*Indian Journal of Agricultural Sciences* **89** (7): 1157–61, July 2019/Article
https://doi.org/10.56093/ijas.v89i7.91689

# Crop diversification for enhancing the productivity for food and nutritional security under the Eastern Himalayas

MANOJ KUMAR[1], RAKESH KUMAR[2], K LILY RANGNAMEI[3], ANUP DAS[4], K L MEENA[5] and D J RAJKHOWA[6]

*ICAR-Research Complex for NEH Region, Medziphema, Nagaland 797 106, India*

Received: 06 July 2018; Accepted: 13 February 2019

ABSTRACT

Monocropping, low productivity, energy–use efficiency and net returns are some of the major factors that contribute to unsustainable agriculture production system in the Eastern Himalayas. Crop diversification is a sustainable option for enhancing the productivity for food and nutritional security of small and marginal farmers of the regions. A field study was carried at the farmers' field by KVK, Longleng, Nagaland during 2013–15 to assess the most profitable rice–based system as rice–fallow, rice–*toria*, rice–vegetable pea (green pod), rice–tomato and rice–cabbage, respectively. Results revealed that rice yield ranges from 1.75–1.86/ha under the different cropping sequences. Significantly higher system rice equivalent yield (SREY) was recorded with rice–cabbage (30.6 t/ha) compared to other sequences. Land use efficiency (LUE), water use efficiency (WUE), system production efficiency (SPE) and system profitability had also significantly higher with rice–cabbage. The system energy returns, system net energy returns and system energy output efficiency had higher with rice–pea. Maximum values of system specific energy, system energy efficiency and energy profitability had noted with rice–fallow. Hence, it may be concluded that adoption of vegetables crops (cabbage/tomato) are the viable options for improving productivity, profitability and energy-use efficiency under foothill condition of Eastern Himalayas.

**Key words:** Crop diversification, Eastern Himalayas, Economics, Energetics

Crop diversification is recognised as an effective strategy for achieving the objectives of food and nutritional security, poverty alleviation, employment generation, judicious use of resources and sustainable agricultural development. It improves the quality of food security mainly because of more availability of pulses/oilseed and vegetables in addition to the cereals (Kumar *et al.* 2015d). Inclusion of pulses/oilseeds and vegetables in cropping system is more beneficial compared to monocropping for achieving the sustainable food and nutritional security (Kumar *et al.* 2016a). Hence, selection of crops should to be suitably planned for efficient utilization of the available resources (Kumar *et al.* 2015a, b, c). Growing of winter crops (carrot, potato, tomato, French bean, pea and lentil) after rice harvest increases the incomes of rural poor's (Kumar *et al.* 2014, Kumar *et al.* 2017a). Diversified cropping systems require increased use of energy. Energy–agriculture relation is an apt more important with intensification of system for resource poor situation (Kumar *et al.* 2016a). The productivity of rice in region is ~1.79 t/ha, which is far below the national productivity (2.26 t/ha). In Nagaland, paddy is grown during March to August and then land remains kept fallows in subsequent season (Kumar *et al.* 2016) but the region receives rainfall up to end of mid October. There is sufficient residual soil moisture in crop fields even after harvest of paddy to raising the succeeding winter crops. Thus, there is potential for growing of winter crops, i.e. vegetable pea, *toria*, tomato, cabbage on residual soil moistures, which increases the cropping intensity of *jhumias*. Keeping these things in view, the present investigation was undertaken.

## MATERIALS AND METHODS

Field investigation was carried out at the farmer's field of KVK, Longleng, Nagaland, during 2013–15 in five villages (Hukphang, Pongching, Orangkong, Pongo, Yongam) covering 20 number of farmers in an area of ~2.0 ha each. Total annual rainfall at experimental site varies between 1336 to 1626 mm during in 2013-14 and 2014-2015, respectively during cropping (Fig 1). Monthly mean maximum and minimum temperature in cropping

[1,3]Subject Matter Specialist, KVK Longleng, ICAR RC for NEH Region, Nagaland Centre, [5]Joint Director, ICAR RC for NEH Region, Nagaland Centre Jharanapani, Nagaland; [2]Scientist (Agronomy), Division of Crop Research, ICAR-RC for Eastern Region, Patna 800 014, (rakeshbhu08@gmail.com); [3]Principal Scientist (Agronomy), ICAR RC for NEH Region, Umiam 797 103, [4]Head and Senior Scientist, KVK Longleng, ICAR RC for NEH Region, Nagaland Centre, Medziphema, Nagaland 797 106.

period ranges from 19.0 to 31.2°C and 5.5 to 23.1°C, respectively. Soil of experimental sites were high in organic carbon (1.7–2.1%), medium in available N (296–340 kg/ha), available P (10–14 kg/ha) and K (170–182 kg/ha), respectively. Before introduction of 2nd crop at the farmer's field, training program was imparted to the progressive farmers on the improved package of practices on tomato (*Solanum lycopersicum* L.), pea (*Pisum sativum* L.), cabbage (*Brassica oleracea* var. *capitata*) and *toria* (*Brassica campestris* L. var. *toria*). Garden pea cultivated as green pod on the residual soil moisture, whereas tomato/cabbage were given life saving irrigation for better seedlings establishment. For comparison of the different cropping sequences (Table 1), yields of winter crop were converted into rice equivalent yield (REY) using the formula:

REY=Yield of paddy (first crop) + yield of second crop × price of second crop/price of paddy

Land use efficiency (LUE) was computed by dividing the total number of days occupied by respective crop by 365 days and multiplying with 100. System productivity was calculated by dividing production of crops in sequence by 365 days and expressed in per cent. System profitability was obtained by system net returns divided by total duration. Relative production efficiency (RPE) and relative economic efficiency (REE) were calculated by using the formula as mentioned below:

$$\text{Relative production efficiency} = \frac{\text{Total productivity (TP of diversified cropping system (CS) –TP of existing cropping system)}}{\text{TP of existing cropping system}} \times 100$$

$$\text{Relative economic efficiency} = \frac{\text{Net returns (NR) of diversified CS–NR of existing cropping system}}{\text{NR of existing cropping system}} \times 100$$

Energy input and output were calculated by converting various inputs used, viz. labour, fertilizer and farmyard manure (FYM) and output i.e. grain and straw into energy units as suggested by Tuti *et al.* (2012). The following formula was used for calculating the energy parameters.

Input energy: Energy equivalents for all inputs were summed to provide an estimate for total energy input; Output energy: Crop biomass yield i.e. yields of grain and by-product (straw/leaves/stalk).

Energy output from product (grain) and by-product were calculated by multiplying amount of production and its corresponding energy equivalent unit.

Net energy return: It is difference between gross energy output produced and total energy required obtaining it (input energy).

$$\text{Energy profitability (PE)} = \frac{\text{Net energy return (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

$$\text{Human energy profitability (HPE)} = \frac{\text{Output energy (MJ/ha)}}{\text{Labour energy (MJ/ha)}}$$

$$\text{Energy profitability (EP)} = \frac{\text{Crop economic yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy intensiveness (EI)} = \frac{\text{Energy input (MJ/ha)}}{\text{Cost of cultivations (Rs/ha)}}$$

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy profitability} = \frac{\text{REY (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy intensity in physical term (MJ/kg)} = \frac{\text{Total input (MJ/ha)}}{\text{Total output (grain + straw (kg/ha))}}$$

$$\text{Energy intensity in economic term (MJ Rs)} = \frac{\text{Gross energy output (MJ/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

Economics were computed at the prevailing market price during both the years for different commodities. Economic yield of paddy and winter crops in different cropping sequences were converted into equivalent value of carbohydrate as suggested by Gopalan *et al.* (2004). Carbon output was calculated based on the plant biomass production in different sequences as suggested by Lal (2004). Water use efficiency (WUE) was computed by dividing SREY with total rainfall received. Mean data of all observations over two years were pooled and statistically analysed using F–test. Differences between treatment mean, which were higher than least significant different considered as significant difference at 5% level of probability (P=0.05).

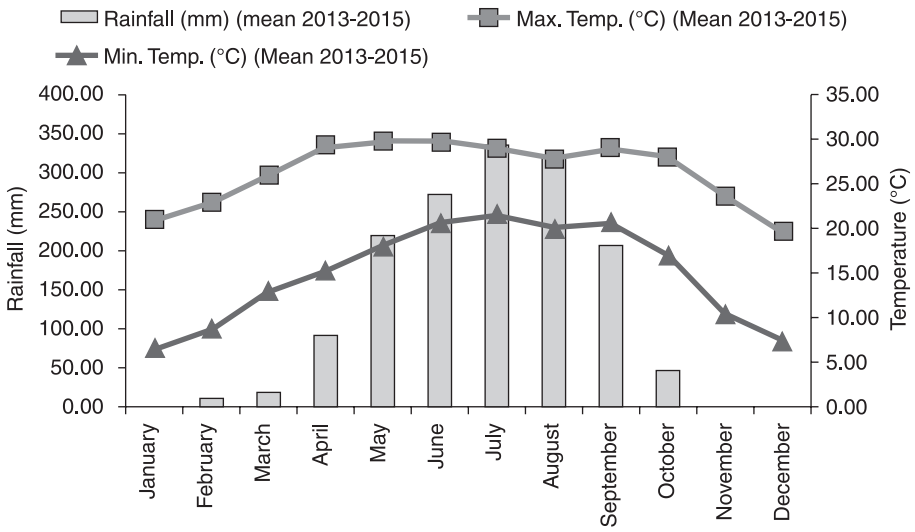


Fig 1. Mean monthly weather parameters during the experimental period (2013-15)

## RESULTS AND DISCUSSION

*Productivity*: Pooled data revealed that crop sequences

Table 1 Details of crops, varieties and cultural operation for different crops in cropping systems

| Cropping system | Varieties | Seed rate (kg/ha) | Spacing (cm) | Sowing/ transplanting | Organic manure (t/ha) | Weed control measures | Irrigation | Harvesting |
|---|---|---|---|---|---|---|---|---|
| Rice | Local | 110 | Broadcast | 15–25$^{th}$ March | - | Hand weeding (HW) | Rainfed | 25$^{th}$ August–5$^{th}$ September |
| Tomato | MT–3 | 500 g | 50×50 | 1–10$^{th}$ September/ 1–10$^{th}$ October | 5 | HW | Life saving | 1–15$^{th}$ January |
| Cabbage | Golden Acre | 600 g | 40×40 | 1–10$^{th}$ September/ 1–10$^{th}$ October | 5 | HW | Life saving | 1–15$^{th}$ January |
| Pea | Azad Pea | 75 | 30×10 | 20–30$^{th}$ September | 5 | HW | Rainfed | 25–30$^{th}$ January |
| Toria | TS–36 | 7 | 30×5 | 20–30$^{th}$ September | 5 | HW | – | 10–20$^{th}$ January |

Table 2 Productivity of main and component crops, rice equivalent yield of different cropping sequences (Pooled data of 2 years)

| Cropping system | Main crop (Rice) yield (t/ha) | 2$^{nd}$ crop yield (t/ha) | REY (t/ha) | SREY (t/ha) | SPE (kg/ ha/day) | RSPE (%) | LUE (%) | WUE (kg/ha/mm) |
|---|---|---|---|---|---|---|---|---|
| Rice–fallow | 1.86 | - | 1.7 | 1.9 | 5.1 | - | 43.8 | 1.5 |
| Rice–Pea | 1.95 | 4.5 | 9.3 | 11.2 | 25.8 | 408 | 78.1 | 7.4 |
| Rice–Toria | 1.75 | 0.6 | 3.3 | 5.3 | 9.6 | 86 | 74.5 | 3.5 |
| Rice–Tomato | 1.83 | 16.6 | 26.9 | 28.7 | 73.4 | 1318 | 76.4 | 18.9 |
| Rice–Cabbage | 1.87 | 20.3 | 30.6 | 32.5 | 83.8 | 1518 | 78.2 | 21.5 |
| SEm (±) | 0.44 | 0.31 | 0.2 | 0.3 | 1.4 | - | - | - |
| LSD (P=0.05) | NS | 0.96 | 0.7 | 0.9 | 4.3 | - | - | - |

REY, rice equivalent yield; SREY, system rice equivalent yield; SPE, system production efficiency; RSPE, relative system production efficiency; LUE, land use Efficiency; WUE,water use efficiency.

having 200% cropping intensity had significantly higher rice equivalent yield (REY). Paddy yield in different cropping sequence ranges from 1.75-1.86 t/ha (Table 2). Pooled yield of vegetable pea (green pod), *toria,* tomato and cabbage were 4.5, 0.6, 16.6 and 20.3 t/ha, respectively. Maximum REY had recorded of 9.3, 3.6, 26.9 and 30.6 t/ha with rice–pea, rice–*toria*, rice–tomato and rice–cabbage sequences, respectively. Per cent increase of REY had 1546.8, 1346.2, 397.3 and 92.5 over rice–cabbage, rice–tomato, rice–pea and rice–*toria* sequence, respectively over sole rice. System productivity/(SREY) had higher with rice–cabbage (32.5 t/ha) followed by rice–tomato (26.9 t/ha). This might be due to higher production potential of tomato and cabbage along with better market price of vegetable pea that fetched remunerative returns (Kumar *et al.* 2018a,b). Kumar *et al.* (2014) reported that rice–cabbage/rice–tomato had maximum productivity in the regions.

Trends of the system production efficiency (SPE) were same as those of SREY. SPE had significantly superior in rice–cabbage (83.8 kg/ha/day). The SPE had 1545.6, 1342.6, 407 and 89.2% higher in rice–cabbage, rice–tomato, rice–pea and rice–*toria* than rice-fallow. Higher SPE due to inclusion of vegetables and *toria* in rice–based sequences had reported by Kumar *et al.* (2015b). Highest system relative production efficiency (SRPE) of 1518% was obtained with rice–cabbage followed by rice–tomato and rice–pea (Table 2). Rice–*toria* sequences had the lowest SRPE (86%) over traditional rice monocropping.

*Land use efficiency (LUE) and water use efficiency (WUE)*: Markedly higher LUE had recorded with rice–cabbage (78.2%) due to the longest duration of sequences (283 days) followed by rice–pea (78.1%), rice–tomato (76.4%) and rice–*toria* (74.5%), respectively. Crop diversification utilizes land efficiently, which would not only enhance the profitability but also generates more employment during the lean period. Kumar *et al.* (2015c) reported that intensification through inclusion of short duration vegetables; and pulses/oilseeds in system increase LUE. Markedly highest WUE had recorded with rice–cabbage (21.5 kg/ha/mm) and lowest with rice–fallow system (1.48 kg/ha/mm).

*Carbohydrate equivalent yields and carbon output*: Maximum system carbohydrate equivalent yields (SCEY) had recorded with rice–cabbage (2357 MJ/ha) followed by rice–pea (2217 MJ/ha). Per cent increase in SCEY had 62.4, 52.8, 39.7 and 5.2% with rice–cabbage, rice–pea, rice–tomato and rice–*toria* sequences, respectively (Table 3). Higher carbohydrate production in a cropping sequence is obtained mainly due to higher economic yield and per unit production of carbohydrate, which is generally higher with cereals (Kumar 2015a,b,c). Inclusion of winter crops in sequences besides contributes to economic yield; improved succeeding rice yields, consequently more carbohydrate yields in sequences having 200% intensity. Maximum system carbon output (SCO) was recorded with rice–pea (6.8 t $CO_2$ eq/ha) followed by rice–tomato sequences (6.6 t $CO_2$ eq/ ha), respectively. The SCO was 65.3, 44.9, 181.3 and 89% higher with rice–pea, rice–*toria*, rice–tomato, rice–cabbage,

Table 3 Economics and employment generation as influenced by different cropping sequences (Pooled data of 2 years)

| Cropping system | System net returns (GJ/ha) | System benefit: cost ratio | System profitability (MJ/ha/day) | System relative economic efficiency (%) | System Carbohydrate equivalent yield (kg/ha) | System carbon output (t $CO_2$ eq/ha) |
|---|---|---|---|---|---|---|
| Rice–Fallow | 5660 | 1.34 | - | - | 1451 | 2.4 |
| Rice–Pea | 64686 | 2.34 | 177 | 1146 | 2217 | 6.8 |
| Rice–Toria | 13948 | 1.45 | 42 | 168 | 1527 | 3.4 |
| Rice–Tomato | 212228 | 2.94 | 583 | 3987 | 2027 | 6.6 |
| Rice–Cabbage | 249782 | 3.13 | 687 | 4710 | 2357 | 4.5 |
| SEm (±) | 5786 | 0.09 | 4.9 | - | 27.3 | 0.1 |
| LSD (P=0.05) | 17347 | 0.25 | 14.9 | - | 81.7 | 0.3 |

Table 4 Energy-use efficiencies as influenced by different cropping sequences (Pooled data of 2 years)

| Cropping system | System energy inputs (GJ/ha) | System energy returns (GJ/ha) | System net energy returns (GJ/ha) | System energy ratio | System efficiency profitability | Human energy profitability | Specific energy (MJ/t) | Energy output efficiency (MJ/ha/day) | Energy intensity in physical terms (MJ/kg) | Energy intensity in economic terms (MJ/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rice–fallow | 4.5 | 84.4 | 79.9 | 18.7 | 17.7 | 30.7 | 45.5 | 528 | 2.44 | 5.08 |
| Rice–Pea | 10.2 | 152 | 140 | 12.4 | 11.4 | 29.6 | 16.1 | 533 | 1.92 | 3.15 |
| Rice–Toria | 10.4 | 96 | 85.6 | 9.4 | 8.4 | 21.8 | 27.3 | 352 | 4.32 | 3.07 |
| Rice–Tomato | 12.2 | 143 | 132.3 | 13.7 | 12.7 | 19.5 | 5.3 | 512 | 0.57 | 1.31 |
| Rice–Cabbage | 12.3 | 107 | 94.8 | 8.8 | 7.8 | 17.9 | 3.5 | 375 | 0.56 | 0.91 |
| SEm (±) | 0.24 | 1.85 | 1.7 | 0.3 | 0.4 | 0.5 | 0.3 | 6.5 | 0.04 | 0.04 |
| LSD (P=0.05) | 0.71 | 5.56 | 5.1 | 0.9 | 1.2 | 1.5 | 1.0 | 19.6 | 0.12 | 0.12 |

respectively, compared as to rice–fallow system.

*Profitability*: Economic analysis revealed that rice–cabbage system had highest system net returns (₹ 250754/ha) followed by rice tomato (₹ 212690/ha) (Table 3). However, the system net returns remained much lower for rice–fallow (₹ 5680/ha). Increase in system net returns was mainly due to the higher market price of vegetables included in rice–based system. Highest system benefit: cost ratio (2.94), system profitability (₹ 687/ha/day) and relative economic efficiency (4018%) had recorded with rice–cabbage, respectively Kumar *et al.* (2016b) reported increase in net profits over traditional system with inclusion of vegetable crops in sequences.

*Energetics*: A system is considered more efficient, when it produces the highest energy output and requires the less energy inputs (Table 4). Highest system energy input had recorded with rice–cabbage (12.3 GJ/ha) followed by rice–tomato (12.2 GJ/ha) and the lowest with rice–fallows system (4.51 GJ/ha). More energy used by rice-cabbage system was mainly due to production of cabbage consumed higher energy inputs in terms of human labour during winter. However, double cropping required more input, which is responsible for consumption of more energy. Kumar *et al.* (2015d) also reported that among different sources of energy input, fertilizer accounted higher per cent of input energy. Amongst cropping system, highest system energy returns (152 GJ/ha) and system net energy return (140 GJ/ha) had recorded with rice–pea system, respectively.

Maximum system energy output efficiency was recorded in rice–pea (533 MJ/ha/day) followed by rice–fallow system (528 MJ/ha/day). Cropping sequences involving the winter crops had more energy productivity due to their lower energy consumption per unit of production. This might be due to less cropping duration and cost of cultivation for sole rice as compared to two crops in sequence (Kumar *et al.* 2017b). However, system energy intensity in physical term (4.32 MJ/kg) and system energy intensity (2.91 MJ/kg) had maximum in rice-*toria* because total energy output was less. Energy input had more in rice–tomato; therefore system energy intensiveness and system energy productivity had recorded of 10.48 MJ/t and 2.57 kg/MJ respectively. Maximum system energy ratio (18.7), system energy efficiency profitability (17.7), system human energy profitability (30.7) and system specific energy (45.5 MJ/t) was recorded in rice-fallow compared to where included winter crop. This indicated that maximum quantum of energy is required to produce one unit of output in rice-fallows, while highest amount of product produced per unit of energy invested in rice–cabbage (Bohra and Kumar 2015).

On the basis of above study, it may be concluded that farmers can cultivate the vegetables after rice for improving their livelihood as well as food and nutritional security in the Eastern Himalayas.

ACKNOWLEDGEMENTS

This research programme was funded by the Tribal Sub Plan (TSP) for promotion of agro-based interventions for sustainable livelihood in Nagaland.

REFERENCES

Bohra J S and Kumar R. 2015. Effect of crop establishment methods on productivity, profitability and energetics of rice *(Oryza sativa*)–wheat (*Triticum aestivum*) system. *Indian Journal of Agricultural Sciences* **85** (2): 217–23.

Gopalan C, Sastri and Balasubramaniam. 2004. *Nutritive Value of Indian Foods*, pp.47–57. (Revised Ed.) Printed by National Institute of Nutrition, ICMR, Hyderabad, India.

Kumar M, Kumar R, Meena K L, Rajkhowa D J and Kumar A. 2016a. Productivity enhancement of rice through crop establishment techniques for livelihood improvement in Eastern Himalayas. *Oryza* **53** (3): 300–8.

Kumar M, Rajkhowa, Meena K L, Kumar R, Zeliang P K, Kikon E L, Rangnamei K L and Namei A.2017a. Effect of nutrient management in lowland rice for improving productivity, profitability and energetics under mid hill altitude of Nagaland. *Journal of AgriSearch* **4** (4): 247–50.

Kumar R, Chatterjee D, Deka B C and Ngachan S V. 2017. Validation of common salt application on productivity, profitability, nutrient uptake and soil health of upland rice (*Oryza sativa* L.) under shifting cultivation area of Nagaland. *Indian Journal of Traditional Knowledge* **16**(2): 341–49.

Kumar R, Deka B C, Kumar M and Ngachan S V. 2015a. Productivity, quality and soil health as influenced by organic, inorganic and biofertilizer on field pea in Eastern Himalaya. *Journal of Plant Nutrition* **38** (13): 2006–798.

Kumar R, Deka B C, Kumawat N and Ngachan S V.2014. Effect of integrated nutrition, biofertilizers and zinc application on production potential and profitability of garden pea (*Pisum sativum* L.) in Eastern Himalaya, India. *Legume Research* **37**(6): 614–20.

Kumar R, Kumar M and Deka B C. 2015b. Production potential, profitability and energetics of transplanted rice as influenced by establishment methods and nutrient management practices in Eastern Himalaya. *Research on Crops* **16**(4): 625–33.

Kumar R, Kumar M, Kumar A and Pandey A. 2015c. Productivity, profitability, nutrient uptake and soil health as influenced by establishment methods and nutrient management practices in transplanted rice (*Oryza sativa*) under hill ecosystem of North East India. *Indian Journal of Agricultural Sciences* **85**(5): 634–9.

Kumar R, Patra M K, Thirugnanavel A, Chatterjee D and Deka B C.2016. Towards the natural resource management for resilient shifting cultivation system in eastern Himalayas, Pp: 409–36. *Conservation Agriculture: An Approach to Combat Climate Change in Indian Himalaya.* (Eds) Bisht J K, Meena V S, Mishra P K and Pattanayak A.ISBN: 978-981-10-2557-0(Print) 978-981-10-25587(Online),http://link.springer. com/book/10.1007/978-981-10-2558-7.

Kumar R, Patra M K, Thirugnanavel A, Deka B C, Chatterjee D, Borah T R, Rajesha G, Talang H D, Ray S K, Kumar M and Upadhyay P K. 2018. Comparative evaluation of different integrated farming system model for small and marginal farmers under the Eastern Himalayas. *Indian Journal of Agricultural Sciences* **88**(11): 1722–29.

Kumar R. 2015a. Effects of NPKS on growth, yield and quality of late sown *toria* varieties (*Brassica rapa* L. var. *toria*) under rain-fed condition of North East India. *Bangladesh Journal of Botany* **44**(4): 521–8.

Kumar R. 2015b. Influence of mulching, liming and farm yard manures on production potential, economics and quality of maize (*Zea mays* L.*)* under rain-fed condition of Eastern Himalaya. *Bangladesh Journal of Botany* **44**(3): 391–8.

Kumar R. 2015c. Productivity, profitability and nutrient uptake of maize *(Zea mays*) as influenced by management practices in North–East India. *Indian Journal of Agronomy* **60**(2): 273–8.

Kumar S, Bohra J S, Kumar R, Goswami G and Kumawat N. 2015. Assessment of productivity, profitability and energetics of rice–based cropping sequences in irrigated ecosystem of Eastern Uttar Pradesh, India. *Ecology, Environment and Conservation* **21** (August Suppl.): AS303–AS310.

Kumar S, Kumar R, Mishra J S, Dwivedi S K, Prakash V, Rao K K, Singh A K, Bhatt B P, Singh S S, Haris A A, Kumar V, Srivastava A K, Singh S and Yadav A. 2018b. Productivity and profitability of rice (*Oryza sativa*) genotypes as influenced by crop management practices under middle Indo–Gangetic Plains. *Indian Journal of Agronomy* **63** (1): 45–9

Lal R. 2004. Carbon emission from farm operations. *Environmental International* **30**: 981–90.

Tuti MD, Prakash V, Pandey BM, Bhattacharya R, Mahanta D, Bisht JK, Mina MK, Mina BL, Kumar N, Bhatt JC, Srivastva AK. 2012. Energy budgeting of colocasia-based cropping systems in the Indian sub-Himalayas. *Energy* **45**: 986–93.