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Direct and residual effect of integrated nutrient management on crop productivity and physico-chemical characteristics of allfisols in okra-pea cropping system

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Abstract

A field experiment was conducted on direct and residual effect of integrated nutrient management on crop productivity and physico-chemical characteristics of allfisols in okra-pea cropping system in Kashmir valley. The okra was grown as main crop and pea as residual crop. The experiment was laid out in simple square lattice design having 25 treatments with two replications. The pooled data revealed that integrated nutrient management significantly influenced the productivity of main as well as residual crop, physico-chemical properties and microbial activity of experimental soil. Among various treatments under study, treatment T_{24} (FYM, sheep manure, poultry manure and vermicompost (3, 2, 0.5, 0.6 tonnes ha^{-1}, respectively) along with biofertilizers (*Azospirillum* and *Phosphobacteria*; both as seed inoculant @ 1.0 kg ha^{-1} and as soil inoculant @ 2.5 kg ha^{-1}) and 50 % recommended dose (RDF) of fertilizers (N:P_2O_5:K_2O, 60:30:30 kg ha^{-1}, respectively) resulted significantly maximum fruit yield of okra (272.71 q ha^{-1}) and pod yield of pea (123.56 q ha^{-1}). The physico-chemical characteristics of the soil under study showed an improvement with organics application as compared to initial, control and RFD. Soil under the treatment T_{24} showed lowest bulk density, particle density and pH; and highest porosity, EC, and organic carbon content. Available nutrients in soil (nitrogen, phosphorus, potassium and sulphar) and microbial population (fungi and bacteria) were also recorded maximum with treatment T_{24}.

Key words: Allfisols, INM, inorganic fertilizers, okra-pea productivity, organic manures, soil quality.

Introduction

Sustainable crop production is an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain, or enhance ecological harmony. Integrated nutrient management (INM) is one of the important component of sustainable crop production system that implies the most efficient use and management of organic, inorganic and biological sources of major nutrients as well as micronutrients to attain higher levels of crop productivity and to maintain the fertility of the soil. Debates are in vogue that the highly productive fertilizer introduced over the past decades may be reaching a point of diminishing.

Prospects for expanding low-cost irrigation, one of the driving forces behind yield increases, are also becoming more limited, as are the prospects for converting marginal lands into productive arable land. Furthermore, new technologies such as genetically engineered, yield-increasing plants are not expected to be major factors in food production increase in developing countries during the next few decades. Consequently, keeping pace with population growth and increasing land scarcity will be more difficult than in the recent past. Concerns also are growing about the long-term sustainability of agriculture. Both the over and under application of fertilizer and the poor management of resources have damaged the environment. In developed countries, for example, over application of inorganic and organic fertilizer has led to environmental contamination of water supplies.

For harnessing higher crop yield, adequate and balanced nutrition is a prerequisite. Substitution of high analysis fertilizers for enhancing crop productivity or insufficient use of organic manures have rendered most of the Indian soils nutrient deficient (Acharya and Mandal, 2002). Large scale use of chemical fertilizers has deteriorated soil structure, decline in microbial population, leaching of plant nutrients (Agarwal, 2003). This indicates there is an urgent need to utilize other sources of plant nutrients which can ensure sustainable productivity and soil quality on long term basis. The answer lies in the use of organic source of nutrients which besides being found helpful in the improvement of soil structural properties, regulate soil pH, maintain soil health, biological diversity, soil micro flora and increases nutrient availability (Wang *et al.*, 1992; Marinari *et al.*, 2000; and Singh *et al.*, 2000). It has been observed that neither chemical fertilizers nor organic manures are able to sustain the crop productivity and soil fertility, when used alone. The integration has proved more effective than individual component application with respect to yield, crop quality as well as soil health. The integrated use of organic and inorganic fertilizers for improving crop productivity in vegetable crops has been reported by several workers (Bhardwaj *et al.*, 2000; Chattoo *et al.*, 2003 and Magray, 2002). Literature also revealed that the residual effect of plant nutrients can be very well utilized for raising the secondary crop without addition of further nutrients (Duraisami and Mani, 2001 and Chattoo *et al.*, 2010).

Okra and pea are important vegetable crop cultivated in Kashmir valley where okra crops is raised during summer months (May-October) followed by pea as winter crop (November-April). Keeping in view the above facts, present investigation was carried out to study the direct and residual effect of integrated nutrient management on crop productivity and soil quality under okra-pea cropping system in Kashmir valley.

Materials and methods

The study was conducted at Experimental Field of the Division of Vegetable Science, Sher-e-Kashmir University of Agricultural Sciences and Technology, Srinagar (Jammu and Kashmir), India. The main crop okra was raised during Khrif 2004 and 2005, and residual crop pea was raised during Rabi after the harvest of okra 2004-2005 and 2005-2006. The soil of experiment plot was loamy in texture (21.90% sand, 41.80% slit and 33.70% clay), almost neutral in reaction (pH 7.2), normal in electrical conductivity (0.09 dsm^{-1}), high organic carbon content (1.08%), low available N (206.95 kg ha^{-1}), medium available phosphorous (21.80 kg ha^{-1}) and potassium (172.48 kg ha^{-1}) and low available sulphur (20.16 kg ha^{-1}). The initial rhizosphere fungal and bacterial population was 4 x 10^5 g^{-1} and 15 x 10^5 g^{-1} soil, respectively. The initial bulk density, particle density was 1.45 and 2.45 g cm^{-3}, respectively with 40.82 % porosity. In present study 25 treatments comprised of variable doses of chemical fertilizers, farm yard manure (FYM), poultry manure (PM), sheep manure (SM) vernicompost (VC) and biofertilizers (BF) alone or in combinations *viz.*: T_1 - 100% RFD (recommended dose of fertilizers - 120:60:60 N: P_2O_5: K_2O kg ha^{-1}), T_2 –FYM (30 t ha^{-1}), T_3 - sheep manure (20 t ha^{-1}), T_4 - poultry manure (6 t ha^{-1}), T_5 – vermicompost (6 t ha^{-1}), T_6 - biofertilizers (*Azospirillum* and *Phosphobacteria*; both as seed inoculant @ 1.0 kg ha^{-1} and as soil inoculant @ 2.5 kg ha^{-1}), T_7 - FYM + SM + PM + VC + BF (6 t + 4 t + 1 t + 1 t + 7.0 kg ha^{-1}, respectively), T_8 - FYM (15 t ha^{-1}) + SM(10 t ha^{-1}), T_9 - FYM (15 t ha^{-1}) + PM (3 t ha^{-1}), T_{10} - FYM (15 t ha^{-1}) + VC (3 t ha^{-1}) ,T_{11} - FYM (15 t ha^{-1}) + BF (7.0 kg ha^{-1}), T_{12} - SM (10 t ha^{-1}) + PM (3 t ha^{-1}), T_{13} – SM (10 t ha^{-1}) + VC (3 t ha^{-1}), T_{14} - SM (10 t ha^{-1}) + BF (7.0 kg ha^{-1}), T_{15} - PM (3 t ha^{-1}) + VC (3 t ha^{-1}), T_{16} - PM (3 t ha^{-1}) + BF (7.0 kg ha^{-1}), T_{17} - VC (3 t ha^{-1}) + BF (7.0 kg ha^{-1}), T_{18} - 50% RFD, T_{19} - FYM (15 t ha^{-1}) + 50% RFD, T_{20} - SM (10 t ha^{-1}) + 50% RFD, T_{21} - PM (3 t ha^{-1}) + 50% RFD, T_{22} - VC (3 t ha^{-1}) + 50% RFD, T_{23} - BF (7.0 kg ha^{-1}) + 50% RFD, T_{24} - FYM + SM + PM + VC + BF (3 t + 2 t + 0.5 t + 0.6 t + 7.0 kg ha^{-1}, respectively) + 50 % RFD, T_{25} - Control (no fertilizer/ organic manure/ biofetlizers). The experiment was conducted in Lattice Square Design with two replications. Organic manures/ vermicompost were applied at the time of land preparation. Biofertilizers were applied both as seed treatment as well as soil inoculant. In case of chemical fertilizers, half dose of nitrogen, full phosphorous and potassium were applied as basal dose and remaining dose of nitrogen was top dressed one month after planting in main crop Okra during both the seasons. In residual crop (pea) no manure/ chemical fertilizer was applied during both seasons. The seeds of okra, SKBS-11, were sown in the first week of June during 2005 and 2006 in a plot of size 3.00 m x 3.00 m with a spacing of 50 cm x 30 cm. Pea seeds variety Bonneville were sown in the same plot with a spacing of 30 cm x 10 cm during second fort night of November during both the seasons. Other cultural operations were carried out as per the ‘Package and practices of vegetables’ of SKUAST-Kashmir. Data on pod/fruit yield in both the crops were recorded on per plot basis and expressed in q ha^{-1}. Representative soil samples of the experimental field before the start of experiment as well as after the crop harvest from each treatment were taken and analyzed for physical, chemical and microbial characteristics as per the standard procedures. Data recorded during the course of investigation were subjected to pooled analysis with 5% level of significance as per standard procedure suggested by Gupta and Prasad (2006).

Results and Discussions

Direct effect of INM on fruit yield of main crop (okra): Treatments under study exhibited a significant influence on fruit yield of okra. Among various treatments, integration of organics with inorganics proved superior to combined application of organics as well as sole application. Pooled analysis revealed that treatment T_{24} (FYM + SM + PM + VC + BF + RFD 50 %) 3 t + 2 t + 0.5 t + 0.6 t + 7.0 kg + 60:30:30 N: P_2O_5: K_2O kg ha^{-1}) registered maximum fruit yield of 272.71 q ha^{-1}, which was significantly superior to rest of the treatments. The extent of increase was 5.26 and 176.69% over T_1 (259.08 q ha^{-1}) and control (98.56 q ha^{-1}), respectively (Table 1). Improvement in fruit yield of okra as a result of integration of organic and inorganic could be due to better decomposition and mineralization of organic manures, resulting better nutrient availability, besides solubulizing effect on fixed forms of nutrients and also improvement in physical and biological properties of soil. Similar observations have also been reported by Narayan *et al.* (2004).

Residual effect of INM on pod yield of succeeding crop (pea): Among various treatments under study, maximum residual influence on pod yield of pea was exhibited by integration of organics and inorganics as compared to sole application and combination of organics. Pooled analysis revealed that treatment T_{24} registered pod yield of 123.56 q ha^{-1} which was found significantly superior to the rest of treatments. The extent of increase was 81.54% and 234.03% over T_1 (68.06 q ha^{-1}) and control (36.99 q ha^{-1}), respectively. The beneficial effect of organics and their integration with organic fertilizers in raising a succeeding crop can be attributed to their residual effects, as organics exhibit a slow release of nutrients, desired organic matter buildup, less loss of nutrients (Rao, 1976; Duraisami and Mani, 2011 and Chattoo *et al.*, 2010)

Physico-chemical properties of soil: After the completion of the experiment (Rabi 2005-06), physical characteristics exhibited an improvement under the influence of various treatments. Sole application of organics, their combinations and integration of organic and inorganic fertilizers exhibited an improvement in bulk density, particle density and porosity. Bulk density of 1.24 g cm^3 was registered with treatment T_{24} which was significantly lower than initial (1.45 g cm^3), control (1.40 g cm^3) and T_1 (1.37 g cm^3). Decrease in bulk density could be attributed to the favourable effect of organics on soil aggregation; increased biomass production and organic matter build up. Treatment T_{24} recorded significantly lower particle density of 2.29 g cm^3 as compared to initial (2.45 g cm^3), control (2.40 g cm^3) and T_1 (2.35 g cm^3). Decrease in particle density could be due to lower weight of organic matter. Porosity registered an increase due to integrated use of organics and inorganics, recording maximum

Table 1. Direct and residual effect of integrated nutrient management on the okra and pea yield

Treatment	Fruit/ pod yield (q ha^{-1})	
	Okra (Main crop)	Pea (Residual crop)
T_1	259.08	68.06
T_2	209.00	77.92
T_3	221.14	78.70
T_4	238.78	87.43
T_5	231.19	76.67
T_6	155.13	52.56
T_7	254.99	115.80
T_8	221.08	87.22
T_9	236.67	100.38
T_{10}	230.37	96.51
T_{11}	214.13	84.71
T_{12}	246.38	108.19
T_{13}	233.00	99.65
T_{14}	223.95	95.35
T_{15}	248.18	109.21
T_{16}	244.77	102.75
T_{17}	238.30	101.15
T_{18}	170.50	52.44
T_{19}	243.34	110.39
T_{20}	254.33	112.41
T_{21}	260.08	118.84
T_{22}	257.56	110.77
T_{23}	237.79	106.30
T_{24}	272.71	123.56
T_{25}	98.56	36.99
LSD (*P*=0.05)	6.59	3.38

Table 2. Effect of integrated nutrient management on physico-chemical properties of soil

Treatment	Bulk density (g cm^3)	Particle density (g cm^3)	Porosity (%)	pH	Electrical conductivity (dsm^{-1})	Organic carbon (%)
T_1	1.37	2.35	41.63	6.74	0.112	1.17
T_2	1.32	2.31	43.00	6.69	0.112	1.48
T_3	1.30	2.30	43.33	6.63	0.122	1.49
T_4	1.29	2.30	43.73	6.54	0.132	1.56
T_5	1.30	2.30	43.40	6.61	0.128	1.48
T_6	1.33	2.30	42.18	6.84	0.115	1.18
T_7	1.26	2.30	45.14	6.50	0.139	1.63
T_8	1.29	2.30	44.03	6.59	0.131	1.54
T_9	1.27	2.29	44.30	6.59	0.133	1.60
T_{10}	1.29	2.29	43.58	6.62	0.121	1.53
T_{11}	1.29	2.29	43.98	6.58	0.122	1.48
T_{12}	1.26	2.28	44.52	6.49	0.136	1.62
T_{13}	1.27	2.28	44.48	6.53	0.127	1.55
T_{14}	1.27	2.28	44.30	6.48	0.123	1.50
T_{15}	1.26	2.29	44.90	6.51	0.138	1.62
T_{16}	1.27	2.29	44.46	6.49	0.134	1.53
T_{17}	1.27	2.29	44.35	6.59	0.129	1.52
T_{18}	1.37	2.33	41.21	6.68	0.106	1.10
T_{19}	1.25	2.28	45.06	6.59	0.134	1.56
T_{20}	1.25	2.28	45.12	6.51	0.135	1.60
T_{21}	1.24	2.29	45.63	6.51	0.140	1.63
T_{22}	1.26	2.29	44.66	6.57	0.137	1.58
T_{23}	1.27	2.29	44.55	6.56	0.127	1.46
T_{24}	1.24	2.29	45.81	6.51	0.145	1.65
T_{25}	1.40	2.37	40.93	7.36	0.087	0.90
LSD (*P*=0.05)	0.03	0.01	1.24	0.18	0.012	0.08

porosity of 45.61% with T_{24} and was found significantly superior than the values recorded with initial (40.82%), control (40.93%) and T_1 (41.63%) (Table 2). Increase in porosity could be attributed to enhanced soil aggregation leading to higher porosity. These results are in conformity with those of Renuka and Sankar (2001) and Bhattacharya *et. al.* (2004).

After the completion of the experiment (Rabi 2005-06), chemical characteristics *viz.,* pH, electrical conductivity and organic carbon content exhibited significant variations under the influence of various treatments. Integration of organic and inorganic fertilizers as well as conjugation of different organic sources proved superior in decreasing soil pH and increasing organic carbon content over sole applications. Treatment T_{24} recorded pH of 6.51, which was significantly lower than the values recorded with initial (7.25), control (7.36) and T_1 (6.74). The decrease in pH could be due to increase in partial pressure of CO_2, release of organic acids during decomposition of organic materials. Significant variations for electrical conductivity due to various treatments were observed. Treatment T_{24} registered significantly higher EC of 0.145 dsm^{-1} as compared to initial (0.112 dsm^{-1}), control (0.087 dsm^{-1}) and T_1 (0.112 dsm^{-1}). The increase in EC could be attributed to decrease in pH. Maximum organic carbon content of 1.65% was observed with T_{24} which was significantly superior over initial (1.08%), control (0.90%) and T_1 (1.17%) (Table 2). Increase in organic carbon content may be attributed to the addition of organic manures, more decomposition, better root growth, more microbial population, enhanced biological conservation leading to higher buildup of organic carbon content. Similar trend has also been reported by other research workers (Sharma *et al.*, 2003; Swain *et al.*, 2003; Walia and Kler, 2003 and Sharma *et al.*, 2009).

Soil nutrient availability: Significant variations due to various treatments regarding the availability of nitrogen, phosphorous, potassium and sulphur were observed after the completion of the experiment (Rabi 2005-06). Integration of organic and inorganic fertilizers proved superior in enhancing the availability of nitrogen, phosphorous, potassium, and sulphur in the soil as compared to sole application of organics, inorganics and organic conjugations. Treatment, T_{24} registered maximum available nitrogen content of 266.13 kg ha^{-1}, which was significantly superior over initial (206.95 kg ha^{-1}), control (74.28 kg ha^{-1}) and T_1 (179.15 kg ha^{-1}). The increase in available N could be attributed to the direct addition of nitrogen through these sources and better mineralization of organic sources due to addition of chemical fertilizers to the available pool of the soil. Maximum available phosphorous 52.36 kg ha^{-1} was registered with T_{24} and was found significantly superior as compared to initial (28.00 kg ha^{-1}), control (6.40 kg ha^{-1}) and T_1 (30.94 kg ha^{-1}). Increase in the available P with integration of organic and inorganic sources

Table 3. Effect of integrated nutrient management on nutrient availability of soil

Treatment	Available nutrient (kg ha^{-1})			
	Nitrogen	Phosphorus	Potassium	Sulphur
T_1	179.15	30.94	163.32	15.80
T_2	207.25	33.71	175.88	20.19
T_3	210.40	34.74	177.96	20.43
T_4	216.31	39.37	180.66	22.04
T_5	215.46	31.64	177.44	21.10
T_6	156.05	21.17	151.10	16.66
T_7	231.79	41.90	188.32	23.76
T_8	210.95	34.35	173.91	20.34
T_9	216.43	40.21	178.98	21.57
T_{10}	212.92	36.52	173.33	20.95
T_{11}	208.56	33.31	177.18	20.28
T_{12}	217.30	39.06	183.90	22.59
T_{13}	215.42	37.19	178.95	22.08
T_{14}	213.92	37.19	177.36	21.43
T_{15}	225.83	41.31	184.36	23.49
T_{16}	219.06	38.71	183.49	21.99
T_{17}	216.90	39.01	180.11	21.71
T_{18}	175.22	27.89	152.16	15.58
T_{19}	251.72	42.70	179.62	22.82
T_{20}	259.53	42.66	178.55	25.75
T_{21}	260.88	50.40	195.86	26.42
T_{22}	252.92	41.63	182.46	25.59
T_{23}	207.63	37.34	179.16	21.38
T_{24}	266.13	52.36	197.10	29.20
T_{25}	74.28	6.40	59.40	2.55
LSD (P=0.05)	14.68	4.49	11.31	0.84

Table 4. Direct and residual effect of integrated nutrient management on rhizosphere microbial population

Treatment	Microbial population (Number g^{-1} of soil x 10^5)	
	Fungi	Bacteria
T_1	11.60	26.40
T_2	20.10	34.80
T_3	21.84	37.25
T_4	26.56	40.45
T_5	24.15	45.10
T_6	31.10	59.80
T_7	47.10	67.70
T_8	29.84	41.65
T_9	40.06	45.85
T_{10}	38.15	44.00
T_{11}	39.84	46.75
T_{12}	41.84	54.65
T_{13}	39.58	49.10
T_{14}	44.80	60.30
T_{15}	45.89	65.45
T_{16}	51.06	70.45
T_{17}	47.56	70.58
T_{18}	10.70	24.00
T_{19}	25.02	39.50
T_{20}	29.11	42.65
T_{21}	40.15	49.60
T_{22}	35.15	56.00
T_{23}	43.89	69.45
T_{24}	60.11	74.15
T_{25}	2.65	10.30
LSD (P=0.05)	6.35	10.37

could be due to direct addition of P through these sources as well as solubolization of native P through release of various organic acids, besides preventing the fixation of added P. Treatment T_{24} recorded significantly maximum available potassium content of 197.10 kg ha^{-1} as compared to initial (172.48 kg ha^{-1}), control (59.40 kg ha^{-1}) and T_1 (163.32 kg ha^{-1}). The increase in potassium under INM can be attributed to decrease in fixation of potassium by organic matter besides, interaction of clay with organic matter (Laxminarayana and Patiram, 2006). Available sulphur registered a maximum value of 29.20 kg ha^{-1} with treatment T_{24} which was significantly superior over initial (20.16 kg ha^{-1}), control (2.55 kg ha^{-1}) and T_1 (15.80 kg ha^{-1}) (Table 3). The increase in available Sulphur could be attributed to the addition of organic manures, besides, better mineralization of native sulphur by growing crops. The results are in accordance with the findings of Machado and Nievees (1993), Datt *et al.* (2003), Dademal *et al.* (2004) and Sharma *et al.* (2009).

Rhizosphere microbial population: After the completion of the experiment (Rabi 2005-06), rhizosphere microbial population *viz.* fungi and bacteria were also influenced by the application of organics and their integration with inorganic fertilizers. Data presented in Table 4 reveals that maximum fungal (60.11x 10^5 g^{-1} soil) and bacterial (74.15 x 10^5 g^{-1} soil) populations were recorded with T_{24} and were found significantly superior over initial (4.00 x 10^5 g^{-1} soil, 15.00 x 10^5 g^{-1} soil), control (2.65 x 10^5 g^{-1} soil, 10.30 x 10^5 g^{-1} soil) and T_1 (11.60 x 10^5 g^{-1} soil, 26.10 x 10^5 g^{-1} soil). The increase in fungal and bacterial population in the soil could be attributed to balanced nutrition for microbial growth and favourable physical and chemical properties of soil. Similar findings have also been reported by other workers (Gogoi *et al.*, 2004; Swain *et. al.*, 2003)

The study revealed that integrated nutrient management significantly influenced the productivity of main as well as residual crop, physico-chemical properties and microbial activity of experimental soil. Among various treatments under study, treatment T_{24} (FYM, sheep manure, poultry manure and vermicompost (3, 2, 0.5, 0.6 tonnes ha^{-1}, respectively) along with biofertilizers (*Azospirillum* and *Phosphobacteria*; resulted maximum fruit yield of okra and pod yield of pea. The physico-chemical characteristics of the soil under study showed an improvement with organics application as compared to initial, control and RFD.

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