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# Productivity, profitability and energy dynamics of rice (*Oryza sativa*) under tillage and organic nitrogen management practices in rice–vegetable pea (*Pisum sativum)* cropping system of Sikkim Himalayas

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ABSTRACT

Fixed plot field experimentation was carried out at Research Farm of ICAR Sikkim Centre during 2013 and 2014 to identify the efficient tillage and organic nitrogen management practices for achieving higher productivity, profitability and energy use efficiency (EUE) of rice (*Oryza sativa* L.) in rice–vegetable pea (*Pisum sativum* L.*)* cropping system of Sikkim Himalaya. The results revealed that higher productive tillers/hill, panicle length (cm), panicle weight (g), grains/panicle, 1000–grain weight (g) and grain yield (3.27 t/ha) were recorded with reduced tillage (RT) followed by conventional tillage (CT) and no–till (NT). Maximum gross returns ($96\times10^3$ ₹/ha) was recorded with RT followed by NT ($95.8\times10^3$ ₹/ha) and CT ($95.5\times10^3$ ₹/ha). However, maximum net returns ($67\times10^3$ ₹/ha) and B:C ratio (2.34) was recorded with NT over RT and CT. NT was most energy efficient practice and had 33% less energy requirement as compared to CT. Amongst the organic nitrogen sources, higher yield attributes and grain yield (3.7 tonnes/ha) were recorded with the application of 50% RDN (recommended dose of nitrogen) through FYM (Farmyard manure)+ 50% RDN through VC (vermicompost)+BF (biofertilizer) which was significantly superior over other organic nitrogen sources. The grain yield increased by 29.7% over the farmers' practice. With respect to the economic and energy indicators, application of 50% RDN through FYM + 50% RDN through VC+BF proved its superiority over others and recorded 32.4% higher net returns and 9.2% higher EUE over the prevailing farmers' practice (FYM @5 tonnes /ha) of the region.

**Key words:** Biofertilizer, Conservation tillage, Energetics, FYM, No–till, Rice, Vermicompost

Rice (*Oryza sativa* L.) is an indispensible diet ingredient for the people of north eastern Himalayan states. It accounts more than 80% of the total cultivated area of the region and 7.8% of the total rice area in India, whereas its share in national rice production is meager (Yadav *et al.* 2013a).The average productivity of rice in the region is very low (1.6 tonnes/ha) compared to national averages, leading to about 1.77 mt deficit of rice (Tomar and Das 2011). Unscientific way of cultivation, low solar radiation, high disease and insect–pests incidence and land topography etc are the reasons for the low productivity of rice in the region. The north east region of India enjoys very intense rainfall during rainy season (June–September). Farmers usually adopt intensive tillage operations in rice for weeds, minimizing percolation rate of water and preparing soft bed for crop establishment. This system requires high energy consumption, drudgery of labour and high cost of cultivation. Further, continuous puddling leads to deterioration of soil physical properties through structural breakdown of soil aggregates and capillary pores which affects the establishment of succeeding crop in the system (Choudhary *et al.* 2008). Contrary to this, reduced tillage and no till practices (Andrade *et al.* 2010) make some improvements in soil aggregation, creates higher micro–porosity and increases soil organic carbon (SOC) concentration. Therefore, alternative method of growing rice in the region which is more efficient and less labour intensive need to be developed to enable farmers to produce higher yields with less production cost.

Energy is one of the valuable inputs in production agriculture. Agriculture itself is energy user and energy supplier in the form of bio–energy (Alam *et al.* 2005). Energy productivity is decreasing with the escalating input cost without proportionate improvement in output of particular crop. Availability of sufficient energy and its effective and efficient use are pre-requisites for improved agricultural production. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production (Babu *et al.* 2014). North

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eastern region of India is a potential hub for organic rice production because the region has huge resources of biomass like weeds, forest litter, leaves and twigs from pruning and lopping of trees, which are very rich in essential nutrients. In the region farmers apply very low amount of organic manure to the rice crop due to low availability of farmyard manure (FYM). Therefore, nitrogen substitution with the available resources especially farmyard manure, vermicompost and suitable strains of biofertilizers is required for economical and sustained production of rice in the region. It is assumed that adoption of conservation tillage practices along with nitrogen substitution may enhance the rice productivity under organic management condition. In view of the above, field experiments were conducted to identify the efficient tillage methods and organic nitrogen sources for enhancing productivity, profitability and energy use efficiency of rice production under rice–vegetable pea (*Pisum sativum* L.) cropping system.

## MATERIALS AND METHODS

Field experiment was carried out during two consecutive *kharif* seasons of 2013 and 2014 at Research Farm of ICAR Research Complex for NEH Region Sikkim Centre, Tadong (1300 m amsl; latitude $27^0$ 33' N; longitude $88^0$ 62' E). The climate of the area is sub–tropical. During cropping period total 1858.5 mm rainfall was received, maximum mean temperature (27.6°C) was observed in June and minimum (11.8°C) in November. The soil of experimental field was clay loam with pH 5.9 (1: 2.5 soil and water ratio), 216.5 kg/ha alkaline permanganate oxidizable N, 26.10 kg/ha Brays $P_1$, 188.3 kg 1 *N* ammonium acetate exchangeable K and 1.88% organic carbon. The experiment was laid in split plot design, assigning three tillage practices, viz. conventional (CT), reduced (RT) and no till (NT) in main plots and four recommended doses of nitrogen through organic sources, viz. control (FP), 100% N through farmyard manure (FYM) + biofertilizer (BF), 100% N through vermicompost (VC) + BF and 50% N through FYM + 50% N through VC+BF to sub–plots and were replicated thrice. The rice field was prepared as per the treatments, in conventional tillage (CT) two deep ploughings followed by puddling and leveling was done with bullock drawn leveler. In reduced tillage (RT) one ploughing followed by harrowing for puddling and leveling was done with bullock drawn plough and leveler. In no-till (NT) only dibbling was done to transplant the rice seedlings. The recommended dose of 60 kg N/ha was applied through organic sources as per the treatments. Nitrogen through organic sources was applied 15 days before planting in case of CT. However, narrow bands were made in between rows and the organic manures were applied as per the treatments in NT and RT during both the years. The crop was planted on 24 and 26 June in 2013 and 2014, respectively. 12 days old single seedling/hill was planted at spacing of 20 cm × 20 cm. For planting seedlings in RT narrow slot in soil was opened and seedling was transplanted. Similarly, in case of NT manual transplanter (locally made) was used for planting of crop. Weeding was manually done followed by cono–weeder in CT and RT (25 and 40 DAT). However, in no till plot only two hand weedings (25 and 40 DAT) were practiced for managing the weeds. Rice variety Geetanjali was grown as per recommended practices of the region and harvested in the second week of November during both years. Effective tillers/hill was counted from randomly selected 10 hills/ plot. Panicle length was measured from a sample of ten panicles drawn randomly from the marked plants. The length was measured from neck to the tip of the panicle and average panicle length was computed. From the sampled 10 panicles which were used for panicle length were also used to record the weight of the panicles and mean panicle weight, grains were separated, cleaned and finally filled grain separated. The total number of grains for the 10 panicles randomly selected from each plot was counted and their average was computed. The 1000–filled grains, taken from sampled panicles, were first counted and then weighed to compute the test weight. After harvesting, threshing, cleaning and drying the grain yield was recorded at 14% moisture. Straw yield was obtained by subtracting grain yield from the total biomass yield. Yield was expressed in t/ha. Cost of cultivation was computed based on the prevailing market prices of the inputs during the respective crop season. Gross returns were computed based on the grain and straw yield and their prevailing market prices during the respective crop season.

Net returns (₹/ha) = Gross returns (₹/ha) – Cost of cultivation (₹/ha)

B: C ratio= Net returns (₹/ha) / Cost of cultivation (₹/ha)

The input energy was divided into direct and indirect and renewable and non–renewable forms for estimation (Hatirli *et al.* 2006). The direct energy consists of diesel, human power and electricity, while the indirect energy contains seed, farmyard manure and machinery (Singh *et al.* 2007). Total physical output referred to both grain/seed and by–product yields. Quantity/numbers of all inputs used in the form of labour, seed and manures used in both crops were taken into consideration. The input energy and its conversion to energy equivalents was done by multiplying their per unit energy equivalents given by Babu *et al.* (2014). The farm produce (seed and straw yield) was also converted into energy in terms of energy output (MJ) using crop yields multiplied by their energy equivalents per unit. Based on the energy equivalents of the inputs and output, energy use efficiency, energy productivity, energy intensity in physical terms and energy intensity in economic terms were calculated.

Energy use efficiency = Gross energy output (MJ/ha)/ Energy input (MJ/ha)

Energy productivity (kg/MJ) = [Total output (grain+straw) (kg/ha)]/Total energy input (MJ/ha)

Net energy output (MJ/ha) = Gross energy output (MJ/ha) – Energy input (MJ/ha)

Energy intensity in physical terms (MJ/kg) = Total energy input (MJ/ha)/Total output (grain+straw) (kg/ha)

Energy intensity in economic terms (MJ/₹) = Gross energy output (MJ/ha)/Cost of cultivation (₹/ha)

All the data obtained from rice for consecutive two years was pooled and subjected to analysis of variance (Gomez and Gomez 1984).

## RESULTS AND DISCUSSION

*Yield attributes and yields*

Pooled data over two years revealed that different tillage practices had failed to show any significant effect on yield attributes and yields of rice (Table 1). Reduced tillage (RT) recorded higher productive tillers (10.8 /hill), longer panicle (23.3 cm), grains per panicle (87.4) , panicle weight (3.3 g) and 1000–grain weight (21.1 g) which resulted in higher grain yield (3.27 tonnes/ha) over conventional tillage (3.26 tonnes/ha) and no till (3.25 tonnes/ha) practices. However, straw yield was higher with NT (5.07 tonnes/ha) followed by RT (4.97 tonnes/ha) and CT (4.85 tonnes/ha). The increase in grain yield under RT could be ascribed due to combined effect of all the yield attributes. In clayey soils, where percolation rates are inherently low, and in areas where the water table is high during the rainy season, puddling has no effect on rice yield (So and Kichhof 1996). Thus, higher rice grain yield with RT (3.27 tonnes/ha) may be also due to reduction in nutrient losses by runoff and erosion.Application of 50% RDN through FYM + 50% RDN through VC+BF recorded the maximum number of productive tillers (11.2/hill), panicle length (23.6 cm), grains per panicle (94) and 1000–grain weight (21.6 g) followed by 100% RDN through vermicompost (VC) + BF (Table 1). This caused 42.3, 15.6 and 5.7 per cent increment in grain yield over farmers practice (FP), 100% RDN through FYM + biofertilizer (BF), and 100% RDN through VC + BF, respectively. This might be due to the combined effect of farmyard manure and vermicompost because of the decomposition and slow release pattern of nutrients from FYM and better mineralization, higher occurrence of beneficial microorganisms, growth promoting hormones and enzymes releasing fromvermicompost (Banik *et al.* 2006) leading to adequate and balance nutrient supply during entire growth period enabled the plants to assimilate sufficient photosynthates and thus increased the transfer from source to the sink resulting higher yields. These results are corroborated with the findings of Meena *et al.* (2014).

*Profitability*

Pooled data over two years revealed that highest cost of cultivation was incurred with CT (32.6× $10^3$ ₹/ha) followed by RT (30.66×$10^3$ ₹/ha) and NT (28.96×$10^3$ ₹/ha), respectively (Table 1). This caused 12.8 and 5.9 per cent higher cost involvement in CT than ZT and RT, respectively. This was due to more number of tillage operations and labour involvement in CT followed by RT. RT recorded the maximum gross returns (96.0 ×$10^3$ ₹/ha) followed by NT (95.8 ×$10^3$ ₹/ha). However, highest net returns (67.0×$10^3$ ₹/ ha) and B:C ratio (2.34) was observed with NT. The higher net return in NT was owing to the substantial saving of labour in tillage operations with minimal yield reduction.

Table 1 Effect of tillage practices and organic N sources on yield attributes, yields and economics of rice (data pooled over 2 years)

| Treatment | Productive tillers/ hill | Panicle length (cm) | Grains/ panicle | Panicle weight (g) | 1000 grain weight (g) | Grain yield (tonnes/ha) | Straw yield (tonnes/ha) | Cost of cultivation (× $10^3$ ₹/ha) | Gross returns (× $10^3$ ₹/ha) | Net returns (× $10^3$ ₹/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Tillage practices* | | | | | | | | | | | |
| CT | 10.3 | 22.8 | 86.0 | 3.0 | 20.5 | 3.26 | 4.85 | 32.6 | 95.5 | 63.0 | 1.94 |
| RT | 10.8 | 23.3 | 87.4 | 3.3 | 21.1 | 3.27 | 4.97 | 30.6 | 96.0 | 65.4 | 2.16 |
| NT | 10.6 | 22.9 | 87.3 | 3.2 | 20.9 | 3.25 | 5.02 | 28.9 | 95.8 | 67.0 | 2.34 |
| SEm± | 0.3 | 0.5 | 1.8 | 0.05 | 0.38 | 0.07 | 0.08 | | 1.8 | 1.5 | 0.07 |
| LSD (*P*=0.05) | NS | NS | NS | 0.12 | NS | NS | NS | | NS | 3.66 | 0.15 |
| *Organic N sources* | | | | | | | | | | | |
| Farmers practice | 9.7 | 22.1 | 78.6 | 2.8 | 19.9 | 2.6 | 4.4 | 26.2 | 78.0 | 51.9 | 2.00 |
| 100% FYM+ BF | 10.4 | 23.1 | 85.1 | 3.3 | 20.7 | 3.2 | 4.9 | 27.4 | 94.4 | 67.1 | 2.46 |
| 100% VC+BF | 11.0 | 23.2 | 89.9 | 3.4 | 20.9 | 3.5 | 5.2 | 37.2 | 101.9 | 64.7 | 1.75 |
| 50% FYM+50% VC+BF | 11.2 | 23.6 | 94.0 | 3.4 | 21.6 | 3.7 | 5.3 | 32.0 | 108.8 | 76.8 | 2.41 |
| SEm± | 0.3 | 0.4 | 2.2 | 0.09 | 0.42 | 0.08 | 0.09 | | 2.1 | 2.1 | 0.08 |
| LSD (*P*=0.05) | 0.6 | 0.8 | 4.6 | 0.19 | 0.86 | 0.17 | 0.18 | | 4.29 | 4.32 | 0.19 |

*CT: Conventional tillage, RT: Reduced tillage, NT: No till, FYM: Farmyard manure, BF: Biofertilizer, VC: Vermicompost

Table 2 Effect of tillage practices and organic N sources on energetic of rice (data pooled over 2 years)

| Treatment | Energy input (GJ/ha) | Gross energy output (GJ/ha) | Net energy output (GJ/ha) | Energy use efficiency (%) | Energy productivity (kg/MJ) | Energy intensity in physical terms(MJ/kg) | Energy intensity in economic terms(₹/MJ) |
|---|---|---|---|---|---|---|---|
| *Tillage practices* | | | | | | | |
| CT | 11.4 | 108.48 | 97.07 | 9.51 | 0.71 | 1.42 | 3.33 |
| RT | 9.4 | 110.12 | 100.72 | 11.74 | 0.88 | 1.15 | 3.61 |
| NT | 7.5 | 110.51 | 102.99 | 14.76 | 1.11 | 0.92 | 3.84 |
| SEm± | | 1.83 | 1.83 | 0.21 | 0.02 | 0.02 | 0.06 |
| LSD (*P*=0.05) | | NS | 4.47 | 0.52 | 0.04 | 0.05 | 0.16 |
| *Organic N sources* | | | | | | | |
| Farmers practice | 8.4 | 93.24 | 84.89 | 11.61 | 0.87 | 1.20 | 3.55 |
| 100% FYM+BF | 9.0 | 108.18 | 99.23 | 12.52 | 0.94 | 1.11 | 3.93 |
| 100% VC+BF | 10.7 | 115.70 | 105.03 | 11.10 | 0.83 | 1.24 | 3.10 |
| 50%FYM+50%VC+BF | 9.8 | 121.69 | 111.91 | 12.79 | 0.96 | 1.08 | 3.79 |
| SEm± | | 1.90 | 1.90 | 0.26 | 0.02 | 0.03 | 0.07 |
| LSD (*P*=0.05) | | 3.89 | 3.89 | 0.54 | 0.04 | 0.06 | 0.15 |

*CT: Conventional tillage, RT: Reduced tillage, NT: No till, FYM: Farmyard manure, BF: Biofertilizer, VC: Vermicompost

Similar results are reported by Sharma *et al.* (1995). Organic sources of nutrition had significant effect on profitability of rice (Table 1). Application of recommended dose of nitrogen through 50% FYM + 50% RDN through VC+BF recorded significantly higher gross returns (108.8×$10^3$ ₹/ha) and net returns (76.8×103 ₹/ha) as compared to control (FP) and 100% RDN through FYM+BF, 100% RDN through VC + BF. However, maximum B:C ratio (2.46) was recorded with 100% RDN through FYM+ BF which was closely followed by 50% RDN through FYM + 50% RDN through VC+BF (2.41). This may be attributed to the higher productivity and variation in cost of cultivation among the treatments. These results are in accordance with the findings of Yadav *et al.* (2014).

*Energy dynamics*

The tillage practices for rice crop had significant effect on the energy requirement, gross and net energy output, and energy use efficiency, energy intensity in physical and economic terms and its productivity. The energy requirement was highest in CT(11.4 GJ/ha) followed by RT and least in NT (Table 2). In NT, the energy requirement was 33 and 17.5% lower than CT and RT, respectively. Due to lower energy requirement in NT and RT, their gross and net output energy was higher. Due to low energy inputand higher output,NT recorded 35.6 and 20.5% higher energy use efficiency over CT and RT, respectively. Similarly, energy productivity, i.e. kg of grain produced per unit of energy invested was highest in NT and least in CT.Energy productivity was 36 per cent higher in NT over the CT. However, in case of energy intensity in physical terms a reverse trend was noticed, maximum value was recorded under CT. Energy intensity in physical terms was lower by 35 and 19% in NT and RT over CT, respectively. Similarly, energy intensity in economic terms was highest under NT and lowest in CT. Higher energy saving due to NT over CT in agricultural production systems was also reported by Khambalkar *et al.* (2010); Mishra and Singh (2012) and Kumar *et al.* (2013). Energetics of rice production was also significantly influenced by substitution of organic N sources (Table 2). Among the organic sources, 50% RDN through FYM + 50% RDN through VC+BF recorded significantly higher values of gross energy output (121.69 GJ/ha), net energy output (105.03 GJ/ha), energy use efficiency (12.79%) and energy productivity (0.96 kg/MJ) over control (FP) and 100% N through vermicompost (VC) + BF. In general higher energy output is directly proportional to energyuse efficiency (ratio of energy out putof total biomass and energy input). These results corroborate the findings of Yadav *et al.* (2013b). However, energy intensity in economic terms (3.93 MJ/₹) was maximum with application of 100% RDN through FYM + BF over all the other organic sources. Energy intensity in physical terms remained minimal under 50% RDN through FYM + 50% RDN through VC+BF (1.08 MJ/ha) and was lower by 10.0, 2.7 and 12.0% as compared to control (FP), 100% RDN through FYM + BF and 100% RDN through VC + BF, respectively. This may be due to the higher harvestable biomass as energy use efficiencies of any production system is directly related to the biomass. Improvements in energy use efficiencies due to substitution of organic N in rice was also reported by Baishya *et al.* (2014).

Based on above study, it may be concluded that planting of rice with no–till (NT) is more profitable, besides, saving energy and labour. Among organic sources, substitution of nitrogen through VC and FYM in equal proportion along with biofertilizers (50% RDN through FYM +50% RDN through VC+BF) is more remunerative and energy efficient for sustainable rice production in mid hill ecosystems of Sikkim Himalaya.

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