Indian Journal of Agricultural Sciences **88** (10): 1558–67, October 2018/Article

Effect of tillage, crop residue and phosphorus management practices on the productivity and profitability of maize (*Zea mays*) cultivation in Inceptisols

AMIT KUMAR[1], U K BEHERA[2], SHIVA DHAR[3], LIVLEEN SHUKLA[4], ARTI BHATIYA[5], M C MEENA[6] GAURENDRA GUPTA[7] and RAMESH KUMAR SINGH[8]

ICAR–Indian Agricultural Research Institute, New Delhi 110 012

Received: 13 April 2018; Accepted: 11 July 2018

ABSTRACT

A field experiment was conducted during *kharif* seasons of 2016–17 and 2017–18 at the research farm of ICAR–Indian Agricultural Research Institute, New Delhi to evaluate the effect of tillage, residue and phosphorus management practices on the growth, yield attributes, yield and economics of maize (*Zea mays* L.). The experiment comprised 15 treatment combinations laid out in a split–plot design with three replications. The main–plot treatments included three different tillage practices : CT–R (Conventional tillage with no residue), ZT–R (Zero tillage with no residue), ZT+R (Zero tillage with residue @ 2.5 t/ha for both maize and wheat) and sub–plot treatments included five phosphorus management practices: P_1 (Control–NK as per recommendation, but no P), P_2 (17.20 kg P/ha), P_3 (17.20 kg P/ha + PSB), P_4 (17.20 kg P/ha + Compost inoculants) and P_5 (34.40 kg P/ha). Results revealed that, among the tillage practices, ZT+R found significant effect on growth and yield attributes of maize compared to CT–R during both the years of experiment. Different phosphorus management practices, application of 34.40 kg P/ha significantly improved the growth and yield attributes of maize compared to control treatment during both the years. Combined use of conservation agricultural practices (zero tillage with crop residue retention of 2.5 t/ha both the crops) along with application of 34.40 kg P/ha resulted significantly higher grain yield (6.40 and 6.49 t/ha), gross returns (105 and 114 $\times 10^3$ ₹/ha) and net returns (64 and 72 $\times 10^3$ ₹/ha) during both the years of experiment but B:C ratio was maximum under combination of ZT–R with application of 34.40 kg P/ha during both the years.

Key words: Productivity, Profitability, Tillage

In recent years, a great threat to sustainability because intensive tillage and monoculture of rice–wheat cropping system has posed that results resource degradation, decline in factor productivity and profitability (Parihar *et al*. 2016). Under this situation, diversification of rice in *kharif* with other alternative crops, viz. maize has better option in order to reverse the above declining factors and increased the profit of farmers (Behera *et al*. 2007). Maize (*Zea mays* L.), an important crop for food and nutritional security in India, is grown in diverse ecologies and seasons. Globally, it provides approximately 30% of the food calories to more than 4.5 billion peoples in 94 developing countries, and the demand of maize is expected to double worldwide by 2050. To meet the rising demand, a quantum jump in maize production is required. In India, maize is cultivated 9.2 million ha, with a productivity of 2700 kg/ha. Productivity of maize is low due to indiscriminate use of chemical fertilizers, intensive tillage and other faulty management practices. Deficiency of phosphorus (P) is considered to be one of the major limiting factors for crop production particularly in low–input agricultural systems. P is a major growth–limiting nutrient, and unlike the case for nitrogen, there is no large atmospheric source that can be made biologically available (Ezawa *et al*. 2002). Currently P fertilizer is very expensive as they are being totally imported. Efficiency of P fertilizer throughout the world is around 10–25% (Goldstein 2000), and concentration of bio–available P in soil is very low reaching the level of 1.0 mg/kg soil (Gyaneshwar *et al*. 2002). Productivity and profitability of maize crop is declining, crop is nutrient exhaustive, deteriorate soil fertility and pose great threat to the natural resources (Prasad 2005). Therefore, there is a need to find out eco–friendly, feasible and cheaper options to meet the P needs of the crops grown in cropping system. Moreover, it becomes imperative to sustain the productivity of this cropping system through alternative and efficient technologies such as zero tillage. Zero tillage is emerging as a way of transition to the sustainability of intensive production systems, besides, generating net social

[1]Ph D student (amitkumaricar13@gmail.com), [2] Principal Scientist (UKb2008@gmail.com), [3]Principal Scientist (e mail: shiva_agro@iari.res.in), Division of Agronomy, [4]Principal Scientist, (e mail: Livleen@ iari.res.in), Division of Microbiology, [5]Principal Scientist (e mail: ab_ensc@iari.res.in), Division of CESCRA, [6]Senior Scientist (e mail: mcmeena@gmail.com), Division of SSAC, [7] Ph D student (e mail: guptagaurendra@gmail.com), [8]Ph D student, (e mail: rksv1990@gmail.com), Division of Agronomy.

Table 1 Growth parameters of maize influenced by tillage, residue and phosphorus management practices during rainy season 2016–17 and 2017–18

Treatment	Plant height (cm)		Dry matter accumulation (g/plant)		Crop growth rate (g/m^2/day)		Relative growth rate (mg/g/day)		Leaf area index		Net assimilation rate (g/m^2/day)	
	At harvest stage		At harvest stage		60–90 DAS		30–60 DAS		30–60 DAS		30–60 DAS	
	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18
Tillage practices												
CT–R	182.02	184.02	129.40	134.93	11.87	13.64	24.80	25.12	3.59	3.62	0.25	0.25
ZT–R	190.93	196.60	142.40	147.45	13.59	15.35	26.97	27.98	3.86	3.89	0.28	0.29
ZT+R	199.52	202.26	149.20	152.35	14.55	16.17	27.90	28.15	3.99	4.10	0.30	0.31
SEm±	2.96	3.41	2.84	2.40	0.37	0.45	2.17	1.63	0.06	0.06	0.01	0.01
LSD (P=0.05)	11.61	13.38	11.15	9.43	1.47	1.37	NS	NS	0.25	0.23	0.03	0.04
Phosphorus management practices												
P1	181.88	185.48	124.56	126.96	11.34	12.45	24.72	25.01	3.43	3.48	0.25	0.26
P2	186.41	189.47	133.67	138.77	12.39	14.14	26.18	26.52	3.65	3.80	0.27	0.27
P3	194.31	198.49	146.67	151.78	14.23	16.04	27.05	27.88	3.96	4.01	0.28	0.30
P4	190.85	194.01	142.00	147.95	13.56	15.24	26.71	27.80	3.91	3.91	0.28	0.29
P5	200.67	204.00	154.78	159.11	15.17	17.39	28.13	28.19	4.11	4.16	0.30	0.31
SEm±	2.66	2.71	3.13	2.60	0.46	0.47	1.38	1.15	0.06	0.07	0.01	0.01
LSD (P=0.05)	7.77	7.91	9.15	7.59	1.35	1.38	NS	NS	0.17	0.20	0.02	0.03
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

gains to society (Bhale and Wanjari 2009). Soil conditions and nutrient dynamics change under reduced tillage. Hence, the nutrient management practices need to be different as compared to conventional tillage systems.

Hence, the study was undertaken to evaluate the performance of maize under varying phosphorus, tillage and crop residue management practices in inceptisols.

MATERIALS AND METHODS

The experiment was conducted in an on–going field experiment on conservation agriculture which was initiated during *kharif* season of 2013 in the Mid–A 5 block of ICAR–IARI research farm, New Delhi is situated at 28°35'N latitude, 77°12'E longitude and at an altitude of about 228.6 m above mean sea level. The soil of experimental field was sandy clay loam in texture, bulk density (1.52 Mg/m^3), pH 8.2, EC (0.35 dS/m), CEC (12.14 Cmol/kg), low in organic carbon (0.43%), available N (191 kg/ha), medium in available P (11.92 kg/ha) and medium in available K (208 kg/ha). The experiment comprised 15 treatment combinations, with main–plot having three tillage practices, i.e. CT–R (Conventional tillage with no residue), ZT–R (Zero tillage with no residue), ZT+R (Zero tillage with residue @ 2.5 t/ha for maize and wheat) and sub–plot treatment having five phosphorus management practices, i.e. P_1 (Control–NK as per recommendation, but no P), P_2 (17.2 kg P/ha), P_3 (17.2 kg P/ha + PSB), P_4 (17.2 kg P/ha + compost inoculants) and P_5 (34.40 kg P/ha) and laid out in split–plot design with three replications. The fertilizer nutrients were supplied through urea, diammonium phosphate and muriate of potash. Full dose of phosphorus (as per treatment), potassium and half of nitrogen were applied at sowing. Remaining half of nitrogen was applied at knee high stage. Maize cultivar PMH–1 was sown in row to row spacing 70 cm and plant to plant spacing 20 cm apart during mid July with a seed rate of 25 kg/ha. Normal standard crop husbandry practices were followed for successful rising of the crop. The observations were recorded on plant height, dry matter accumulation, yield attributes and yield. The information were analysed statistically among the standard procedure of ANOVA technique and treatments compressions are made at 5% level of significance.

RESULTS AND DISCUSSION

Growth parameters

Among the different tillage management practices found significant effect on plant height at harvest stages of crop growth. However, at harvest, maximum plant height (199.52 and 202.26 cm) was found under ZT+R treatment which was statistically at par with ZT–R treatment and significantly higher than CT–R treatment during both the years of experiment. The increase in plant height might be due to adequate availability of NPK attributed to better nutritional environment for plant growth at active vegetative stages as a result of enhancement in cell multiplications, cell elongation and cell expression in the plant body which ultimately increased the height of plant. The results of present investigation are also in agreement with the findings of (De Vita *et al.* 2007).

The different phosphorus management practices had significant effect on plant height at harvest stages of crop growth during both the years of experiment. The maximum plant height (201 and 204 cm) at harvest stage was found with the application of P_5 (34.4 kg P/ha) treatment which was statistically similar with P_3 (17.2 kg P/ha+ PSB) treatment

Table 3 Yield of maize influenced by tillage, residue and phosphorus management practices during rainy season 2016–17 and 2017–18

Treatment	Seed yield (t/ha)		Stover yield (t/ha)		Biological yield (t/ha)		Harvest index	
	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18
Tillage practices								
CT–R	4.91	5.01	7.98	8.44	13.84	13.94	35.47	35.96
ZT–R	5.45	5.55	8.82	9.34	15.33	15.45	35.57	35.98
ZT+R	5.91	6.00	9.44	10.04	16.55	16.64	35.80	36.22
SEm±	0.13	0.12	0.23	0.26	0.37	0.40	0.82	0.72
LSD (P=0.05)	0.51	0.48	0.92	1.02	1.44	1.59	NS	NS
Phosphorus management practices								
P1	4.02	4.06	6.59	6.94	11.49	11.40	35.08	35.75
P2	5.25	5.37	8.72	9.14	14.86	15.04	35.25	35.68
P3	5.86	5.95	9.45	9.98	16.45	16.53	35.73	36.08
P4	5.58	5.73	8.97	9.63	15.70	15.93	35.62	35.99
P5	6.40	6.49	10.01	10.69	17.69	17.83	36.40	36.77
SEm±	0.10	0.11	0.24	0.26	0.44	0.49	0.73	0.61
LSD (P=0.05)	0.28	0.32	0.69	0.76	1.28	1.44	NS	NS
Interaction	S	S	NS	NS	NS	NS	NS	NS

Table 2 Yield attributes of maize influenced by tillage, residue and phosphorus management practices during rainy season 2016–17 and 2017–18

Treatment	Cob length (cm)		Cob girth (cm)		Number of grains row/cob		Number of grains/row		Number of grains/cob		1000 grain weight (g)	
	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18
Tillage practices												
CT–R	16.76	16.96	10.95	12.50	12.90	13.09	30.77	31.73	399.43	421.15	257.52	259.86
ZT–R	17.27	17.60	11.54	13.50	13.33	13.80	33.58	34.27	450.07	474.70	258.98	260.14
ZT+R	17.35	17.74	12.14	13.77	14.00	14.55	35.89	36.13	505.17	528.94	262.87	263.73
SEm±	0.32	0.32	0.29	0.31	0.19	0.23	0.53	0.45	11.72	12.39	2.95	3.78
LSD (P=0.05)	NS	NS	1.12	1.20	0.76	0.89	2.07	1.75	46.02	48.65	NS	NS
Phosphorus management practices												
P1	14.22	15.33	10.05	11.83	12.00	12.28	28.43	29.78	340.80	367.67	257.22	257.44
P2	16.60	16.53	11.03	12.65	12.78	12.78	31.42	32.56	401.47	419.72	259.52	260.33
P3	18.36	18.60	12.24	13.81	14.11	14.56	36.25	36.44	511.54	532.33	260.36	261.87
P4	17.72	17.80	11.64	13.68	13.50	14.26	34.07	34.11	461.68	488.12	259.94	263.39
P5	18.73	18.93	12.74	14.31	14.67	15.20	36.89	37.33	542.28	566.80	261.91	263.19
SEm±	0.31	0.38	0.21	0.35	0.25	0.31	0.77	0.83	13.13	15.05	3.25	4.73
LSD (P=0.05)	0.92	1.10	0.61	1.03	0.73	0.90	2.24	2.42	38.32	43.94	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

and significantly higher than all the remaining treatments respectively. Because favourable effect on plant growth with different phosphorus levels over control treatment may be attributed to better nutrient availability and number of metabolic processes taking place in the plant body, which in turn are affected by a variety of inherent and environmental factors to which plant is exposed (Kumar *et al.* 2014).

Dry matter accumulation was slow during initial stages of crop growth but increased drastically at 60 DAS. The different tillage management practices found significant effect on dry matter accumulation at harvest stages. However, at harvest stage, maximum dry matter accumulation (149 and 152 g/plant) was found under conservation tillage treatment which was statistically at par with zero tillage treatment and significantly higher than conventional tillage treatment during both the years of experiment. Dry matter accumulation per plant is an ultimate result of all the metabolic processes occurring inside the plant. The higher value of total dry matter/plant might be due to higher values of more number of leaves, primary, secondary and total branches and also higher uptake of nutrients by the crop, more photosynthesis which is reflected from the LAI values and ultimately results higher dry matter accumulation. The results of present investigation are also confirming the observations of Singh *et al.* (2001).

Different phosphorus management practices recorded significant effect on dry matter accumulation at harvest stages during both the years of experiment. However, highest dry matter accumulation (155 and 159 g/plant) at harvest stage was found with the application of P_5 (34.4 kg P/ha) which was statistically at par with P_3 (17.2 kg P/ha + PSB) treatment and significantly higher than all other treatments respectively. The recommended nutrient application made higher nutrients available to plants resulted in to more dry matter accumulation (Pooniya *et al.* 2015). The results also revealed higher available nutrients at prime vegetative growth of the crop at higher fertility levels as dry matter accumulation varied sharply from 30 to 60 DAS and maintaining higher leaf area index which might have resulted higher photosynthetic activity at higher fertility levels (Dwivedi *et al.* 2003).

In general, the CGR decreased with advancement of crop age resulting from senescence of leaves. Crop growth rate were influenced significantly by different tillage practices at 60-90 DAS during both the years of experiment. However, at 60–90 DAS, maximum crop growth rate (14.5 and 16.7 g/m^2/day) was found under ZT+R treatment which was statistically at par with ZT–R treatment but, significantly higher than CT–R treatment. The increase in crop growth rate might be due to adequate availability of nutrients (NPK) attributed to better nutritional environment for plant growth at active vegetative stages as a result of enhancement in cell multiplications, cell elongation and cell expression in the plant body which ultimately increased the CGR. The results

Table 4 Interaction effect of tillage, residue and phosphorus management practices on grain yield of maize during rainy season 2016–17 and 2017–18

Treatment	Grain yield (t/ha)							
	2016–17				2017–18			
	CT–R	ZT–R	ZT+R	Mean	CT–R	ZT–R	ZT+R	Mean
P1	3.79	4.08	4.19	4.02	3.86	4.14	4.17	4.06
P2	4.70	5.27	5.78	5.25	4.88	5.29	5.92	5.37
P3	5.20	6.00	6.39	5.86	5.27	6.09	6.50	5.95
P4	5.20	5.68	5.88	5.58	5.26	5.93	5.99	5.73
P5	5.68	6.22	7.30	6.40	5.75	6.31	7.41	6.49
Mean	4.91	5.45	5.91	5.42	5.01	5.55	6.00	5.52
	SEm±		*LSD (P=0.05)*		*SEm±*		*LSD (P=0.05)*	
Factor(A)at same or different level of B	0.20		0.68		0.21		0.69	
Factor(B)at same level of A	0.29		0.57		0.28		0.62	

of present investigation are also in agreement with the finding of Hulugalle *et al.* 1(997). Various phosphorus management practices influence significant effect on crop growth rate at 60–90 DAS during both the years of experiment. However, higher value of crop growth rate (15.2 and 17.4 g/m^2/day) at 60–90 DAS was obtained with the application of P_5 (34.4 kg P/ha) treatment, which was statistically at par with P_3 (17.2 kg P/ha+ PSB) treatment and significantly higher than P_1 (Control – NK as per recommendation, but no P) and P_2 (17.2 kg P/ha) and P_4 (17.2 kg P/ha+ Compost inoculants) treatments. CGR is a function of dry matter accumulation which is reflected from LAI, as higher fertility levels also maintaining higher leaf area index though both decreased with advancement of crop age (Gupta *et al*. 2011).

Among the different tillage management practices found non–significant effect on relative growth rate at 30–60 DAS. However, higher relative growth (27.9 and 18.1 mg/g/day) rate at 30–60 DAS was found under conservation tillage treatment and lowest relative growth rate was found under conventional tillage treatment during both the years of experiment. This might be due to the facts that the nitrogen is directly involved in multiplication, elongation and expansion of cells which ultimately produced the more plant height and number of leaves/plant, LAI, and CGR, thereby directly

Table 5 Economics of maize influenced by tillage, residue and phosphorus management practices during rainy season 2016–17 and 2017–18

Treatment	Gross returns (10^3 × ₹/ha)		Cost of cultivation (10^3 × ₹/ha)		Net returns (10^3 × ₹/ha)		B:C ratio	
	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18
Tillage practices								
CT–R	81.07	88.24	39.49	40.85	41.58	47.36	1.05	1.15
ZT–R	89.84	97.82	36.43	37.60	53.41	60.21	1.46	1.59
ZT+R	97.15	105.55	39.35	40.70	57.80	64.85	1.46	1.58
SEm±	1.96	1.98	0.00	0.00	1.29	1.60	0.03	0.03
LSD (P=0.05)	7.68	7.76	0.00	0.00	5.07	6.28	0.11	0.12
Phosphorus management practices								
P1	66.46	71.70	36.17	37.29	30.28	34.38	0.84	0.93
P2	86.99	94.74	38.33	39.62	48.66	55.11	1.27	1.39
P3	96.57	104.81	38.41	39.70	58.16	65.11	1.52	1.65
P4	91.94	100.88	38.71	40.00	53.23	60.88	1.38	1.53
P5	104.81	113.87	40.50	41.96	64.32	71.88	1.59	1.71
SEm±	1.26	1.33	0.00	0.00	1.23	1.31	0.02	0.03
LSD (P=0.05)	3.67	3.88	0.00	0.00	3.60	3.82	0.07	0.10
Interaction	S	S			S	S	S	S

Table 6 Interaction effect of tillage, residue and phosphorus management practices on gross return of maize during rainy season 2016–17 and 2017–18

Treatment	Gross return (×10³ ₹/ha)							
	2016–17				2017–18			
	CT–R	ZT–R	ZT+R	Mean	CT–R	ZT–R	ZT+R	Mean
P1	62.98	67.60	68.79	66.46	68.59	73.19	73.32	71.70
P2	78.28	87.43	95.27	86.99	86.56	93.29	104.38	94.74
P3	85.66	98.87	105.17	96.57	92.83	107.32	114.27	104.81
P4	85.56	93.55	96.70	91.94	92.61	104.63	105.40	100.88
P5	92.85	101.75	119.82	104.81	100.60	110.67	130.35	113.87
Mean	81.07	89.84	97.15	89.35	88.24	97.82	105.55	97.20
	SEm±		*LSD (P=0.05)*		*SEm±*		*LSD (P=0.05)*	
Factor (A) at same or different level of B	3.18		10.66		3.31		11.01	
Factor (B) at same level of A	4.37		9.41		4.42		9.88	

and hence reflecting increased dry matter accumulation in plants at higher levels of phosphorus resulted increased RGR when the crop reached to maturity, shedding of leaves and resulted CGR also reduced. Similar observations were also reported by Das *et al*. (2018). The different phosphorus management practices influenced non–significant effect on relative growth rate at 30–60 DAS during both the years of experiment. However, higher value (28.13 and 28.19 mg/g/day) of relative growth rate at 30–60 was found with the application of P_5 (34.4 kg P/ha) treatment and lowest value of relative growth rate was found with the application of control treatment.

The different tillage management practices found significant effect on leaf area index at 30–60 DAS. However, at 30–60 DAS, maximum leaf area index (3.9 and 4.1) was found under ZT+ R treatment which was statistically at par with ZT–R treatment but significantly higher than CT–R treatment during both the years of experiment. Higher LAI under ZT+ R treatment might be ascribed to better growth of maize plant due to more supply of nitrogen, phosphorus and potash. Nitrogen being essential part of protoplasm involves in cell division and thus favours more production of leaves (Karuna Karan and Behera 2015). Similar observations were reported by Wang *et al.* (2007).

Among the phosphorus management practices were recorded significant effect on leaf area index at 30–60 DAS during both the years of experiment. At 30–60 DAS, maximum leaf area index (4.11 and 4.16) was found with the application of P_5 (34.4 kg P/ha) treatment which was statistically similar with P_3 (17.2 kg P/ha+ PSB) treatment and significantly higher than all other treatments respectively. Because availability of nutrients in adequate amount resulted sufficient formation of photosynthates which promote the metabolic activities, accelerated cell

Table 7 Interaction effect of tillage, residue and phosphorus management practices on net return of maize during rainy season 2016–17 and 2017–18

Treatment	Net return (×10³ ₹/ha)							
	2016–17				2017–18			
	CT–R	ZT–R	ZT+R	Mean	CT–R	ZT–R	ZT+R	Mean
P1	25.74	33.42	31.69	30.28	30.07	38.02	35.05	34.38
P2	38.88	51.09	56.00	48.66	45.75	55.81	63.78	55.11
P3	46.19	62.46	65.83	58.16	52.00	69.74	73.59	65.11
P4	45.79	56.83	57.06	53.23	51.48	66.75	64.42	60.88
P5	51.29	63.25	78.43	64.32	57.51	70.73	87.41	71.88
Mean	41.58	53.41	57.80	50.93	47.36	60.21	64.85	57.47
	SEm±		*LSD (P=0.05)*		*SEm±*		*LSD (P=0.05)*	
Factor (A) at same or different level of B	2.78		8.82		3.06		9.92	
Factor (B) at same level of A	2.88		8.73		3.57		9.46	

division and formation of meristemtic tissues, number of functional leaves per plant increased, ultimately enhanced leaf area index. These results are in conformity with the findings of Modak *et al.* (1994) the higher leaf area is also reflected from better survival lower leaves, results from prolonged nutrition of the crop and growth activities at higher fertility levels as evidenced from the data.

The various tillage management practices influence significant effect on net assimilation rate at 30–60 DAS. However, maximum net assimilation (0.30 and 0.31 $g/m^2/day$) rate at 30–60 DAS was found under ZT+R treatment which was statistically at par with ZT–R treatment but significantly higher than CT–R treatment during both the years of experiment. In cereals such as maize an increase in photosynthetic capacity is associated with decrease in specific leaf area resulting in increased N content and thus higher photosynthetic capacity that ultimately resulted more dry matter accumulation and net assimilation rate (Kang and Yunusa 1989).Various phosphorus management practices influenced significant effect on net assimilation rate at 30–60 DAS during both the years of experiment. However, highest value of net assimilation rate (0.30 and 0.31 $g/m^2/day$) at 30–60 DAS was obtained with the application of P_5 (34.4 kg P/ha) treatment, which was statistically at par with P_3 (17.2 kg P/ha + PSB) and P_4 (17.2 kg P/ha + Compost inoculants) treatment but significantly higher than P_1 (Control – NK as per recommendation, but no P) and P_2 (17.2 kg P/ha) treatments respectively. The increase in NAR with increase in P probably may be due P being the components of ATP might have contributed to a higher photosynthetic rate, abundant vegetative growth and assimilates formation and partitioning that resulted more dry matter accumulation and leaf area/plant (Lu *et al*. 1995). The results are also in accordance with those of (Amanullah *et al*. 2014) who reported increase in NAR by increasing dry matter partitioning and accumulation while increasing rate of P.

Yield attributes and yield

Among the different tillage management practices influence significant effect on yield attributing characters of crop except cob length and 1000 grain weight. However, maximum cob length and 1000 grain weight was found under ZT+R treatment and minimum cob length and 1000 grain weight was found under conventional tillage treatment during both the years of experiment. While, significantly maximum cob girth and number of grain rows/cob was found under ZT+R treatment which was statistically similar with ZT–R treatment and significantly higher than CT–R treatment during both the years of experiment. But, maximum number of grains/row and grains/cob was found under ZT+R treatment which was significantly higher over ZT–R and CT–R treatment during both the years of experiment. This might be due to early and better establishment of maize on zero tillage with residue retention, as these might have helped to maintain favourable soil moisture, moderate soil temperature and improve nutrient condition (Ram *et al.* 2010, Amgain *et al.* 2013). Residue retention in zero tillage increased crop yields more than their soil incorporation in conventional tillage. Zero tillage and residue retention improve soil organic C, microbial biomass C, dehydrogenase activity, earthworm population and water availability, consequently results in good crop growth and productivity (Ghosh *et al.* 2010, Das *et al*. 2013).

Among the different phosphorus management practices influence significant effect on yield attributing characters of crop except 1000 grain weight during both the years of experiment. However, maximum cob girth was found with the application of P_5 (34.4 kg P/ha) treatment which was statistically at par with P_3 (17.2 kg P/ha+ PSB) treatment and significantly higher than rest of the treatments during first year but during the second year maximum cob girth

Table 8 Interaction effect of tillage, residue and phosphorus management practices on B:C ratio of maize during rainy season 2016–17 and 2017–18

Treatment	B:C ratio							
	2016–17				2017–18			
	CT–R	ZT–R	ZT+R	Mean	CT–R	ZT–R	ZT+R	Mean
P1	0.69	0.98	0.85	0.84	0.78	1.08	0.92	0.93
P2	0.99	1.41	1.42	1.27	1.12	1.49	1.57	1.39
P3	1.17	1.72	1.67	1.52	1.27	1.86	1.81	1.65
P4	1.15	1.55	1.44	1.38	1.25	1.76	1.57	1.53
P5	1.23	1.64	1.89	1.59	1.34	1.78	2.03	1.71
Mean	1.05	1.46	1.46	1.32	1.15	1.59	1.58	1.44
	SEm±		*LSD (P=0.05)*		*SEm±*		*LSD (P=0.05)*	
Factor (A) at same or different level of B	0.05		0.17		0.07		0.23	
Factor (B) at same level of A	0.06		0.16		0.06		0.18	

was found with the application of P_5 (34.4 kg P/ha) treatment which was statistically at par with P_3 (17.2 kg P/ha+ PSB) and P_4 (17.2 kg P/ha + Compost inoculants) treatments and significantly higher over P_1 (Control – NK as per recommendation, but no P) and P_2 (17.2 kg P/ha) treatments. While, maximum cob length, number of grains rows/cob, number of grains/row and grains/cob was found with the application of P_5 (34.4 kg P/ha) treatment which was statistically at par with P_3 (17.2 kg P/ha + PSB) treatment and significantly higher than rest of the treatments. The maximum 1000 grain weight was found with the application of P_5 (34.4 kg P/ha) treatment and lowest 1000 grain weight was found with the application of control treatment. The higher values of yield attributes were due to the effect on root development, energy transformation and metabolic processes of plant and resulted in more translocation of photosynthates towards the sink development (Khan *et al.* 2010).

Seed yield, stover yield and biological yield were influenced significantly by different tillage practices except harvest index during both the years of experiment. However, maximum seed yield (5.9 and 6 t/ha), stover yield (9.4 and 10.0 t/ha) and biological yield (16.5 and 16.6 t/ha) was found under ZT+R treatment which was statistically similar with ZT–R treatment and significantly higher than CT–R treatment during both the years of experiment. While, highest harvest index was found under ZT+R treatment and lowest harvest index was found under CT–R treatment. The increase in grain and biological yield may be due to the availability of nutrients at various critical crop growth stages in optimal amount which might have increased the growth and yield attributes of maize thus resulting in the increased grain and biological yield. This is in conformity to the results of Kumar and Yadav (2005). Enhancement in growth and yield attributes leads to better photosynthetic partitioning and source–sink relationship, which gave higher yield in maize. The similar findings were reported by Ameta and Hargilas (2014) and Hargilas (2016). Yield improvements in RT systems over CT systems could be due to a host of factors, namely, lower weed density, reduced competition to resources, improved soil water regimes and better water extraction, aeration and fertilizer use rather than tillage methods per se (Unger and Jones 1989).

The significant effect of various phosphorus management practices was found on seed yield, stover yield and biological yield of crop except harvest index during both the years of experiment. However, maximum seed yield (6.4 and 6.5 t/ha) was found with the application of P_5 (34.4 kg P/ha) treatment which was significantly higher than rest of the treatments. But, maximum stover (10 and 10.7 t/ha) and biological yield (17.7 and 17.8 t/ha) was found with the application of P_5 (34.4 kg P/ha) treatment which was statistically similar with P_3 (17.2 kg P/ha+ PSB) treatment and significantly higher than all other treatments. While, maximum harvest index was found with the application of P_5 (34.4 kg P/ha) treatment and minimum harvest index was found with the application of control treatment. Thus, the increase in grain yield due to phosphorus was directly related to the vegetative and reproductive phases of the crop and attributes complex phenomenon of phosphorus utilization in plant metabolism. It also helped in the efficient absorption and utilization of the other required plant nutrients which ultimately increased the grain yield (Sepat and Rai 2013). The similar results and observations were also reported by Singaram and Kothandaraman (1991).

The interaction effect between tillage and phosphorus management practices on grain yield was found significant during both the years of experiment (Table 4). ZT+R along with application of 34.40 kg P/ha gave the higher grain yield (7.30 and 7.41 t/ha) than other treatment combinations during both the years respectively.

Economics

Economics of different treatments were influenced significantly due to various tillage management practices during both the years of experiment (Table 5). However, higher gross (97 and 105 $\times 10^3$ ₹/ha) and net returns (57 and 64.8 $\times 10^3$ ₹/ha) were found under ZT+R treatment which was statistically at par with ZT–R treatment and significantly higher than CT–R treatment. Cost of cultivation varies from treatment to treatment but highest cost of cultivation (39.5 and 40.8 $\times 10^3$ ₹/ha) was found under CT–R followed by ZT+R treatment and lowest cost of cultivation was found under ZT–R treatment. While, maximum B: C ratio (1.46 and 1.49) was found under ZT–R treatment which was statistically at par with ZT+R treatment and significantly higher than CT–R treatment.

Among the different phosphorus management practices influence significant effect on economics of different treatments during both the years of experiment. However, maximum gross return (104.8 and 113.8 $\times 10^3$ ₹/ha), cost of cultivation (40.5 and 41.9 $\times 10^3$ ₹/ha) and net returns (64.3 and 71.8 $\times 10^3$ ₹/ha) were found with the application of P_5 (34.4 kg P/ha) treatment which was significantly higher than all remaining treatments. While, maximum B: C ratio was found with the application of P_5 (34.4 kg P/ha) treatment which was statistically similar with P_3 (17.2 kg P/ha+ PSB) treatment and significantly higher than remaining treatments. The results of present investigation indicated appreciable variation in net return due to different tillage and phosphorus levels. In general, net return and B: C ratio is a function of total cost of cultivation and gross return per hectare. Higher the B: C ratio, net return was more. These results are in close conformity with those of Khan *et al.* (2010).

The interaction studies indicated that ZT+R treatment along with application of 34.40 kg P/ha was found to interact significantly with other combinations in respect to gross returns (119.8 and 130.3 $\times 10^3$ ₹/ha) and net returns (78.4 and 87.4 $\times 10^3$ ₹ /ha) during both the years of experiment. Interaction effect of tillage and phosphorus management practices on B: C ratio was found to be significant during both the years of experiment. ZT–R along with application of 34.40 kg P/ha has found superior over rest of the combinations regarding B: C ratio (1.89 and 2.03).

Conclusion

Conservation agricultural practices (zero tillage with crop residue application of 2.5 t/ha both the crops) along with application of 34.40 kg P/ha resulted significantly maximum grain yield (6.40 and 6.49 t/ha), gross returns (104.81 and 113.87 $\times 10^3$ ₹ /ha) and net returns (64.32 and 71.88 $\times 10^3$ ₹ /ha) during both the years of experiment.

REFERENCES

Amanullah, Majidullah and Khan I. 2014. Pheno–morphological traits of mungbean as influenced by phosphorous and tillage under irrigated and un–irrigated conditions. *Pure* and *Applied Biology* **3**(2): 55–9.

Ameta G S and Hargilas. 2014. Enhancing productivity and profitability of maize–wheat cropping system through site–specific nutrient management. (*In*) *Extended Summaries, 12 Asian Maize Conference and Expert Consultation on Maize for Food, Feed, Nutrition and Environment Security*. 30 October–1 November 2014, Bangkok, pp 90–1.

Amgain L P, Sharma A R, Das T K and Behera U K. 2013. Effect of residue management on productivity and economics of pearlmillet (*Pennisetum glaucum*) – based cropping system under zero–till condition. *Indian Journal of Agronomy* **58**(3): 298–302.

Behera U K, Sharma A R and Pandey H N. 2007. Sustaining productivity of wheat soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant and Soil* **297**: 185–99.

Bhale V M and Wanjari S S. 2009. Conservation agriculture: A new paradigms to resource use efficiency. *Indian Journal of Agronomy* **54**(2):167–77.

Das T K, Bhattacharyya Ranjan, Sharma A R, Das S, Saad A A and Pathak H. 2013. Impacts of conservation agriculture on total soil organic carbon retention potential under an irrigated agro–ecosystem of the western Indo–Gangetic Plains. *European Journal of Agronomy* **51**: 34–42.

Das T K, Saharawat Y S, Bhattacharyya R, Sudhishri S, Bandyopadhyay K K, Sharma A R and Jat M L. 2018. Conservation agriculture effects on crop and water productivity, profitability and soil organic carbon accumulation under a maize–wheat cropping system in the North–western Indo–Gangetic Plains. *Field crops Research* **215**: 22–231.

De Vita P, Di Paolo E, Fecondo G, Di Fonzo N and Pisante M. 2007. No tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy. *Soil and Tillage Research* **92**: 69–78.

Dwivedi B S, Shukla A K, Singh V K and Yadav R L. 2003. Improving nitrogen and phosphorus use efficiencies through inclusion of forage cowpea in the rice–wheat systems in the Indo–Gangetic Plains of India. *Field Crops Research* **84**: 399–418.

Ezawa T S Eand Smith F A. 2002. P metabolism and transport in A M fungi. *Plant and Soil* **244**: 221–30.

Ghosh P K, Das A, Saha R, Kharkrang E, Tripathi A K, Munda G C and Nagachan S V. 2010. Conservation agriculture towards achieving food security in North East India. *Current Science* **99**(7): 915–21.

Goldstein A H. 2000. Bio processing of rock phosphate ore: essential technical considerations for the development of a successful commercial technology. Proc. 4th Int. Fert. Assoc. Tech. Conf, IFA, Paris, p 220.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*. Second. Edition, p 680, John Wiley and Sons, New York.

Gupta M, Bali S A, Kour S, Bharat R and Bazaya B R. 2011. Effect of tillage and nutrient management on resource conservation and productivity of wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **56**(2): 116–20.

Gyaneshwar P, Kumar G N, Parekh L J and Poole P S. 2002. Role of soil microorganisms in improving P nutrition of plants. *Plant and Soil* **245**: 83–93.

Hargilas. 2016. Evaluation of site–specific nutrient management approach in transplanted rice under sub–humid condition of Rajasthan. *Journal of Plant Development Sciences* **8**(1): 33–6.

Hulugalle N R, Lobry de Bruyn L A, Entwistle P. 1997. Residual effects of tillage and crop rotation on soil properties, soil invertebrate numbers and nutrient uptake in an irrigated vertisol sown to cotton. *Applied Soil Ecology* **7**: 11–30.

Kang B T, and Yunusa M. 1977. Effects of tillage methods and phosphorus fertilization on maize in the humid tropics. *Agronomy Journal* **69**: 291–4.

Karunakaran and Behera U K. 2015. Influence of sequential tillage and residue management practices on soil and root parameters in soybean (*Glycine max*) – wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Sciences* **85**(2): 182–8.

Kumar R and Yadav D S. 2005. Effect of zero and minimum tillage in conjunction with nitrogen management in wheat after rice. *Indian Journal of Agronomy* **50**(1): 54–7.

Kumar V, Singh A K, Parihar C M, Pooniya V, Sharma S and Singh B. 2014. Influence of site–specific nutrient management on growth and yield of maize (*Zea mays*) under conservation tillage. *Indian Journal of Agronomy* **59**(4): 657–60.

Lu N and Barber S A. 1995. Phosphorus uptake rate and growth characteristics of wheat roots. *Journal of Plant Nutrition* **8**: 449–56.

Modak S B, Rai R K and Sinha M N. 1994. Effect of phosphorus and phosphor bacteria on yield, N, P uptake and P balance in pigeon pea–wheat sequence. *Annals of Agricultural Research* **5**(1): 36–40.

Pooniya V, Jat S L, Choudhary A K, Singh A K, Parihar C M, Bana R S, Swarnalakshmi K and Rana K S. 2015. Nutrient Expert assisted site–specific–nutrient–management: An alternative precision fertilization technology for maize–wheat cropping system in South–Asian Indo–Gangetic Plains. *Indian Journal of Agricultural Sciences* **85**(8): 996–1002.

Prasad Rajendra. 2005. Rice–wheat cropping systems. *Advances in Agronomy* **86**: 285–339.

Parihar C M , Yadav M R, Jat SL, Singh AK, Kumar B, Pradhan S, Chakraborty D, Jat M L, Jat R K, Saharawat Y S and Yadav O P. 2016. Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north–western Indo–Gangetic Plains. *Soil and Tillage Research* **161**: 116–28.

Ram H, Kler D S, Singh Y and Kumar K. 2010. Productivity of maize (*Zea mays*)–wheat (*Triticum aestivum*) system under different tillage and crop establishment practices. *Indian Journal of Agronomy* **55**(3): 185–90.

Sepat S and Rai R K. 2013. Effect of phosphorus levels and sources on productivity, nutrient uptake and soil fertility of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **58**(3): 292–7.

Singaram P and Kothandaraman G V. 1991. Direct, residual and cumulative effect of phosphatic fertilizers on the yield attributes and yield of finger millet, maize and black gram grown in a cropping system. *Fertilizer News* **36**(8): 21–7.

Singh Mahinder, Azad B S and Bali Amarjit S. 2001. Effect of *in–situ* crop residue management techniques on productivity of rice–wheat cropping system. *Environment and Ecology* **23**(4): 673–6.

Unger P W and Jones O R. 1989. Effective tillage practices for conserving soil and water resources. (*In*) *Proceedings of the IBSRAM Inaugural Workshop on Management of Vertisols for Improved Agricultural Production*, ICRISAT Centre, India, pp 161–71.

Wang X, Cai D, Willem B, Hoogmoed, Udo D, Perdok and Oenema O. 2007. Crop residue, manure and fertilizer in dryland maize under reduced tillage in northern China: I grain yields and nutrient use efficiencies. *Nutrient Cycling in Agro ecosystems* **79**: 1–16.