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Studies on nutrient budgeting in different vegetable based cropping sequences

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Abstract
A field experiment was carried out to study the nutrient budgeting in some important vegetable based cropping sequences for two consecutive year, 2010-11 and 2011-12 during summer, kharif and rabi season at Horticultural farm, BAU, Ranchi. The negative N balance was observed in almost all treatments after two years of experimentation. The highest net loss (–118.00 kg/ha) of N, after two years was observed in watermelon-maize-pea whereas, it was lowest (-53.00 kg/ha) in bottle gourd-chilli-radish sequences. The net gain of P after two years was in ridge gourd-cowpea-tomato and bottle gourd-chilli-radish sequences with +2.00 and +7.00 kg/ha, respectively whereas, net loss of P was observed in rest of the sequences. The negative K balance was observed in almost all sequences except bottle gourd-chilli-radish (+36.00 kg/ha) and okra-maize-cabbage (+16.00 kg/ha) sequences, where there was gain in net potassium. The rice equivalent yield was obtained higher in sponge gourd-rice-broccoli (144.40 q/ha) sequences and was at par with ridge gourd-cowpea-tomato (143.34 q/ha) and sponge gourd-brinjal-capsicum (124.89 q/ha) sequences. At the completion of two years experiment, highest (3.26) benefit: cost ratio was observed in sponge gourd-rice-broccoli sequence.

Keywords: Sequence cropping, nitrogen, phosphorus and potassium balancing, crop diversification, rice equivalent

Introduction
The state of Jharkhand offers ample opportunity for successful cultivation of wide range of vegetables in different seasons of the year due to its mild climatic conditions. An effective vegetable crop combination and balance nutrient management in sequences can provide regular income and nutritional support to both the grower and the consumer. However, per capita consumption of vegetables in India is 140 g and in Jharkhand it is only135 g against a minimum of about 300 g per day per capita recommended by Indian Council of Medical Research and National Institute of nutrition, Hyderabad. However, with the introduction of various lift irrigation projects, now farmers are substituting rice by some more remunerative crops in kharif and further it is superimposed by some vegetable crops during rabi and also in summer seasons. During 2008-09 vegetable production of the state was 3637.00 thousand metric tones with an area of 242.10 thousand hectare and productivity of 15.00 metric tones per hectare (Indian Horticulture Database 2009) [5].

The total amount of nutrients added through fertilizers and their removal by crops during 7-8 annual cycles of cropping showed changes in soil fertility status of soils (Ghosh, 1981). The low native soil nitrogen and very low phosphorus coupled with apathy of farmers towards use of fertilizer are the main or constraints limiting rice productivity in north eastern hill reason of India (Singh and Prasad, 1994 and Das *et al.*, 2008) [2]. An experiment conducted at Assam revealed that incorporation of green manure increased K_2O balance but P_2O_5 balance was decreased in rice-wheat-green manure sequences, while all three major nutrients decreased in rice-wheat or rice-rice-wheat sequences (Devi and Thakur, 1994) [3]. Salvagiotti *et al* (2010) [12] revealed that continuous application of P & K in maize-wheat/soybean cycle had positive impact in soil K and P levels were lower than that at the beginning of the experiment. Hence, the present investigation was undertaken to study the some important vegetable based cropping sequence on nutrient budgeting with rice equivalent yield and profit.

Materials and Methods

The present investigation was planned on the nutrient balance in some important vegetable based cropping sequences and carried out for two consecutive years 2010-11 and 2011-12 at Horticultural farm, BAU, Ranchi. The experiment was laid out in Randomized Block Design with three replications, which comprised of nine cropping sequences viz; bitter gourd-rice-potato, ridge gourd-cowpea-tomato, watermelon-maize-garden pea, bottle gourd-french bean-cauliflower, sponge gourd-brinjal-capsicum, cucumber-okra-wheat, sponge gourd-rice-broccoli, bottle gourd-chilli-radish and okra-maize-cabbage. The recommended dose of fertilizer was followed with improved management practices for each crop under different cropping sequences. The FYM added in vegetable crops was @ 200 q/ha whereas in cereal crop @ 50 q/ha. The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 5.6), low in organic carbon (3.70 g/kg), available N (238.00 kg/ha) and medium in available P (49 kg/ha) and K(157 kg/ha). Nitrogen, phosphorus and potassium of soils were determined by Kjeldahal's method (Subbiah and Asija, 1956) [16], Bray's P method (Bray and Kurtz, 1945) [1] and Flame photometer method (Jackson, 1973) [6] whereas, plant samples were analyzed by Kissler's ragent (Nocholas and Nasan, 1957) diacids digestion method, Vandomo-spectro photometer determination (Jackson, 1973) [6] and by Flame photometer determination after diacid digestion (Jackson, 1973) [6] method, respectively. Nitrogen, phosphorus & potassium uptake by different cropping sequences were computed from their respective nutrient concentrations (%) in plant component by using expression:

Nutrient uptake (kg ha^{-1}) = concentration (%) × yield (q ha^{-1})

Uptake of nitrogen, phosphorus & potassium by individual crop component (fruits/grains and plant parts/straw) were added to get the total nutrient uptake by the sequences and were expressed in kg ha^{-1}.

For preparing balance sheet of nutrient (N, P & K) after two cycle of vegetable based cropping sequences, total quantity of NPK removed by crops were obtained by subtracting from the sum of initial available soil nutrients and nutrient supplied through fertilization and organic manure to give the expected nutrient balance. The deviation of this from final available soil nutrients gave the actual change in soil fertility and positive balance showed gain and negative balance showed depletion of nutrient from the soil.

Rice equivalent yield under vegetable based cropping sequences was calculated by using following formula.

$$\text{Rice equivalent yield (q ha}^{-1}) = \frac{\text{Yield of crop (q/ha)} \times \text{Price of crop (Rs/q)}}{\text{Price of rice (Rs q}^{-1})}$$

Results and Discussion

The data on soil nutrient balance (N, P & K kg/ha) under different vegetable based cropping sequences have been presented in Table 1 to 3. The initial available N status was 238.00 kg/ha. The maximum (1390.00 kg/ha) N was added as input fertilizer in okra-maize-cabbage sequence in two years i.e., 2010-11 and 2011-12. The maximum (850.00 kg/ha) N was removed by bitter gourd-rice-potato and was followed by sponge gourd-rice-broccoli with 745.00 kg/ha removal. This could be attributed due to potato cultivation in sequence, which is heavy feeder of nutrients and removed higher N from the soil, while, bottle gourd-chilli-radish sequence removed minimum of 388.00 kg/ha nitrogen. The highest (–118.00 kg/ha) net loss of nitrogen, after two years was observed in watermelon-maize-pea whereas, it was lowest (-53.00 kg/ha) in bottle gourd-chilli-radish sequence. The negative N balance was observed in almost all treatments after two years of experimentation. This might be due to excessive removal of N by all the sequences which accompanied with low efficiency of applied N, inspite of recommended dose of N applied to all the crops in different sequences.

The initial P status of the soil was 49.00 kg/ha and maximum of 840.00 kg/ha P was added through fertilizer in sponge gourd-brinjal-capsicum treatment in two years. The balance sheet of P was found negative in all the sequences except that of ridge gourd-cowpea-tomato (+2.00 kg/ha) and bottle gourd-chilli-radish (+7.00 kg/ha), where positive balance was observed. This could be ascribed to the application of recommended doses of P to these sequences but P uptake was found comparatively low. The negative P balance in other sequences might be due to excessive removal of P inspite of recommended dose of P was applied to them. The maximum P loss was recorded in okra-maize-cabbage (-13.00 kg/ha) sequence and was followed by sponge gourd-brinjal-capsicum (–11.00 kg/ha) while bottle gourd-chilli-radish (+7.00 kg/ha) removed minimum phosphorus. The major portion of applied P gets fixed in the soil due to mineralization process, as the soil of the experimental site was acidic in reaction. These results are in agreement with the findings reported by Singh and Prasad (1994), Devi and Thakur (1994) [3] and Sharma and Prasad (1974), they also reported negative P balance on different sequences.

The initial K status in soil was 157.00 kg/ha and maximum of 800.00 kg/ha K was added through fertilizer in ridge gourd-cowpea-tomato and sponge gourd-brinjal-capsicum in two years. The maximum (553.00 kg/ha) K was removed from bitter gourd-rice-potato and was followed by okra-maize-cabbage (508.00 kg/ha) sequences. The highest loss of K was observed in Sponge gourd-capsicum-brinjal and cucumber-okra-wheat (–48 kg/ha) sequences. However, negative balance was observed in almost all sequences except bottle gourd-chilli-radish (+36.00 kg/ha) and okra-maize-cabbage (+16.00 kg/ha) sequences. This negative balance was mainly due to heavy removal of K accompanied with low efficiency of applied K inspite of recommended dose of K was applied to all the crops under sequences and positive balance might be due to crop diversification and recycling of residual potassium in the sequences. These results are in close conformity with the findings of Sharma *et al.* (1987) [13, 14], Kumar, *et al.* (2002) [7], Nambiar *et al.* (1984) [8] and Prasad, *et al.* (1995) [11]. However, Sharma *et al.* (2008) reported that potassium balance was negative in all cropping system (rice-potato-onion + maize, rice-berseem-maize-cowpea and rice-berseem-maize-cowpea) due to its removal by the crops which resulted in mining of soil potassium.

The significantly higher of 158.64 q/ha REY was obtained in ridge gourd-cowpea-tomato sequences in the first year of experiment and was found superior to all the treatment combinations. However, it was followed by sponge gourd-rice-broccoli and sponge gourd-brinjal-capsicum sequences with 123.45 and 114.62 q/ha REY, respectively. In the second year, sponge gourd-rice-broccoli sequences recorded significantly maximum of 165.34 q/ha REY and was also found superior to all the sequences under different cropping sequences. It was followed by sponge gourd-brinjal-capsicum and ridge gourd-cowpea-tomato sequences with 135.17 and 128.03 q/ha yields, respectively. Pooled data also differed significantly with respect to REY under different cropping sequences and maximum of 144.40 q/ha REY was found in

sponge gourd-rice-broccoli sequence and was at par with ridge gourd-cowpea-tomato sequence with 143.34 q/ha whereas, significantly minimum of 87.90 q/ha REY was recorded in cucumber-okra-wheat sequence.

In the first year, Ridge gourd-Cowpea-tomato sequence exhibited superiority over other sequences and produced highest (158.64 q/ha) rice equivalent yield than the rest of the sequences. Higher production potential of tomato along with good yield of cowpea & ridge gourd and better market prices were instrumental for attaining higher REY, it was followed by sponge gourd-rice-broccoli (123.45 q/ha). In the second year, sponge gourd-rice-broccoli sequence was found superior (165.34 q/ha) in REY than the other sequences. However, in the second year decreasing trend were observed in almost all sequences with respect of yield attributing characters but due to higher market price and higher production of sponge gourd and broccoli along with good rice yield fetched better returns in these sequences. At the end of both year experimentation in pooled data, sponge gourd-rice-broccoli sequence recorded highest (144.40 q/ha) REY and was closely followed by ridge gourd-cowpea-tomato (143.34q/ha) sequence. Urkurkar *et al.* (2008) [19] observed that inclusion of more than two crops in a year particularly vegetables lowered down the stability of the system in respect of yield and economics. Addition of leguminous crop (cowpea) with ridge gourd and tomato might be the reason for higher yield of the sequence which resulted in higher REY and are in agreement with earlier findings of Soni and Kaur (1984) [17]. These results are in close conformity with the findings of Saroch *et al.* (2005) [18], Nayak *et al*. (2003) [9] and Nanda *et al*. (2008) [10] though the sequences taken with rice were with different vegetables.

From the present study, it can be concluded that recommended dose of fertilizers was not enough to fully exploit production/productivity level of different crops under sequences. The N, P and K balance was negative in almost all sequences except in few, where it was positive. Therefore, there is need for modification in the existing N, P and K fertilizer recommendation for different cropping sequences to compensate gradual loss of native N, P and K fertility in the soil in the Jharkhand context.

Table 4.1: Rice equivalent yield (q/ha) of different cropping sequences

Treatments	2010-11 (q/ha)	2011-12 (q/ha)	Pooled (q/ha)	Net Benefit Ratio		
				2010-11	2011-12	Pooled
T_1 - Bitter gourd–Rice–Potato	88.62	116.39	102.51	2.14	2.76	2.46
T_2 - Ridge gourd–Cowpea–Tomato	158.64	128.03	143.34	2.66	2.16	2.41
T_3 - Watermelon–Maize–Pea	95.91	100.60	98.25	1.62	1.87	1.75
T_4 - Bottle gourd–French bean–Cauliflower	98.45	97.66	98.06	1.69	1.66	1.68
T_5 - Sponge gourd–Brinjal–Capsicum	114.62	135.17	124.89	1.70	2.15	1.93
T_6 - Cucumber–Okra–Wheat	93.09	82.71	87.90	2.08	1.77	1.93
T_7 - Sponge gourd–Rice–Broccoli	123.45	165.34	144.40	2.99	3.53	3.26
T_8 - Bottle gourd–Chilli–Radish	113.54	125.35	119.45	2.15	2.57	2.36
T_9 - Okra–Maize–Cabbage	75.35	109.72	92.53	1.52	2.12	1.82
SEm ±	3.63	5.49	3.59	0.09	0.07	0.08
CD at 5%	10.96	16.61	10.87	0.29	0.23	0.25
CV%	5.88	8.07	5.54	8.00	5.72	6.66

Table 1: Balance sheet of available N (kg/ha) in soil under different cropping sequences

Treatments	Added N (kg/ha) through fertilizer & FYM							Amount of N (kg/ha) removed by the sequences			Expected balance	Expected gain(+)/ loss(–)	Soil value at harvest (kg/ha)	Net loss(–)/ gain (+) in soil
	B							C						
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	Total	2010-11	2011-12	Total	A+B-C=D	D-A	E	E-A
	Summer		Kharif		Rabi									
T_1 – Bitter gourd – Rice – Potato	150.00	150.00	85.00	85.00	200.00	200.00	870.00	454.00	396.00	850.00	258.00	20.00	175.00	-63.00
T_2 – Ridge gourd – Cowpea – Tomato	150.00	150.00	160.00	160.00	220.00	220.00	1060.00	304.00	246.00	550.00	748.00	510.00	127.00	-111.00
T_3 – Watermelon – Maize – Pea	180.00	180.00	175.00	175.00	180.00	180.00	1070.00	263.00	247.00	510.00	798.00	560.00	120.00	-118.00
T_4 – Bottle gourd – French bean – Cauliflower	150.00	150.00	160.00	160.00	175.00	275.00	1170.00	259.00	184.00	443.00	965.00	727.00	161.00	-77.00
T_5 – Sponge gourd – Brinjal – Capsicum	150.00	150.00	220.00	220.00	160.00	160.00	910.00	234.00	226.00	460.00	688.00	450.00	169.00	-69.00
T_6 – Cucumber – Okra – Wheat	150.00	150.00	220.00	220.00	145.00	145.00	1030.00	301.00	267.00	568.00	700.00	462.00	147.00	-91.00
T_7 – Sponge gourd – Rice – Broccoli	150.00	150.00	85.00	85.00	275.00	275.00	1020.00	400.00	345.00	745.00	513.00	275.00	166.00	-72.00
T_8 – Bottle gourd – Chilli – Radish	150.00	150.00	160.00	160.00	150.00	150.00	920.00	213.00	175.00	388.00	770.00	532.00	185.00	-53.00
T_9 – Okra – Maize – Cabbage	220.00	220.00	175.00	175.00	300.00	300.00	1390.00	336.00	320.00	656.00	972.00	734.00	151.00	-87.00
*Initial available N(kg/ha)in soil	***A=238.00**													

Table 2: Balance sheet of available P (kg/ha) in the soil under different cropping sequences.

Treatments	Added P (kg/ha) through fertilizer & FYM							Amount of P (kg/ha) removed by the sequences			Expected balance	Expected gain (+)/ loss (–)	Soil value at harvest(kg/ha)	Net loss (–)/ gain(+) in soil
	B							C			A+B-C=D	D-A	E	E-A
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	Total	2010-11	2011-12	Total				
	Summer		Kharif		Rabi									
T_1 – Bitter gourd – Rice – Potato	120.00	120.00	45.00	45.00	180.00	180.00	690.00	92.00	74.00	166.00	573.00	524.00	48.00	-1.00
T_2 – Ridge gourd – Cowpea – Tomato	120.00	120.00	110.00	110.00	120.00	120.00	700.00	83.00	69.00	152.00	597.00	548.00	51.00	+2.00
T_3 – Watermelon – Maize – Pea	160.00	160.00	90.00	90.00	120.00	120.00	740.00	75.00	74.00	149.00	640.00	591.00	41.00	-8.00
T_4 – Bottle gourd – French bean – Cauliflower	120.00	120.00	110.00	110.00	135.00	135.00	730.00	41.00	42.00	83.00	696.00	647.00	44.00	-5.00
T_5 – Sponge gourd – Brinjal – Capsicum	120.00	120.00	140.00	140.00	160.00	160.00	840.00	48.00	41.00	89.00	800.00	751.00	38.00	-11.00
T_6 – Cucumber – Okra – Wheat	100.00	100.00	140.00	140.00	75.00	75.00	630.00	87.00	82.00	169.00	510.00	461.00	41.00	-8.00
T_7 – Sponge gourd – Rice – Broccoli	120.00	120.00	45.00	45.00	135.00	135.00	600.00	86.00	76.00	162.00	487.00	438.00	39.00	-10.00
T_8 – Bottle gourd – Chilli – Radish	120.00	120.00	110.00	110.00	120.00	120.00	700.00	49.00	39.00	88.00	661.00	612.00	56.00	+7.00
T_9 – Okra – Maize – Cabbage	140.00	140.00	90.00	90.00	140.00	140.00	740.00	101.00	95.00	196.00	593.00	544.00	36.00	-13.00
*Initial available N(kg/ha)in soil	***A=49.00**													

Table 3: Balance sheet of available K (kg/ha) in the soil under different cropping sequences

Treatments	Added K (kg/ha) through fertilizer & FYM							Amount of K (kg/ha) removed by the sequences			Expected balance	Expected gain (+)/ loss (–)	Soil value at harvest(kg/ha)	Net loss (–)/ gain(+) in soil
	B							C			A+B-C=D	D-A	E	E-A
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	Total	2010-11	2011-12	Total				
	Summer		Kharif		Rabi									
T_1 – Bitter gourd – Rice – Potato	130.00	130.00	40.00	40.00	180.00	180.00	700.00	295.00	258.00	553.00	304.00	147.00	134.00	-23.00
T_2 – Ridge gourd – Cowpea – Tomato	130.00	130.00	130.00	130.00	140.00	140.00	800.00	157.00	141.00	298.00	659.00	502.00	116.00	-41.00
T_3 – Watermelon – Maize – Pea	140.00	140.00	60.00	60.00	140.00	140.00	680.00	163.00	136.00	299.00	538.00	381.00	137.00	-20.00
T_4 – Bottle gourd – French bean – Cauliflower	130.00	130.00	130.00	130.00	130.00	130.00	780.00	170.00	118.00	288.00	649.00	492.00	156.00	-1.00
T_5 – Sponge gourd – Brinjal – Capsicum	130.00	130.00	140.00	140.00	130.00	130.00	800.00	194.00	174.00	368.00	589.00	432.00	109.00	-48.00
T_6 – Cucumber – Okra – Wheat	120.00	120.00	140.00	140.00	60.00	60.00	640.00	220.00	199.00	419.00	378.00	221.00	109.00	-48.00
T_7 – Sponge gourd – Rice – Broccoli	130.00	130.00	40.00	40.00	130.00	130.00	600.00	211.00	190.00	401.00	356.00	199.00	129.00	-28.00
T_8 – Bottle gourd – Chilli – Radish	130.00	130.00	130.00	130.00	130.00	130.00	780.00	162.00	137.00	299.00	638.00	481.00	193.00	+36.00
T_9 – Okra – Maize – Cabbage	140.00	140.00	60.00	60.00	140.00	140.00	680.00	273.00	235.00	508.00	329.00	172.00	173.00	+16.00
*Initial available N(kg/ha)in soil	*A=157.00													

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