



Effect of organic mulches and vermicompost on productivity, profitability and energetic of mustard (*Brassica campestris*) in popcorn (*Zea mays everta*)-mustard cropping system in rainfed Sikkim Himalaya

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ABSTRACT

A three year fixed plot field experiment was conducted during *rabi* seasons of 2011 to 2014 at Research Farm of ICAR Research Complex for NEH Region, Sikkim Centre to study the effect of organic mulches and vermicompost on productivity, profitability and energetics of mustard under popcorn (*Zea mays everta*)-mustard (*Brassica campestris*) cropping system. The results revealed that crop residue and/or forest litter mulching exhibited significant effect on yield attributes, yields, economics and energetics of mustard. Among the mulches, application of tree leaf mulch (TLM) @ 5 t/ha recorded the significantly higher seed yield (1.05 t/ha), net returns (19.86 × 10³ ₹/ha) and net rupees per rupees invested (NRPRI) (1.87) over other mulching materials including control. Systematic energy analysis also showed that the maximum values of gross energy output (59.69 GJ/ha) and net energy output (52.85 GJ/ha) was recorded with TLM @ 5 t/ha, whereas energy productivity (0.54 kg/MJ) was higher with rice residue mulch (RRM) @ 5 t/ha followed by maize residue mulch (MRM) @ 5 t/ha. Among the different levels of vermicompost (VC), application of VC @ 1.5 t/ha recorded the highest seed yield (1.05 t/ha) and net return (15.38 × 10³ ₹/ha) followed by VC @ 1.0 t/ha and control (no vermicompost). However, NRPRI was higher with VC @ 1.0 t/ha (1.62) followed by VC @ 1.5 t/ha. With regards to the energy budgeting, among the various levels of VC, application of VC @ 1.5 t/ha recorded 2.1% and 18.9% higher energy use efficiency (EUE) over VC @ 1.0 t/ha and control, respectively.

Key words: Crop residue mulch, Energetics, Mustard, Tree leaf mulch, Vermicompost

Maize–mustard cropping system is very protuberant in sub-tropical rainfed hill ecosystems of north-eastern, Rajasthan and Jammu regions of India. Rapeseed and mustard is important oilseed crop of the India. It is cultivated in an area of 6.90 M ha with a production and productivity of 8.18 Mt and 1185kg/ha, respectively and accounts 23% and 25% of the total oilseeds area and production of the country, respectively (Jakhar *et al.* 2017).

Sikkim is the first fully certified organic state of India. The state as a whole is about 64.5% deficient in oilseeds to fulfil its populace requirement. Hence, the production and productivity of rapeseed-mustard is needed to increase

in Sikkim to shrink the gap between supply and demand. Rapeseed and mustard are the most important winter season oilseed crop of the state, cultivated in 3.66 -thousand ha area with a production and productivity of 3.12 thousand tonne and 853 kg/ha, respectively. The productivity of rapeseed and mustard in Sikkim is lagging behind the India's national average. In Sikkim, rapeseed and mustard are generally cultivated by the farmers after harvesting of *kharif* crops, i.e. maize and rice on residual soil moisture and fertility, which resulted in poor productivity. Maize is number one cereal crop of the state grown on upland terraces in rainfed conditions. After harvesting of maize. It is very difficult to cultivate *rabi* season crop due to non-availability of adequate soil moisture especially during later phase of crop growth. Hence, proper management practices for utilization of the soil moisture during *rabi* season are essential for profitable cultivation of winter season crops under rainfed ecosystem of Sikkim Himalayas. Crop residue and/or forest litter mulching can play an important role for enhancing the productivity of rainfed crops (Mandal and Ghosh 1984). Mulching enhances the water use efficiency and crop yield, besides decreasing the weed pressure (Qin *et al.* 2015, Massimo *et al.* 2016), reduces evaporation

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(Pawar *et al.* 2004), increases soil water retention capacity and controls soil temperature fluctuations (Lalitha *et al.* 2001). Organic mulching has put forth a positive impact on vegetation dynamics and crop productivity (Burkhard *et al.* 2009). Mulching also improves soil condition by altering soil resistance to root penetration, hydraulic conductivity and water holding capacity, which in turn affects crop growth and yield (Mondal *et al.* 2008). Moreover, organic mulches add soil organic matter, plant nutrients (Leblanc *et al.* 2006, Teame *et al.* 2017) and enhances crop yield.

Adequate nutrients management is a major issue in organic farming for harvesting potential yield of any crop. Organic nutrients applied to preceding crops exhibit significant residual effects on succeeding crops due to slow decomposition process (Babu *et al.* 2013); hence nutrient management must be done keeping the whole cropping system in view rather than the individual crops. Sikkim has very huge biomass potential, which can be effectively utilized as an organic fertilizer through vermicomposting. Vermicompost is semi bulky organic manure holds very high macro-and micro-nutrients.

Energy is an important indicator of sustainable production systems. Therefore, energy input-output analysis is necessary for effective management of scarce resources for improved agricultural production. A systematic assessment of energy and economic feasibility of an agro-ecosystem can provide insights on environmental and crop management practices interactions (Yadav *et al.* 2017). Rapeseed and mustard generally considered a residual fertility and soil moisture eating crop, hence, most of the research works on rapeseed and mustard is focused on the assessment of residual effect of nutrients on its performance and information on direct effect of organic mulching and nutrients management practices is very meagre. Hence, it was hypothesized that direct imposition of crop residue and/or forest litter mulching and vermicompost may enhance the productivity, profitability and energy use efficiency of mustard in system mode under organically managed rainfed condition of Sikkim Himalayas. Therefore, a fixed plot field study in upland terraces was conducted during *rabi* seasons from 2011 to 2014 at Research Farm of ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim to assess the direct effect of mulching and vermicompost on productivity, economics and energy dynamics of mustard (*Brassica campestris*) under popcorn (*Zea mays everta*)-mustard cropping system.

MATERIALS AND METHODS

A field experiment was conducted in three consecutive *rabi* seasons of 2011 to 2014 at Experimental Block, Research Farm, ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim situated at latitude of 27°32' N and longitude of 88°60' E, and altitude of 1350 meters above the mean sea level. Soil of experimental field was sandy loam in texture with pH 5.8 (1:2.5 soil and water ratio), 225.5 kg/ha alkaline permanganate oxidizable N, 27.50 kg/ha Brays available P, 198.3 kg/ha 1 N ammonium

acetate exchangeable K and 1.93% organic carbon.

The experiment was laid out in split-plot design assigning four types of mulching, viz. control (NM), tree leaf mulch (TLM) @ 5 t/ha, maize residue mulch (MRM) @ 5 t/ha and rice residue mulch (RRM) @ 5 t/ha to main plots and three levels of vermicompost (control, vermicompost @ 1.0 t/ha and vermicompost @ 1.5 t/ha) to sub-plots. All the treatments were replicated four times. After harvesting of *kharif* popcorn, two tillage was done to make the soil well pulverized and free from clods and mustard seed @ 5 kg/ha was sown manually in the first week of October in all the years. Vermicompost was applied in furrow just before seed sowing in all the plots as per the treatments. Recommended organic package of practices was followed to raise the crop. Observations on yield attributes and yields were recorded as per the standard procedures. 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 seed and stover yield and their prevailing market prices during the respective crop season. Net returns and net return per rupee invested (NRPRI) were computed by subtracting cost of cultivation from gross returns.

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

NRPRI = Gross returns (₹/ha) / Cost of cultivation (₹/ha)

For energetics, the input energy was divided into direct and indirect and renewable and non-renewable forms (Hatirli *et al.* 2006). The direct energy consisted of diesel and human power, while the indirect energy contains seed, organic manures and machinery (Singh *et al.* 2007). The energy equivalents given by Chaudhary *et al.* (2006), Yadav *et al.* (2013) and Yadav *et al.* (2017) were used for energy calculations, whereas energy equivalent of rice and maize residue and tree leaves were quantified based on the nitrogen content on dry weight basis in particular product. Different energy indices were calculated as per the equations suggested by Babu *et al.* (2016).

All the data obtained from mustard for consecutive three years was statistically analysed using the *F*-test as per the procedure given by Gomez and Gomez (1984). LSD values at *P* = 0.05 were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Yield attributes and yield

Mean data of three years revealed that mulching exhibited significant effects on yield attributes and yield of mustard (Table 1). Maximum number of siliquae/plant (163.9), seeds/siliqua (15.42) and 1,000-seed weight (3.10 g) was recorded with TLM @ 5 t/ha followed by MRM @ 5 t/ha. Similarly, seed, stover and biological yield were also significantly affected with the application of mulches and maximum values of all these parameters were recorded with the application of TLM @ 5 t/ha. Application of TLM

Table 1 Effect of mulching and vermicompost on yield attributes and yields of mustard under maize (popcorn)-mustard cropping system (Mean data of three years)

Treatment	Siliquae/plant (No.)	Seeds/siliqua (No.)	1000 grain weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)
<i>Effect of mulching</i>						
Control	128.50	11.75	2.86	0.65	1.45	2.10
Tree leaf mulch @ 5 t/ha	163.92	15.42	3.10	1.05	2.53	3.58
Maize residue mulch @ 5 t/ha	160.33	15.33	3.07	0.99	2.47	3.46
Rice residue mulch @ 5 t/ha	155.75	14.83	3.04	0.96	2.26	3.22
SEm±	1.59	0.27	0.02	0.009	0.02	0.05
LSD (P=0.05)	5.07	0.87	0.07	0.03	0.05	0.15
<i>Effect of vermicompost (VC)</i>						
Control	134.06	12.56	2.88	0.71	1.69	2.40
VC @ 1 t/ha	156.63	14.50	3.04	0.99	2.28	3.27
VC @ 1.5 t/ha	165.69	15.94	3.13	1.05	2.56	3.61
SEm±	1.43	0.21	0.02	0.010	0.02	0.04
LSD (P=0.05)	4.18	0.60	0.05	0.03	0.06	0.12

@ 5 t/ha resulted in 61.5, 9.4 and 6.0% higher yield over NM, RRM @ 5 t/ha and MRM @ 5 t/ha, respectively. The increase in seed yield in TLM applied treatment might be due to the fast decomposition and timely mineralization of nutrients, mainly readily available nitrogen to the mustard crop as compared to the RRM and MRM which might take longer time to decompose. Availability of the mineralized N induced the photosynthetic activity, which results in enhanced crop growth (Tisdale *et al.* 2003). Yield improvement in rapeseed due to mulching of crop residue in the mid-hills of north-eastern hills region of India was also reported by Sarangi *et al.* (2010).

Application of vermicompost also significantly influenced the yield attributes and yield of mustard and the maximum number of siliquae/plant, seeds/siliqua and 1,000-seed weight was recorded with the application of VC @ 1.5 t/ha followed by 1.0 t/ha. The improvement was to the tune of 47.9 and 6.1% higher seed yield of mustard with the application of VC @ 1.5 t/ha over control and 1.0 t/ha, respectively. Similarly, application of VC @ 1.5 and 1.0 t/ha also registered 51.5 and 12.3% higher stover yield over control. Biological yield also exhibited the same pattern and significantly higher value was associated with the VC level of 1.5 t/ha (3.61 t/ha) followed by VC @ 1.0 t/ha and control (2.40 t/ha). Increased application of vermicompost enhances the soil nutrients availability to the crop which might be the reason for higher yields of mustard. These results corroborated with the findings of Singh *et al.* (2015).

Economics

An economic return is the basic determinant of any crop management practice. Management practices which recorded maximum net rupees per rupees invested (NRPRI) are economically more feasible over others. Mean data of three years revealed that cost of cultivation varied according to the treatments (Table 2) and maximum cost of cultivation was

recorded with application of RRM @ 5 t/ha (26.56×10^3 ₹/ha) followed by MRM @ 5 t/ha (24.06×10^3 ₹/ha) and the lowest in control (22.22×10^3 ₹/ha). Gross returns, net returns and NRPRI were significantly influenced by the application of mulches. Among the mulches, TLM @ 5 t/ha recorded the highest values of gross returns (42.42×10^3 ₹/ha), net returns (19.86×10^3 ₹/ha) and NRPRI (1.87) over other mulching materials including control. Higher yield and economic returns of mustard due to mulching under rainfed condition was also reported by Awal and Sultana (2011). Similarly, VC levels also exhibited the significant effect on gross returns, net returns and NRPRI. Increase in gross returns was noticed with correspondence increase in VC level up to 1.5 t/ha hence, the maximum gross returns (42.64×10^3 ₹/ha) was recorded with VC @ 1.5 t/ha followed by VC @ 1.0 t/ha (40.06×10^3 ₹/ha). Similarly, net returns (15.38×10^3 ₹/ha) was higher with VC @ 1.5 t/ha over its lower level (15.29×10^3 ₹/ha) and control (9.22×10^3 ₹/ha). However, higher NRPRI (1.62) was recorded with the application of VC @ 1.0 t/ha followed by VC @ 1.5 t/ha (1.57) and the lowest with control (1.47). The higher NRPRI associated with the application of VC @ 1.0 t/ha was due to the combination of lower cost and higher yield as compared with VC @ 1.5 t/ha and control.

Energetics

Energy input-output analysis provides a way to choose the sustainable agriculture production systems. Crop management practice is considered more efficient when it produces higher output energy and requires less input energy. Mean data revealed that energy input varied according to the treatments of mulching and vermicompost application (Table 3). Higher energy input was incurred with TLM @ 5 t/ha (6.84 GJ/ha) followed by MRM @ 5 t/ha (6.39 GJ/ha). Application of mulches induced marked variation in gross and net energy output, energy use efficiency, energy

Table 2 Effect of mulching and vermicompost on economics of mustard under maize (popcorn)-mustard cropping system (Mean data of three years)

Treatment	COC ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	NRPRI	Energy input (GJ/ha)
<i>Effect of mulching</i>					
Control	22.22	26.53	4.31	1.19	4.44
Tree leaf mulch @ 5 t/ha	22.56	42.42	19.86	1.87	6.84
Maize residue mulch @ 5 t/ha	24.06	40.55	16.49	1.68	6.39
Rice residue mulch @ 5 t/ha	26.56	39.08	12.52	1.47	5.94
SEm \pm		0.38	0.38	0.01	
LSD (P=0.05)		1.20	1.20	0.05	
<i>Effect of vermicompost (VC)</i>					
Control	19.52	28.73	9.22	1.47	5.15
VC @ 1 t/ha	24.77	40.06	15.29	1.62	6.05
VC @ 1.5 t/ha	27.27	42.64	15.38	1.57	6.50
SEm \pm		0.41	0.41	0.02	
LSD (P=0.05)		1.19	1.19	0.05	

Table 3 Effect of mulching and vermicompost on energetics of mustard under maize (popcorn)-mustard cropping system (Mean data of three years)

Treatment	Gross energy output (GJ/ha)	Net energy output (GJ/ha)	EUE (%)	EP (kg/MJ)	Specific energy (MJ/kg)
<i>Effect of mulching</i>					
Control	35.46	31.02	7.92	0.47	2.14
Tree leaf mulch @ 5 t/ha	59.69	52.85	8.66	0.52	1.95
Maize residue mulch @ 5 t/ha	57.69	51.31	8.99	0.53	1.86
Rice residue mulch @ 5 t/ha	53.98	48.04	9.03	0.54	1.86
SEm \pm	0.29	0.29	0.05	0.003	0.02
LSD (P=0.05)	0.94	0.94	0.17	0.011	0.05
<i>Effect of vermicompost (VC)</i>					
Control	40.12	34.97	7.74	0.46	2.17
VC @ 1 t/ha	54.78	48.73	9.01	0.54	1.87
VC @ 1.5 t/ha	60.21	53.71	9.20	0.55	1.82
SEm \pm	0.38	0.38	0.06	0.004	0.02
LSD (P=0.05)	1.12	1.12	0.19	0.012	0.05

productivity and specific energy. Application of TLM @ 5 t/ha recorded significantly higher gross energy output (59.69 GJ/ha) and net energy output (52.85 GJ/ha). The output energy was determined by the amount and quality of harvestable biomass (Gelfand *et al.* 2010). However, energy use efficiency, i.e. the ratio of energy output to energy input and energy productivity, i.e. kg of grain produced per unit of energy invested was significantly higher with RRM (9.03 kg/MJ) compared to NM (7.92 kg/MJ) and TLM (8.66 kg/MJ) but remained at par with MRM (8.99 kg/MJ). However, the lowest value of specific energy (energy intensity in physical terms) was recorded with RRM (1.86 MJ/kg) and MRM (1.95 MJ/kg) but gradually increases in TLM (1.95 MJ/kg) and NM (2.14 MJ/kg). This indicated that the highest amount of product produced per unit of energy invested was in RRM and MRM while maximum

quantum of energy was required to produce one unit of output with NM treatment.

Vermicompost application also caused the significant variation in energetics of mustard production (Table 3). Among the different levels of VC, application of VC @ 1.5 t/ha recorded significantly higher values of gross energy output (60.21 GJ/ha), net energy output (53.71 GJ/ha) and energy productivity (0.55 MJ/ha) over VC @ 1 t/ha and control. Similarly, the application of VC @ 1.5 t/ha also resulted in maximum energy use efficiency (9.20%) as compared to other levels of VC. This was mainly due to higher biomass yield in particular treatment. Increase in energy use efficiencies are directly related to the harvestable biomass in any production system. On the contrary, the specific energy was significantly lowest with VC @ 1.5 t/ha (1.82) over VC @ 1 t/ha (1.87) and control (2.17). This

indicates that application of VC @ 1.5 t/ha requires less energy for unit production of mustard. Increased gross and net energy output due to application of organic manures was also reported by Deike *et al.* (2008) and Singh *et al.* (2016).

Thus, it can be concluded that direct application of TLM (tree leaf mulch) @ 5 t/ha and VC @ 1.5 t/ha enhances the productivity, profitability and energy balance of rainfed mustard under maize (popcorn)-mustard cropping systems in mid hills of Sikkim. Therefore, application of TLM@ 5 t/ha and VC @ 1.5 t/ha may be recommended for profitable organic mustard production in rainfed ecosystem of Sikkim Himalayas.

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