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INTEGRATED NUTRIENT MANAGEMENT IN POTATO BASED CROPPING SYSTEM IN ALLUVIAL SOIL OF WEST BENGAL

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ABSTRACT

Field experiment was carried out during two consecutive winter seasons of 2012-13 and 2013-14 at Block Seed Farm, Adisaptagram, West Bengal to standardize INM practice in potato based cropping system for achieving sustainable yields in sandy loam soil with assured irrigation. The experiment was laid out in a split plot design with 18 treatment combinations replicated thrice. Treatments of Potato crop comprised of three organic sources (O_1: no FYM, O_2: 20 t FYM ha^{-1} and O_3: Residue incorporation + bio-fertilizers) and two levels of inorganic fertilizers (F_1: 75% RDF and F_2: 100% RDF, 200:150:150 kg N, P_2O_5 and K_2O ha^{-1} respectively. The succeeding crop Okra was fertilized with three levels of inorganic fertilizer (F_3: 50% RDF. F_4: 75% RDF and F_5: 100% RDF. Crop preceding potato (rice) was supplied with recommended doses of nutrients (60:30:30 kg N, P_2O_5 and K_2O ha^{-1} respectively). Experimental results revealed that under FYM 20 t ha^{-1} + 100% RDF plant emergence was maximum (93.37%). But the higher tuber yield was obtained with residue incorporation + bio-fertilizers + 100% RDF (25.71 t ha^{-1}) which was statistically at par with residue incorporation of all crops + bio-fertilizers + 75% RDF (24.81 t ha^{-1}) and 20 t FYM ha^{-1} + 75% RDF (24.11 t ha^{-1}). Similarly total number of tuber produced per hectare was higher under residue incorporation + bio-fertilizers + 100% RDF treatment (` 4, 63,734) closely followed by residue incorporation of all crops + bio-fertilizers + 75% RDF treatment (` 3, 99,434). Grade-wise tuber yield also exhibited similar trend to that of total number of tuber ha^{-1}. Maximum yield of Okra (17.7 t ha^{-1}) and net return (` 54,420 ha^{-1}) was recorded with 100% RDF + 20 t FYM ha^{-1}. The nutrient uptake by the crops receiving residue incorporation and seed treatment with Azotobacter and Phosphobacteria at 75 and 100% RDF was also higher as compared to the crop fertilized with 50% RDF only. As compared to initial status of soil, the available NPK of post-harvest soil was improved only in some of plots where 20 t FYM ha^{-1} was applied in conjunction with both 75% and 100% RDF. Therefore, rice-potato-okra based cropping system could be promising with integrated nutrient management in alluvial soil of West Bengal.

Key words: INM, Potato based cropping system, Nutrient balance, yield.

INTRODUCTION

Rice-Potato-Okra is a promising vegetable-based cropping sequence in West Bengal which keeps the land occupied for about 7 months of the year. Usually the crop preceding potato is kharif rice which takes another 4 months to complete the sequence. Rice and potato, both are exhaustive in nature. Even the introduction of high yielding varieties and intensive cultivation with excess and imbalanced use of chemical fertilizers showed reduction in soil fertility status (Roy and Singh, 2014). These causes have led to renewed interest in the use of renewable sources (organic manures). Organic wastes (FYM) is the source of primary, secondary and micronutrient to the plant growth and constant source of energy for heterotrophic micro-organism which help in increasing availability of nutrients, quality and quantity of crop produce (Roy and Singh, 2014). As on single source is capable of supplying the required amount of plant nutrients, integrated use of all source of plant nutrients is a must to supply balanced nutrition to the crop (Dash *et al.* 2010). Being a heavy feeder crop, potato requires considerable amount of organic manure and NPK for optimum growth. However, being a short duration crop, it does not utilize the applied nutrients fully and leaves a substantial residual effect on subsequent crops in the sequence. For example, wheat and sunflower following optimally-fertilized potato are reported to require 50-70% of recommended dose of N (Pandey *et al.* 2008). Further, in potato-groundnut-sesame sequence, both the succeeding crops required only 50% of the recommend dose of N if the potato received RDF+FYM (Sasani *et al.* 2002). In old alluvial zone of West Bengal, okra grown after potato is believed to be benefitted from the residual fertility of potato. Over the years, there has been stagnation or decline in yield of crops in various cropping system in this agro-climate

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zone. Declining soil fertility, especially soil-organic matter, is one of the important factors responsible for this (Oik *et al.* 1996). Giving emphasis on building up soil-organic matter and recycle the crop residues could be the only viable option left with us. After harvesting all the crops in the sequence generally leave significant quantities of residues or stubbles in the field. The effect of residue incorporation in such fields has been formed inevitable (Sindhu and Beri, 1989). Hence, the present investigation was planned to find out the effect of organic manures, residue incorporation and NPK on the performance of potato and their effect on okra along with nutrient balance and residual fertility in alluvial soil of West Bengal conditions.

MATERIALS AND METHODS

Field experiment was carried out at the Block Seed Farm, Adisaptagram, West Bengal (situated $23^0$26' North latitude and $88^0$22' East longitude with an elevation of 12 m above mean sea level) during winter seasons of 2012-13 and 2013-14 at fixed site. The soil was sandy clay loam in texture with pH 5.5, oxidizable organic carbon 0.48% and available N, P and K were 155, 24 and 243 kg ha^{-1} respectively. Meteorological data during the cropping seasons revealed that average maximum and minimum temperatures were 31.6 and 18.6°C, respectively. Average relative humidity prevailed between 89.3 (maximum) and 55.5% (minimum). The total annual rainfall during the experimental period was recorded 437.8 mm. The experiment was laid out in a split plot design with 18 treatment combinations replicated thrice. Treatments of Potato crop comprised of three organic sources (O_1: no FYM, O_2: 20 t FYM ha^{-1} and O_3: Residue incorporation + bio-fertilizers) and two levels of inorganic fertilizers (F_1: 75% RDF and F_2: 100% RDF, 200:150:150 kg N, P_2O_5 and K_2O ha^{-1} respectively). The succeeding crop Okra was fertilized with three levels of inorganic fertilizer (F_3: 50% RDF. F_4: 75% RDF and F_5: 100% RDF. Crop preceding potato (Rice) was supplied with recommended doses of nutrients (60:30:30 kg N, P_2O_5 and K_2O ha^{-1} respectively). Half of N with full dose of P_2O_5 and ¾th of K_2O were applied in potato during final land preparation. Rests ½ of N along with ¼th K_2O were applied at first earthing up (at 35 DAS). In case of okra, 300 kg of $(NH_4)_2SO_4$ (ammonium sulphate), 350 kg single super phosphate and 125 kg of muriate of potash were drilled per hectare in the rows before sowing. Ammonium sulphate at a rate of 300 kg was top-dressed after 30 DAS. Crop preceding potato i.e. kharif rice cultivar 'IET 4094' was supplied with recommended doses of NPK 60:30:30 kg ha^{-1}. Medium sized seed tubers (40-50g) of potato var. 'Kufri Jyoti' were planted at a spacing of 60 cm × 20 cm with a seed rate of 20 q ha^{-1} in the third week of November and harvested in late February. Succeeding crop okra cv. 'Arka Abhaya' was sown at 50 cm × 20 cm spacing with a seed rate of 30 kg ha^{-1} in first week of March and harvested in three pickings in May-June. Both the crops were raised following standard package of practices. Counting and weighting of tubers was done to get total tuber number and yield ha^{-1}. Data were analyzed using analysis of variance (ANOVA) to evaluate the differences among treatments while the means were separated using the critical difference (CD) test at the 5% level of significance using SPSS (version 18.0; SPSS, Inc., Chicago, IL, USA).

RESULTS AND DISCUSSIONS

Crop yield and economics under the crop sequence

The tuber yield of potato was maximum (25.80 t ha^{-1}), where the crop was fertilized with 100% RDF + 20 t FYM ha^{-1}. In the present study, crop residue incorporation and inoculating of seed tubers with bio-fertilizers before planting at both 75% and 100% RDF, also showed higher tuber yield as compared to no FYM + 75% RDF treatment, where no organic sources of nutrients was applied (Table 1). The maximum net returns (` 28,650 $ha^{-1}$) and B:C ratio (1.23) was recorded in potato crop fertilized with 100 % RDF + 20 t FYM $ha^{-1}$. In contrary minimum net returns (` 10,380 ha^{-1}) and B:C ratio (1.09) was recorded from the treatment receiving only 75% of RDF. Incorporation of crop residue along with bio-fertilizers at 75% and 100% RDF also showed higher net returns as compared to control (without organic sources of nutrient) (Table 2). Similarly, the maximum yield (17.7 t ha^{-1}), net return (` 54,420 $ha^{-1}$) and B:C ratio (1.27) of okra was recorded with the application of 100% RDF + 20 t FYM $ha^{-1}$. While minimum yield (10.9 t $ha^{-1}$), net return (` 29,060 ha^{-1}) and B:C ratio (1.22) was recorded in the treatment receiving only 50% RDF.

Table 1: Emergence, total number and yield of tuber (cv. Kufri Jyoti) and net return of potato (mean data of two years)

Treatment combination	Emergence (%)	Total no. of tubers ha^{-1}	Total yield (t ha^{-1})	Net return (` ha^{-1})	B:C ratio
O_1F_1	81.17	2,42,541	20.23	10,380	1.09
O_2F_1	81.83	2,87,294	24.11	20,400	1.16
O_3F_1	82.67	3,99,434	24.81	22,280	1.18
O_1F_2	90.33	3,10,956	23.36	13,810	1.11
O_2F_2	93.37	3,80,401	25.80	28,650	1.23
O_3F_2	93.17	4,63,734	25.71	25,200	1.20
SEm ±	1.29	5758	0.30	-	-
CD (P=0.05)	5.53	24776	1.31	-	-

O_1F_1: No FYM + 75% RDF, O_2F_1: FYM 20 t ha^{-1} + 75% RDF, O_3F_1: Residue incorporation of all crops + bio-fertilizers + 75% RDF, O_1F_2: No FYM + 100% RDF, O_2F_2: FYM 20 t ha^{-1} + 100% RDF, O_3F_2: Residue incorporation + bio-fertilizers + 100% RDF

Comparatively higher yield of okra was also found at 75% and 100% RDF along with incorporation of crop residue and seed inoculation with bio-fertilizers before sowing (Table 2). Venkatasalam *et al.* (2012) also had the similar opinion that the use of organic amendments such as FYM (in conjunction with chemical fertilizer) is an effective means of increasing potato yield. This might be accorded to improving soil structure, enhancing soil fertility, increasing microbial activity (Zink and Allen, 1998) and improving the water holding capacity of the soil (Yadav *et al.* 2014), ultimately resulting into increased tuber number and weight plant^{-1} (Venkatasalam *et al.* 2012). Other investigators also suggested that the superiority of crop performance under combined use of chemical fertilizers, organic manures and bio-fertilizers in right proportion might be due to increased nutrient availability resulting in improved growth rates in terms of AGR, RGR and dry matter translocation as reflected by harvest index (Singh and Kushwah, 2006; Mohapatra *et al.* 2008; Zaman *et al.* 2008). Yadav *et al.* (2014) obtained maximum net return and B:C ratio in potato cultivation with 70% RDF and 25% RDN through organic manure treatment because of higher value of crop produce.

Table 2: Percent emergence, yield and net return of okra (cv. Arka Abhaya) (mean data of two years)

Treatment combination	Emergence (%)	Yield (t ha^{-1})	Net return (` ha^{-1})	B:C ratio
O_1F_3	96.3	10.9	29,060	1.22
O_1F_4	96.7	13.0	36,840	1.23
O_1F_5	94.7	13.7	39,030	1.23
O_2F_3	95.7	13.3	36,110	1.22
O_2F_4	96.6	16.5	53,108	1.26
O_2F_5	96.7	17.7	54,420	1.27
O_3F_3	95.0	15.7	47,230	1.25
O_3F_4	97.3	14.7	42,830	1.24
O_3F_5	97.0	16.4	48,920	1.25
SEm ±	1.01	1.34	-	-
CD (P=0.05)	2.81	3.73	-	-

O_1F_3: No FYM + 50% RDF, O_1F_4: No FYM + 75% RDF, O_1F_5: No FYM + 100% RDF, O_2F_3: FYM 20 t ha^{-1} + 50% RDF, O_2F_4: FYM 20 t ha^{-1} + 75% RDF, O_2F_5: FYM 20 t ha^{-1} + 100% RDF, O_3F_3: Residue incorporation + bio-fertilizers + 50% RDF, O_3F_4: Residue incorporation + bio-fertilizers + 75% RDF, O_3F_5: Residue incorporation + bio-fertilizers + 100% RDF

Nutrient removal by different crops in rotation and residual soil fertility

The maximum N, P and K (146.2, 30.4 and 95.2 kg ha^{-1}, respectively) was removed from the plots where potato crop was fertilized with 100% RDF + residue incorporation + bio-fertilizer application (Table 3). The least removal of N, P and K (60.1, 18.5 and 54.1 kg ha^{-1} respectively) was noticed in the plots where the potato crop received 75% of RDF only. Combined application of organic and inorganic nutrients also exhibited higher uptake of

nutrients as compared to sole use inorganic sources only. Significantly increased NPK uptake by the potato crop with combined application of organic manure and inorganic fertilizers was earlier reported by Islam *et al.* (2013). Yadav *et al.* (2013a) also recorded higher total uptake of nutrients by potato crop with the application of fertilizers in combination with organic manure mainly because of better root penetration leading to higher absorption of nutrients.

Table 3: Nutrient (N, P and K) removal (kg ha^{-1}) by different crops in rotation

Treatment combination	Nutrients applied (kg ha^{-1}) to complete sequence			Nutrient removed (kg ha^{-1})								
				1st crop (Potato)			2nd crop (Okra)			Total removal (1st Crop + 2nd crop)		
	N	P	K	N	P	K	N	P	K	N	P	K
O_1F_1	150	112.5	112.5	60.1	18.5	54.1	31.5	10.2	24.0	91.6	28.7	78.1
O_2F_1	200	112.5	112.5	84.6	19.0	65.0	32.4	13.1	29.3	117.0	32.1	94.3
O_3F_1	200	150	150	105.1	21.5	69.2	40.2	15.0	30.1	145.3	36.5	99.3
O_1F_2	200	150	150	125.0	24.6	71.5	45.1	18.9	35.6	170.1	43.5	107.1
O_2F_2	250	150	150	135.6	28.1	80.4	42.0	20.1	40.1	177.6	48.2	120.5
O_3F_2	250	200	200	146.2	30.4	95.2	47.8	21.5	45.6	194.0	51.9	140.8

The nutrient removal by okra grown after potato was highest with the application of 100% RDF in combination with residue incorporation and bio-fertilizer application. The nutrient uptake by the crop receiving residue incorporation and seed treatment with *Azotobacter* and PSB at 75 and 100% RDF was also higher as compared to the crop fertilized with 50% RDF only. The positive balance of N, P and K was observed in all the plots after harvesting of potato crop (Table 4). The maximum positive N balance was obtained in plots receiving O_2F_1 treatment, while O_3F_2 treatment exhibited positive P and K balance in post-harvest soil. Application of organic and inorganic sources of nutrients to potato crop changed the fertility status of soil. The NPK status of soil was improved in all the plots, however, the magnitude of improvement was maximum in the plots where potato crop was fertilized with 100% RDF + 20 t FYM ha^{-1}. As compared to initial status of soil, the available NPK of post-harvest soil was improved only in some of plots where 20 t FYM ha^{-1} was applied in conjunction with both 75% and 100% RDF. Islam *et al.* (2013) also recorded positive effect of INM (Organic manure in combination with chemical fertilizer) on the availability of NPK after harvest of potato. Availability of NPK was increased in soil which might be due to their release from organic manures (Islam *et al.* 2011).

Table 4: Effect on soil fertility after completion of two year sequence

Treatment combination	Nutrient balance (kg ha^{-1})*			Soil fertility after the complete sequence (kg ha^{-1})			Initial soil fertility (kg ha^{-1})			Change in soil fertility (kg ha^{-1})**		
	N	P	K	Av N	Av P	Av K	Av N	Av P	Av K	Av N	Av P	Av K
O_1F_1	58.4	83.8	34.4	213.4	107.8	277.4	155.0	24.0	243.0	+58.4	+83.8	+34.4
O_2F_1	83.0	80.4	18.2	238	104.4	261.2	155.0	24.0	243.0	+83.0	+80.4	+18.2
O_3F_1	54.7	113.5	50.7	209.7	137.5	293.7	155.0	24.0	243.0	+54.7	+ 113.5	+50.7
O_1F_2	29.9	106.5	42.9	184.9	130.5	285.9	155.0	24.0	243.0	+29.9	+106.5	+42.9
O_2F_2	72.4	101.8	29.5	227.4	125.8	272.5	155.0	24.0	243.0	+72.4	+101.8	+29.5
O_3F_2	56.0	148.1	59.2	211.2	172.1	302.2	155.0	24.0	243.0	+56.2	+148.1	+59.2

*Where Av = Available, *Nutrient balance = Total nutrient applied - Total nutrient removed, ** Change in soil fertility = soil fertility after the complete sequence - initial soil fertility*

The soil fertility status was slightly improved after harvesting of okra (at the end of cropping sequence) due to integrated nutrient management practices. The improvement of NPK status was found in some plots where okra crop was fertilized with 75 and 100% RDF + incorporation of crop residue + seed inoculation with bio-fertilizes before sowing. Application of 100% RDF + 20 t FYM ha^{-1} witnessed the maximum overall improvement of soil fertility status. Yadav *et al.* (2014) also found higher organic carbon and available NPK contain of the

experimental soil over the initial value at manurial treatments. Narayan *et al.* (2013) while studying the effect on INM on potato (cv. Shalimar Potato-1) demonstrated that combined use of organic manures with reduced dose of chemical fertilizer will not only pave the way for higher and sustainable yields but also helpful in improving the soil health. They further opined that use of bio-fertilizers (*Azotobacter* and PSB) improves the soil nitrogen and phosphorus availability to the crop. Roy and Singh (2014) also noticed considerable improvement in the fertility status of soil after two years of rice-potato cropping by the integration of NPK, organic manure and *Azotobacter* compared to initial value and it was even better than 100% NPK through chemical fertilizer. The higher N availability in post-harvest soil treated with INM practice suggesting the fact that *Azotobacter* helped in atmospheric nitrogen fixation in the soil. Increase in available N may be attributed to higher microbial activity in the INM treatments which favoured the conversion of organically bound N to inorganic form (Yadav *et al.* 2014). Available P content in soil was also increased with INM practices which might be due to solubilization of native P in the soil through release of various organic acids and CO_2 during deposition of organic manures (Tripathi *et al.* 2009) as well as reduced the fixation of phosphate by providing protective cover on sesqueoxides and chelating cation which in turn enhanced the availability of P (Chadha *et al.* 2006). Roy and Singh (2014) while working on rice potato cropping sequence also noticed the increased K status in post-harvest soil due to combined application of organic manures, bio-fertilizers and inorganic fertilizers. This might be due to reduction of K fixation, solubilization and release of K due to the interaction of organic matter with clay, besides the direct K addition to the K-pool of the soil (Yadav *et al.* 2013b).

Thus, it may be concluded from the above study that substitution of recommended chemical fertilizer dose with organics particularly FYM, *Azotobacter* and crop residues increase the productivity of rice-potato-okra cropping sequence, improved the nutrient utilization by all the crops and finally reduced the use of chemical fertilizers without any deteriorations of soil health.

REFERENCES

Dash, D., Patro, H., Tiwari, R.C. and Shahid, M. (2010) Effect of organic and inorganic sources of nitrogen on Fe, Mn, Cu and Zn uptake and content of rice grain at harvest and straw at different stages of rice (*Oryza sativa*) crop growth. *Advances in Applied Science Research* 1(3):36–49.

Islam, M.M., Karim, A.J.M.S., Jahiruddin, M., Majid, N.M., Miah, M.G., Ahmed, M.M., Hakim, M.A. (2011) Effects of organic manure and chemical fertilizers on crops in the radish-stem amaranth-Indian spinach cropping pattern in homestead area. *Australian Journal of Crop Science* 5:1370-1378.

Islam, M.M., Akhter, S., Majid, N.M., Ferdous, J. and Alam, M.S. Integrated nutrient management for potato (Solanum tuberosum) in grey terrace soil (Aric Albaquipt) (2013) *Australian Journal of Crop Science* 7(9):1235-1241.

Mohapatra, B. K., Maiti, S., & Satapathy, M. R. (2008) Integrated nutrient management in potato (*Solanum tubnerosum*)-Jute (*Corchorus olitorius*) sequence. *Indian Journal of Agronomy* 53, 205–209.

Narayan, S., Kanth, R.H., Khan, F.A., Narayan, R., Nabi, A. and Mir, S. A. (2013) Growth and yield response of potato to date of planting and integrated nutrient management. *Indian Journal of Plant Physiology* 18(3):270–276.

Oik, D.G., Cassman, K.G., Randall, E.W., Kindhesh, P., Sanger, L.J. and Anderson, J.M. (1996) Changes in the chemical properties of soil organic matter in tropical lowland soils. *Environmental Journal of Soil Science* 47: 293-303.

Pandey, S.K., Singh, J.P. and Gopal, J. (2008) Potato varieties and cropping systems in India. *Potato Journal* 35*:*103-110.

Roy, R. and Singh, K. (2014) Effect of integrated nutrient management on sequential productivity, economics and nutrient uptake of rice (*Oryza sativa*) - potato (*Solanum tuberosum*) cropping sequence. *Indian Journal of Agricultural Sciences* 84(9):1096–1101

Sasani, G.V., Patel, C.K., Patel, N.I I. and Patel., R.N. (2002) 'Fertilizer management in potwo-bajra-groundnut and potato-groundnut cropping systems under North Gujarat conditions. *Indian Potato Association* **29**: *1*43-*1*46.

Sidhu, B.S. and Beri, V. (1989) Effect of crop residue management on the yields of different crops and on soil properties. *Biological Wastes* 27:15-27.

Singh, F., Kumar, R., and Pal, S. (2008) Integrated nutrient management in rice-wheat cropping system for sustainable productivity. *Journal of the Indian Society of Soil Science* **56** (2): 205-208.

Singh, S. P., and Kushwah, V. S. (2006). Effect of integrated use of organic and inorganic sources of nutrients on potato (*Solanum tuberosum* L.) production. *Indian Journal of Agronomy* **51:**236-238.

Tripathi, M.K., Majumdar, B., Sarkar, S.K., Chowdhury, H. and Mahapatra, B.S. (2009) Effect of integrated nutrient management on sunnhemp (*Crotalaria juncea*) and its residual effect on succeeding rice (*Oryza sativa*) in eastern Uttar Pradesh. *Indian Journal of Agricultural Sciences* **79**(9): 694–8.

Venkatasalan, E.P., Singh, S. and Sharma, S. (2012) Effect of organic manures on yield and yield attributing character of potato. *Potato Journal* **39**(1):84-87.

Yadav, S.K., Babu, S., Singh, Y., Yadav, G.S., Singh, K., Singh, R. and Singh, H. (2013a) Effect of organic nitrogen sources and biofertilizers on production potential and energy budgeting of rice (*Oryza sativa*)-based cropping systems. *Indian Journal of Agronomy* **58**(4): 459-64.

Yadav, S.K., Singh, Y., Kumar, R.P., Yadav, M.K. and Singh, K. (2013b) Effect of organic nitrogen sources on yield, quality and nutrient uptake of rice (Oryza sativa) under different cropping system. *Vegetos-An International Journal of Plant Research* **26**(1): 58–66.

Yadav, S.K., Srivastava, A.K. and Bag, T.K. (2014) Effect of integrated nutrient management on production of seed tubers from true potato (*Solanum tuberosum*) seed. *Indian Journal of Agronomy* **59**(4): 646-650.

Zaman, A., Patra, S. K., Das, P. P., & Mandal, S. C. (2008). Effect of combined application of organic and inorganic sources of nutrients for potato (*Solanum tuberosum* L.) in Gangetic alluvial soil. National Symposium on ''*New Paradigms Agronomic Research*'' (pp. 534–535), 19–21 Nov., Gujarat.

Zink, T.A. and Allen, M.F. (1998) The effects of organic amendments on the restoration of a distributed coastal sage scrub. *Restor. Ecology* **6** (1):52-58.