	9810	9619	0.46	0.43	0.45
P_2	7934	7541	7738	9628	9933	9781	0.46	0.43	0.45
S.Em.±	304	278	278	374	427	381	0.00	0.00	0.00
CD (p=0.05)	875	799	826	1077	1230	1133	0.01	NS	0.00

P_1: Normal planting (60×30 cm), N_1: Base crop RDF, P_2: Paired row planting (30/90×30 cm), N_2: Base crop RDF + Proportionate RDF for intercrops
I_1: French bean, I_2: Cowpea, I_3: Field bean, I_4: Pole bean

Table 2: Nitrogen uptake (kg ha^{-1}) by maize as influenced by planting geometry and nutrient management in maize based intercropping system

Treatments	Grain (kg ha^{-1})			Stover (kg ha^{-1})			Total (kg ha^{-1})		
	2016	2017	pooled	2016	2017	pooled	2016	2017	pooled
Planting Geometry (P)									
P_1	99.54	89.89	94.72	37.20	36.05	36.63	136.74	125.94	131.34
P_2	105.09	101.17	103.13	39.84	41.26	40.55	144.93	142.43	143.68
S.Em.±	1.61	1.49	1.53	0.60	0.65	0.61	2.19	2.10	2.13
CD (p=0.05)	4.66	4.30	4.46	1.75	1.88	1.80	6.31	6.07	6.17
Intercrops (I)									
I_1	107.17	99.99	103.58	40.07	40.20	40.14	147.24	140.19	143.72
I_2	98.54	92.01	95.28	37.47	37.59	37.53	136.01	129.60	132.81

I_3	98.95	92.44	95.70	37.67	37.78	37.73	136.61	130.22	133.42
I_4	104.61	97.69	101.15	38.88	39.03	38.96	143.49	136.72	140.11
S.Em.±	2.28	3.10	2.17	0.85	1.31	0.89	3.09	3.97	3.03
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1	97.18	88.35	92.77	36.26	35.39	35.83	133.45	123.74	128.60
N_2	107.45	102.71	105.08	40.78	41.91	41.35	148.23	144.63	146.43
S.Em.±	1.61	1.49	1.53	0.60	0.65	0.61	2.19	2.10	2.13
CD (p=0.05)	4.66	4.30	4.46	1.75	1.88	1.80	6.31	6.07	6.17
Interaction (P×I×N)									
$P_1 \times I_1 \times N_1$	99.48	87.26	93.37	37.32	35.15	36.24	136.80	122.41	129.61
$P_1 \times I_1 \times N_2$	108.45	99.90	104.18	41.00	40.73	40.87	149.45	140.63	145.04
$P_1 \times I_2 \times N_1$	89.16	78.40	83.78	33.50	31.51	32.51	122.66	109.91	116.29
$P_1 \times I_2 \times N_2$	104.33	96.57	100.45	40.01	39.74	39.88	144.34	136.31	140.33
$P_1 \times I_3 \times N_1$	88.58	77.89	83.24	32.66	30.70	31.68	121.24	108.59	114.92
$P_1 \times I_3 \times N_2$	103.04	95.38	99.21	38.87	38.57	38.72	141.91	133.95	137.93
$P_1 \times I_4 \times N_1$	95.83	84.27	90.05	34.55	32.53	33.54	130.38	116.80	123.59
$P_1 \times I_4 \times N_2$	107.47	99.48	103.48	39.68	39.43	39.56	147.16	138.90	143.03
$P_2 \times I_1 \times N_1$	107.81	101.20	104.51	39.68	40.06	39.87	147.50	141.26	144.38
$P_2 \times I_1 \times N_2$	112.95	111.59	112.27	42.27	44.86	43.57	155.22	156.45	155.84
$P_2 \times I_2 \times N_1$	96.24	90.13	93.19	36.32	36.57	36.45	132.57	126.71	129.64
$P_2 \times I_2 \times N_2$	104.41	102.93	103.67	40.05	42.54	41.30	144.47	145.47	144.97
$P_2 \times I_3 \times N_1$	97.20	91.03	94.12	37.42	37.65	37.54	134.62	128.69	131.66
$P_2 \times I_3 \times N_2$	106.96	105.44	106.20	41.72	44.21	42.97	148.68	149.65	149.17
$P_2 \times I_4 \times N_1$	103.14	96.60	99.87	38.67	38.95	38.81	141.81	135.54	138.68
$P_2 \times I_4 \times N_2$	112.01	110.43	111.22	42.62	45.21	43.92	154.62	155.64	155.13
S.Em.±	4.57	4.21	4.37	1.71	1.84	1.76	6.18	5.95	6.05
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sole Maize									
P_1	114.03	111.23	112.63	42.73	45.79	44.26	156.76	157.02	156.89
P_2	116.37	112.36	114.37	43.75	46.47	45.11	160.12	158.83	159.48
S.Em.±	4.37	4.05	4.19	1.63	1.78	1.69	5.92	5.72	5.80
CD (p=0.05)	12.55	11.64	12.09	4.70	5.11	4.89	17.00	16.43	16.70

P_1: Normal planting (60×30 cm), N_1: Base crop RDF
P_2: Paired row planting (30/90×30 cm), N_2: Base crop RDF + Proportionate RDF for intercrops
I_1: French bean, I_2: Cowpea, I_3: Field bean, I_4: Pole bean

Table 3: Phosphorus uptake (kg ha^{-1}) by maize as influenced by planting geometry and nutrient management in maize based intercropping system

Treatments	Grain (kg ha^{-1})			Stover (kg ha^{-1})			Total (kg ha^{-1})		
	2016	2017	pooled	2016	2017	pooled	2016	2017	pooled
Planting Geometry (P)									
P_1	20.61	18.63	19.62	16.68	16.07	16.38	37.29	34.70	36.00
P_2	21.24	20.48	20.86	17.31	17.82	17.57	38.55	38.30	38.43
S.Em.±	0.20	0.27	0.21	0.19	0.23	0.20	0.36	0.48	0.42
CD (p=0.05)	0.58	0.79	0.60	0.55	0.65	0.58	1.04	1.39	1.25
Intercrops (I)									
I_1	22.76	21.25	22.01	19.25	19.19	19.22	42.00	40.44	41.22
I_2	20.65	19.30	19.98	16.82	16.77	16.80	37.46	36.07	36.77
I_3	20.23	18.92	19.58	16.19	16.14	16.17	36.42	35.06	35.74
I_4	20.06	18.75	19.41	15.74	15.68	15.71	35.79	34.44	35.12
S.Em.±	0.63	0.98	0.86	0.66	1.51	1.32	3.79	3.68	3.51
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1	19.71	17.94	18.83	15.81	15.32	15.57	35.52	33.26	34.39
N_2	22.13	21.18	21.66	18.19	18.57	18.38	40.32	39.75	40.04
S.Em.±	0.20	0.27	0.21	0.19	0.23	0.20	0.36	0.48	0.42
CD (p=0.05)	0.58	0.79	0.60	0.55	0.65	0.58	1.04	1.39	1.25
Interaction (P×I×N)									
$P_1 \times I_1 \times N_1$	21.42	18.84	20.13	17.70	16.57	17.14	39.12	35.40	37.26
$P_1 \times I_1 \times N_2$	23.81	22.03	22.92	19.93	19.68	19.81	43.73	41.71	42.72
$P_1 \times I_2 \times N_1$	18.62	16.38	17.50	15.07	14.10	14.59	33.70	30.48	32.09
$P_1 \times I_2 \times N_2$	22.24	20.59	21.42	18.25	18.03	18.14	40.49	38.61	39.55
$P_1 \times I_3 \times N_1$	18.04	15.87	16.96	14.35	13.41	13.88	32.39	29.28	30.84
$P_1 \times I_3 \times N_2$	21.44	19.84	20.64	17.30	17.07	17.19	38.74	36.91	37.83
$P_1 \times I_4 \times N_1$	18.28	16.07	17.18	14.23	13.31	13.77	32.51	29.39	30.95
$P_1 \times I_4 \times N_2$	21.00	19.43	20.22	16.63	16.41	16.52	37.63	35.85	36.74
$P_2 \times I_1 \times N_1$	22.82	21.42	22.12	18.79	18.84	18.82	41.61	40.26	40.94

$P_2 \times I_1 \times N_2$	22.98	22.70	22.84	20.57	21.68	21.13	43.55	44.38	43.97
$P_2 \times I_2 \times N_1$	19.77	18.56	19.17	15.94	15.96	15.95	35.71	34.51	35.11
$P_2 \times I_2 \times N_2$	21.97	21.70	21.84	17.99	19.00	18.50	39.96	40.70	40.33
$P_2 \times I_3 \times N_1$	19.42	18.23	18.83	15.37	15.38	15.38	34.79	33.61	34.20
$P_2 \times I_3 \times N_2$	22.02	21.75	21.89	17.75	18.70	18.23	39.76	40.46	40.11
$P_2 \times I_4 \times N_1$	19.33	18.15	18.74	14.99	15.00	15.00	34.32	33.14	33.73
$P_2 \times I_4 \times N_2$	21.62	21.36	21.49	17.09	18.02	17.56	38.71	39.37	39.04
S.Em.±	1.25	0.77	0.99	0.66	0.64	0.63	1.59	1.36	1.44
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sole Maize									
P_1	22.09	27.83	24.96	17.30	22.90	20.10	39.39	50.73	45.06
P_2	22.47	28.16	25.32	17.58	23.26	20.42	40.05	51.42	45.74
S.Em.±	1.19	1.05	1.10	0.63	1.15	0.87	1.51	2.15	1.81
CD (p=0.05)	3.43	3.01	3.20	1.80	3.29	2.53	4.35	6.18	5.25

P_1: Normal planting (60×30 cm), N_1: Base crop RDF

P_2: Paired row planting (30/90×30 cm), N_2: Base crop RDF + Proportionate RDF for intercrops

I_1: French bean, I_2: Cowpea, I_3: Field bean, I_4: Pole bean

Table 4: Potassium uptake (kg ha^{-1}) by maize as influenced by planting geometry and nutrient management in maize based intercropping system

Treatments	Grain (kg ha^{-1})			Stover (kg ha^{-1})			Total (kg ha^{-1})		
	2016	2017	pooled	2016	2017	pooled	2016	2017	pooled
Planting Geometry (P)									
P_1	100.24	90.61	95.43	38.05	36.87	37.46	138.29	127.48	132.89
P_2	105.82	102.04	103.93	40.74	42.18	41.46	146.56	144.22	145.39
S.Em.±	1.63	1.48	1.55	0.62	0.66	0.63	2.21	2.11	2.15
CD (p=0.05)	4.69	4.28	4.48	1.78	1.92	1.84	6.38	6.10	6.23
Intercrops (I)									
I_1	107.91	100.85	104.38	40.97	41.11	41.04	148.89	141.97	145.43
I_2	99.23	92.76	96.00	38.32	38.44	38.38	137.55	131.20	134.38
I_3	99.65	93.20	96.43	38.52	38.64	38.58	138.17	131.84	135.01
I_4	105.33	98.48	101.91	39.76	39.91	39.84	145.09	138.39	141.74
S.Em.±	2.30	3.09	2.20	0.87	1.94	1.91	3.13	4.99	3.98
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1	97.86	89.07	93.47	37.10	36.20	36.65	134.96	125.27	130.12
N_2	108.20	103.58	105.89	41.69	42.85	42.27	149.89	146.43	148.16
S.Em.±	1.63	1.48	1.55	0.62	0.66	0.63	2.21	2.11	2.15
CD (p=0.05)	4.69	4.28	4.48	1.78	1.92	1.84	6.38	6.10	6.23
Interaction (P×I×N)									
$P_1 \times I_1 \times N_1$	100.17	88.08	94.13	38.17	35.95	37.06	138.34	124.04	131.19
$P_1 \times I_1 \times N_2$	109.20	101.08	105.14	41.92	41.65	41.79	151.12	142.72	146.92
$P_1 \times I_2 \times N_1$	89.79	78.96	84.38	34.27	32.23	33.25	124.06	111.19	117.63
$P_1 \times I_2 \times N_2$	105.06	97.24	101.15	40.91	40.63	40.77	145.96	137.87	141.92
$P_1 \times I_3 \times N_1$	89.21	78.44	83.83	33.43	31.43	32.43	122.64	109.87	116.26
$P_1 \times I_3 \times N_2$	103.77	96.05	99.91	39.76	39.46	39.61	143.53	135.51	139.52
$P_1 \times I_4 \times N_1$	96.50	84.85	90.68	35.36	33.30	34.33	131.86	118.15	125.01
$P_1 \times I_4 \times N_2$	108.21	100.16	104.19	40.59	40.32	40.46	148.80	140.48	144.64
$P_2 \times I_1 \times N_1$	108.56	101.89	105.23	40.60	40.98	40.79	149.16	142.88	146.02
$P_2 \times I_1 \times N_2$	113.72	112.36	113.04	43.22	45.87	44.55	156.94	158.22	157.58
$P_2 \times I_2 \times N_1$	96.92	90.97	93.95	37.15	37.41	37.28	134.07	128.37	131.22
$P_2 \times I_2 \times N_2$	105.14	103.88	104.51	40.95	43.49	42.22	146.09	147.36	146.73
$P_2 \times I_3 \times N_1$	97.89	91.88	94.89	38.26	38.50	38.38	136.15	130.38	133.27
$P_2 \times I_3 \times N_2$	107.71	106.42	107.07	42.64	45.18	43.91	150.35	151.60	150.98
$P_2 \times I_4 \times N_1$	103.85	97.47	100.66	39.54	39.82	39.68	143.38	137.29	140.34
$P_2 \times I_4 \times N_2$	112.77	111.42	112.10	43.55	46.21	44.88	156.32	157.62	156.97
S.Em.±	4.60	4.19	4.38	1.75	1.88	1.80	6.25	5.97	6.09
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sole Maize									
P_1	114.81	111.51	113.16	43.67	47.10	45.39	158.48	158.61	158.55
P_2	117.16	112.60	114.88	44.71	47.82	46.27	161.87	160.42	161.15
S.Em.±	4.40	4.02	4.19	1.67	1.82	1.73	5.98	5.74	5.84
CD (p=0.05)	12.64	11.56	12.08	4.80	5.22	4.99	17.20	16.50	16.83

P_1: Normal planting (60×30 cm), N_1: Base crop RDF

P_2: Paired row planting (30/90×30 cm), N_2: Base crop RDF + Proportionate RDF for intercrops

I_1: French bean, I_2: Cowpea, I_3: Field bean, I_4: Pole bean

Table 5: Available NPK in soil (kg ha^{-1}) after harvest of maize as influenced by planting geometry and nutrient management in maize based intercropping system

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	2016	2017	pooled	2016	2017	pooled	2016	2017	pooled
Planting Geometry (P)									
P_1	337.50	303.75	320.63	41.71	38.37	40.04	287.90	259.11	273.51
P_2	322.56	290.30	306.43	39.12	35.99	37.56	275.71	248.14	261.93
S.Em.±	4.89	4.40	4.21	0.73	0.67	0.62	3.42	3.07	3.18
CD (p=0.05)	14.13	12.71	12.60	2.11	1.94	1.88	9.87	8.88	9.24
Intercrops (I)									
I_1	327.40	294.66	311.03	38.82	35.71	37.27	279.73	251.76	265.75
I_2	332.63	299.36	316.00	41.58	38.25	39.92	285.54	256.99	271.27
I_3	330.65	297.58	314.12	40.79	37.53	39.16	281.00	252.90	266.95
I_4	329.45	296.51	312.98	40.48	37.24	38.86	280.93	252.84	266.89
S.Em.±	6.92	6.23	6.34	1.03	0.95	0.98	4.83	4.35	4.55
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1	322.95	290.66	306.81	33.25	30.59	31.92	276.14	248.52	262.33
N_2	337.11	303.40	320.26	47.58	43.78	45.68	287.47	258.72	273.10
S.Em.±	4.89	4.40	4.21	0.73	0.67	0.62	3.42	3.07	3.18
CD (p=0.05)	14.13	12.71	12.60	2.11	1.94	1.88	9.87	8.88	9.24
Interaction (P×I×N)									
$P_1 \times I_1 \times N_1$	328.70	295.83	312.27	33.20	30.54	31.87	279.80	251.82	265.81
$P_1 \times I_1 \times N_2$	340.73	306.66	323.70	47.40	43.61	45.51	290.37	261.33	275.85
$P_1 \times I_2 \times N_1$	327.60	294.84	311.22	34.80	32.02	33.41	283.70	255.33	269.52
$P_1 \times I_2 \times N_2$	349.51	314.56	332.04	51.40	47.29	49.35	305.30	274.77	290.04
$P_1 \times I_3 \times N_1$	331.90	298.71	315.31	38.57	35.48	37.03	281.70	253.53	267.62
$P_1 \times I_3 \times N_2$	350.44	315.39	332.92	43.80	40.30	42.05	290.94	261.85	276.40
$P_1 \times I_4 \times N_1$	327.40	294.66	311.03	35.30	32.48	33.89	281.30	253.17	267.24
$P_1 \times I_4 \times N_2$	343.73	309.36	326.55	49.20	45.26	47.23	290.07	261.06	275.57
$P_2 \times I_1 \times N_1$	316.60	284.94	300.77	29.70	27.32	28.51	269.40	242.46	255.93
$P_2 \times I_1 \times N_2$	323.57	291.21	307.39	44.97	41.37	43.17	279.37	251.43	265.40
$P_2 \times I_2 \times N_1$	314.10	282.69	298.40	31.80	29.26	30.53	270.60	243.54	257.07
$P_2 \times I_2 \times N_2$	331.37	298.23	314.80	48.30	44.44	46.37	282.57	254.31	268.44
$P_2 \times I_3 \times N_1$	318.20	286.38	302.29	32.70	30.08	31.39	271.30	244.17	257.74
$P_2 \times I_3 \times N_2$	329.97	296.97	313.47	48.10	44.25	46.18	280.07	252.06	266.07
$P_2 \times I_4 \times N_1$	319.10	287.19	303.15	29.90	27.51	28.71	271.30	244.17	257.74
$P_2 \times I_4 \times N_2$	327.57	294.81	311.19	47.50	43.70	45.60	281.07	252.96	267.02
S.Em.±	13.83	12.45	12.99	2.07	1.90	1.95	9.66	8.70	9.11
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sole Maize									
P_1	291.24	278.10	284.67	29.88	30.17	30.02	265.90	236.31	251.10
P_2	294.10	280.50	287.30	30.41	29.66	30.03	267.54	237.79	252.66
S.Em.±	14.07	12.66	11.95	2.07	1.90	1.85	9.41	8.32	8.01
CD (p=0.05)	39.39	36.58	32.55	5.95	5.47	5.74	26.98	25.10	23.04

P_1: Normal planting (60×30 cm), N_1: Base crop RDF

P_2: Paired row planting (30/90×30 cm), N_2: Base crop RDF + Proportionate RDF for intercrops

I_1: French bean, I_2: Cowpea, I_3: Field bean, I_4: Pole bean

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