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Evaluation of nutrient management practices under different cropping systems in north western Indo-Gangetic plains of India

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ABSTRACT

A field experiment was conducted during 2012-13 to evaluate the performance of different cropping systems under organic, inorganic and integrated nutrient management practices. The nutrient management practices were i) organic, ii) integrated and iii) inorganic and cropping systems under evaluation were i) basmati rice–wheat-Sesbania green manure; ii) Rice–barley+mustard–mungbean; iii) maize (grain)–potato–okra and iv)maize (green cobs)–mustard+radish- Sesbania green manure. Results revealed that significantly higher grain yield of Kharif and summer crops i.e. basmati rice (38.2 q ha^{-1}), maize (grain) (45.9 q ha^{-1}), mungbean (8.9 q ha^{-1}) and okra (106 q ha^{-1}) were recorded in organic nutrient management. However, rabi crops like wheat (46.8 q ha^{-1}), barley (30.1 q ha^{-1}), mustard (6.90 q ha^{-1}) and vegetables like potato (229 q ha^{-1}) and radish (157 q ha^{-1}) produced significantly highest yield in integrated nutrient management. Integrated nutrient management being statistically at par to organic nutrient management registered significantly highest N, P and K uptake and produced noticeably higher system productivity in terms of rice equivalent yield and net returns (Rs. 152297 ha^{-1}) of different cropping systems. Organic nutrient management also recorded 36.6, 51.0, 51.3 and 81.1 % higher available N, P, K and SOC content over inorganic nutrient management. From the results, it is suggested that among the cropping systems, maize (grain)– potato–okra recorded significantly highest N, P and K uptake, maximum system productivity, highest net returns and highest soil available N (205 kg ha^{-1}).

Key words: Cropping systems, nutrient uptake, organic nutrient management, productivity, soil fertility

INTRODUCTION

The ill-effects of green revolution technologies in all intensively cultivated irrigated areas are threatening the very sustainability of the agricultural production system and national food security. In this scenario organic farming is considered as one of the best options for protecting and sustaining the soil health and produce healthy foods (Das *et al.*, 2013). One of the important aspects in organic farming that needs attention is the soil fertility management to optimize the productivity of crops/cropping systems. As organic manures influence soil productivity through their effect on soil physical, chemical and biological properties (Ramesh *et al.,* 2009, Ram Bharaose etal. 2018) the use of manures from livestock and *in-situ* green manuring are the important way of recycling or out-turning nutrients to the soil. Farmyard manure and vermicompost are the most available animal manures and raising *Sesbania in-situ* is the most feasible option for green manuring. Judicious management of these organic manures within a crop rotation can have large effects on yields and crop quality (Ramesh *et al.*, 2008, Sharma *et al.* 2017). Besides, in crop rotations including a mixture of leguminous crops as pulse or green manure and cash crops like basmati rice and vegetables are the main mechanism for sustained productivity, profitability and nutrient supply within organic systems. Hence, the development and implementation of well-designed crop rotations are central to the success of organic production systems (Das *et al.*, 2013). Among the prevailing crop rotations, rice-wheat is the predominant cropping system in the western Uttar Pradesh. Considering the stagnation in productivity, profitability and sustainability of this cropping system in the region; crop diversification through cereals like maize and barley; mustard among oilseeds and vegetable crops, depending on the marketing facilities available for the produce under the prevailing climatic conditions, can also be explored.

Due to growing purchasing power and health cautiousness, demand for organic vegetables is steadily increasing even in domestic markets (Das *et al.*, 2013). Growing of vegetables like potato and radish after *Kharif* maize and okra in summer not only increases the cropping intensity but also utilizes the land efficiently while providing employment and

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economic benefits to small and marginal farmers (Das *et al.*, 2013). Considering the potential and demand, these crops can be included in the cropping systems to identify component crops with optimum productivity, profitability with emphasis on soil health. Scientific information regarding the influence of organic management practices *vis-à-vis* chemical or integrated management practices on the crop/cropping system productivity, soil fertility and economics is important to the farmers and community at large. Hence, the present experiment as part of 'Network Project on Organic Farming' was conducted to study the effect of organic, inorganic and integrated nutrient management practices on the productivity, soil fertility and economics of different cropping systems in North western Indo-Gangetic plains of India.

MATERIALS AND METHODS

A field experiment was conducted during 2012-13 at research farm of ICAR-IIFSR, Modipuram, Meerut (UP), India (29.4' N latitude, 77.5' E longitude and 230 m amsl). It falls under the North western plain agro-climatic zone. The climate of Modipuram is broadly classified as semi-arid sub-tropical characterized by very hot summers and cold winters. The rainfall during cropping seasons was 920 mm. The soil at site was Typic Ustochrept deep sandy loam and slightly saline in nature (pH 8.1). The experimental site was already maintained since 2004-05 as part of long term 'Network Project on Organic Farming' and the data being presented are from the 8th cropping cycle. Soil fertility status at the end of previous cropping cycle is mentioned in Table 1.

Table 1: Soil fertility status before experimentation

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	SOC (%)
Organic	198.5±4.69	21.4±1.75	251.8±6.47	0.656±0.012
Integrated	173.4±2.96	17.2±1.90	223.2±5.96	0.586±0.010
Inorganic	148.3±5.01	15.0±3.16	169.5±5.05	0.369±0.005

The treatments include three nutrient management practices viz., organic, integrated and inorganic in main plots; and four cropping systems viz., basmati rice –wheat- *Sesbania* green manure (CS_1); rice–barley+mustard–mungbean (CS_2); maize (grain)–potato– okra (CS_3) and maize (green cobs) – mustard + radish- *Sesbania* green manure (CS_4). The experiment was carried out in strip plot design with four replicates. The manures and fertilizers in different treatments were applied based on recommended fertilizer N equivalent (Table 2).

Table 2: Details of crop cultivar and agronomic practices adopted in the experiment

Crop	Variety	Seed rate (kg ha^{-1})	Spacing	No. of Irrigations	Recommended N:P:K (kg ha^{-1})
Basmati Rice	Basmati-370	25	20x15	12	70:50:50
Coarse Rice	Saket-4	25	20x15	12	100:60:40
Maize (Grain)	Star-56	20	60x20	3	80:60:40
Green (Cob)	Star-56	20	60x20	3	80:60:40
Wheat	PBW-343	100	20x5	6	120:60:60
Barley	Azad	80	20x5	5	80:50:50
Mustard	Pusa Bold	4	45x10	5	40:60:40
Mungbean	Pusa Vishal	20	30x10	3	40:40:10
Potato	Chipsona-3	3000	60x20	5	140:80:100
Okra	Arka Anamika	18	45x30	9	80:60:40
Radish	Ivory white	10	45x8	5	

The equivalent quantity of the manures was calculated based on the nutrient content in different manures (Table 3). In the organic treatment the recommended N was supplied through green manure, crop residues incorporation, FYM and vermicompost. In integrated nutrient management 50% of N was supplied through FYM and vermicompost equally and remaining 50% of N was supplied through fertilizers. While in inorganic treatment 100% of recommended N was supplied through chemical fertilizers. For inorganic and integrated treatments urea, DAP and MOP were used as source of NPK. In all the crops half dose of N and full dose of P and K were applied as basal dose at sowing; while remaining half dose of N was applied during crop growth period as per recommendations.

The FYM was incorporated in soil at final land preparation (15 days before sowing) and the vermicompost was applied at first irrigation. In organic treatments *Sesbania* green manure was incorporated in the soil at least 20 days before sowing and green plant biomass of mungbean and okra were incorporated in the soil after picking the pods. Nutrient contribution through *Sesbania* green manure incorporation in CS_1 and CS_4, through mungbean residue in CS_2 and through okra residues in CS_3 in the previous cropping cycle were accounted for *Kharif* crops and commensurate adjustments were done in quantities of FYM and vermicompost application in organic tratments. Details of other agronomic practices adopted in the experiment are mentioned in Table 3. Some bioagents and organic preparations were employed as plant protection measures. The observations on growth attributes, yield attributes and yields of the crops were recorded through standard procedures. Plant samples (grain and straw) were collected at harvest and analyzed for N, P and K content (Jackson). Soil samples up to the depth of 15 cm were collected at the end of cropping cycle and analyzed for soil organic carbon (SOC), available N, P and K content by following standard laboratory procedures (Jackson 1973). Production economics of different crops was calculated based on prevailing market prices of different inputs and crop produce. For returns, 20% premium price was assumed for organic produce. System productivity was estimated in terms of Rice Equivalent Yield (BREY) as per the formulae; REY = Yx (Px / Pr), where; Yx is the yield of non-rice crops (q/ha), Px is the price of non-rice crops (Rs./q), and Pr is the price of rice. The data pertaining to each parameter were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by "F" test (Gomez and Gomez, 1984). Where significant differences were detected, the means were separated by the least significant difference (LSD) at 5 % probability level.

Table 3: N, P and K concentration in different organic amendments used in the experiment

Organic sources	N (%)	P_2O_5 (%)	K_2O (%)
FYM	0.56±0.03	0.33±0.04	0.61±0.06
Vermicompost	1.24±0.08	0.43±0.04	1.43±0.09
Sesbania	2.18±0.16	0.43±0.03	3.06±0.11
Mungbean	1.11±0.08	0.32±0.03	1.30±0.07
Okra	1.12±0.08	0.20±0.03	1.15±0.07

RESULTS AND DISCUSSION

Economic Yield and Biomass production

Nutrient management practices influenced significantly the yield of most of the crops under study (Table 4). Organic nutrient management being at par with integrated management recorded significantly higher grain yield of *Kharif* and summer crops like basmati rice (38.2 q ha^{-1}), maize (45.9 q ha^{-1}), mungbean (8.9 q ha^{-1}) and okra (105.8 q ha^{-1}) as compared to inorganic nutrient management. This might be due the positive effect of *Sesbania* green manure incorporation in organic treatments just before sowing of *Kharif* crops. The potential effects of leguminous green manure crops in cropping systems under organic crop production have been widely reported (Mueller and Thorup-Kristensen, 2001). However, *Rabi* crops like wheat (46.8 q ha^{-1}), barley (30.1 q ha^{-1}), mustard (6.9 q ha^{-1}) and vegetables like potato (229.0 q ha^{-1}), and radish (157.3 q ha^{-1}) produced significantly highest yield in integrated nutrient management. Yield differences in coarse rice and maize (cob) could not differ significantly. The yield increment in organic nutrient management in basmati rice, coarse rice, maize (grains), wheat, barley, mustard, mungbean, maize (cob), potato, radish and okra was 32.2, 20.1, 20.2, 30.2, 27.2, 25.0, 29.0, 8.8, 23.0, 23.1 and 27.9%, respectively higher over inorganic. The highest yield per cent yield increment over inorganic was observed in basmati rice followed by wheat. The significant yield increment of *Kharif* and summer crops under organic nutrient management indicates that under sufficient moisture and temperature the mineralization of nutrients form organic manures applied and soil pool might have been faster which provided the sufficient amount of macro and micronutrients to growing plants (Mishra *et al.* 2018). The higher yield of *Rabi* crops in integrated nutrient management might be ascribed to the increased availability of nutrients at initial stage through fertilizers in addition to nutritional and other benefits from organic manures at later stages might have created favorable effect on vegetative growth and yield attributes. These trends clearly indicates that organic manures *per se* is not sufficient to supply nutrients in soil but availability to plants during initial growth stages through their mineralization is required.

Table 4: Economic yield of different crops under different nutrient management practices

Treatment	Grain yield of field crops (qha^{-1})							Yield of vegetables (qha^{-1})			
	Basmati Rice	Coarse Rice	Maize (grains)	Wheat	Barley	Mustard	Mung bean	Maize (cob)	Potato (Tuber)	Radish (Root)	Okra (Pod)
Organic	38.2	44.8	45.9	43.5	28.5	6.5	8.9	88.6	223.9	146.9	105.8
Integrated	35.7	43.7	44.4	46.8	30.1	6.9	8.6	91.5	229.0	157.3	102.4
Inorganic	28.9	37.3	38.2	33.4	22.4	5.2	6.9	81.4	182.0	119.3	82.7
SEm±	2.29	2.22	1.78	2.53	1.80	0.42	0.55	3.57	10.94	9.68	6.24
CD (P=0.05)	7.9	NS	6.1	8.8	6.2	1.5	1.9	NS	37.8	33.5	21.6
CV (%)	11.7	9.3	7.2	10.2	11.8	11.7	11.8	7.1	9.0	12.1	11.2

Nutrient (NPK) uptake

Data on total nutrient uptake by different cropping systems under the influence of different nutrient management practices (Table 5) revealED that significantly highest N, P and K uptake by different cropping systems was recorded under integrated nutrient management which being statistically at par to organic nutrient management recorded 37.9, 41.4 and 28.9% higher N, P and K uptake, respectively over inorganic treatment.

Table 5: Total uptake of N, P and K (kg ha^{-1}) as influenced by nutrient management practices under different cropping systems

Treatment	Nitrogen	Phosphorus	Potassium
Nutrient management practices (M)			
Organic	208.0	40.1	245.3
Integrated	215.6	47.8	269.4
Inorganic	156.3	33.8	209.0
SEm±	4.63	1.18	7.42
CD (P=0.05)	16.0	4.1	25.7
Cropping Systems (S)			
Basmati rice–wheat *Sesbania* (CS_1)	166.7	36.8	244.5
Rice– barley + mustard – mungbean (CS_2)	225.8	48.9	272.1
Maize (grain)– potato–okra (CS_3)	276.4	54.1	305.3
Maize (cobs)–mustard +radish- *Sesbania* (CS_4)	104.4	22.3	143.0
SEm±	3.71	1.41	8.75
CD (P=0.05)	11.9	4.5	28.0
M x S			
SEm±	11.87	2.07	11.51
CD (P=0.05)	NS	NS	NS

Due to adequate supply of required nutrients through fertilizers at early stages of plant growth and also due to overall improvement in soil physico-chemical and biological properties due to application of organic manures might have increased the nutrient uptake of crops. It is further inferred from the results (Table 5) that different cropping systems differed significantly in terms of total N, P and K uptake and significantly highest N, P and K uptake was recorded in maize (grain)– potato–okra (CS_3) while lowest being the maize (green cobs)–mustard +radish (CS_4). A total of 164.8, 142.6 and 113.5% higher N, P and K uptake, respectively were recorded under CS_3 as compared to CS_4. The supply of N, P and K in more readily available form from organic manures to the crop during active growth period of crop resulted in increased nutrient content and uptake in grain and straw/stover. Besides, higher nutrient uptake in maize (grain)–potato–okra system might also be ascribed due to higher biomass production of different crops of the system. It is evident that interaction for nutrient uptake between cropping systems and nutrient management practices was found non-significant.

System productivity and economics

On mean basis, the integrated nutrient management produced noticeably higher REY (137.3 q ha^{-1}) as compared to organic (135.5 q ha^{-1}) and inorganic means of nutrient supply (104.4 q ha^{-1}). The highest system productivity in integrated nutrient management could be ascribed to higher yield of *Rabi* crops and vegetables under this treatment as evident in data (Table 6). Enhanced soil microbial activities provided ease in supplying available nutrients to plants due to organic manures coupled with plant growth stimulus imparted by fertilizer application resulted in higher yield the crops. Among the cropping systems, maize (grain)-potato-okra system followed by maize (green cobs) - mustard + radish cropping system registered maximum system productivity. The better utilization of favorable plant nutrition regime in soil by diverse crops of high yield potential and commensurate yield improvement and market value resulted in higher system productivity and net returns under maize (grain)–potato–okra cropping system (CS_3) as compared to basmati rice–wheat cropping system (CS_1).

Table 6: System productivity as rice equivalent yield (REY) and economics of different cropping systems under different nutrient management practices

Nutrient management practices	Cropping Systems	Rice equivalent Yield (q ha^{-1})	Total Net returns (Rs.ha^{-1})	B:C ratio
Organic	Basmati rice – wheat- *Sesbania* (CS_1)	82.8	95894	1.39
	Rice– barley + mustard – mungbean (CS_2)	106.2	104074	1.31
	Maize (grain)– potato–okra (CS_3)	240.7	280312	2.82
	Maize (green cobs)–mustard +radish- *Sesbania* (CS_4)	112.6	128909	2.83
	Mean	135.5	152297	2.09
Integrated	Basmati rice – wheat- *Sesbania* (CS_1)	84.7	89123	1.75
	Rice– barley + mustard – mungbean (CS_2)	106.1	93447	1.56
	Maize (grain)– potato–okra (CS_3)	237.4	216138	2.89
	Maize (green cobs)–mustard +radish- *Sesbania* (CS_4)	120.8	120877	3.45
	Mean	137.3	129896	2.41
Inorganic	Basmati rice – wheat- *Sesbania* (CS_1)	63.9	73980	2.22
	Rice– barley + mustard – mungbean (CS_2)	85.3	82244	2.03
	Maize (grain)– potato–okra (CS_3)	173.6	161706	3.17
	Maize (green cobs)–mustard +radish- *Sesbania* (CS_4)	95.7	99728	4.03
	Mean	104.4	104415	2.86

The data on economic analysis of different cropping systems (Table 6) revealed that across the nutrient management practices the highest net returns (Rs. 152297 ha^{-1}) were recorded under organic nutrient supply, while due to least cost the highest B:C ratio (2.86) was noticed under inorganic nutrient management. Studies have shown that returns from organic farm management are equal to, or exceed those from conventional management systems (Das *et al.*, 2013 and Ram Bharose *et al.* 2018). Irrespective of nutrient management options, maize (grain)-potato-okra (CS_3) recorded the highest net returns. The higher net return in maize-potato-okra system could be explained on the basis of increased yield under the application of organic and integrated nutrient management in the present investigation.

Soil fertility status

Data on soil nutrient analysis (Table 7) revealed that SOC content and availability of N, P and K into the soil were significantly influenced by nutrient management practices and organic nutrient management being statistically at par to integrated nutrient management recorded 36.6, 51.0, 51.3 and 81.1% higher available N, P, K and SOC content, respectively over inorganic nutrient management. Higher SOC has been owing to addition of FYM and vermicompost with greater biological activity resulting higher available nutrients (Rudragouda *et al.*, 2015). Higher levels of SOC, total N, soluble P and microbial activity were also reported earlier from soils under organic production system (Mader *et al.*, 2002 and Sharma *et al.* 2017).

Among the cropping systems, the significantly highest available N (204.9 kg/ha) was recorded under CS_3 while, available P (22.6 kg ha^{-1}), available K (256.1 kg ha^{-1}) and SOC (0.616%) were recorded significantly highest in CS_4. Interaction between cropping systems and nutrient management practices was found significant for available N, P and SOC content in soil. Higher amounts of organic C and available N were observed in the crop rotation having a green manure crop (*Sesbania aculeata*) in the rotation i.e. CS_1 and CS_4. The benefits of crop rotations and green manuring in maintaining soil organic matter have been well established (Engels *et al.*, 1995).

Table 7: Soil properties after completion of crop cycle

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	SOC (%)
Nutrient management practices (M)				
Organic	207.6	21.9	253.8	0.663
Integrated	179.8	18.0	227.4	0.599
Inorganic	152.0	14.5	167.7	0.366
SEm±	5.25	0.60	7.00	0.008
CD (p=0.05)	18.2	2.1	24.2	0.029
Cropping Systems (S)				
Basmati rice – wheat (CS_1)	197.8	18.2	238.2	0.557
Rice– barley + mustard – mungbean (CS_2)	174.5	11.9	176.6	0.392
Maize (grain)– potato–okra (CS_3)	204.9	19.9	194.3	0.605
Maize (green cobs)–mustard +radish (CS_4)	141.8	22.6	256.1	0.616
SEm±	3.73	0.50	7.02	0.008
CD (p=0.05)	11.9	1.6	22.4	0.025
M x S				
SEm±	10.91	1.05	11.36	0.023
CD (p=0.05)	32.4	3.1	NS	0.068

Choices of organic source of nutrients and crops in crop rotations are key for higher productivity, profitability and sustainability of organic cultivation. From the results of present study, it is concluded that organic farming can be profitable by diversifying the organic nutrient management through available manures like FYM, vermicompost, *Sesbania* green manure and crop residue incorporation and inclusion of diverse crops in crop rotations. It is also concluded that *Kharif* and summer crops yielded higher under organic nutrient management, while *Rabi* crops performed superior under integrated nutrient management. Besides, the inclusion of crops of high production potential and market price and demand like vegetables can make the organic system profitable as maize (grain)– potato–okra recorded maximum system productivity, highest N, P and K uptake and net returns. It is conclusively suggested that crop rotations having vegetables as one of the component crops can produced profitably with application of organic source of nutrients.

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