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Tillage-Mulch-Nutrient Interaction Effect on N, P and K Balance in Soil and Plant Uptake in Maize-Black Gram Cropping System in an Acid Soil of North Bengal

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Field experiments were conducted to evaluate tillage-mulch-nutrient (partial replacement of inorganic with organic) interaction through soil conservation techniques in maize-black gram rotation. The nutrient balance was positive for nitrogen (N) and potassium (K), but was negative for phosphorus (P). Larger negative P balances were recorded in all the treatments with vermicompost over sole chemical fertilizer treatments. Net negative balance diminished over years in organic manure treatments, but increased with sole chemical fertilizers, indicating that with the passage of time, P may slowly became available in acid soils of north Bengal.

Key words: Nutrient balance, mulching, vermicompost, zero tillage

Nutrient disparity and mining by cereal crops have led to nutrient deficiency and poor soil quality in foothills of the Himalayan range. In many areas, most of the crop residues are removed for animal feeding. Imbalanced fertilizer recommendations hastened the degradation of soil over decades (Yadav and Gahlot 2011). Inherent problems with light textured soil, abundant rainfall (2000 to 3500 mm), strong soil acidity (pH 4.5-5.5) led to leaching of bases, poor nutrient holding capacity and input-use-efficiency, restrict the plant nutrient availability which is aggravated due to inappropriate use of chemical fertilizers. Declining soil fertility is evident from the deceleration in growth of total factor productivity in agriculture, especially in important food grain producing states (Das *et al*. 2010). Continuous monitoring of long-term changes in soil quality under conservation tillage in different agro-ecological zones is needed. To address the soil health issue and to boost crop productivity in West Bengal state and North Bengal region in particular, resource conservation technology, mulching and inclusion of adequate amount of high-quality organic matter could be the feasible options. With this background, the present study aims to standardise nutrient budget in maize-black gram cropping system by following soil conservation techniques.

Materials and Methods

The experiment was carried out at Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar (26°19′86″ N and 89°23′53″ E and at an altitude of 43 m above mean sea level) during 2013 and 2014. The experiment was laid out in split-split plot design with two main-plot treatments (C_1= conventional tillage and C_0= zero tillage), two sub-plot treatments (M_1= wheat straw mulching @ 4 t ha^{-1} and M_0= unmulched) and four sub-sub-plot treatments (V_1=75% RD + vermicompost @ 5 t ha^{-1}; V_2=75% RD + vermicompost @ 7.5 t ha^{-1}; V_3=75% RD + vermicompost @ 10 t ha^{-1}, and V_4=100% RD), where RD = Recommended dose of fertilizers as 120-60-60 kg nitrogen (N), phosphorus (P) as P_2O_5 and potassium (K) as K_2O ha^{-1} for maize, and replicated thrice with a plot size of 3 m × 4 m. The chemical fertilizers applied in the form of urea (46% N), single superphosphate (SSP) (16% P_2O_5) and muriate of potash (MOP) (60% K_2O). Blackgram was grown on the residual nutrient, and no fertilizers and/or organics were added. The variety of maize was "DMH-1, while for black gram, it was "Pant U-35" variety. Conventional tillage was done using tractor drawn disc plough followed by power tiller. The weeds and stubbles were removed and cleaned for even distribution of non-selective herbicide and left untouched for 2 weeks in case of zero tillage.

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Table 1. Physicochemical and chemical properties of soil of the experimental field (A) and applied manures/mulching materials (B)

A.Physicochemical properties of Soil

Particulars	Year		Methods employed
	2013	2014	
pH (soil-water ratio of 1:2.5	4.7	5.5	Jackson (1973)
Organic carbon (g kg^{-1})	6.39	6.85	Walkley and Black (1934)
Cation exchange capacity [cmol(p^+)kg^{-1}]	14.54	20.17	Ammonium acetate method (Jackson 1973)
Available N (kg ha^{-1})	107.5	119.14	Alkaline $KMnO_4$ method (Subbiah and Asija 1956)
Available P (kg ha^{-1})	15.36	21.73	Bray's No. 1 method (Bray and Kurtz 1945)
Available K (kg ha^{-1})	71.68	83.95	Neutral normal ammonium acetate method (Hanway and Heidel 1952)

B. Chemical properties of applied manures/mulching material

	Vermicompost	Wheat straw	
Total N (%)	0.75	0.0176	Modified Macro Kjeldahl method (Jackson 1973)
Total P (%)	0.26	0.0033	Di-acid extract method (Page *et al.* 1982)
Total K (%)	0.03	0.0182	Flame photometer method (Jackson 1973)

Samples from the experimental plots were collected at 0.15 m depth with the help of a soil auger before sowing and after harvesting maize and blackgram cropping sequence. The samples were then thoroughly dried in shade, mixed together, pulverized, sieved through 0.2 mm sieve and analyzed using following methods (Table 1).

The plant samples were collected from each plot, dried at 65 °C, ground by plant grinder separately and preserved in polythene bags for chemical analysis. Nitrogen, P and K contents of the above-ground plant parts after harvest were analyzed by modified Kjeldahl method, spectrophotometrically by vanadomolybdo-phosphoric yellow colour method using spectro-photometer, and by flame photometer, respectively (Jackson 1973). Nutrient contents of the plant parts were multiplied by their respective dry weights to workout total uptake of nutrients. Data were analyzed by using statistical package IndoStat services, Hyderabad. The balance sheet was worked out by calculating the expected or computed balance and net-balance (gain or loss) as follows (Ravankar *et al.* 2001): Computed balance = (Initial content + Added through fertilizer) - (Removed by crop); Net Balance = (Actual after harvest) – (computed balance). Total cost of cultivation involved in production of maize-black gram cropping system for conventional and zero tillage was calculated excluding the cost of fertilizers and manures. Prices of the produce were taken as per the farmers' selling price, Rs. 150/- per quintal for maize and Rs. 400/- per quintal for black gram. Benefit:cost ratio was also calculated.

Results and Discussion

Nutrient uptake in maize-black gram cropping system

Higher uptake of N, P and K were ascertained under conventional tillage @ of 22.20, 11.76 and 10.68 per cent compared to zero tillage condition which could be attributed to lower yields under zero tillage (Sarma and Gautam 2010). The magnitude of decrease in the uptake of all nutrients by adoption of zero tillage was similar in maize and black gram crops. In mulching @ 4 t ha^{-1} (M_1), nutrient uptake was significantly higher compared to unmulched (M_0) condition in maize during both the years of study (Table 2). Mulching practices increased the NPK uptake by 4.54, 8.70 and 4.86 per cent, which corroborated the results obtained by Narendra and Gautam (2004). Wheat straw as mulch decomposed slowly, releasing nutrients that benefited black gram in terms of production and nutrient uptake (Singh *et al.* 2011). Mulching in maize not only conserved soil moisture, but also affected fertilizer N dynamics and higher black gram yield (Sharma *et al.* 2011). Again the highest nutrient uptake was recorded in treatment V_3 *i.e.*, 75% RD + vermicompost @ 10 t ha^{-1} applied, which differed significantly from V_2 (75% RD + vermicompost @ 7.5 t ha^{-1}) followed by V_1 (75% RD + vermicompost @ 5 t ha^{-1}) and V_4 (100% RDF) (Table 2). Organic matter increased plant nutrients (N, P and K) and certain microorganisms like phosphate solubilizing microorganism at the time of crop establishment and early growth that helped in solubilization of fixed P (Shukla and Tyagi 2009). It

Table 2. Tillage-mulch-nutrient management effect on uptake and residual N, P and K in soil in maize-black gram cropping system (pooled of 2 years)

Treatments	Nutrient uptake (kg ha^{-1})			Available soil nutrient status (kg ha^{-1})		
	N	P	K	N	P	K
Tillage system (C)						
C_1	128.1	31.1	90.4	307.1	38.2	123.3
C_0	104.8	27.8	81.7	320.3	45.4	141.2
S.E. ±	1.18	0.53	1.16	0.25	0.01	1.18
CD (p=0.05)	5.29	NS	NS	4.55	0.18	ns
Mulch levels (M)						
M_1	119.0	31.0	88.1	321.4	43.0	135.5
M_0	113.8	28.5	84.0	305.9	40.57	129.0
S.E. ±	0.30	0.01	0.08	1.34	1.24	0.71
CD (p=0.05)	NS	0.03	0.49	8.13	ns	4.34
Nutrient combination (V)						
V_1	115.9	28.8	84.6	312.6	42.6	127.9
V_2	121.4	31.5	89.1	347.0	43.5	145.9
V_3	128.4	33.9	95.5	383.3	44.5	163.0
V_4	100.0	24.8	74.9	211.8	36.6	92.2
S.E. ±	0.38	0.06	0.28	2.38	0.49	1.00
CD (p=0.05)	1.18	0.18	0.86	7.32	1.51	3.08
Tillage system × Mulch level (C × M)						
S.E. ±	2.01	0.53	1.17	1.36	1.24	1.38
CD (p=0.05)	NS	9.57	NS	NS	NS	NS
Tillage system × Nutrient (C × V)						
S.E. ±	0.55	0.53	0.21	2.92	0.60	1.71
CD (p=0.05)	1.68	9.51	20.4	NS	1.85	17.6
Mulch levels × Nutrient (M × V)						
S.E. ±	0.56	0.07	0.35	3.20	1.38	1.42
CD (p=0.05)	2.21	0.22	1.14	Ns	Ns	5.45

C_1 = Conventional tillage, C_0 = Zero tillage, M_1 = Mulching @ 4 t ha^{-1}, M_0 = Unmulched, V_1 = 75% RD + Vermicompost @ 5 t ha^{-1}, V_2 = 75% RD + Vermicompost @ 7.5 t ha^{-1}, V_3= 75% RD + Vermicompost @ 10 t ha^{-1}, V_4 = 100% RD, RD = 120-60-60 kg N-P-K ha^{-1}

was also found that intake of N, P and K in black gram was more in succeeding years, due to higher biomass and grain yield was recorded. Again, N fixation by legume (black gram) helped in N uptake apart from soil available nutrients.

A significant difference has been observed in case of tillage and mulching interactions with nutrient combinations except for N and K which showed marginal differences with tillage-mulching interactions.

Residual soil nutrient status in maize-black gram cropping system

Effect of both tillage on soil N and P was significant, but marginal for soil K (Table 2). Two-year pooled data revealed that the highest rate of net soil N, P and K mineralization was top with the conventional tillage @ of 4.13, 15.70 and 12.64 per cent compared to zero till treatment, with the increase in uptake of nutrients consequently lowering their availability (Pandey *et al.* 2010). Therefore, more nutrient was available in soil in case of zero tillage. Again, variations in nutrient accessibility in tillage treatments were greatly due to differences in biomass yield as because the uptake followed dry matter accumulation. Pooled values observed that in mulching condition the accessible N (321.4 kg ha^{-1}) and K (135.4 kg ha^{-1}) was considerably higher than the unmulched condition except P which was 43.03 kg ha^{-1} in conventional and 40.57 kg ha^{-1} in zero tilled treatments. Thus, straw incorporation into the soil improved soil fertility, although no appreciable yield differences were recorded between NPK with straw incorporation and NPK fertilization solely (She *et al.* 2008). Direct effects of mulching on maize were less pronounced, but the residual effects on the subsequent black gram crop were mostly because of improved moisture and nutrient supply through decomposition of residues over the period (Sharma *et al.* 2011). The combined values of both the years under chemical fertilizer plus vermicompost application conserved highest nutrient (NPK) in case of V_3 (383.3, 44.5 and 163.0 kg ha^{-1}) followed by V_2 and V_1, compared to sole application of chemical fertilizer treatment V_4 (211.8, 36.6 and 92.1 kg ha^{-1}), which was due to the fact that nutrient released from inorganic fertilizer was highly susceptible to leaching in a short period of time, but the same released from organic fertilizer like vermicompost occurred slowly over time, *i.e.* the plant nutrient available for leaching at a given time is relatively lower (Nyakatawa *et al.* 2001). Combination of inorganics and organics *i.e.*, the effect of RDF and vermicompost for available nutrients varied significantly during both the years. Soil fertility status significantly improved because of utilization of manures (Das *et al.* 2010). Increase in N, P and K content with progressive addition of vermicompost or their diverse blends, supported the accessibility of higher P in soil. Soil sampling for residual nutrient was taken at complete decomposition of the black gram biomass which further elevated the amount of nutrient retained in the final year.

Overall interactions of tillage-mulching-nutrient combinations were non-significant. However, for P and K, tillage-nutrient combinations were significantly affecting as reflected in the pooled values for both the years.

Nutrient balance in maize-black gram cropping system

The highest net N balance was observed in conventional tillage (unmulched) with application of 75% RDF and vermicompost @ 10 t ha^{-1} ($C_1M_1V_3$) whereas, the lowest value was recorded under mulch with sole application of chemical fertilizer ($C_1M_1V_4$) for both the years. On the other side, zero tillage with no-mulching and the application of 75% RDF and vermicompost @ 10 t ha^{-1} ($C_0M_0V_3$) achieved higher net N balance in the consecutive years. In case of net K balance, highest and the lowest value was observed in zero tillage with different mulch-nutrient combination ($C_0M_0V_3$ and $C_0M_1V_4$, respectively). Net balance of P was negative with the highest loss in conventional tillage ($C_1M_1V_4$) for both the years of study.

Conventional tillage had a general advantage over zero tillage, although when the comparison was made between the individual years, the increment of net N balance corresponding to zero tillage varied significantly, indicating that with the passage of time, zero tillage may improve net N balance over the conventional tillage (Table 3). Same trend was observed with net K balance (Table 5), although for both the year of investigation, zero tillage had the greater value over conventional tillage with the

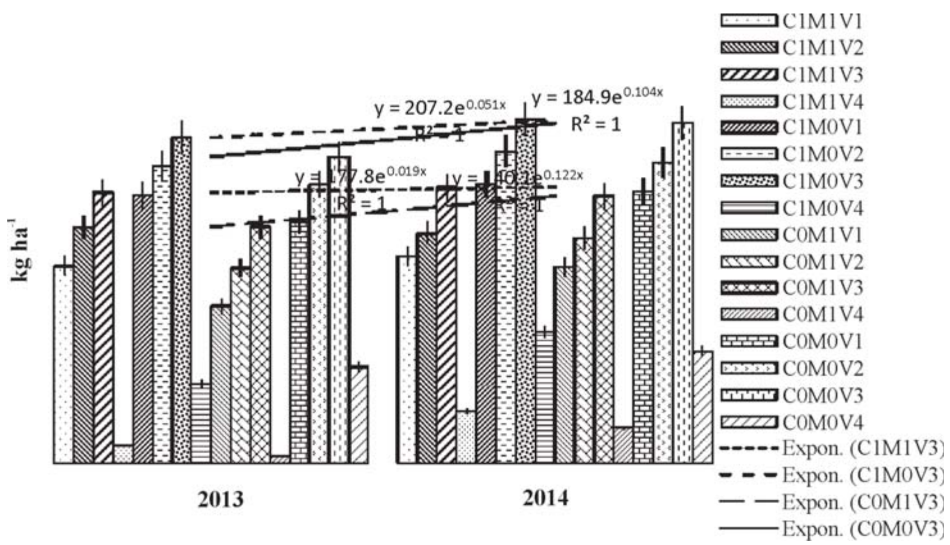
Table 3. Nitrogen balance in maize-black gram cropping system under tillage-mulch-nutrient combinations

Treatments	Soil available N (Initial + Applied) (kg ha^{-1})		N uptake (Maize + Black gram) (kg ha^{-1})		Computed N balance (kg ha^{-1})		Actual N balance (kg ha^{-1})		Net N balance (kg ha^{-1})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
$C_1M_1V_1$	305.6	317.2	130.2	130.0	175.4	187.1	307.4	325.8	132.0	138.6
$C_1M_1V_2$	324.4	335.9	138.6	136.3	185.7	199.6	343.3	353.4	157.6	153.8
$C_1M_1V_3$	343.1	354.7	145.3	145.3	197.8	209.4	379.1	394.2	181.2	184.8
$C_1M_1V_4$	288.1	309.7	106.8	110.4	181.3	199.3	192.8	234.0	11.5	34.7
$C_1M_0V_1$	235.0	246.6	125.5	126.3	109.5	120.3	289.5	307.3	179.9	187.0
$C_1M_0V_2$	253.8	265.3	131.3	132.2	122.4	133.1	321.0	342.1	198.6	208.9
$C_1M_0V_3$	272.5	284.1	139.5	139.4	133.0	144.6	351.2	374.4	218.2	229.8
$C_1M_0V_4$	227.5	239.1	103.8	107.5	123.7	131.5	176.8	219.7	53.0	88.2
$C_0M_1V_1$	305.6	317.2	105.7	110.7	199.9	206.5	305.1	338.2	105.2	131.7
$C_0M_1V_2$	324.4	335.99	107.8	113.4	216.6	222.5	347.4	373.2	130.8	150.6
$C_0M_1V_3$	343.1	354.7	113.2	119.5	229.9	235.2	388.2	414.1	158.3	178.8
$C_0M_1V_4$	298.1	309.7	92.1	98.4	206.0	211.3	210.9	235.1	4.90	23.8
$C_0M_0V_1$	235.0	246.6	95.8	102.4	139.2	144.1	300.5	326.3	161.2	182.1
$C_0M_0V_2$	253.8	265.3	102.0	109.5	151.7	155.8	338.4	357.1	186.7	201.3
$C_0M_0V_3$	272.5	284.1	108.5	116.2	164.0	167.9	369.2	395.6	205.2	227.6
$C_0M_0V_4$	227.5	239.1	87.2	93.7	140.3	145.3	204.6	220.4	64.2	75.0

Applied = through fertilizer, vermicompost and wheat straw mulching, C_1 = Conventional tillage, C_0 = Zero tillage, M_1 = Mulching @ 4 t ha^{-1}, M_0 = Unmulched, V_1 = 75% RD + Vermicompost @ 5 t ha^{-1}, V_2 = 75% RD + Vermicompost @ 7.5 t ha^{-1}, V_3 = 75% RD + Vermicompost @ 10 t ha^{-1}, V_4 = 100% RD, RD= 120-60-60 kg N-P-K ha^{-1}

indication of significant progress in terms of net K balance over conventional tillage (Borin *et al.* 1997). The overall net balance (application-uptake) of N and K was positive under all the treatments. In general, more than 50% of the nutrients applied were left unutilized in the soil (Dua *et al.* 2009). Moreover, maize being a crop with high nutrient demands during the early crop growth period required higher application of nutrients, a substantial amount of which was left in soil for the succeeding crop. A development of soil N and K in maize-black gram system treated with various dimensions of RDF and organic matter has additionally been accounted by numerous researchers (Kumar 2009; Liu *et al*. 2003). In spite of the fact that N and K net balance were most reduced in unmulched condition under both the tillage, however looking at the individual years, there was a critical increment in the second year which may be the consequence of incorporation of a legume (black gram) in the system and less usage of the soil N by the crop without the additional natural excrements (vermicompost) (Rao *et al.* 1982).

The nutrient balance showed positive balance of N and K, but a negative balance for P was seen (Fig. 1, 2 and 3). Wherever the vermicompost was applied and with the increment of doses, higher net balance



C_1 = Conventional tillage, C_0 = Zero tillage, M_1 = Mulching @ 4 t ha^{-1}, M_0 = Unmulched, V_1 = 75% RD + Vermicompost @ 5 t ha^{-1}, V_2 = 75% RD + Vermicompost @ 7.5 t ha^{-1}, V_3 = 75% RD + Vermicompost @ 10 t ha^{-1}, V_4 = 100% RD, RD = 120-60-60 kg N-P-K ha^{-1}

Fig. 1. Apparent nitrogen balance in maize-black gram cropping system

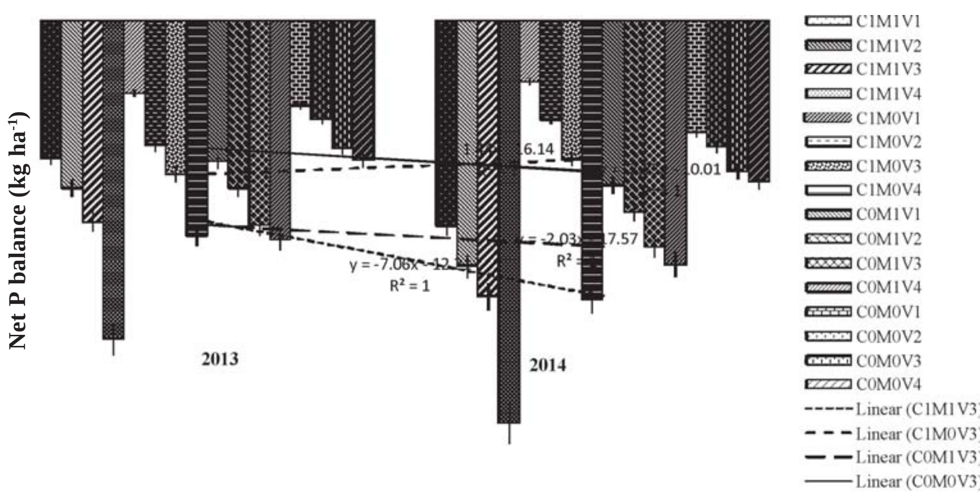


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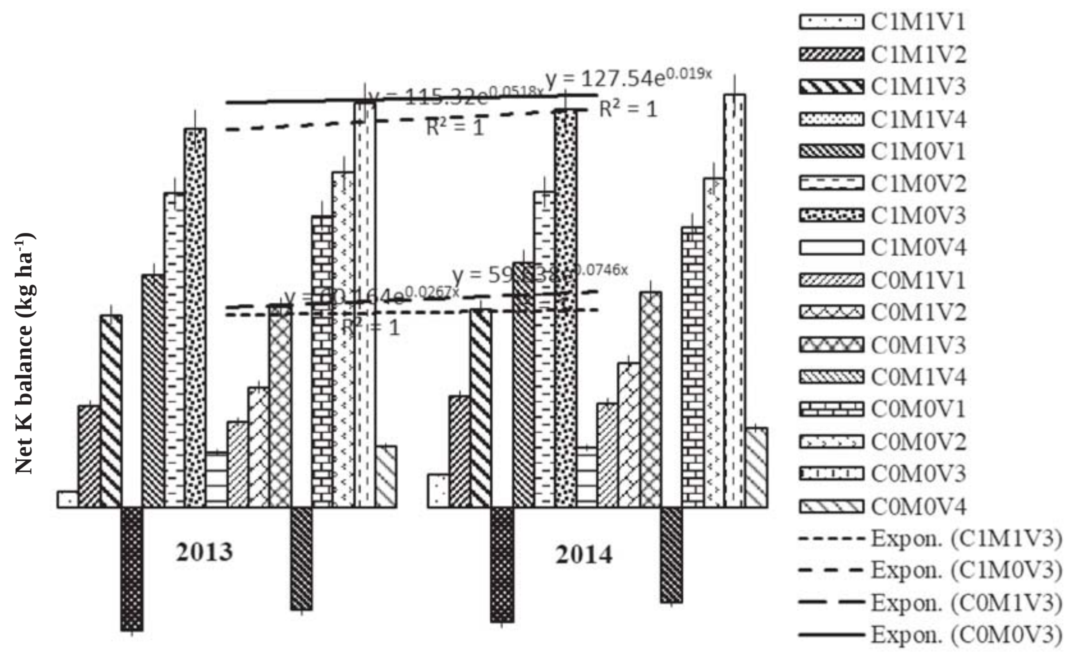
Fig. 2. Apparent phosphorus balance in maize-black gram cropping system



C_1 = Conventional tillage, C_0 = Zero tillage, M_1 = Mulching @ 4 t ha^{-1}, M_0 = Unmulched, V_1 = 75% RD + Vermicompost @ 5 t ha^{-1}, V_2 = 75% RD + Vermicompost @ 7.5 t ha^{-1}, V_3 = 75% RD + Vermicompost @ 10 t ha^{-1}, V_4 = 100% RD, RD = 120-60-60 kg N-P-K ha^{-1}

Fig. 3. Apparent potassium balance in maize-black gram cropping system

Table 4. Phosphorus balance affected by tillage-mulch-nutrient combinations in maize-black gram cropping system

Treatments	Soil available P (Initial + Applied) (kg ha^{-1})		P uptake (Maize + Black gram) (kg ha^{-1})		Computed P balance (kg ha^{-1})		Actual P balance (kg ha^{-1})		Net P balance (kg ha^{-1})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
$C_1M_1V_1$	86.4	92.8	31.9	32.3	54.5	60.5	41.3	40.8	-13.1	-19.6
$C_1M_1V_2$	92.9	99.3	34.2	34.2	58.6	65.0	42.6	41.6	-16.0	-23.4
$C_1M_1V_3$	99.4	105.8	35.4	36.2	64.0	69.5	44.7	43.2	-19.2	-26.3
$C_1M_1V_4$	88.4	94.8	27.6	27.9	60.8	66.8	30.4	28.4	-30.4	-38.4
$C_1M_0V_1$	73.3	79.7	30.6	30.9	42.7	48.7	35.8	42.9	-6.9	-5.84
$C_1M_0V_2$	79.8	86.2	31.9	32.3	47.9	53.9	35.9	44.3	-11.9	-9.53
$C_1M_0V_3$	86.3	92.7	34.3	34.7	52.0	58.0	37.3	44.7	-14.7	-13.2
$C_1M_0V_4$	75.3	81.7	26.0	26.3	49.3	55.4	28.7	28.7	-20.6	-26.7
$C_0M_1V_1$	86.4	92.8	27.2	29.0	59.2	63.7	45.7	47.9	-13.5	-15.7
$C_0M_1V_2$	92.9	99.3	30.9	32.8	61.9	66.5	45.9	48.2	-16.0	-18.3
$C_0M_1V_3$	99.4	105.8	33.5	35.6	65.8	70.2	46.2	48.5	-19.6	-21.6
$C_0M_1V_4$	88.4	94.8	22.3	24.1	66.1	70.7	45.1	47.3	-21.0	-23.3
$C_0M_0V_1$	73.3	79.7	23.1	24.8	50.2	54.9	42.0	44.1	-8.13	-10.7
$C_0M_0V_2$	79.8	86.2	27.0	28.6	52.8	57.6	43.3	45.5	-9.49	-12.0
$C_0M_0V_3$	86.3	92.7	29.5	31.5	56.7	61.2	44.5	46.7	-12.2	-14.4
$C_0M_0V_4$	75.3	81.7	20.9	23.2	54.4	58.4	41.0	43.0	-13.3	-15.4

Applied = through fertilizer, vermicompost and wheat straw mulching, C_1 = Conventional tillage, C_0 = Zero tillage, M_1 = Mulching @ 4 t ha^{-1}, M_0 = Unmulched, V_1 = 75% RD + Vermicompost @ 5 t ha^{-1}, V_2 = 75% RD + Vermicompost @ 7.5 t ha^{-1}, V_3 = 75% RD + Vermicompost @ 10 t ha^{-1}, V_4 = 100% RD, RD = 120-60-60 kg N-P-K ha^{-1}

for both N and K were observed in comparison with sole chemical fertilizer. So far the P was concerned, the higher net negative balance (Table 4) were observed in all the treatments associated with vermicompost over sole chemical fertilizers and this was because of loculation of P through different organic acids under compost. However, the comparison between individual years clearly revealed that the value of net negative balance was diminishing under organic manure treatments. Similar, loss or gain

Table 5. Potassium balance in maize-black gram cropping system under tillage-mulch-nutrient combinations

Treatments	Soil available K (Initial + Applied) (kg ha^{-1})		K uptake (Maize + Black gram) (kg ha^{-1})		Computed K balance (kg ha^{-1})		Actual K balance (kg ha^{-1})		Net K balance (kg ha^{-1})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
$C_1M_1V_1$	190.9	203.2	90.6	90.8	100.3	112.4	105.5	122.9	5.17	10.5
$C_1M_1V_2$	191.7	209.0	96.9	95.1	94.8	113.8	127.6	149.5	32.8	35.6
$C_1M_1V_3$	192.4	204.7	102.7	106.0	89.7	98.6	151.5	162.1	61.7	63.4
$C_1M_1V_4$	204.4	216.7	77.8	78.9	126.6	137.8	87.2	101.	-39.3	-36.7
$C_1M_0V_1$	118.1	130.4	87.1	87.2	31.0	43.1	105.6	121.7	74.6	78.5
$C_1M_0V_2$	118.9	136.2	92.0	93.1	26.8	43.0	127.6	144.2	100.8	101.2
$C_1M_0V_3$	119.6	131.9	98.7	99.9	20.9	31.9	142.4	159.8	121.4	127.9
$C_1M_0V_4$	131.6	143.9	73.8	74.7	57.8	69.1	75.6	88.3	17.7	19.1
$C_0M_1V_1$	190.9	203.2	82.2	86.2	108.7	117.0	136.4	150.4	27.7	33.4
$C_0M_1V_2$	191.7	209.0	83.6	87.9	108.0	121.1	146.7	167.6	38.6	46.5
$C_0M_1V_3$	192.4	204.7	87.5	91.6	104.9	113.0	169.2	182.3	64.2	69.2
$C_0M_1V_4$	204.4	216.7	72.9	77.7	131.4	139.0	98.6	108.6	-32.8	-30.4
$C_0M_0V_1$	118.1	130.4	74.5	77.7	43.6	52.6	137.2	142.6	93.5	90.0
$C_0M_0V_2$	118.9	136.2	80.1	84.0	38.7	52.1	146.2	157.8	107.5	105.6
$C_0M_0V_3$	119.6	131.9	86.4	90.9	33.2	40.9	163.2	173.4	129.9	132.4
$C_0M_0V_4$	131.6	143.9	69.5	73.3	62.0	70.6	81.6	96.2	19.5	25.6

Applied = through fertilizer, vermicompost and wheat straw mulching, C_1 = Conventional tillage, C_0 = Zero tillage, M_1= Mulching @ 4 t ha^{-1}, M_0 = Unmulched, V_1= 75% RD + Vermicompost @ 5 t ha^{-1}, V_2 = 75% RD + Vermicompost @ 7.5 t ha^{-1}, V_3 = 75% RD + Vermicompost @ 10 t ha^{-1}, V_4= 100% RD, RD= 120-60-60 kg N-P-K ha^{-1}

of P was observed in various experiments in different soils by Liu *et al.* (2003) and Dua *et al.* (2009).

Yield characters in maize-black gram cropping system

Maize

Grain yields in conventional and zero tillage were similar having 3.34 and 3.27 t ha^{-1}, respectively, whereas mulching recorded an increase of 10.19 per cent yield. Higher grain yield in maize may be accomplished by continuous zero tillage practice, which steadily improves the soil condition for better root systems contributing to yield gains (100 seed weight) (Izumi *et al*. 2004). Wheat straw mulch created ideal soil temperature and soil moisture conditions which impacted in accumulating higher dry matter accumulation in plants (Wang *et al.* 2011).

Use of vermicompost likewise demonstrated variation. There were 7.77, 13.51 and 25.34 per cent expansion in yield in V_1, V_2 and V_3 when compared with V_4. Significant interactions were observed except for tillage-nutrient combination in case of grain yield of maize.

Succeeding black gram

Pooled value (Table 6) showed that the yield of black gram was higher on conventional tillage (1.11 t ha^{-1}) compared to zero tillage (0.96 t ha^{-1}). Mulching and nutrient combination showed significant yield gains. Mulching @ 4 t ha^{-1} had higher 100-seed weight (3.43 g) and seed yield (1.07 t ha^{-1}) due to enhanced moisture conservation and plant nutrient addition from the mulched biomass which might have improved nutrient supply. However, in case of vermicompost application, relatively significant yield attributing and yield characters were observed with the successive increase in vermicompost application in combination with 75% RDF applied in maize (Sharma *et al.* 2011). For yield attributing characters, tillage-mulch, tillage-nutrient combination and mulch-nutrient combination interactions were found to be significant for 100-seed weight where, only tillage-mulch interactions were found to be significant for seed yield.

Economics in maize-black gram cropping system

Net return was similar between tillage. Higher net return was observed in V_3 (10 t vermicompost ha^{-1} with 75% of RDF) compared to V_4 (100% RD (120-60-40 kg N-P-K ha^{-1}) by 39.73 per cent, owing to the fact that higher gross income from the preceding crop maize (Table 7). The highest benefit:cost ratio of 1.73 was recorded in zero tillage due to lower cost and marginally higher yield from maize and blackgram compared to the conventional tillage, during the years, respectively (Sharma *et al*. 2009). The lowest were

Table 6. Tillage-mulch-nutrient combinations on 100-seed weight, grain and straw yields of maize and succeeding black gram crop (Pooled of two years)

Treatments	Maize			Black gram		
	100-seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	100-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
Tillage system (C)						
C_1	22.72	3.34	7.61	3.35	1.11	3.87
C_0	21.07	3.27	6.82	3.21	0.96	3.44
SE±	0.07	0.001	0.14	0.004	0.002	0.04
CD (P=0.05)	1.33	NS	0.64	0.07	0.032	0.19
Mulch levels (M)						
M_1	22.49	3.46	7.51	3.43	1.07	3.75
M_0	21.30	3.14	6.92	3.13	1.01	3.56
SE±	0.12	0.03	0.14	0.001	0.005	0.04
CD (P=0.05)	0.72	0.16	NS	0.006	0.027	NS
Vermicompost (V)						
V_1	21.92	3.19	7.00	3.22	1.13	3.68
V_2	22.36	3.36	7.47	3.40	1.17	3.89
V_3	22.99	3.71	8.02	3.55	1.22	4.13
V_4	20.31	2.96	6.35	2.95	0.63	2.92
SE±	0.11	0.02	0.05	0.002	0.015	0.03
CD (P=0.05)	0.33	0.05	0.15	0.005	0.045	0.08
Tillage system × Mulch level (C × M)						
SE±	0.14	0.03	0.20	0.004	0.005	0.06
CD (P=0.05)	NS	0.16	NS	0.071	0.037	NS
Tillage system × Vermicompost (C × V)						
SE±	0.15	0.02	0.15	0.004	0.02	0.05
CD (P=0.05)	NS	NS	0.66	0.067	NS	0.21
Mulch level × Vermicompost (M × V)						
SE ±	0.18	0.03	0.15	0.002	0.02	0.05
CD (P=0.05)	NS	0.17	NS	0.008	NS	0.21

C_1 = Conventional tillage, C_0 = Zero tillage, M_1 = Mulching@ 4 t ha^{-1}, M_0 = Unmulched, V_1 = 75% RD + Vermicompost @ 5 t ha^{-1}, V_2 = 75% RD + Vermicompost @ 7.5 t ha^{-1}, V_3 = 75% RD + Vermicompost @ 10 t ha^{-1}, V_4 = 100% RD, RD = 120-60-60 kg N-P-K ha^{-1}

Table 7. Economics (INR × 10^3 Rs. ha^{-1}) involved in maize-black gram cropping system and change in income (Pooled of two years)

Treatments	Total cost	Gross income	Net return	Benefit: cost ratio	Income change (%)	
					Combinations	1st year-2nd year
Tillage system (C)						
C_1	36.77	94.76	57.99	1.56	$C_1M_1V_1$	7.46
C_0	32.27	88.59	56.32	1.73	$C_1M_1V_2$	7.29
SE±	0.0001	0.58	0.58	0.02	$C_1M_1V_3$	6.99
CD (P=0.05)	0.0001	3.50	ns	0.11	$C_1M_1V_4$	-1.81
Mulch levels (M)					$C_1M_0V_1$	10.34
M_1	34.92	95.39	60.47	1.72	$C_1M_0V_2$	9.62
M_0	34.12	87.96	53.84	1.57	$C_1M_0V_3$	10.15
SE±	0.0001	0.29	0.29	0.01	$C_1M_0V_4$	5.39
CD (P=0.05)	0.0001	1.15	1.15	0.04	$C_0M_1V_1$	7.71
Vermicompost (V)					$C_0M_1V_2$	10.79
V_1	33.72	93.80	60.07	1.78	$C_0M_1V_3$	8.26
V_2	36.22	98.09	61.87	1.71	$C_0M_1V_4$	-0.33
V_3	38.72	105.28	66.55	1.72	$C_0M_0V_1$	9.72
V_4	29.42	69.54	40.11	1.37	$C_0M_0V_2$	10.44
SE±	0.001	0.55	0.55	0.02	$C_0M_0V_3$	13.12
CD (P=0.05)	0.003	1.62	1.62	0.05	$C_0M_0V_4$	1.72

C_1 = Conventional tillage, C_0 = Zero tillage, M_1 = Mulching @ 4 t ha^{-1}, M_0 = Unmulched, V_1 = 75% RD + Vermicompost @ 5 t ha^{-1}, V_2 = 75% RD + Vermicompost @ 7.5 t ha^{-1}, V_3 = 75% RD + Vermicompost @ 10 t ha^{-1}, V_4 = 100% RD, RD = 120-60-60 kg N-P-K ha^{-1}
Wheat straw = Rs. 200 t^{-1}, Urea = Rs. 5.02 kg^{-1}, SSP = Rs. 3.20 kg^{-1}, MOP = Rs. 4.60 kg^{-1}, Vermicompost (production cost only) = Rs. 1.00 kg^{-1}

with no mulching at both the tillages indicating the saving of a considerable amount of money (Sharma *et al*. 2011).

Irrespective of tillage and mulch, recommended dose of chemical fertilizer brought a higher gross income from the preceding maize crop due to the higher yield obtained during the experimentation. As a whole, the cumulative effect of applications of vermicompost had the total gross income and better B:C ratio over recommended dose of chemical fertilizer from the maize-black gram cropping system (Satyajeet *et al*. 2007). Furthermore, when the comparison was made between the individual years, zero tillage showed higher positive increment in income which indicated that with the passage of time, zero tillage may bring improvement in terms of income generation over the conventional tillage.

Conclusions

It can be concluded that positive balance sheet of N, K and a trend of minimizing negative balance of P over the years indicated that with the passage of time, zero tillage may improve soil fertility over the conventional tillage. Under conventional tillage associated with mulching, vermicompost application beyond 5 t ha^{-1} didn't give the remunerative return, but under zero tillage (with mulching), farmers could go up to highest level of vermicompost application (10 t ha^{-1}) and thereby reducing the cost. Therefore, the adverse impact of tillage on soil can be reduced, and also an advantage from the higher amount of vermicompost application can be achieved.

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References

Borin, M., Menini, C. and Sartori, L. (1997) Effects of tillage systems on energy and carbon balance in north-eastern Italy. *Soil and Tillage Research* **40**, 209-216.

Bray, R.H. and Kurtz, L.T. (1945) Determination of total organic carbon and available forms of phosphorus in soils. *Soil Science* **59**, 39-45.

Das, A., Baiswar, P., Patel, D.P., Munda, G.C., Ghosh, P.K. and Chandra, S. (2010) Productivity, nutrient harvest index, nutrient balance sheet and economics of lowland rice (*Oryza sativa*) as influenced by composts made from locally available plant biomass. *Indian Journal of Agricultural Sciences* **80**, 686–690.

Dua, V.K., Lal, S.S. and Govindakrishnan, P.M. (2009) Nutrient requirement of Frenchbean (*Phaseolus vulgaris*) in potato (*Solanum tuberosum*) - Frenchbean intercropping system. *Indian Journal of Agricultural Sciences* **79**, 329-333.

Hanway, J.J. and Heidel, H. (1952) Soil analysis methods as used in Iowa State College of Soil Testing Laboratoy, Iowa. *Agriculture* **57**, 1-31.

Izumi, Y., Uchida, K. and Iijima, M. (2004) Crop production in successive wheat-soybean rotation with no-tillage practice in relation to the root system development. *Plant Production Science* **7**, 329-336.

Jackson, M.L. (1973) *Soil Chemical Analysis*. Prentice Hall of India (Pvt.) Ltd., New Delhi.

Kumar, A. (2009) Production potential and N-use efficiency of sweet corn (*Zea mays*) as influenced by different planting densities and N levels. *Indian Journal of Agricultural Research* **79**, 351-355.

Liu, X.J., Wang, J.C., Lu, S.H., Zhang, F.S., Zeng, X.Z., Ai, Y.W., Peng, S.B. and Christie, P. (2003) Effects of non-flooded mulching cultivation on crop yield, nutrient uptake and nutrient balance in rice-wheat cropping systems. *Field Crops Research* **83**, 297-311.

Narendra, K. and Gautam, R.C. (2004) Effect of moisture conservation and nutrient management practices on growth and yield of pearl millet (*Pennisetum glaucum*) under rainfed conditions. *Indian Journal of Agronomy* **49**, 182-185.

Nyakatawa, E.Z., Reddy, K.C. and Brown, G.F. (2001) Residual effect of poultry litter applied to cotton in conservation tillage systems on succeeding rye and corn. *Field Crops Research* **71**, 159-171.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982) *Methods of Soil Analysis.* Part 2, *Chemical and Microbiological Properties*. 2nd Edition, American Society of Agronomy, Madison, Wisconsin, USA.

Pandey, C.B., Chaudhari, S.K., Dagar, J.C., Singh, G.B. and Singh, R.K. (2010) Soil N mineralization and microbial biomass carbon affected by different tillage levels in a hot humid tropic. *Soil and Tillage Research* **110**, 33-41.

Rao, A.S., Babrekar, P.G. and Ghosh, A.B. (1982) Total N and P balance sheet in a typic ustochrept soil under intensive cropping and fertilizer use. *Plant and Soil* **68**, 125-129.

Ravankar, H.N., Deshmukh, V.A. and Deshmukh, P.W. (2001) Balance sheet of N and P on low and high lime soils under soil and foliar application of N and P to soybean. *Agriculture Science Digest* **21**, 215-218.

Sarma, C.K. and Gautam, R.C. (2010) Weed growth, yield and nutrient uptake in maize (*Zea mays*) as influenced by tillage, seed rate and weed control method. *Indian Journal of Agronomy* **55**, 299-303.

Satyajeet., Nanwal, R.K., Yadav, V.K. and Kumar, P. (2007) Effect of integrated nutrient management on productivity of pearl millet (*Pennisetum glaucum*) and its residual effect on succeeding mustard (*Brassica juncea*). *Haryana Agricultural University Journal of Research* **37**, 15-18.

Sharma, P., Abrol, V., Sankar, G.R.M. and Singh, B. (2009) Influence of tillage practices and mulching options on productivity, economics and soil physical properties of maize (*Zea mays*).wheat (*Triticum aestivum*) system. *Indian Journal of Agricultural Sciences* **79**, 865-870.

Sharma, P., Singh, G. and Singh, R.P. (2011) Conservation tillage, optimal water and organic nutrient supply enhance soil microbial activities during wheat (*Triticum aestivum* L.) cultivation. *Brazilian Journal of Microbiology* **42**, 531-542.

She, D.L., Wang, K.R., Xie, X.L., Chen, M. and Lin, Y.H. (2008) Impact of incorporation of rice straw into the soil on soil fertility and yield. *Chinese Journal Eco-Agriculture* **16**, 100-104.

Shukla, L. and Tyagi, S.P. (2009) Effect of integrated application of organic manures on soil parameters and growth of mungbean (*Vigna radiata*) *Indian Journal of Agricultural Sciences* **79**, 174-177.

Singh, R., Sharma, A.R., Dhyani, S.K. and Dube, R.K. (2011) Tillage and mulching effects on performance of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system under varying land slopes. *Indian Journal of Agricultural Sciences* **81**, 330-335.

Subbiah, B.V. and Asija, G.L. (1956) A rapid procedure for estimation of available N in soils. *Current Science* **25**, 259-260.

Walkley, A. and Black, I.A. (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **37**, 29-38.

Wang, X., Dai, K., Zhang, D., Zhang, X., Wang, Y., Zhao, Q., Cai, D., Hoogmoed, W.B. and Oenema, O. (2011) Dryland maize yields and water use efficiency in response to tillage/crop stubble and nutrient management practices in China. *Field Crops Research* **120**, 47-57.

Yadav, A.K. and Gahlot, D. (2011) Sustained soil health and better profitability. *The Hindu Survey of Indian Agriculture* 31-32.

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