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Studies on the influence of liquid biofertilizers and integrated nutrient management practices on growth, yield attributes and yield of maize

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Abstract

Field experiments were carried out at Department of Millets, Tamil Nadu Agricultural University, Coimbatore during *kharif*, 2016, *kharif*, 2017, *kharif*, 2018 and *kharif*, 2019 in sandy clay loam soil to study the influence of various liquid biofertilizers and integrated nutrient management practices on growth, yield attributes and yield of maize. Based on the results, it could be concluded that application of 60 kg P_2O_5/ha + NPK consortia recorded higher grain yield (5293 kg ha^{-1}), net return (Rs.44,656/ha) and B: C ratio (2.02) which is the optimum level of phosphorus and suitable liquid biofertilizer for maize. The results of integrated nutrient management practices revealed that application of 100% recommended dose of fertilizers (RDF-250:75:75 NPK kg/ha) recorded higher grain yield (7318 kg ha^{-1}), net return (Rs.72, 772/ha) and B: C ratio (2.49) in maize.

Abbreviations

B:C - Benefit Cost ratio
CD - Critical Difference
FYM - Farm Yard Manure
N Nitrogen
PSB - Phosphorus Solubilizing Bacteria
P - Phosphorus
K - Potassium
RCBD - Randomized Complete Block Design
RDF - Recommended Dose of Fertilizers
Zn - Zinc

Introduction

Maize (*Zea mays* L.) is the most promising crop in India after rice and wheat in respect of area and production owing to its wide ecological adaptability. It is grown throughout the year in almost all parts of India with an area and production of more than 8.5 million ha and 20 million tones, respectively (Begam *et al.*, 2018). Nevertheless, the productivity of maize in India is 2345 kg ha^{-1}, which is very low. This is ascribed to frequent occurrence of drought, inadequate soil moisture storage due to improper soil and moisture conservation practices, improper planting density, imbalanced application of manures and fertilizers resulting in widespread occurrence of nutrient deficiencies in soils (Adhikary *et al.*, 2020). Nutrient removal by crops and loss of nutrients through erosion leads to depletion of nutrients in the soil. Depletion of nutrients in the soil occurs when sufficient quantities of organic manures and inorganic fertilizers are not added to the soil. (Sharma *et al.*, 2019). Since the nutrients in the soil are not present in adequate quantities and proportion as required for plants to produce maximum yields on a sustainable basis, there is a necessity to add plant nutrients to the soil through organic manures and inorganic fertilizers (Prasad, 2012).

Maize being an exhaustive crop, removes large quantities of nutrients during different phenological phases. Balanced application of nitrogenous, phosphorus and potassic fertilizers plays a significant role in increasing the productivity of maize and their contribution to yield is 40 - 45 per cent (Fahad Khan *et al.*, 2014). Excessive application of inorganic fertilizers is generally associated with decline in soil physical, chemical and biological properties and crop yield (Hepperly *et al.*, 2009). The afore mentioned problems can be solved by application of appropriate combination of different sources of organic manures and inorganic fertilizers to achieve sustainable productivity without deteriorating the soil and other natural resources (Chandrashekara *et al.*, 2000, Shrestha *et al.*, 2018).

Among organic sources of nutrients, biofertilizers form an integral part of nutrient supply system. In India,

most of the biofertilizers are solid carrier based with shorter shelf life, poor quality and low performance in the field on application. In recent years, the carrier based biofertilizers are replaced by liquid formulations as they spread well and mix uniformly without any sticking agent over the seed surface (Gomathy *et al.*, 2007). Liquid biofertilizer is a special formulation containing high number of desired microorganism with high shelf life and zero contamination which has the potential to replace conventional inorganic fertilizers and carrier based organic fertilizers (Hedge, 2008). These microbial inoculants enhance crop productivity through biological nitrogen fixation, increased availability or uptake of nutrients by plants through solubilization or increased absorption, stimulation of plant growth through hormonal action or antibiosis etc. These biofertilizers are easy for usage, handling and storage and the recommended dosage is ten times less than that indicated for powder form. (Verma *et al.*, 2011). Thus, integrated nutrient supply approach is inevitable for realizing high crop productivity without deteriorating soil fertility through the adoption of integrated nutrient management practices. Hence, experiments were conducted to study the influence of various liquid biofertilizers and integrated nutrient management practices on growth, yield attributes and yield of maize.

Material and methods

Kharif (2016-2017)

Experimental site

Field experiments were carried out at Department of Millets, Tamil Nadu Agricultural University, Coimbatore in Western Zone of Tamil Nadu during *kharif*, 2016 and *kharif*, 2017 to study the effect of phosphorus and various liquid biofertilizers on growth, yield attributes and yield of maize hybrid CO 6. The soil was sandy clay loam and low in available N, medium in available P and high in available K.

	Treatments
T1	Control (Recommended N - 250 kg/ha and K - 75 kg/ha
T2	PSB I*
T3	PSB II*
T4	NPK consortia
T5	60 kg P_2O_5/ha
T6	30 kg P_2O_5/ha + PSB I*
T7	60 kg P_2O_5/ha + PSB I*
T8	30 kg P_2O_5/ha + PSB II*
T9	60 kg P_2O_5/ha + PSB II*
T10	30 kg P_2O_5/ha + NPK consortia*
T11	60 kg P_2O_5/ha + NPK consortia*
T12	90 kg P_2O_5/ha

Experimental design

The experiments were laid out in a Randomized Complete Block Design (RCBD) with the following treatments and replicated thrice.

Kharif (2018-2019)

Experimental site

Field experiments were carried out at Department of Millets, Tamil Nadu Agricultural University, Coimbatore in Western Zone of Tamil Nadu during *kharif*, 2018 and *kharif*, 2019 to study the influence of organic manures and inorganic fertilizers on growth, yield attributes and yield of maize. The soil was sandy clay loam and low in available N, medium in available P and high in available K

Experimental design

The experiments were laid out in a Randomized Complete Block Design (RCBD) with the following treatments and replicated thrice.

Measurements

	Treatments
T1	Unmanured
T2	100% RDF - 250:75:75 NPK kg/ha
T3	75% RDF
T4	50% RDF
T5	FYM 10t/ha + Azatobactor
T6	Maize + legume intercropping with FYM 10 t/ha + Azatobactor
T7	100% RDF + 5 t/ha FYM
T8	75% RDF + 5 t/ha FYM
T9	50% RDF + 5 t/ha FYM
T10	100% RDF + 5 kg Zn/ha
T11	FYM 5 t/ha
T12	90 kg P_2O_5/ha

Five plants in each plot were selected and tagged for recording plant height at harvest. Yield attributes *viz.*, cob length (cm), cob girth (cm), No. of grain rows/cob, No. of grains/row and 100 seed weight (g) were recorded from the five randomly selected plants in each plot. The cobs of maize from the net plot were harvested and threshed for calculating grain yield per plot and converted to kg per hectare. After the harvest of cobs, stover from the net plot was harvested and weighed. This was converted to kg per hectare.

Statistical analysis

The data on various characters studied during the investigation were statistically analyzed by Gomez and Gomez (2010) for Randomized Complete Block Design.

Table 1 - Effect of phosphorus and liquid biofertilizers on plant height, 50% tasseling and 50% silking in maize

Treatments	Plant height (cm)		Days to 50% tasseling		Days to 50% silking	
	Kharif, 2016	Kharif, 2017	Kharif, 2016	Kharif, 2017	Kharif, 2016	Kharif, 2017
T1	222.3	229.4	53.3	53.7	57.0	57.3
T2	197.3	208.7	50.3	50.3	54.3	54.3
T3	198.1	209.4	50.3	50.7	54.3	54.3
T4	199.7	210.7	50.3	50.7	54.0	55.0
T5	193.3	204.1	49.7	50.0	53.3	54.0
T6	202.4	212.9	50.7	51.0	54.7	55.0
T7	204.9	214.9	51.0	51.3	55.3	55.0
T8	203.6	213.7	50.7	51.0	54.3	55.0
T9	205.7	215.4	51.0	51.3	55.0	55.3
T10	207.2	216.7	51.3	51.7	55.7	55.3
T11	210.4	219.3	51.7	52.0	55.7	56.0
T12	195.2	206.3	49.7	50.0	53.7	54.0
CD (p=0.05)	NS	NS	NS	NS	NS	NS

Wherever the treatment difference was significant, critical differences were worked out at 5 per cent probability level.

Results and discussion

Kharif (2016-2017)

Effect of phosphorus and liquid biofertilizers on plant height, 50% tasseling and 50% silking in maize

Experimental results revealed that different levels of phosphorus and various liquid biofertilizers failed to exert significant influence on plant height at harvest during both the years. However, T_1 - control (Recommended N - 250 kg/ha and K - 75 kg/ha) recorded significantly higher plant height of 222.3 cm during experiment I during *kharif*, 2016 and 229.4 cm during second experiment laid out in *kharif*, 2017 at harvest. This was followed by T_{11} - 60 kg P_2O_5/ha + NPK consortia in both the years. This might be ascribed to prolonged vegetative growth which favored the plant height. The results are in accordance with the findings of Bakht *et al.*, (2006) and Masood *et al.*, (2011).The lowest plant height was recorded in T_5 - 60 kg P_2O_5/ha. There was no significant influence of treatments in respect of 50% tasseling and 50% silking in both the years. Nevertheless, 50% tasseling and 50% silking were earlier in T_5 (60 kg P_2O_5/ha) and T_{12} (90 kg P_2O_5/ha). Similar view has been expressed by Farnham (2001).

Effect of phosphorus and liquid biofertilizers on yield attributes of maize

The yield attributes except No. of grain rows/cob were not significantly influenced by the treatments in both the years. However, T_1 – control (Recommended N and K) recorded higher cob length, cob girth, no. of grain rows/cob, no. of grains/row and 100 seed weight in both the years. With respect to No. of grain rows/cob, T_1 (Recommended N and K) recorded higher no. of grain rows/cob (14.3) which was comparable with

Table 2 - Effect of phosphorus and liquid biofertilizers on yield attributes of maize

Treatments	Cob length (cm)		Cob girth (cm)		No. of grain rows/cob		No. of grains/row		100-seed weight (g)	
	Kharif 2016	Kharif 2017	Kharif 2016	Kharif 2017	Kharif 2016	Kharif 2017	Kharif 2016	Kharif 2017	Kharif 2016	Kharif 2017
T1	19.3	18.9	14.7	14.5	14.3	14.1	36.3	36.1	38.7	38.9
T2	15.3	15.3	13.4	13.4	13.0	13.0	32.2	32.3	36.0	36.0
T3	15.3	15.4	13.4	13.4	13.0	13.0	32.5	32.7	36.0	36.2
T4	15.4	15.5	13.7	13.7	13.0	13.0	32.7	33.0	36.3	36.2
T5	14.8	14.7	13.2	13.2	12.4	12.4	32.0	32.2	35.7	35.8
T6	15.9	15.8	13.9	13.7	13.5	13.5	33.1	33.5	36.3	36.2
T7	16.4	16.3	14.1	13.9	13.5	13.5	34.0	34.3	37.0	37.1
T8	16.1	16.2	14.0	13.9	13.5	13.5	33.3	33.7	36.7	36.7
T9	16.5	16.5	14.1	14.0	13.6	13.5	34.3	34.3	37.3	37.4
T10	16.8	16.7	14.2	14.0	13.7	13.7	34.3	34.3	37.3	37.4
T11	17.2	17.1	14.4	14.2	13.7	13.7	34.7	34.6	37.6	37.8
T12	14.9	14.8	13.2	13.2	12.4	12.4	32.0	32.2	35.7	35.8
CD(p=0.05)	NS	NS	NS	NS	0.7	0.7	NS	NS	NS	NS

Table 3 - Effect of phosphorus and liquid biofertilizers on yield and economics of maize

Treatments	Grain yield (kg/ha		Stover yield (kg/ha)		Net returns (Rs./ha)		BC ratio	
	Kharif 2016	Kharif 2017	Kharif 2016	Kharif 2017	Kharif 2016	Kharif 2017	Kharif 2016	Kharif 2017
T1	6523	6387	11185	11078	63292	61145	2.38	2.34
T2	4461	4544	7718	7962	33629	35123	1.82	1.86
T3	4493	4571	7873	8096	34264	35657	1.84	1.87
T4	4552	4611	7975	8187	35251	36348	1.86	1.89
T5	4363	4468	7548	7792	29189	31008	1.67	1.71
T6	4691	4733	8105	8308	35826	36659	1.84	1.86
T7	4896	4916	8471	8651	37842	38322	1.86	1.87
T8	4785	4814	8278	8472	37409	38038	1.88	1.89
T9	4967	4995	8593	8753	39029	39609	1.88	1.90
T10	5092	5097	8809	8941	42540	42757	2.00	2.00
T11	5308	5278	9283	9376	44834	44477	2.02	2.01
T12	4394	4492	7702	7931	28388	30082	1.63	1.67
CD (p=0.05)	821	670	1843	1937				

T_9, T_{10} and T_{11} during *kharif*, 2016. In *kharif* 2017, T_1(Recommended N and K) recorded higher No. of grain rows/cob (14.1) which was comparable with T_6, T_7, T_8, T_9, T_{10} and T_{11} but was superior to other treatments. This might be due to increased levels of N and K applied to the crop which favored more availability of nutrients thus improved the uptake resulting in improved yield attributes. The results confirm the findings of Thakur *et al.*, (1997) and Sharar *et al.* (2003). In respect of phosphorus and liquid biofertilizers, T_{11} - 60 kg P_2O_5/ha + NPK consortia recorded higher cob length, cob girth, no. of grain rows/cob, no. of grains/row and 100 seed weight which was followed by T_{10} (30 kg P_2O_5/ha + NPK consortia) in both the years. This might be ascribed to nitrogen fixation, P solubilization and K mobilization by the liquid fertilizer which enhanced the availability of nutrients in the soil for plant growth and development thus improved the yield attributes. The results are in accordance with the findings of Wu *et al* . (2005), Gomathy *et al.* (2007) and Sheraz Mahdi *et al.* (2010).

Effect of phosphorus and liquid biofertilizers on yield and economics of maize

During *kharif* 2016, T_1 - Control (Recommended N and K) recorded higher grain yield of 6523 kg ha^{-1} and 6387 kg ha^{-1} during *kharif*, 2017 which were significantly superior to other treatments. This was ascribed to adequate supply of nutrients to the crop leading to improved yield attributes resulting in higher yield. The results are in accordance with the findings of Paramasivan *et al.* (2011) and Majid *et al.* (2017). Among the different levels of phosphorus and liquid biofertilizers, T_{11} - 60 kg P_2O_5/ha + NPK consortia recorded higher grain yield of 5308 kg ha^{-1}, which was comparable with T_{10}, T_9, T_7 ,T_8 ,T_6,T_4 and T_3 but was superior to other treatments during *kharif*, 2016. In *kharif* 2017, T_{11} - 60 kg P_2O_5/ha + NPK consortia recorded higher grain yield

Table 4 - Effect of integrated nutrient management practices on growth and yield attributes of maize

Treatments	Plant height (cm) at harvest		Cob length (cm)		Cob girth (cm)		No. of grain rows/ cob		No. of grains/ row		100 seed weight (g)	
	Kharif 2018	Kharif 2019	Kharif 2018	Kharif 2019	Kharif 2018	Kharif 2019	Kharif 2018	Kharif 2019	Kharif 2018	Kharif 2019	Kharif 2018	Kharif 2019
T1	211.6	253.4	14.9	17.4	12.8	13.3	13.7	14.3	31.4	32.9	30.2	30.4
T2	223.7	259.2	18.9	21.6	15.6	16.1	14.5	14.8	33.3	35.8	37.6	38.1
T3	221.7	257.1	18.4	21.2	15.5	16.0	14.3	14.5	32.8	34.7	36.5	36.8
T4	215.8	255.7	17.0	19.6	15.2	15.8	14.3	14.5	31.8	34.0	35.2	35.8
T5	213.1	253.9	15.9	18.4	13.2	13.7	14.3	14.3	31.8	33.5	32.7	32.3
T6	212.5	255.0	15.8	18.5	13.0	13.7	14.2	14.3	31.7	33.7	32	32.3
T7	224.8	261.5	19.3	22.3	15.9	16.3	14.9	14.9	34.1	36.7	38.1	38.7
T8	222.9	257.9	18.5	21.3	15.5	16.0	14.4	14.7	33.3	35.3	36.5	36.9
T9	216.2	256.0	17.1	19.8	15.4	15.9	14.3	14.5	32.3	34.1	36	36.2
T10	224.1	260.4	19	22.0	15.6	16.2	14.9	14.9	33.9	36.4	37.8	38.3
T11	212.2	253.5	15.2	17.8	12.9	13.4	14.1	14.3	31.5	33.2	31.8	32.1
CD (p=0.05)	NS	NS	2.1	2.0	1.0	1.0	NS	NS	NS	NS	NS	3.0

Table 5 - Effect of integrated nutrient management practices on yield and economics of maize

Treatments	Grain yield (kg/ha)		Stover yield (kg/ha)		Net return (Rs/ha)		B:C ratio	
	Kharif,2018	Kharif,2019	Kharif,2018	Kharif,2019	Kharif,2018	Kharif,2019	Kharif,2018	Kharif,2019
T1	3533	3476	5924	6283	18930	18429	1.47	1.46
T2	7244	7319	12403	12553	72132	73412	2.48	2.50
T3	6732	6844	11259	11483	65304	67213	2.39	2.43
T4	5814	5956	9497	9775	51739	54147	2.15	2.21
T5	4167	4363	7038	7233	21005	24145	1.44	1.50
T6	4645	4814	6882	7374	20824	30171	1.37	1.61
T7	7324	7392	12698	12803	69882	71007	2.33	2.35
T8	6819	6918	11491	11684	63091	64774	2.24	2.28
T9	5912	6043	9738	10001	49700	51928	2.02	2.07
T10	7265	7346	12511	12641	70894	72239	2.40	2.43
T11	3597	3821	6043	6442	15244	18993	1.34	1.42
CD (p=0.05)	805	816	1466	1262				

of 5278 kg ha^{-1}, which was comparable with T_{10}, T_9, T_7 ,T_8 ,T_6 and T_4 but was superior to other treatments. This was ascribed to more solubilization of unavailable form of nutrients and growth promoting substances in the rhizosphere on application of liquid biofertilizers which enhanced the yield. The results are in accordance with the findings of Yazdani *et al.*, (2009), Gomathy *et al.*, (2007), Kanimoli *et al.*, (2004), Yadav *et al.*, (2011), El-Kholy *et al.*, (2005) and Puenete *et al.*, (2009). The lowest grain yield was recorded in T_5 and T_{12}. The highest stover yield of 11185 kg ha^{-1} and 11078 kg ha^{-1} was recorded in T_1 - Control (Recommended N and K) during *kharif*, 2016 and *kharif*, 2017, respectively. This was significantly superior to other treatments.

With respect to economics, the highest net return of Rs. 63,292/ha and B:C ratio of 2.38 during *kharif*, 2016 and Rs. 61145/ha and BC ratio of 2.34 during *kharif*, 2017 were registered in T_1. In respect of different levels of phosphorus and liquid biofertilizers, application of 60 kg P_2O_5/ha + NPK consortia (T_{11}) registered the highest net return of Rs. 44,834/ha and BC ratio of 2.02 during *kharif*, 2016 and Rs. 44,477/ha and B:C ratio of 2.01 during *kharif*, 2017

Kharif (2018-2019)

Effect of integrated nutrient management practices on growth and yield attributes of maize

Experimental results revealed that the treatments failed to exert significant influence on plant height in both the years. Nevertheless, T_7 –100% RDF + FYM 5 t/ha recorded higher plant height of 224.8 cm and 261.5 cm at harvest during *kharif*, 2018 and *kharif*, 2019, respectively. Application of FYM and inorganic fertilizers improved the soil physical properties and nutrient status of soil which resulted in prolonged vegetative growth leading to increased plant height. The results confirm the findings of Omar (2014).

The treatments evinced significant influence on yield attributes and yield of maize in both the years. During *kharif* 2018, among the different treatments, T_7 –100% RDF + FYM 5 t/ha recorded higher cob length of 19.3

Table 6 - Analysis of variance (pooled mean squares) for yield attributes and yield of maize as influenced by phosphorus and various liquid biofertilizers (kharif, 2016-2017)

Source of Variance	df	Pooled mean squares						
		Cob length	Cob girth	No. of grains/ row	No. of grain rows/cob	100 seed weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)
Replication	2	4.707222	2.932917	81.115135	1.326667	58.223751	1586691.875000	1991004.750000
Environments	1	0.050139	0.180000	0.390139	0.008889	0.073472	18208.679688	503171.687500
Interactions	2	7.790556	10.780416	0.622644	0.028889	11.902638	30664.285156	314257.281250
Total	5	5.009139	5.521333	32.773139	0.544000	28.065250	650584.213889	1022739.113889
Treatments	11	8.591957**	1.175000	9.294684	1.750909**	5.186402	1909053.892677**	5397820.529040**
Error	55	3.340775	1.869879	11.714412	0.145455	12.056765	157880.965404	1000012.610859
S.E.Diff from Mean		0.7144	0.5345	1.3378	0.1491	1.3572	155.3084	390.8704
CD(P= 0.05)		1.4317	1.0711	2.6810	0.2987	2.7199	311.2433	783.3175

(* = Significant at 5% level of probability, ** = Highly significant at 1% level of probability)

Table 7 - Analysis of variance (Pooled mean squares) for yield attributes and yield of maize as influenced by integrated nutrient management practices (kharif, 2018-2019)

Source of Variance	df	Pooled mean squares						
		Cob length	Cob girth	No. of grains/ row	No. of grain rows/cob	100 seed weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)
Replication	2	2.271061	0.189545	3.736515	0.426061	11.427320	418822.968750	179999.109375
Environments	1	120.015152	4.378788	64.212273	0.582424	1.744438	209785.468750	1059693.500000
Interactions	2	1.411060	0.636515	2.586818	0.258788	12.907228	221362.625000	1755218.750000
Total	5	25.475879	1.206182	15.371788	0.390424	10.082707	298031.324242	986025.833333
Treatments	11	17.367667**	9.884273**	7.060939*	0.515152	49.091879 **	13312613.536364**	41855019.527273**
Error	55	1.182612	0.453982	3.435521	0.292024	6.366806	180679.390909	523506.560000
S.E. Diff from Mean		0.4233	0.2623	0.7215	0.2103	0.9822	165.4559	281.6366
CD(P= 0.05)		0.8502	0.5268	1.4491	0.4225	1.9727	332.3268	565.6817

(* = Significant at 5% level of probability, ** = Highly significant at 1% level of probability)

cm which was comparable with T_2, T_3, T_8 and T_{10}. In *kharif* 2019, T_7 –100% RDF + FYM 5 t/ha recorded higher cob length of 22.3 cm which was comparable with T_8 and T_{10}. In respect of cob girth, T_7 –100% RDF + FYM 5 t/ha recorded higher cob girth of 15.9 cm and 16.3 cm during *kharif*, 2018 and *kharif*, 2019,respectively which was comparable with T_2, T_3, T_4, T_8, T_9 and T_{10} in both the years. The number of grain rows/cob and number of grains/row were not significantly influenced by the treatments in both the years. However, T_7 –100% RDF + FYM 5 t/ha recorded higher no. of grain rows/cob and no. of grains/row in both the years. During *kharif* 2018, there was no significant influence of treatments on 100 seed weight. Whereas in *kharif* 2019, T7 –100% RDF + FYM 5 t/ha recorded higher 100 seed weight of 38.7 g which was comparable with T_2, T_3, T_4, T_8, T_9 and T_{10} but was significantly superior to other treatments. The yield attributes of maize increased with application of FYM and increased levels of fertilizers which might be due to better availability of nutrients. The results are in accordance with the findings of Negassa *et al.*, 2001, Sharar *et al.*, 2003 and Shrestha *et al.*, 2018 who reported that the yield attributes increased with application of FYM and increased levels of fertilizer.

Table 8 - Correlations among yield and yield attributes of maize as influenced by phosphorus and various liquid biofertilizers (kharif, 2016-2017)

Yield attributes/yield	Year (cm)	Cob length	Cob girth (cm)	No. of grains/ row	No. of grain rows/cob	100 seed weight(g)	Grain yield (kg/ha)	Stover yield (kg/ha)
Cob length (cm)	2016	**1.0000**	0.0877	0.2593	0.3076	0.2098	0.5148	0.3831
	2017	**1.0000**	-0.0557	0.2788	0.3223	0.1319	0.6072*	0.4909
	Pooled	**1.0000**	0.0167	0.2689	0.3147	0.1716	0.5562	0.4353
Cob girth (cm)	2016	-	**1.0000**	-0.1080	0.2974	-0.2912	0.0672	0.2938
	2017	-	**1.0000**	0.1119	0.1141	-0.1164	0.0946	0.1356
	Pooled	-	**1.0000**	0.0046	0.2067	-0.2033	0.2151	0.0798
No. of grains/row	2016	-	-	**1.0000**	0.1329	0.2839	0.3323	0.4061
	2017	-	-	**1.0000**	0.1810	0.2283	0.1967	-0.1135
	Pooled	-	-	**1.0000**	0.1568	0.2557	0.2672	0.1460
No. of grain rows/cob	2016	-	-	-	**1.0000**	0.2567	0.6220*	0.5270
	2017	-	-	-	**1.0000**	0.2061	0.4897	0.4580
	Pooled	-	-	-	**1.0000**	0.2319	0.5611	0.4937
100 seed weight(g)	2016	-	-	-	-	**1.0000**	0.5516	0.1495
	2017	-	-	-	-	**1.0000**	0.2741	0.1431
	Pooled	-	-	-	-	**1.0000**	0.4220	0.1463
Grain yield (kg/ha)	2016	-	-	-	-	-	**1.0000**	0.6107*
	2017	-	-	-	-	-	**1.0000**	0.5976*
	Pooled	-	-	-	-	-	**1.0000**	0.6038*
Stover yield (kg/ha)	2016	-	-	-	-	-	-	**1.0000**
	2017	-	-	-	-	-	-	**1.0000**
	Pooled	-	-	-	-	-	-	**1.0000**

(* = Significant at 5% level of probability, ** = Highly significant at 1% level of probability)

Table 9 - Correlations among yield and yield attributes of maize as influenced by integrated nutrient management practices (kharif, 2017-2018)

Yield attributes/yield	Year	Cob length (cm)	Cob girth (cm)	No. of grains/ row	No. of grain rows/cob	100 seed weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)
Cob length (cm)	2018	**1.0000**	0.8182*	0.3981	0.5413	0.4078	0.8575*	0.9073*
	2019	**1.0000**	0.6090*	0.5951	0.1746	0.6895*	0.8282*	0.8287*
	Pooled	**1.0000**	0.7029*	0.5103	0.3498	0.5376	0.8386*	0.8611*
Cob girth (cm)	2018	-	**1.0000**	0.2688	0.4120	0.5588	0.8452*	0.8604*
	2019	-	**1.0000**	0.2189	0.3919	0.6807*	0.8200*	0.8596*
	Pooled	-	**1.0000**	0.2419	0.4020	0.6109*	0.8327*	0.8598*
No.of grains/row	2018	-	-	**1.0000**	0.1294	0.4842	0.3633	0.4971
	2019	-	-	**1.0000**	0.2863	0.5981	0.5565	0.5547
	Pooled	-	-	**1.0000**	0.2070	0.5323	0.4643	0.5252
No.of grain rows/cob	2018	-	-	-	**1.0000**	0.2775	0.5283	0.4228
	2019	-	-	-	**1.0000**	0.4952	0.4627	0.4456
	Pooled	-	-	-	**1.0000**	0.3696	0.4968	0.4331
100 seed weight(g)	2018	-	-	-	-	**1.0000**	0.7068*	0.6726*
	2019	-	-	-	-	**1.0000**	0.8548*	0.8252*
	Pooled	-	-	-	-	**1.0000**	0.7699*	0.7377*
Grain yield (kg/ha)	2018	-	-	-	-	-	**1.0000**	0.9145*
	2019	-	-	-	-	-	**1.0000**	0.9248*
	Pooled	-	-	-	-	-	**1.0000**	0.9194*
Stover yield (kg/ha)	2018	-	-	-	-	-	-	**1.0000**
	2019	-	-	-	-	-	-	**1.0000**
	Pooled	-	-	-	-	-	-	**1.0000**

(* = Significant at 5% level of probability, ** = Highly significant at 1% level of probability)

Effect of integrated nutrient management practices on yield and economics of maize

During *kharif*, 2018 and *kharif* 2019, T_7 –100% RDF + FYM 5 t/ha recorded higher grain yield of 7324 kg ha^{-1} and 7392 kg ha^{-1}, respectively which was comparable with T_{10}, T_2, T_8 and T_3 in both the years. The lowest yield of 3533 kg ha^{-1} and 3476 kg ha^{-1} was recorded in T_1 - Unmanured treatment during *kharif*, 2018 and *kharif*, 2019, respectively. The increase in yield due to application of FYM and increasing level of fertilizers might be ascribed to adequate quantities and balanced proportion of nutrients applied to the crop during the growth period. This improved the yield attributes, which finally resulted in higher grain yield. The results are in accordance with the findings of Thakur *et al.* (1997), Paramasivan *et al.* (2011) and Adhikari *et al.* (2021). During *kharif* 2018, T_7 –100% RDF + FYM 5 t/ha recorded higher stover yield of 12698 kg ha^{-1} which was comparable with T_2, T_3, T_8 and T_{10}. In *kharif* 2019, T_7 –100% RDF + FYM 5 t/ha recorded higher stover yield of 12803 kg ha^{-1} which was comparable with T_2, T_8 and T_{10}. The highest stover yield was due to greater contribution of nutrients and favorable change in physical properties of soil. Similar findings were reported by Khan *et al.*, 2011 and Shahzad Imran *et al.*, 2015. In respect of economics, during *kharif* 2018, T_2 -100% RDF recorded higher net return (Rs.72132/ha) and B:C ratio (2.48). In *kharif* 2019 also, T_2 –100% RDF recorded higher net return (Rs.73412/ha) and B:C ratio (2.50).This was followed by T_{10}, T_3 and T_7 in both the years.

Correlations among yield and yield attributes of maize

Experiment on phosphorus and various liquid biofertilizers in maize revealed that cob length evinced positive and significant (P = 0.05) correlation with grain yield (r = 0.6072) during 2017. The cob length was positively correlated with yield during 2016 and for pooled analysis (2016 and 2017) which was more than 0.5. Rafique *et al.* (2004) reported positive correlation (P= 0.05) of cob length with 1000 grain weight and grain yield. Number of grain rows/cob showed positive and significant (P = 0.05) correlation with grain yield (r = 0.6220) during 2016. The pooled analysis evinced positive correlation with grain yield (r = > 0.5). It was observed that grain yield showed positive and significant (P = 0.05) correlation with stover yield during 2016 (r = 0.6107), 2017 (r = 5976) and for pooled analysis(r = 0.6038).

Experiment on integrated nutrient management practices in maize revealed that cob length evinced positive and significant (P = 0.05) correlation with cob girth in both the years (r = 0.8182 and 0.6090), with 100 seed weight (r = 0.6895) during 2019 and with the grain yield in both the years (r = 0.8575 and 0.8282) and also for pooled analysis. (r = 0.8386). Cob girth showed positi-

ve and significant (P = 0.05) correlation with 100 seed weight during 2019 and for pooled analysis and with the grain yield in both the years (r = 0.8452 and 0.8200) and also for pooled analysis. (r = 0.8327). Positive and significant (P = 0.05) correlation of 100 seed weight was observed with grain yield in both the years (r = 0.7068 and 0.8548) and also for pooled analysis. (r = 0.7699). Grain yield showed positive and significant (P = 0.05) correlation with stover yield in both the years. Wajid *et al.* (2007) also reported similar correlation (P 0.05) between yield attributes and grain yield. Based upon the significance of correlations, improvement in yield attributes enhanced the yield of maize in both the experiments.

Conclusions

Based on the results of various experiments and significance of correlations, it could be concluded that application of 60 kg P_2O_5/ha + NPK consortia recorded higher grain yield (5293 kg ha^{-1}), net return (Rs.44,656/ha) and B: C ratio (2.02) which is the optimum level of phosphorus and suitable liquid biofertilizer for maize and application of 100% RDF (250:75:75 kg NPK/ha) recorded higher grain yield (7318 kg ha^{-1}), net return (Rs.72772/ha) and B:C ratio (2.49) in maize.

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