The Pharma Innovation Journal 2021; 10(6): 1319-1326

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(6): 1319-1326

www.thepharmajournal.com
Received: 02-04-2021
Accepted: 16-05-2021

MP Singh
Associate Professor, Department of Agronomy, Janta College Bakewar, Etawah, Uttar Pradesh, India

Ram Narayan Meena
Associate Professor, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Corresponding Author:
Ram Narayan Meena
Associate Professor, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

The impact of sustainable farming in improving household food security of marginal farmers in the eastern indo-gangetic plains of India

MP Singh and Ram Narayan Meena

Abstract
The basic challenge for sustainable agriculture is to make best use of available biophysical and human resources. But growth being at the centre-stage of the policy agenda of almost all countries in the world has led to fast depletion of natural resources. Land and water constitute two important renewable resources extensively used in agricultural sector. The sustainable farming and diversification of agriculture is an alternate way for the regeneration and conservation of land and water. The present paper attempts to study if diversification can ensure sustainability in agriculture. For this purpose, secondary data at two points of time 2014-15 and 2015-16 are used. It is observed that area under coarse cereals has declined from 2.10 to 1.76 per cent. For rest of crops it has increased and in case of sugarcane it is constant. The index values for the country as a whole reveals the fact that there is crop concentration in favour of fruits and vegetables. At the state level, sustainable farming and crop diversification is found to be highest in Andhra Pradesh followed by West Bengal, Bihar, Maharashtra and Karnataka. Rest of the states has concentration of crops with highest in Odisha followed by Madhya Pradesh. These evidences suggest that the use of organic manures like farmyard manure, vermicompost and poultry manure along with biofertilizers could be a key factor for achieving and maintaining high level of production in high value crops and crop sequences as sustainable farming and crop diversification. Therefore, an investigation entitled "The Impact of Sustainable Farming in Improving Household Food Security of Marginal Farmers in the Eastern Indo-Gangetic Plains of India" was carried out at Varanasi in *Inceptisol* soil between 2014-15 and 2015-16 to compare organic and chemical fertilizer nutrient inputs packages in rice and maize-based cropping sequence. Pooled data analysis revealed that the application of 100% RDN through organic manures as 1/3 farmyard manure (FYM) + 1/3 *Trichoderma* compost + 1/3 Vermi compost (VC) + *Azotobacter/Rhizobium* + PSB (M_2) had the highest rice equivalent grain yield (system productivity), production efficiency, as well as net monetary return and profitability in different rice and maize-based cropping sequence. Among the different cropping sequences maize-chickpea sequence had higher value with respect to system productivity, production efficiency and economic efficiency. However, rice-mustard sequence proved superior with respect to land use efficiency. The different cropping sequences differ with respect to nutrient uptake, e.g., maize-frenchbean had the highest removal of N, P and K than the rest of cropping sequence, which was significantly superior to the rest of the sequences. The organic nutrition with organic manures along with biofertilizers (M_2) proved superior due to its visible favorable effect on soil health with respect to nutrient status and microbial count and this indicates the utilization of this low-cost but long-term beneficial practice under high-intensity cropping for sustainable crop production.

Keywords: Organic nutrient management, Cropping systems, *Trichoderma* compost, Biofertilizers, System productivity, Soil health

Introduction
Sustainable farming and crop diversification provides the farmers with a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to bring down the possible risk. Sustainable farming and crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops. The sustainable farming and crop diversification is also taking place due to governmental policies, thrust on some crops, market reforms, infrastructure development, government subsidies, certain other price related support mechanisms, higher profitability and stability in production also induces crop diversification. Sustainable farming and crop diversification and growing of large number of crops are practiced in dryland areas to reduce the risk factor of crop failures due to recurring droughts. Crop substitution and crop shift are also taking place in the areas suffering with some specific soil related problems. The country has made considerable progress in the farm sector during the last 50 years. From 'hand to mouth' conditions in the early sixties, the country has not only become self-reliant in food grains but have acquired sufficient resilience to tide over the

adverse conditions. The achievements in food production is the outcome of a policy framework of improving rural infrastructure including irrigation, research, extension, provision of agricultural inputs at reasonable prices, mechanization in farming, marketing support through minimum price mechanism, promotion of FPOs etc. Though an impressive achievement has been made in Indian agricultural sector farming continues to face poor infrastructure conditions and vagaries of climate change. Only around 40 per cent of the cultivated land is under irrigation system and farmers on the on the remaining 60 per cent of the land are completely dependent on rainfall, which is also greatly characterized by large variations in terms of precipitation both spatially and temporally. This has been further complicated by the vagaries of climate change. For a large majority of farmers in different parts of the country gains from application of science tools and technologies in agriculture have yet to be realized. As a result, the productivity levels of many major crops in India do not compare very favourably with the yields obtained in agriculturally advanced countries. Due to limited capacities of the farmers to take advantage of the opportunities presented by liberalization is further limited. Efficient and effective management of agriculture is a crucial aspect in the years to come for acquiring enduring self-reliance and ensuring sustainable growth.

The greatly increased agricultural production from farms because of the use of high-yielding varieties which were demanded excessive input *i.e.* chemical fertilizers and pesticides for supporting plant nutrition (Kibblewhite *et al.* 2008; Lorenz *et al.* 2013) [15, 19]. Chemical fertilizers have a major in boost up the crop productivity by supply essential plant nutrients to sustain the crop growth (Santos *et al.*, 2012; Meena *et al.*, 2019) [34]. However, excessive use of chemical inputs into the agricultural system led to serious harmful polluting impact on soil health, crop production, nutritional produce quality, environment and human health (Saigusa 2000; Power, 2010; Popp *et al.*, 2013; Bhattacharyya *et al.* 2015; Jaishankar *et al.*, 2014; Khatri and Tyagi, 2015) [32, 27, 26, 5, 12, 14]. Simultaneously, demand of food to feed the ever increasing population cause overexploitation of land resources under intensive agricultural production systems (Lal, 2015) [17] and stagnated the productivity of different cropping systems (Youssef, 2014) [49]. These impart a serious concern to the sustainability of agricultural system and there is urgent need of some alternative practices for sustainable development to preserve these natural resources (Raja, 2013; Bohlke, 2002; Aktar *et al.*, 2009; Mohanty *et al.*, 2013; Hongsibsong *et al.*, 2017) [29, 6, 1, 24, 11]. Hence, need is being increasingly felt to identify and use some new indigenous input to the crops (FAO 2017) [10]. In this direction, use of organic source of nutrients like farmyard manure, *Trichoderma* compost, vermicompost holds a great promise in improving and sustaining soil and environmental quality (Ashoka *et al.*, 2017) [3]. Currently, animal based organic manures are become more popular among farmers due to the high cost of inorganic fertilizers and its negative impacts on soil quality (Arancon *et al.*, 2008; Meena *et al.*, 2018) [2]. Some studies show that application of composted materials with bio-fertilizers improved soil microbial community and diversity in degraded soils (Zhen *et al.*, 2014). The further advantages of bio-fertilizers include longer shelf life causing no undesirable effects to ecosystem (Sahoo *et al.*, 2014) [31]. Use of organic manures helps to protect the soil health by maintaining the equilibrium of soil organic matter, enzymes and microbial biomass ultimately helping to improve physical, chemical, and biological properties of the soil (Bulluck *et al.*, 2002; Pullmeman *et al.*, 2003; Doni *et al.*, 2014; Schütz *et al.*, 2018; Sinha *et al.*, 2014) [7, 9, 36]. The yield increases effects of organic sources of nutrient in various rice-based cropping systems had been reported by several researchers (Tripathi *et al.*, 2008) [47]. The farmers can consecutively, get good profit from the organically produced crops and vegetables if incorporated high value crop in sequences due to their higher demands in domestic, national as well as international markets (Singh, 2005). These evidences suggest that the use of organic manures like farmyard manure, vermicompost and *Trichoderma* compost could be a key factor for achieving and maintaining high level of production in different cropping sequences.

Materials and Methods

A field experiment was carried out at Agricultural Research Farm, Banaras Hindu University, Varanasi, Uttar Pradesh (India) during 2014-2016. Geographically, it is located at 25°18' North latitudes, 83°03' East longitude and at an altitude of 80.71 m mean sea level. The soil was sandy-clay loam classified as *inceptisol* having pH of 7.3 and 0.35 percent organic carbon. The experimental soil was low in available nitrogen (195.50 kg ha^{-1}), medium in available phosphorus (17.88 kg ha^{-1}) and medium in available potassium (207.15 kg ha^{-1}). Six cropping sequences taken in main plot were Rice – Mustard (R-M), Rice – Table pea (R-TP), Rice – Lentil (R-LT), Maize (Green cob) – lentil (M-LT), Maize (Green cob) – French bean (M-FB) and Maize (Green cob) – Chickpea (M-C). Sub plot consisting three manurial treatments were100% RDN through organic manures as 1/3 FYM + 1/3 *Trichoderma* compost + 1/3 Vermicompost (M1), 100% RDN through organic manures as 1/3 FYM + 1/3 *Trichoderma* compost + 1/3 Vermicompost + *Azotobacter/Rhizobium* + PSB (M_2) and 100% RDN through inorganic sources (M3). These eighteen treatment combination were tested in a split plot design with a plot size of 5.0 m x 4.0 m.

Table 1: Details of the variety, seed rate and spacing of different crops

Crop	Variety	Seed rate (kg ha^{-1})	Spacing (cm)
Rainy season			
Rice	HUR-105	30	20x10
Maize	MRM 3777	20	60x20
Winter season			
Mustard	NRC-HB-101	5	45x15
Table pea	HUDP-15	70	45x10
Lentil	Malika (K-75)	45	30x10
French bean	Malviya Rajmash – 137	60	40x15
Chickpea	JG -315	60	30x10

Application of treatments

The organic manures were applied as per treatment during puddling and in other crops 20 days before sowing and mixed thoroughly in 15 cm top soil layer. In control treatment, recommended dose of nutrient through urea, DAP and MOP was drilled at sowing, 10 cm deep and 5 cm away from seed. The NPK contents of FYM, VM and *Trichoderma* compost on dry weight basis were 0.50, 2.30 and 2.80% N, 0.20, 0.75 and 2.20% P_2O_5 and 0.50, 1.23 and 1.30% K_2O, respectively. For the preparation of *Trichoderma* compost an area of 5 m × 1.5 m is marked out in elevated shaded place. The farm residue to be composted was chopped into 10-15 cm in size. About 100 kg of chopped residue was spread over the marked area. In the order of 50 g of *Trichoderma viride* was sprinkled over this layer. About 100 kg of crop residue were spread on this layer. One kg of urea was sprinkled uniformly over the layer. Same process was repeated until the level rises to 1 m. Water were sprinkled as required to maintain a moisture level of 50-60 percent. After that, the surface of the mound is covered with a thin layer of soil. The heap requires a careful turning on the twenty-first day. The *Trichoderma* compost was prepared in about forty days.

Crop management

Rainy season crops

The experimental plot was plowed once by disc plow followed by two cross disc harrowing and leveling. The plot was first prepared by power tiller and then lay out and bunds were made manually. After that, each plot was flooded with water and puddling and leveling were done manually. Four week old seedlings of rice were transplanted at a spacing of 20 cm x 10 cm on 05th July and two seedlings per hill were kept. After 10 days of transplanting, the missing hills in the plots were gap filled with the seedling of the same age. A thin film (2–3 cm) of water was maintained up to the seedling establishment; thereafter the water level was slowly raised to 5 cm. All the other crop management was done according to recommended package of practices. For sowing of maize the land was ploughed by mould board plough, soil was brought to fine tilth by crushing the clods and harrowing one times later the land was smoothened with wooden plank. The layout was made as per the treatment. Sowing was done in furrows on 08th July.

Winter season crops

After harvesting of previous season crops mustard, table pea, lentil, french bean and chickpea were grown. As a thumb rule, these crops require a well pulverized but compact seedbed for good and uniform germination. To avoid the mixing of soil with other treatments, the individual plot was ploughed twice by power tiller at good tilth and finally the planking was done. All the sowing practices followed according to Table No. 2. In both years of the experiment, irrigation was given according to the requirements of the different crops. One irrigation was given to lentil, table pea, and chickpea, two irrigations to mustard, and frenchbean. Only minor appearances of pests and diseases occurred. Hence, bio-insecticides were used due to the minor impact of the insect pests and diseases.

Harvesting and threshing

In general, all the crops were harvested by notched edge sickle manually at the physiological maturity of the respective crops. However, in case green peas, two to three pickings of green pods were done. In all the crops, the border rows and 50 cm either side of plot rows were harvested and removed then harvesting of each net plot was done separately. The harvested material from each net plot was carefully bundled, tagged and kept individually for sun drying at the threshing floor. Each bundle was weighed after suitable sun drying and then threshed separately. The grain/seed/pod yield of different crops were weighed and recorded individually after winnowing and cleaning. The straw/stover yield were also recorded separately and converted to kg/ha based on the net plot size harvest.

Nutrient uptake

The seed and plant samples at harvest were dried in an oven and grained thoroughly in a wily mill to pass through a 30 mesh sieve. These were used for N (Subbiah and Asija, 1973) [45], P (0.05 M $NaHCO_3$ using Barten's reagent) and K (Bhargava and Raghuipathi, 1993) [4] analysis. Nitrogen accumulations in grain and straw were obtained by multiplying the respective nutrient concentrations (%) with their dry weights (kg ha^{-1}).

System study

Rice equivalent as well as system productivity were worked out by converting the yields of crops into rice equivalent, taking the help of price values used for the calculation of the economics. Production efficiency of the system was estimated by dividing the equivalent yield of rice in a sequence by 365 days. Land use efficiency was calculated by the total duration of crops in the sequence divided by 365 days and expressed in per cent as defined by Jamwal, (2001) [13].

Economic analysis

Cost of cultivation, gross return and net return under different treatments were calculated on the basis of prevailing cost of different inputs. Power and labor for different operations were calculated on a per hectare basis as per normal rates prevalent in the country. The costs of other inputs were considered as per market price. The relative economic efficiency (REE) of the system was calculated and expressed in percentage (Samanta, 2015) [33].

Results and discussion

Effects of organic sources on different cropping sequence

System productivity

System productivity pooled data (Table 2) indicated that system productivity in terms of rice-equivalent yield (REY) was maximum in case of maize-chickpea sequence. It can be attributed mainly to higher yield of maize and chickpea and also which fetched higher prices in the market. The next in the order was maize-frenchbean cropping sequence. In case of rice based cropping sequences the maximum rice-equivalent yield (REY) was observed with rice-table pea cropping sequence. These results in line with the findings of Singh *et al*. (2007) who stated that rice-pea-okra followed by rice-pea-onion were most productive cropping sequence for eastern Uttar Pradesh. Mishra *et al.* (2007) also revealed higher productivity and profitability with inclusion of vegetables and pulses in rice-based cropping system. The system productivity was higher with M2 treatment in all the cropping sequences.

Production efficiency, economic efficiency and land use efficiency

Critical observation of data (Table -3) was indicated that the maximum production efficiency and economic efficiency was recorded in sequence of maize-chickpea followed by maize - frenchbean cropping sequence. Land use efficiency lower observed with maize-chickpea cropping sequence. The production efficiency (kg ha^{-1} day^{-1}), economic efficiency (Rs ha^{-1} day^{-1}) and land use efficiency (%) was higher with M_2 treatment in all the copping sequences. Shah *et al*. (2000) also recorded lower rice-equivalent yield in rice-oilseed crop sequence as compared to rice-wheat. Similar results were also been reported by Padhi (1993) [25].

Economics

Economic analysis (Table 7) showed that the highest net returns (Rs. 104057 ha^{-1}) were recorded with maize- chickpea followed by maize-frenchbean [M-FB (Rs. 93488.33 ha^{-1})]. It was owing to higher system productivity and higher price of maize green cobs over other cropping systems. The lowest net return (Rs. 55548.33 ha^{-1}) was recorded in rice - mustard followed by rice - linseed (Rs. 59193.33 ha^{-1}) because of lower productivity in system. Kumar *et al.* (2008) also stated that inclusion of vegetable crops in rice - based cropping sequences improved the net returns. Singh *et al.* (1997) reported that multiple cropping systems with legumes offer special advantage to farmer. Vegetable based cropping sequences also showed more production efficiency, gross and net returns than a traditional sequence. Similar results have also been reported by Saroch *et al.* (2005) [35] and Prasad (2016) [28].

Nutrient uptake

It could be noticed from the data presented in Table - 4 that uptake of nitrogen; phosphors and potassium by crops differ significantly due to different treatments under both the years of investigation. With respect to the uptake of nitrogen ranged from 90.7 to 140.4 $kgha^{-1}$, phosphorus ranged from 13.8 to 21.1 $kgha^{-1}$ and potassium ranged from 84.6 to 103.2 $kgha^{-1}$ in different cropping sequences by *kharif* crops. Whereas, the similar trend was also found after harvest of *rabi* crop with different numerical valuesunder bothe years of experimentation. The highest uptake of nutrients in M-FB cropping sequence after harvest of the *kharif* crop and the similar trend was also found after harvest of *rabi* crop except phosphorus and potassium in *rabi* crops. In case of manurial treatments the highest value was also found maximum with M_2 treatment which was N; 122.1 $kgha^{-1}$, phosphorus; 15.4 $kgha^{-1}$ and potassium; 90.7 $kgha^{-1}$ of *kharif* and the similar trend was found in *rabi* crops with different numerical values. Farm yard manure application has beneficial effect on nutrients availability in soil that increases the uptake of nutrients by rice crop as reported by Saha *et al.* (2000) [30] and Yadav *et al.* (2000) [48]. The increase in available N content with the incorporation of organic sources may be attributed to N mineralization from organic sources (Sharma *et al.*, 2013) [38].

Soil fertility status

From the pooled data presented in Table- 5, it has been noticed that the soil organic carbon (OC) content (per cent) was significantly influenced by the different cropping sequences but not with significantly higher over rest of the different manurial treatments after harvest of *kharif* as well as *rabi* crops. The highest OC value was found with M-C cropping sequence and in case of manurial treatment higher value obtained with the M_2 treatment. Available nitrogen, phosphors, potassium and sulphur of the soil differ significantly due to different treatments. With respect to the available nitrogen ranged from 247.3 to 262.2 $kgha^{-1}$, phosphorus ranged from 17.9 to 21.8 $kgha^{-1}$, potassium ranged from 317.1 to 333.5 $kgha^{-1}$ and sulphur ranged from 14.7 to 16.7 $kgha^{-1}$ in different copping sequences after harvest of *kharif* crops. Whereas, the similar trend was found after harvest of *rabi* crop with different numerical values. The highest available nutrients present in M-C cropping sequence after harvest of the *kharif* crop and the similar trend was also found after harvest of *rabi* crop. In case of manurial treatments the highest value was found with M2 treatment which was N; 259.1 $kgha^{-1}$, phosphorus; 22.6 $kgha^{-1}$, potassium; 335.6 $kgha^{-1}$ and sulphur; 17.6 $kgha^{-1}$ after harvest of *kharif* and the similar trend was also found after harvest of *rabi* crops with different numerical values. Similar findings also reported by Singh and Dwivedi (1996) [39] and Chhonkar and Tilak (1997) [8]. The application of FYM with *Rhizobium* and co-inoculation of PSB with *Rhizobium* has been found to augment soybean production (Sharma and Namdeo, 1999; Tripathi *et al.*, 2010) [38, 46].

Soil health

Critical study of the polled data of two years presented in Table-6 indicated that the effectiveness of application of organic manures and biofertilizers lies in the microbial load of soil. The growth and yield advantage in organic farming is attributed to increased organic matter thereby organic carbon content of the soil under both the years of trial. It is achieved by better activity of decomposers in soil. Biological properties of soil *i.e.;* viable count of bacteria, fungi and actinomycetes were influenced by cropping sequences and different manurial treatmentsin both experimental year. Both during first and second year of the experiment microbial population were enhanced at the end of the *rabi* season from the initial count in different cropping systems. The application of different organic manures resulted in a more pronounced increment in microbial load of the soil. Among the different cropping sequences M-C cropping sequence resulted in maximum increment in microbial count at the end of the *rabi* season during both the years of experimentation. The minimal microbial count was observed in R-M cropping sequence in the first year while a reduced bacteria count was observed in R-LS cropping system in the second year. Manurial treatments had a pronounced effect on biological properties of soil. Treatment M_2 resulted in the maximum increment in viable count of bacteria fungi and actinomycetes in both the years of investigation at the end of *rabi* season. The bacterial counts were nearly double and fungal counts were nearly triple at the end of the *rabi* season in treatment M_2. Among the manurial treatments M_3 had the least effect in favouring microbial growth in the soil thus resulting in least increment in the viable counts of bacteria, fungi and actinimycetes. The results are in line with the findings of Meena *et al.* (2016).

Table 2: Effect of different treatments on crop yield and system productivity in different cropping sequences

System productivity (kg/ha) as rice equivalent yield (REY)																		
Treatment	R	M	R-M	R	TP	R-TP	R	LS	R-LS	M	LT	M-LT	M	FB	M-FB	M	C	M-C
M1	4242	1908	7469	4250	7163	10311	4239	1113	6504	17493	973	13755	17293	753	14369	17693	1853	15436
M2	4383	1953	7686	4353	7253	10490	4323	1193	6751	18556	1053	14617	18356	803	15265	18756	1903	16258
M3	4064	1883	7248	4093	7113	10111	4073	1073	6256	16510	953	13032	16410	718	13646	16610	1813	14618
Mean	4230	1914	7468	4232	7176	10304	4211	1126	6504	17519	993	13801	17353	758	14427	17686	1856	15437

Table 3: Effect of different treatments on production efficiency (kg ha^{-1} day^{-1}), economic efficiency (Rs ha^{-1} day^{-1}) and land use efficiency (%) in different cropping sequences

Treatment	R-M			R-TP			R-LS			M-LT			M-FB			M-C		
	PE	EE	LUE	PE	EE	LUE	PE	EE	LUE	PE	EE	LUE	PE	EE	LUE	PE	EE	LUE
M1	221.08	24.19	74.20	188.57	25.35	64.39	206.24	21.10	73.05	244.76	24.87	65.36	269.18	29.38	67.35	269.07	31.17	64.51
M2	220.70	24.89	73.20	188.53	25.82	63.66	207.56	22.03	72.28	251.88	26.50	64.96	277.30	31.24	66.25	281.70	32.62	63.26
M3	218.71	23.51	74.92	186.52	24.79	64.34	204.01	21.17	73.78	239.93	23.65	65.85	263.25	27.89	67.90	261.71	29.71	65.18
Mean	220.16	24.20	74.11	187.87	25.32	64.13	205.94	21.43	73.04	245.52	25.01	65.39	269.91	29.50	67.17	270.83	31.17	64.32

Table 4: Effect of treatments on N, P and K uptake in different cropping sequences

Cropping Sequence	Uptake by *kharif* crops (kg ha^{-1})			Uptake by *rabi* crops (kg ha^{-1})		
	N kg/ha	P kg/ha	K kg/ha	N kg/ha	P kg/ha	K kg/ha
R-M	96.30	14.35	84.65	77.80	17.10	44.90
R-TP	90.70	13.85	86.20	60.80	16.40	48.90
R-LS	102.90	15.75	85.90	86.30	17.60	51.60
M-LT	135.35	19.85	95.35	65.80	14.80	45.60
M-FB	140.42	21.15	103.25	79.50	16.30	48.60
M-C	130.10	18.65	92.70	59.60	10.60	47.50
S.Em±	3.86	0.36	2.70	2.40	0.39	2.30
CD at 5%	11.30	1.36	7.96	6.98	1.14	6.56
Manurial Treatments						
M1	113.55	13.60	85.57	80.60	10.35	53.65
M2	122.10	15.45	90.75	84.70	12.75	57.35
M3	104.90	12.10	82.60	75.85	9.62	50.00
S.Em+-	1.74	0.35	1.83	1.64	0.39	1.01
CD at 5%	6.21	1.42	5.98	6.30	1.60	3.87

Table 5: Effect of different treatments on soil fertility status in different cropping sequence

Cropping sequence	Soil available nutrients (kg/ha)									
	After harvest of *kharif* crops					After harvest of *rabi* crops				
	OC (%)	N kg/ha	P kg/ha	K kg/ha	S Kg/ha	OC (%)	N kg/ha	P kg/ha	K kg/ha	S Kg/ha
R-M	0.53	250.10	18.05	320.70	15.30	0.54	253.60	19.40	325.20	17.35
R-TP	0.56	258.30	20.60	328.50	16.30	0.58	260.80	21.89	332.50	18.40
R-LT	0.54	251.40	19.45	318.10	14.75	0.56	254.40	20.80	320.60	16.70
M-LT	0.56	256.50	19.90	323.60	16.05	0.57	258.50	21.40	329.10	17.85
M-FB	0.56	247.30	17.90	317.10	15.10	0.57	251.80	20.65	319.60	16.60
M-C	0.58	262.20	21.80	333.50	16.70	0.59	264.70	23.35	336.50	18.65
S.Em±	0.02	1.94	0.42	3.90	0.33	0.03	1.99	0.51	3.99	0.34
CD at 5%	0.06	7.60	1.64	11.14	1.01	0.07	7.52	1.53	11.50	1.10
Manurial Treatments										
M1	0.55	256.80	20.45	325.90	16.40	0.57	259.80	21.96	329.41	18.45
M2	0.61	259.10	22.65	335.60	17.60	0.63	262.60	24.15	339.61	19.55
M3	0.47	249.80	17.85	313.00	15.50	0.49	252.40	19.35	316.55	17.41
S.Em+-	0.02	2.72	0.81	2.55	0.18	0.01	2.59	0.89	2.58	0.19
CD at 5%	NS	7.70	2.29	10.15	0.69	NS	7.74	2.29	10.95	0.38

Table 6: Effect of different treatments on biological properties in different cropping sequence

Cropping Sequence	After harvest of *kharif* crops			After harvest of *rabi* crops		
	Viable count (cfu/g)			Viable count (cfu/g)		
	Bacteria ($x10^3$)	Fungi ($x10^3$)	Actinomycetes ($x10^3$)	Bacteria ($x10^3$)	Fungi ($x10^3$)	Actinomycetes ($x10^3$)
R-M	44.35	14.91	35.10	45.19	15.01	35.57
R-TP	46.52	16.26	38.13	46.78	16.90	38.84
R-LS	44.31	15.39	36.21	44.50	15.40	36.49
M-LT	46.18	15.97	37.41	46.52	16.20	37.71
M-FB	45.92	15.42	36.87	46.13	15.84	37.18
M-C	48.45	17.82	38.29	48.98	18.82	39.19
Initial	40.15	11.75	31.47	42.30	12.78	33.17

Manurial Treatments						
M1	74.65	28.63	43.18	76.89	30.13	44.98
M2	80.55	35.72	56.33	83.75	37.72	59.33
M3	62.82	22.50	41.75	64.90	25.75	44.19
Initial	40.15	11.75	31.47	42.30	12.78	33.17

Table 7: Effect of different treatments on total net return of different cropping sequences

	R-M	R-TP	R-LS	M-LT	M-FB	M-C
Total cost of cultivation (Rs. ha^{-1})						
M1	50300	40100	41100	43200	47200	42900
M2	47100	36900	38900	40710	45010	40910
M3	51600	41000	42200	44200	48700	43900
Mean	49666.67	39333.33	40733.33	42703.33	46970	42570
Net return (Rs. ha^{-1})						
M1	55050	74180	58535	74355	92770	103338
M2	60245	80110	65270	84394	103807	112682
M3	51350	70455	53775	67596	83888	96151
Mean	55548.33	74915	59193.33	75448.33	93488.33	104057

Conclusion

Overall, we found no evidence that the allocation of resources to non-staple (‘high-value crop’) production hurts or enhances household food security. In the Eastern region, however, there are significant synergies; the allocation of resources to non-staples had a positive and significant effect on food security. The more diverse crop portfolio enhanced household food security, was inconclusive. The sign of the coefficient was positive but not statistically significant. Even though all households had diverse crop portfolios, a more diverse crop portfolio is not associated with a higher probability of being food secure. Other important predictors of rural household food security in the entire sample estimates include age, education, household composition, wealth, remittance income and other non-farm sources of income. In order to speed up poverty reduction in eastern India through income growth, there would be the need for farmers to participate more in both staple and non-staple markets. But this would not just happen. It would be conditioned on, among other things, increased staple crop productivity. This is because, as productivity of staples increases, households are more likely be food secure, which is important for both staple crop market participation and the allocation of resources to the production of non-staples for the growing urban. A policy approach that aims at increasing staple crop productivity is likely to have two effects: first, household food security would be enhanced and, second, households would then allocate more resources towards the production of ‘high-value’ crops to increase household income and reduce rural poverty. Use of organic manures for sustainability resulted in the highest rice equivalent grain yield (system productivity), production efficiency, as well as net monetary return and profitability in different rice and maize-based cropping sequences of crop diversification under both the years of investigation. Among the different cropping sequences maize-chickpea sequence had recorded higher value with respect to system productivity, production efficiency and economic efficiency. However, rice-mustard sequence proved superior with respect to land use efficiency in conducting of both years of the field trial. The different cropping sequences vary with respect to nutrient uptake, *i.e.,* maize-frenchbean had significantly higher removal nutrients than the rest of cropping sequence. Organic nutrient management with organic manures along with biofertilizers (M_2) proved superior because of its visible positive effect on soil health with respect to nutrient status and microbial count. Thus, the existing rice based cropping system can effectively be diversified with the maize based cropping system and the inclusion of vegetable crops (high value crops like tablepea during *rabi* season in eastern Uttar Pradesh. The maize-chickpea and rice-tablepea were viable system in productivity and economical point of view for the farmers of the locality and also systems have still scope to sustain productivity in long term basis due to better market price in eastern India.

References

1. Aktar MW, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture: their benefits and hazards. Interdiscip Toxicol. 2009;2:1-12.
2. Arancon NQ, Edwards CA, Babenko A, Cannon J, Galvis P, Metzger JD. Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. Applied Soil Ecology. 2008;39:91-99.
3. Ashoka P, Meena RS, Kumar S, Yadav GS, Layek J. Green nanotechnology is a key for eco-friendly agriculture. Journal of Cleaner Production. 2017;142:4440–4441.
4. Bhargava BS, Raghuipathi HB. Analysis of plant materials for macro and micronutrients “Methods of Analysis of Soils, Plants, Waters and Fertilizers” Fertilizer Development and Consultation Organization. 1993, 49-82.
5. Bhattacharyya R, Ghosh BN, Mishra PK, Mandal B, Rao CS, Sarkar D, *et al*. Soil degradation in India: challenges and potential solutions. Sustainability. 2015;7(4):3528–3570.
6. Bohlke JK. Groundwater recharge and agricultural contamination. Hydrogeology Journal. 2002;10:153-179.
7. Bulluck LR, Brosius M, Evanylo GK, Ristaino JB. Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. Applied Soil Ecololy. 2002;19(2):147-160.
8. Chhonkar PK, Tilak KVBR. Biofertilizers for sustainable agriculture research gaps and future needs. In Plant Nutrients Needs, Supply, Efficiency and Policy Issues: 1997. 2000- 2025, 52-56. (Eds.J.5. Kanwarand J. e. Katyal). National Academy of Agricultural Sciences New Delhi.
9. Doni S, Macci CE, Peruzzi B, Masciandaro G. Factors

Controlling Carbon Metabolism and Humification in Different Soil Agroecosystems. Scientific World Journal. 2014, 8.
10. FAO. The future of food and agriculture-trends and challenges, Rome. http://www.fao.org/3/a-i6583 e.pdf. Accessed 18 Dec 2018.
11. Hongsibsong S, Sittitoon N, Sapbamrer R. Association of health symptoms with low-level exposure to organophosphates, DNA damage, AChE activity, and occupational knowledge and practice among rice, corn, and double-crop farmers. Journal Occup Health. 2017;59:165-176.
12. Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary Toxicology 2014;7:60-72.
13. Jamwal JS. Productivity and economics of different maize (*Zea mays*) based crop sequences under dryland conditions. Indian Journal of Agronomy. 2001;46(4):601-604.
14. Khatri N, Tyagi S. Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. Frontier in Life Sciences 2015;8:23-39.
15. Kibblewhite MG, Ritz K, Swift MJ. Soil health in agricultural systems. Philos Trans R Soc. Lond B Biol Sci. 2008;363:685-701.
16. Kumar A, Tripathi HP, Yadav RA, Yadav SR. Diversification of rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping system for sustainable production in eastern Uttar Pradesh. Indian Journal of Agronomy. 2008;53(1):18-21.
17. Lal R. Restoring soil quality to mitigate soil degradation. Sustainabilit. 2015;7:5875-5895.
18. Lian S. Combined use of chemical and organic fertilizer. Technical Bull. no. 11. University Pertanian, Malaysia and Food and Fertilizer Technology Center, Taiwan. 1994.
19. Lorenz M, Fürst C, Thiel E. A methodological approach for deriving regional crop rotations as basis for the assessment of the impact of agricultural strategies using soil erosion as example. Journal of Environment Management. 2013;04:050.
20. Meena AK, Singh DK, Pandey PC, Nanda G.. Growth, yield, economics, and nitrogen use efficiency of transplanted rice (*Oryza sativa* L.) as influenced by different nitrogen management practices through neem (*Azadirachta indica*) coated urea. International Journal of Chemical Studies 2018;6(3):1388-1395.
21. Meena AK, Singh DK, Pandey PC, Nanda G. Dynamics of dry matter and nitrogen distribution in transplanted rice on mollisols. Journal of Plant Nutrition. 2019;42(7):749-758.
22. Meena RN, Singh RK, Meena R, Singh K. Effect of organic matter and soil-microbial community on physical, chemical and biological properties of soil. Journal of Plant Development Sciences. 2016;8(3):137-141.
23. Mishra MM, Nanda SS, Mohanty M, Pradhan KC, Mishra SS. Crop diversification under rice based cropping system in western Orissa. In: Extended Summaries of the 3rd National Symposium on Integrated Farming Systems;; Durgapura, India.Meerut (India): Project Directorate for Cropping System Research, Modipuram. 2007 Oct 26-28.
24. Mohanty MK, Behera BK, Jena SK, Srikanth S, Mogane C, Sama S. Knowledge attitude and practice of pesticide use among agricultural workers in Puducherry, South India. Journal Forensic Leg Med. 2013;20:1028-1031.
25. Padhi AK. Productivity and economics of rice (*Oryza sativa*)- based cropping sequences. Indian Journal of Agronomy. 1993;38(3):351-356.
26. Popp J, Pető K, Nagy J. Pesticide productivity and food security. A review. Journal of Agronomy and Sustainable Development. 2013;33:243.
27. Power AG. Ecosystem services and agriculture: tradeoffs and synergies. Philos Trans R Soc Lond B Biol Sci. 2010;365:2959–2971.
28. Prasad D, Rana DS, Babu S, Choudhary AK, Rajpoot S. Influence of tillage practices and crop diversification on productivity and soil health in maize (*Zea mays*)/soybean (*Glycine max*) based cropping systems. Indian J Agric Sci. 2016;86(1):96-102.
29. Raja N. Biopesticides and biofertilizers: ecofriendly sources for sustainable agriculture. J Biofertil Biopestici. 2013;1000:112.
30. Saha PK, Saleque MA, Panaullah GM, Bhuiyan NJ. Fertilizer managernent for rice based cropping systems productivity. Bangladesh J Agric. 2000;25:(4):555-560.
31. Sahoo RK, Ansari MW, Pradhan M, Dangar TK, Mohanty S, Tuteja N. Phenotypic and molecular characterization of efficient native Azospirillum strains from rice fields for crop improvement. Protoplasma. 2014. Doi:10.1007/s00709-013-0607-7.
32. Saigusa M. Broadcast application versus band application of polyolefin coated fertilizer on green peppers grown on andisol. Journal of Plant Nutrition. 2000;23:1485-1493.
33. Samanta TK. International Journal of Agriculture Sciences. 2015;7(11):0975-9107.
34. Santos VB, Araujo SF, Leite LF, Nunes LA, Melo JW. Soil microbial biomass and organic matter fractions during transition from conventional to organic farming systems. Geoderma. 2012;170:227-231.
35. Saroch K, Bhargava M, Sharma JJ. Diversification of existing rice (*Oryza sativa*) based cropping system for sustainable productivity under irrigated conditions. Indian Journal of Agronomy. 2005;50(2):86-8.
36. Schütz L, Gattinger A, Meier M, Müller A, Boller T, Mäder P. Improving crop yield and nutrient use efficiency via biofertilization-a global meta-analysis. Front. Plant Sci. 2018;8:2204.
37. Sharma KN, Namdeo KN. Effect of biofertilizers and phosphorus on growth and yield of soybean. Crop Res, 1999;17(2):160-163.
38. Sharma SB, Sayyed RZ, Trivedi MH. Phosphate solubilizing microbes: sustainable approach for managing phosphorus deficiency in agricultural soils. Springerplus. 2013;2:587.
39. Singh GB, Dwivedi BS. Indian Farming. 1996;46:9-15.
40. Singh G, Singh VP, Singh OP, Singh RK. Production potential of various cropping systems in flooed-prone areas of eastern Uttar Pradesh. Indian J Agron. 1997;42(1):9-12.
41. Singh K. Final Annual Report Development of sustainable Farming system model for the Irrigated Agro-Ecosystem of Eastern UP, ICAR, Ad-hoc project, Department of Agronomy, I. Ag. Sci., B.H.U., Varanasi, India. 2005.

42. Singh P, Singh JP, Gill MS, Singh Y. lternate cropping systems to sugarcane- ratoon-wheat in peri urban areas of Meerut. In: Extended summaries of the 3rd National Symposium on Integrated Farming Systems; Durgapura, India. Meerut (India): Project Directorate for Cropping System Research, Modipuram. 2007.
43. Singh RN, Mishra GM. Heterosis and combiningability in pea (*Pisum sativum* L). Hort. J. 1996;9(2):129-133.
44. Sinha RK, Valani D, Chauhan K, Agarwal S. Embarking on a second green revolution for sustainable agriculture by vermiculture biotechnology using earthworms: reviving the dreams of Sir Charles Darwin. Int. J Agric Health Saf. 2014;1:50-64.
45. Subbiah BV, Asija GL. A rapid procedure for estimation of available nitrogen in soils. Current Sciences. 1973;28(8):259-260.
46. Tripathi MK, Chaturvedi S, Shukla DK, Mahapatra BS. Yield performance and quality in Indian mustard (*Brassica juncea*) as affected by integrated nutrient management. Indian Journal of Agronomy. 2010;55:138-142.
47. Tripathi S, Chakraborty A, Bandyopadhyay BK, Chakrabarti K. Effect of long-term application of fertilizers on soil quality and rice yield in a salt-affected coastal region of India. Archives of Agronomy and Soil Scienc. 2008;54(4):439-50.
48. Yadav RL, Dwivedi BS, Prasad K, Tomar OK, Shurpali, NJ, Pandey PS. Yield trends and changes in soil organic C and available NPK in a long-term rice-wheat system under integrated use of manures and fertilizers. Field Crops Research. 2000;68:219-246.
49. Youssef MMA, Eissa MFM. Biofertilizers and their role in management of plant parasitic nematodes A review. E3 J Biotechnol. Pharm Res. 2014;5:1-6.