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Long Term Evaluation of Reduced Tillage and Low Cost Conjunctive Nutrient Management Practices on Productivity, Sustainability, Profitability and Energy Use Efficiency in Sorghum (Sorghum bicolor (L.) Moench) - Mung Bean (Vigna radiata (L.) Wilczek) System in Rainfed Semi-Arid Alfisol

K.L. Sharma, D. Suma Chandrika, Munna Lal, K. Srinivas, Uttam Kumar Mandal, A.K. Indoria, B. Sanjeeva Reddy, Ch. Srinivasa rao, K. Sammi Reddy, M. Osman, Pushpanjali, G. Rajeshwar Rao and K. Usha Rani

Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad-500 059, Telangana

Email: klsharma@crida.in

ABSTRACT: A long term experiment was conducted at Central Research Institute for Dryland Agriculture for 14 years to evaluate the effect of low tillage and low cost conjunctive nutrient management practices in terms of productivity, sustainability, profitability and energy use efficiency in sorghum-mung bean system in rainfed semi-arid tropical Alfisol. Results of the study revealed that of the tillage practices, conventional tillage (CT) recorded 11.0% higher yields (1534 kg/ha) over the low tillage (LT) (1382 kg/ha) practice. Among the conjunctive nutrient management treatments, the application of 2 t Gliricidia loppings + 20 kg N through urea to sorghum crop recorded significantly highest grain yield of 1712 kg/ha followed by application of 4 t compost + 20 kg N through urea (1650 kg/ha) as well as 40 kg N through urea (1594 kg/ha). As in case of sorghum, CT showed a significant influence on mung bean grain yield (888 kg/ha) which was 6.7% higher compared to LT (832 kg/ha). Application of 2 t compost + 10 kg N through urea and 2 t compost + 1 t Gliricidia loppings performed significantly well and recorded higher mungbean grain yields of 960 kg/ha. In case of mung bean, the long-term trends revealed that, the performance of minimum tillage on an average, was near to that of conventional tillage with slight fluctuation depending upon the rainfall distribution during the cropping season. In both the crops, conventional tillage recorded significantly higher net returns compared to low tillage. In case of Sorghum, net returns obtained were significantly higher with 4 t compost + 20 Kg N/ha through urea (T_3) (₹ 30,262) . The benefit-cost ratio (BCR) in sorghum crop was significantly higher (3.0) with application of 40 kg N through urea alone followed by 2 t Gliricidia loppings + 20 kg N through urea (2.77). Highest BCR (4.02) was observed with application of 2 t Gliricidia loppings + 20 kg N through urea under minimum tillage followed by recommended nitrogen dose of 40 kg/ha (through inorganic fertilizer) and application of 2 t compost + 10 kg N through urea (3.97) in mung bean. Low tillage recorded higher energy use efficiency (10.16, 5.05) compared to conventional tillage (7.21, 3.36) in case of Sorghum and mung bean, respectively.

Key words: INM, pooled yield, profitability, benefit cost ratio, energy use efficiency

The rainfed Alfisol soils of the tropics are degraded in terms of soil quality mainly due to loss of topsoil by wind and water erosion, depletion of organic carbon, and losses of nutrients (ICRISAT, 1987). Tillage is a predominant factor determining the loss of soil organic matter (Rasmussen *et al.*, 1989), and in order to maintain a high level of soil organic matter to enhance soil tilth, fertility, and productivity, there has been a growing concern among researchers to identify management practices suitable to soil climatic and edaphic conditions.

Low organic matter, in these soils results in diversity of constraints in terms of physical, chemical, and biological properties (Lal 1998; Sharma *et al.,* 2005, Sharma *et al.,* 2008) and lead to low productivity. Majority of the farmers in the rainfed SAT regions use small amounts of inorganic fertilizer because of poor economic condition and higher cost of inorganic fertilizers. To meet these challenges and to provide good soil and nutrient management options, it was felt necessary to look for innovative low cost alternative soil and nutrient management options that could (i) improve the productivity , sustainability, profitability and energy use efficiency of rainfed crops and cropping systems. Conservation agriculture techniques of zero or reduced tillage, green manuring, recycling of crop residues, etc., have proved quite efficient in irrigated systems and in temperate regions (Unger, 1990). Such options have not been extensively studied on long term basis in rainfed SATs having severe climatic and edaphic constraints. Research on zero and reduced tillage has also not been much taken up in SAT regions mostly in developing countries because of (i) constraints in weed control; (ii) low water infiltration in soil owing to compacted conditions in the absence of adequate residue cover; and (iii) non- availability of suitable seeding devices suiting to reduced tillage conditions. The inclusion of farm-based organics as low cost nutrient inputs may reduce the cost of cultivation. Thus, the major focus should be on developing an alternate system that is energy, water and labour efficient, as well as can help to sustain soil and environmental quality, and produce more at less cost (Gupta Raj and Seth, 2007; Jat *et al.,* 2011a; Gathala *et al.,* 2011b).

Materials and Methods

A long-term experiment was conducted during 1998 to 2011 with sorghum (variety CSH-9) and mung bean (variety ML-267) as test crops at Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad. Soils of the experimental field belong to the Hayathnagar series (Typic Haplustalf) and are slightly acidic to neutral in reaction (pH 6.5) with sandy loam texture and increasing clay content in the lower horizons. The experiment was conducted in a split- strip-plot design with two tillage [conventional (CT) and low (LT)] and five low-cost, farm-based, conjunctive nutrient-use treatments using three replicates. Sorghum [Sorghum bicolor (L.) Moench] and mung bean [Vigna radiata (L.) Wilkzeck] were used as test crops. Sorghum strips were rotated with mung bean strips with similar treatments every year. Conventional tillage consisted of two plowings before planting + harrowing + one plow planting + operation for top-dressing (this includes summer tillage/off-season tillage), whereas low tillage comprised of one plow planting + operation for top-dressing of N using light implements such as pick-axes. The five conjunctive nutrient-use treatments equivalent to 40 kg N/ha applied to sorghum crop were : Control (no N) (T1), 40 kg N through urea (T2), 4 t compost + 20 kg N (T3), 2 t gliricidia loppings (Gliricidia maculata) (a N-fixing tree containing 33.3 g N/kg on dry-weight basis in leaves and twigs) + 20 kg N (T4), and 4 t compost + 2 t gliricidia loppings (T5). Mung bean crop received 50% of the dose of N (equivalent to 20 kg N /ha) applied to sorghum. Compost (N content 5.0 g/kg) was spread before sowing the crops. In case of sorghum, fertilizer N in the form of urea was applied in two equal splits: one half as basal at the time of sowing and another half at 30-35 days after sowing (DAS), whereas in mung bean, it was applied in a single split as basal dose. Fresh loppings of gliricidia were applied to both the crops at 30-35 DAS as per the treatments along with second split of N. Recommended level (30 kg P_2O_5 /ha) of P as single superphosphate was applied by broadcasting in both sorghum and mung bean crops uniformly before sowing. Every year, crops were seeded with the onset of monsoon during the month of June. Mung bean crop was harvested in the month of August and sorghum in October. The grain yields were recorded for each year from 1998 to 2011, except for the year 2003, when the crop failed because of severe drought. The data on sorghum and mung bean yields were statistically analysed using ANOVA design

Sustainability Yield Index:

The sustainability yield indices (SYI) which represents minimum guaranteed yield in response to soil and nutrient management treatment as a percentage of the maximum observed yield with high probability were calculated as follows:

$$SYI = (Y - \sigma) / Y_{max}$$

Where Y is the average yield of the treatments across the years; σ is the treatments standard deviation and Y_{max} was the maximum observed yield over years in the experiment (Singh *et al.,* 1990). In rainfed agriculture, the computation of the sustainability of the yield becomes more important than simple mean as the magnitude of the yield is predominantly influenced by rainfall besides other factors (FAO, 1989).

Agronomic efficiency (AE), a parameter representing the ability of the plant to increase yield in response to per unit N applied, was computed based on the average grain yield data using the following relationship:

$$AE = \frac{(Y_{TP} - Y_{CP})}{FN}$$

Where Y_{TP} is the grain yield (kg/ha) of treated plot, Y_{CP} is grain yield of control plot and FN is the applied dose of fertilizer N (kg/ha).

Computation of energy use efficiency

In order to evaluate the soil and nutrient management treatments in terms of energy use efficiency, the input energy (MJ/ha) was computed for each treatment by cumulating all the energy values (MJ/ha) used for different inputs like seed, fertilizer, herbicide, labour, animal and implements for land preparation, sowing, interculture, harvesting and other agricultural operations. The output energy was computed from the grain and straw yield harvested, and was expressed in terms of MJ/ha. The EUE could be derived as a ratio of output and input energy for each treatment.

Profitability of the management treatments:

In order to study the relative profitability of the management treatments for sorghum and mung bean, the per hectare cost of inputs incurred on total cost of cultivation (TC) such as, seed, fertilizers, herbicides and pesticides, green leaves collection and their application, cost of human labour, cost of bullock labour and /or traction power were considered. To compute the gross returns (GR) accrued, the prevailing market rates of outputs per ha including main product and by product for the year 2012 were considered. The price used for 1 kg of sorghum and dry stover was ₹ 11/- (Indian Rupees) and ₹ 3, respectively. Per ha net returns (NR) accrued was calculated by subtracting the per ha total cost of cultivation incurred from the per ha gross returns accrued. Finally, for studying the techno-economic feasibility of the soil management treatments, benefit-cost ratio (BCR) for each of the soil management treatments was worked out as ratio of GR and TC (Maruthi Sankar *et al.*, 2011). The test for significance of the treatments for profitability and energy use was performed using LSD (least square difference values).

Results and Discussions

In the present study, it was observed that the crop yields were significantly different over the years. The overall sorghum grain yields varied between 764 to 1792 kg/ha with an average yield of 1458 kg/ha during the period of 14 years. Of all the years, sorghum grain yields were highest during the year 2002 (1929 kg/ ha) followed by the year 2010 (1721 kg/ha) while the years 2009 (1162 kg/ha) and 2005 (1165 kg /ha) recorded the lowest grain yields (Table 1 & 2). Tillage practices as well as the nutrient management treatments also showed a significant influence on sorghum grain yield. When averaged over years, between the tillage practices, conventional tillage recorded 11.0 % higher yield (1534 kg/ ha) over low tillage (1382 kg/ ha) practice. In these rainfed Alfisols, low tillage could not establish its superiority, may be because of lack of adequate amount of crop residue left on the soil surface. Moreover, in tropical soils, rapid decomposition of the organic residues owing to the prevailing high temperatures and erratic rainfall hinders the beneficial effects of low tillage. It was observed that, among the nutrient management treatments, application of 2 t Gliricidia loppings + 20 kg N through urea to sorghum crop recorded significantly highest grain yield of 1712 kg/ha followed by application of 4 t compost + 20 kg N through urea (1650 kg/ha) as well as 40 kg N through urea (1594 kg/ha) and were at par with each other (Table 1). The sole organic treatment *viz.,* 4 t compost + 2 t gliricidia loppings recorded relatively lower yield compared to other INM treatments (1610 kg/ha) except control. The order of sequence in terms of percent increase in sorghum grain yields under all the nutrient management treatments over the control was: T4 = 2 t Gliricidia loppings + 20 kg N through urea (113.8 %) > T3 = 4 t compost + 20 kg N through urea (109.2%) = T2 = 40 kg N through urea (104.1%) > T5 = 4 t compost + 2 t gliricidia loppings (101.2%).

The mung bean grain yield data obtained for the period of 13 years was also subjected to pooled analysis and the results are presented in Table 2. From the data, it was observed that the average mung bean grain yields significantly varied over the years and ranged from 459 to 1310 kg/ha across the years with an average value of 860 kg/ha. The lowest mung bean grain yield was observed during the year 2000 (459 kg /ha) while the years 2010 and 2004 recorded higher yields of 1310 and 1204 kg/ha, respectively. Similar to sorghum, conventional tillage showed a significant influence on mung bean grain yields (888 kg/ha) which was 6.7% higher compared to low tillage (832 kg/ha) (Table 2). The nutrient management treatments also showed a significant influence on mung bean grain yields. Among all the treatments, 2 t compost + 10 kg N through urea and 2 t compost + 1 t Gliricidia loppings performed significantly well and recorded similar yields of 960 kg/ ha each followed by 1 t Gliricidia loppings + 10 kg N through urea (930 kg/ha). Sole application of urea maintained lower mung bean yield of 862 kg/ ha. When compared with control, the percent increase in mung bean grain yields under nutrient management treatments were: 64% in 2 t compost + 10 kg N through urea (T3) and 2 t compost + 1 t Gliricidia loppings (T5), 59% in Gliricidia loppings + 10 kg N through urea (T4) and (47%) 20 kg N through urea (T2). The long-term trends in mung bean yield as influenced by tillage revealed that after 13th year of the study, the performance of low tillage on an average, was coming near to that of conventional tillage with slight fluctuation depending upon the rainfall distribution during the cropping season. This trend indicated that in case of legume like mungbean, the probability of success of reduced tillage is quite higher in rainfed Alfisol soils which are susceptible to hard setting and compaction. Hence, this finding raised the hope of success of reduced tillage practices in rainfed semi-arid tropical soils.

Sustainability Yield Indices (SYI) and Agronomic Efficiency (AE) as influenced by INM and tillage practices under sorghum-mung bean cropping system

In case of sorghum crop, the sustainability yield indices varied from 0.25 to 0.47 while the agronomic efficiency varied from 13.0 to 20.3 kg grain/kg N across the management treatments under both conventional and low tillage (Table 1). When averaged over the treatments, conventional tillage maintained the highest SYI (0.53) as well as agronomic efficiency (17.3 kg grain/kg N) compared to low tillage with an average SYI of 0.44 and agronomic efficiency of 15.4 kg grain/kg N. When averaged over the tillage effects, 2 t compost + 1 t gliricidia maintained the highest SYI (0.56) as well as agronomic efficiency (18.8 kg grain/kg N). Among all the treatments, practice of conventional tillage + application of 2 t Gliricidia loppings + 20 kg N through urea in case of sorghum crop recorded significantly highest SYI (0.62) as well as AE (23.7 kg grain/kg N).

In case of mung bean crop, the sustainability yield indices varied from 0.25 to 0.47, while the agronomic efficiency varied from 13.0 to 20.3 kg grain/kg N across the management treatments under both conventional and low tillage plots (Table 2). In mung bean crop, similar to sorghum, when averaged over the treatments, conventional tillage maintained higher SYI (0.42) as well as agronomic efficiency (13.9 kg grain/kg N) compared to low tillage which maintained SYI of 0.35 and AE of 12.9 kg grain/kg N. When averaged over the tillage effects, both application of 2 t compost + 1 t gliricidia loppings as well as 2 t compost + 10 kg N through urea more or less maintained similar level of SYI. Among all the treatments, practice of conventional tillage + 2 t compost + 10 kg N through urea maintained higher SYI (0.47) and agronomic efficiency (20.3 kg grain/kg N) under mung bean crop.

Effect on energy inputs out-put and use efficiency

Sorghum:

In the present study, input, output energy and energy use efficiency of the treatments was also calculated using standard procedure. It was observed that under conventional tillage, the input energy (14803. 5 MJ/ha) required for sorghum crop was higher compared to low tillage (9491. 5 MJ/ha). Under low tillage, sorghum crop needed 35.88% less input energy compared to conventional tillage. Among the INM treatments, T_2 (40 kg N through urea) required highest input energy compared to other treatments. The maximum input energy was significantly higher with T2 under conventional tillage. Similarly, the output energy of sorghum was significantly influenced by tillage and INM treatments. Output energy of various treatments varied from 76938 MJ/ha to 131337 MJ/ha. Significantly higher output energy was obtained with conventional tillage (107280 MJ/ ha) compared to low tillage (96588 MJ/ha). Application of 4t compost + 20 kg N through urea under conventional tillage recorded significantly highest output energy (131337

MJ/ha) across all the treatment combinations (Table 3). The reduction in the energy use by 14% in reduced-till green gram and 2% in semi mechanized rice has been reported by Khambalkar *et al.* (2010) and Cherati *et al.* (2011). In the present study, the EUE of the tillage and INM treatments varied from 5.56 to 11.4. Both tillage and INM treatments significantly influenced EUE in which low tillage recorded higher EUE (10.16) compared to conventional tillage (7.21). When averaged over the tillage treatments, it was found that, significantly higher EUE was obtained with application of 4t compost + 20 kg N through urea (10.11). Of all the treatment combinations, significantly highest EUE (11.53) was observed with application of 4t compost + 20 kg N through urea under low tillage which was on par with application of 4t compost + 2t Gliricidia loppings (11.4).

Mung bean

In the present study, input and output energy and energy use efficiency were significantly influenced by the tillage and INM treatments. The input energy varied from 8388 MJ/ ha to 16124 MJ/ha. The input energy required for conventional tillage (14759.3 MJ/ha) was significantly higher compared to low tillage (9447.3 MJ/ ha). Of all the INM treatments, significantly higher input energy (16124 MJ/ha) was recorded with T_2 treatment under conventional tillage. The output energy obtained with the tillage and conjunctive nutrient use treatments varied from 33179 MJ/ha to 57834 MJ/ha across the treatments. Output energy was significantly higher (49665 MJ/ha) with conventional tillage compared to low tillage (47691 MJ/ha). Among the conjunctive nutrient treatments, significantly higher output energy was obtained with T_3 treatment (56077 MJ/ ha) compared to control (34134 MJ/ha).

Energy use efficiency varied from 2.56 to 6.21 across the tillage and INM treatments. The energy use efficiency was significantly higher (5.05) with low tillage compared to conventional tillage (3.36). Application of 4 t compost + 2t Gliricidia loppings proved to be significantly superior (5.07) in terms of energy use efficiency when compared to other conjunctive nutrient use treatments. The energy use efficiency increased with a reduction in tillage intensity, despite a lower net energy gain. This has been observed in other studies (Kuesters and Lammel, 1999; Rathke *et al.,* 2007).

Table 3 : Effect of tillage and INM treatments on input and input energy of Sorghum-Mung bean system

Treatments	Sorghum			Mung bean		
	Input energy (MJ/ha)	Output energy (MJ/ha)	EUE	Input energy (MJ/ha)	Output energy (MJ/ha)	EUE
CTT1	13744.52	76938	5.60	13700.4	35089.0	2.56
CTT2	16168.52	108578	6.72	16124.4	50264.3	3.12
CTT3	15097.64	131337	8.70	15053.5	57834.5	3.84
CTT4	15038.84	120193	7.99	14994.7	50374.6	3.36
CTT5	13967.96	99355	7.11	13923.9	54764.0	3.93
LTT1	8432.52	68156	8.08	8388.4	33179.8	3.96
LTT2	10856.52	98626	9.08	10812.4	48534.7	4.49
LTT3	9785.64	112928	11.54	9741.5	54321.1	5.58
LTT4	9726.84	104690	10.76	9682.7	48910.2	5.05
LTT5	8655.96	98542	11.38	8611.9	53513.8	6.21
CD (P = 0.05)						
Tillage	323	775.46	0.10	35.32	264.4	0.065
Treatments	119.4	613.93	0.14	177.98	159.6	0.067
Tillage x Treatments	NS	868.24	0.20	NS	225.3	0.094

CT; Conventional Tillage; LT- Low Tillage; *For Sorghum:* T1 = Control, T2 = 40 kg N through urea, T3 = 4 t compost + 20 kg N through urea, T4 =2 t Gliricidia loppings + 20 kg N through urea, T5 = 4 t compost + 2 t gliricidia loppings; *For Mungbean:* T1 = Control. T2 = 20 kg N through urea, T3 = 2 t compost + 10 kg N through urea, T4 =1 t Gliricidia loppings + 10 kg N through urea, T5 = 2 t compost + 1 t gliricidia loppings

Profitability and economics of tillage and INM treatments:

Sorghum

In case of sorghum crop, the per ha total input cost of cultivation incurred across the tillage and INM treatments varied from ₹8,713 to 15,553. In case of conventional tillage, the total input cost was significantly higher (₹15,553) in T_5 treatment followed by T_3 treatment (₹14,523) (Table 4). The total cost of cultivation involved per ha was significantly higher with conventional tillage practices compared to low tillage. The relatively lesser total cost of cultivation per ha (keeping others constant) was due to the reduced number of tillage operations under low tillage compared to conventional tillage. Irrespective of tillage, among the INM treatments, significantly higher per ha total cost of cultivation (₹ 15,553) was recorded in T_5 treatment. The higher total cost of cultivation per ha incurred in this case was due to employment of more number of manpower for preparation, spreading and application of compost as well as mulching with Gliricidia loppings. The per ha net returns obtained with tillage and nutrient treatments varied from ₹ 12,847 to ₹ 31,393. In case of conventional tillage the net returns obtained were significantly higher with T_3 (₹ 30,262) followed by T_4 treatment (₹ 29,446). Similar results in wheat cultivation have been reported by Saharawat *et al.,* 2010; Jat *et al.,* 2009 and 2011.

Across the treatments, the BCR varied from 1.06 to 3.00 in conventional and low tillage, respectively. The higher BCR under low tillage treatment is due to incurring lesser total cost of cultivation per ha despite higher net returns accrued per ha.

Table 4 : Long term effect of tillage and conjunctive nutrient use treatments on economics and profitability (₹/ha) of sorghum crop

INM Treatments equal to 40 kg N/ha	Input Cost	Net returns	B:C ratio
CTT1	12133	12847	1.06
CTT2	12594	28020	2.22
CTT3	14523	31393	2.16
CTT4	13623	30616	2.25
CTT5	15553	22538	1.45
LTT1	8713	13603	1.56
LTT2	9174	27562	3.00
LTT3	11103	29131	2.62
LTT4	10203	28277	2.77
LTT5	12133	24658	2.03
Tillage (T)	37.4	70.7	
Treatments (Tr)	67.8	33.4	
T x Tr	NS	47.3	

CT- Conventional Tillage, LT- Low tillage

T1 = Control, T2 = 40 kg N through urea, T3 = 4 t compost + 20 kg N through urea, T4 =2 t Gliricidia loppings + 20 kg N through urea, T5 = 4 t compost + 2 t gliricidia loppings

Mung bean

In case of mung bean crop, the total cost of cultivation incurred per ha varied from ₹ 8,788 to 14,008 across the treatments. The total cost was significantly less (₹ 9,600) with low tillage compared to conventional tillage (₹ 13,020) which was attributed to reduced number of tillage operations. The INM treatments significantly varied in terms of total input cost. Significantly higher input cost was incurred with T_5 treatment (₹ 12,298) followed by T_3 treatment (₹ 11,694) (Table 5).

The net returns varied from ₹ 22,006 to 40,907 across the tillage and INM treatments. The benefit cost ratio (BCR) of tillage and INM treatments varied from 1.67 to 4.02 across the treatments. Highest BCR (4.02) was observed with T4 treatment under low tillage followed by T_2 and T_3 (3.97).

Table 5 : Long term effect of tillage and conjunctive nutrient use treatments on economics and profitability (Rupees) of mung bean crop

INM Treatments equal to 20 kg N/ha	Input cost	Net returns	B:C ratio
CTT1	12209	20431	1.67
CTT2	12439	35094	2.82
CTT3	13404	40907	3.05
CTT4	13044	36435	2.79
CTT5	14009	38621	2.76
LTT1	8789	22007	2.50
LTT2	9019	35820	3.97
LTT3	9984	39616	3.97
LTT4	9624	38701	4.02
LTT5	10589	38657	3.65
Tillage (T)	62.9	72.0	
Treatments (Tr)	40.7	60.2	
T x Tr	NS	85.1	

CT- Conventional Tillage, LT- Low tillage

T1 = Control. T2 = 20 kg N through urea, T3 = 2 t compost + 10 kg N through urea, T4 =1 t Gliricidia loppings + 10 kg N through urea, T5 = 2 t compost + 1 t gliricidia loppings

Table 1 : Long-term effects of tillage and integrated nutrient management treatments on sorghum grain yields

Treatments	Sorghum grain yields (kg/ha)													Pooled Yield	SYI	Agron Efficiency (kg grain/kg N)
	1998	1999	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011			
CTT1	1067	1035	1114	900	923	795	816	827	869	708	701	333	877	843	0.27	-
CTT2	1675	1624	1760	1680	2344	2006	1596	1845	1613	1466	1099	1967	1141	1678	0.56	20.9
CTT3	1665	1458	1923	1617	2383	2027	1470	1849	1774	1556	1331	2096	1439	1738	0.60	22.4
CTT4	1645	1871	2002	1950	2367	2003	1427	1827	1890	1578	1414	2044	1276	1792	0.62	23.7
CTT5	1675	1721	1733	1700	1931	1796	1310	1711	1734	1385	1602	1727	1027	1619	0.58	19.4
LTT1	1171	888	867	750	893	704	586	731	917	604	633	377	813	764	0.24	
LTT2	1652	1448	1305	1434	2130	1843	1107	1455	1701	1287	1010	2164	1091	1510	0.48	18.6
LTT3	1913	1086	1313	1458	2264	1938	1091	1440	1737	1336	1181	2271	1284	1563	0.48	20.0
LTT4	1540	1235	1451	1542	2132	1931	1120	1434	1789	1393	1297	2195	1168	1556	0.50	19.8
LTT5	1663	1568	1285	1550	1918	1777	1135	1352	1673	1321	1352	2030	1088	1516	0.51	18.8
Tillage (T)	187	118	206	13	270	280	132	57.59	291.1	36.0	55.6	127	42.6	20.5	-	-
Treatments (Tr)	121	114	279	197	192	517	71	102.3	124.6	136	54.3	211	65.4	31.6	-	-
Years (Y)	-	-	-	-	-	-	-	-	-	-	-	-	-	51.0	-	-
Y x T	-	-	-	-	-	-	-	-	-	-	-	-	-	76.1	-	-
Y x Tr	-	-	-	-	-	-	-	-	-	-	-	-	-	124.2	-	-
T x Tr	-	-	-	-	-	-	-	-	-	-	-	-	-	53.4	-	-
Y x T x Tr	-	-	-	-	-	-	-	-	-	-	-	-	-	NS	-	-

CT; Conventional Tillage; LT- Low Tillage
T1 = Control, T2 = 40 kg N through urea, T3 = 4 t compost + 20 kg N through urea, T4 =2 t Gliricidia loppings + 20 kg N through urea, T5 = 4 t compost + 2 t gliricidia loppings

Table 2 : Long-term effects of tillage and integrated nutrient management treatments on mung bean grain yields during 1998 to 2011

Treatments	Mung bean grain yields (kg/ha)													Pooled Yield	SYI	Agron Efficiency (kg grain/kg N)
	1998	1999	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011			
CTT1	447	847	485	517	537	711	521	565	763	624	394	830	646	603	0.29	-
CTT2	653	1056	614	830	900	1129	962	889	877	948	516	1320	843	891	0.43	14.0
CTT3	827	1141	599	870	900	1438	938	1067	1110	992	640	1579	1056	1008	0.47	20.3
CTT4	684	1059	592	710	993	1402	901	910	1069	1089	666	1227	830	942	0.44	16.3
CTT5	780	1137	702	830	721	1386	886	959	1180	1074	722	1541	912	993	0.46	19.0
LTT1	628	633	224	490	520	700	408	604	867	481	399	863	619	568	0.25	
LTT2	656	887	284	770	765	1288	692	929	1039	839	499	1356	809	834	0.34	13.0
LTT3	998	792	310	760	843	1392	747	955	1093	971	551	1539	970	913	0.38	17.2
LTT4	1021	761	418	700	743	1372	754	1042	1213	1082	569	1352	842	919	0.39	17.0
LTT5	1046	912	366	880	706	1217	724	1013	1087	1070	619	1491	731	928	0.39	17.0
Tillage (T)	73	93	18	67	210	35	171	NS	254	NS	NS	20.5		17.1	-	
Treatments (Tr)	56	81	44	48	83	96	38	61.1	143	119	15.4	215.9		27.1	-	
Years (Y)	-	-			-	-	-	-	-	-	-	-		41.9	-	
Y x T	-	-			-	-	-	-	-	-	-	-		59.3	-	
Y x Tr	-	-			-	-	-	-	-	-	-	-		93.5	-	
T x Tr	-	-			-	-	-	-	-	-	-	-		NS	-	
Y x T x Tr	-	-			-	-	-	-	-	-	-	-		132.6	-	

CT; Conventional Tillage; LT- Low Tillage

T1 = Control. T2 = 20 kg N through urea, T3 = 2 t compost + 10 kg N through urea, T4 =1 t Gliricidia loppings + 10 kg N through urea, T5 = 2 t compost + 1 t gliricidia loppings

Conclusions

In the present study, it was clearly observed that 50% of the fertilizer N required by sorghum and mung bean could be saved by following INM treatments using farm based organics. Significantly higher BCR ratio under sorghum and mung bean could be achieved through INM treatments. The practice of cultivating sorghum and mung bean under low tillage with low cost farm based organics reduced the input of energy and fertilizer use in semi arid Alfisols. Beside these benefits, the present study will help in conserving the soil resource, improving its fertility and quality on long term basis.

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