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Improving potato (*Solanum tuberosum*) yield and soil health through integrated nutrient management approach in east coast climatic conditions of India

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ABSTRACT

A field experiment was conducted consecutively for two cropping seasons of 2007-08 and 2008-09 to study the effect of organic (FYM: farmyard manure, vermicompost and neem cake) and inorganic (chemical fertilizers) sources of plant nutrients at different combinations on the growth and yield of potato (*Solanum tuberosum* L.) tubers and economics besides assessing its impact on soil health in terms of available OC, N,P and K status after its harvest during both the seasons. The experimental soil was slightly acidic (pH 6.4) in nature, low in organic carbon (0.481%), available N (228 kg/ha) and medium in available K (122 kg/ha) and P (18 kg/ha). Results indicated that the application of 50 % recommended dose of fertilizers (RDF) as inorganic sources in conjunction with rest 50% RDF as organic sources as FYM or vermicompost or *neem* cake (T_6, T_7 and T_8) 15 days before final land preparation, registered significantly higher tuber growth, tuber bulking rate, weight of tubers/plant and yield of potato tubers as compared to rest of the treatments including 100% RDF as inorganic sources alone. Accordingly, the above treatments, on an average, recorded higher tubers yield (19.65 t/ha) to the tune of 6.72, 11.70 and 57.71 % than that of 75% RDF as inorganic fertilizers + 25% as organic manures (FYM or vermicompost or *neem* cake), 100% RDF as chemical fertilizers and control (no manure or chemical fertilizer), respectively. Moreover, T_6, T_7 and T_8 treatments also exhibited higher uptake of N, P and K from soils in addition to more net returns (Rs. 56993/ha) and benefit: cost ratio (1.94) as compared to rest of the treatments. Integrated nutrient management approach not only proved beneficial in enhancing the yield of potato, but also improved the contents of available organic carbon, N, P and K in treatments where 50% recommended dose of NPK was applied through inorganic and remaining 50% RDF through organic sources.

Key words: Integrated nutrient management, Nutrients uptake, Potato, Soil health, Tuber yield

Indiscriminate use of chemical fertilizers apart from their higher cost often leads to nutritional imbalance causing deterioration of physicochemical properties of soil and decreases crop yield (Gupta *et al*., 2000). There is a need for launching a national movement to safeguard soil health and improve soil fertility and yield of potato (*Solanum tuberosum* L.). As no single source is capable of supplying the required amount of plant nutrients, integrated use of all sources of plant nutrients is a must to supply balanced nutrition for sustained crop production (Arora 2008). It is true that sustainable crop production can not be maintained by using only chemical fertilizers and similarly, it was not possible to obtain higher crop yield by using organic manure alone (Singh and Rai 2007 and Urkurkar *et al*. 2010). Moreover, the soils of Odisha, in general, are slightly acidic in nature due to leaching of bases owing to fairly high rainfall (>1500 mm). The low availability of P due to fixation as Fe/Al – complex is also a problem of sustained crop production in the region. The beneficial effects of organic manures are manifested through increase in soil organic matter and humus over the period of time. Soil organic matter and humus act in several ways; it serves as slow release source of plant nutrients to the potato and also act as a buffer against change in soil pH (Upadhyay and Singh 2003) Integrated nutrient management (INM) involving combination of organic manures (FYM, vermicompost, *neem* cake etc.) and chemical fertilizers is an essential tool for balanced fertilization and sustainability of crop production on long term basis (Hegde and Dwivedi 1993). Application of organic manures in conjunction with chemical fertilizers improves physical, chemical and biological properties of the soil besides improving fertilizer use efficiency and crop yield. Asiegbu and Oikeh (1995) found that in addition to supply of N, P and K to the growing plants, organic manures had also an advantage to supply other micronutrients in a regular and efficient way. But no such systematic study was made in the east coast zone of India, i.e. Odisha state where soils are lateritic and slightly acidic in nature. Keeping this in view a field study was undertaken to investigate the effect of integrated use of

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organic manures and chemical fertilizers on the yield of potato, soil health and its economics in Odisha under east coast climatic conditions of India.

MATERIALS AND METHODS

A field experiment was conducted for two consecutive crop seasons (2007-08 and 2008-09) at Central Research Station of the Odisha University of Agriculture and Technology, Bhubaneswar, India located at 20° 15' N latitude and 85° 52' E longitude and 25.9 m above the mean sea level and about 65 km west of the bay of Bengal. The place is characterized by warm and moist climate with hot and humid summers and mild winters. The mean annual rainfall of Bhubaneshwar is 1502 mm (1980-2008). South-west monsoon sets by 10 June and recedes by 15 October. The rainfall is uni modal and the distribution is uneven. Nearly 88% of the total annual rainfall is received during the period from June to October. December and January are relatively dry months. Evaporation loss in the month of June was in the range of 4.6 to 6.0 mm/day during both the years of experimentation. The mean maximum and minimum temperatures in June were in the range of 32.5 to 34.8 °C and 25.6 to 26.5 °C, respectively. Those of January were between 29.5 to 30.9 °C and 14.6 to 16.9 °C during both the years of experimentation. The mean relative humidity during morning hours (0700 h) was within the range of 87 to 96 per cent in different months of the two years. The soil of experimental field was well drained upland lateritic soil (*Aeric Haplaquept*) having sandy loam (13.15% clay, 12.35% silt and 74.50% sand) texture, slightly acidic (pH 6.4) in nature, low in organic carbon (0.541%) and available N (228 kg/ha) and medium in available K (122 kg/ha) and P (18 kg/ha). Before planting of potato crop, soil samples from 0 to 15 cm depth were collected by a core sampler of 8 mm diameter from five spots in the field. These samples were pooled together and the representative homogeneous sample was analyzed for determination of organic carbon (Walkley and Black method), available N ($KMnO_4$ method), 0.5 M sodium bicarbonate ($NaHCO_3$, pH 8.5) – extractable P and 1N, NH_4OAC-extractable K, following Jackson (1973).

The experimental treatments consisted of basically eight different combinations of organic and inorganic sources of nutrients, namely, T_1 (Control: no manure and chemical fertilizer), T_2 (100% recommended dose of fertilizers, ie RDF as inorganic fertilizers ie CF – chemical fertilizers), T_3 (75% RDF as CF+25% RDF as farmyard manure, ie FYM), T_4 (75% RDF as CF+25% RDF as vermicompost, ie VC),T_5 (75% RDF as CF+25% RDF as n*eem* cake), T_6 (50% RDF as CF+50% RDF as FYM), T_7 (50% RDF as CF+50% RDF as VC) and T_8 (50% RDF as CF+50% RDF as *neem* cake) were tested in a randomized block design having four replications (blocks). Each block contained all the eight treatments and their distribution was randomized block-wise. Plot area for each treatment was 6 m × 5 m (30 m^2). The potato cultivar 'Kufri Jyoti' was planted in the third week of November on the same field without disturbing the lay-out and harvested in the third week of February during both the years of experimentation. Planting was done with potato tubers @ 2.5 tonnes/ha at the spacing of 50×20 cm and fertilized with the recommended doses of N, P and K @ 150, 80 and 100 kg/ha. The nutrient contents (N, P and K) given through organic sources, viz. FYM (0.52, 0.20 and 0.50%), *neem* cake (2.80, 0.50 and 1.00%) and vermicompost (1.80, 1.00 and 1.00%) at 30% moisture were taken into account while applying through organic and inorganic modes at the respective treatments. Well decomposed FYM, VC (vermicompost) and *neem* cake as per treatments were applied 15 days before final land preparation. After application of organic sources of plant nutrients, additional requirements of nitrogen, phosphorous and potassium was met out through chemical fertilizers in the form of urea (46%N), single super phosphate(16% P_2O_5) and muriate of potash (60% K_2O), respectively. Full doses of P_2O_5 and K_2O were applied as basal while half of the total N was applied as basal and the rest was top dressed during earthing up. The earthing up was done at 35 days after planting along with weeding to facilitate the development of tubers. Chlorpyriphos 1.5 % dust @25 kg/ ha was applied at the time of land preparation to control incidence of termites and white grubs (*Holotrichia consanguinea*) in potato. To control the infestation of early blight, 0.4 % mancozeb was sprayed in the standing crop in the first week of January as a precautionary measure. The crop received 6 and 7 irrigations during 2007-08 and 2008-09 cropping seasons.

Five sample plants were selected randomly and the fresh weight of tubers were taken at 45, 60 and at harvest and tuber bulking rate (TBR) was estimated by using the formula

$$TBR = \frac{W_2 - W_1}{t_2 - t_1} \quad (g/m^2/day)$$

Tuber growth rate (TGR) was calculated using the same formula as above except in place of fresh weight, dry weight of tubers were used for computing TGR.

$$TGR = \frac{W_2 - W_1}{t_2 - t_1} \quad (g/m^2/day)$$

To determine the uptake of nutrients at harvest, the dried haulm and tuber samples of potato were analyzed for estimation of nitrogen, phosphorous and potassium as per Micro Kjeldahl, Tri-acid extraction followed by Spectro-Photometric method, Flame Photometry and Soxhlet's methods, respectively as described by Jackson (1973). To study the nutrients status in the soil after the harvest of the crop during both the seasons, samples were collected at random from each plot and were mixed to have composite samples treatment wise. The samples were air dried, ground and passed through a 2 mm sieve and were analyzed for estimation of available organic carbon, nitrogen, P and K following Jackson, 1973. The potato crop was harvested when 90 percent of the haulms completely dried up. The tubers were allowed to stand in the field for 4 to 5 days for

skin hardening. After harvest the yield of potato tubers in each plot was recorded, and accordingly converted into tonnes per hectare. The economics of cultivation of potato for different treatments was worked out taking into account the cost of various inputs as well as the price of potato tubers as per the prevailing market price during 2007-2008 and 2008-2009. The net returns for each treatment were calculated by deducting the cost of cultivation from the gross returns. Net returns per rupee invested were worked out by dividing the gross returns with the cost of cultivation.

For statistical analysis of the experimental data, analysis of variance method as described by Cochran and Cox (1957) was followed. The significance of different sources of variation was tested by "Error mean square method" of Fisher- Snedecor's F-test at probability level of 0.05 for approximate degrees of freedom. The critical difference (CD) was computed to determine statistically significant treatment differences.

$$CD = (\sqrt{2}\ VEr\text{-}1)t_{5\%}$$

where, VE is the error variance, r is the number of replications, $t_{5\%}$ is the table value of t at 5% level of significance for the error degree of freedom.

RESULTS AND DISCUSSION

Growth and yield of potato tubers

Experimental data presented in Table 1 clearly revealed that the various integrated nutrient management practices had significant effect on the tubers growth rate, tubers bulking rate, weight of tubers/plant and tubers yield during both the years of experimentation. Integrated use of 50% recommended dose of fertilizers (RDF) through inorganic and remaining 50% RDF through organic sources (FYM: farmyard manure, VC or *neem* cake) recorded significantly higher potato tubers growth and yield than that of other fertility treatments during both the years. The highest potato tubers growth and yield were obtained with the application of 50% RDF through inorganic and remaining 50% RDF through FYM (T_6), which were at par with the crop receiving 50% RDF through inorganic and remaining 50% RDF through VC (T_7) or *neem* cake (T_8). The above treatments (T_6, T_7 and T_8), on an average, recorded higher tubers yield (19.65 tonnes/ha) to the tune of 6.72, 11.70 and 57.71 % than that of 75% RDF as chemical fertilizers + 25% as organic manures (FYM or VC or *neem* cake, i.e. T_3, T_4 and T_5), 100% RDF as chemical fertilizers (T_2) and control (no manure or chemical fertilizer, i.e. T_1), respectively. These results amply emphasized the need of integrated use of 50% RDF through inorganic fertilizers and remaining 50% RDF through organic sources (FYM, VC or *neem* cake) for producing higher yield of potato tubers in Odisha state under east coast climatic conditions of India. The results further indicated that supply of 100% NPK only through inorganic fertilizers was not much helpful in recording high production of potato tubers under this situation. It might be due to gradual mineralization of FYM, VC and *neem* cake which paved the way for demand driven and sustained supply of plant nutrients to potato plants. Moreover, organic sources of fertilizers as buffer of plant nutrients must have restricted the losses of N and non-availability of P on

Table 1 Effect of integrated nutrient management on growth, yield attribute and yield of potato tubers

Treatment	Tuber growth rate at 45-60 DAP (g/m²/day)			Tuber bulking rate at 45-60 DAP (g/m²/day)			Weight of tubers/plant			Tuber yield (t/ha)		
	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled
T_1 -Control (no manure and fertilizer)	3.83	3.98	3.91	33.73	31.67	32.70	103.40	96.00	99.7	8.62	8.00	8.31
T_2 -100% RDF as chemical fertilizer (CF)	6.92	6.84	6.88	51.33	50.67	51.00	209.08	207.33	208.2	17.42	17.28	17.35
T_3 -75% RDF as CF+25% RDF as FYM	8.70	8.31	8.50	56.64	54.67	55.66	233.27	226.74	230.01	18.40	18.44	18.42
T_4-75% RDF as CF+25% RDF as vermicompost (VC)	8.84	8.48	8.66	55.82	54.67	55.25	229.72	226.01	227.87	18.31	18.08	18.20
T_5 -75% RDF as CF+25% RDF as *neem* cake	9.09	9.35	9.22	55.00	56.00	55.50	230.72	226.85	228.79	18.39	18.49	18.44
T_6-50% RDF as CF+50% RDF as FYM	11.99	11.01	11.90	63.10	62.67	62.88	244.55	227.23	235.9	20.38	18.93	19.66
T_7-50% RDF as CF+50% RDF as vermicompost	11.05	11.09	11.48	61.12	59.67	60.39	247.85	243.94	245.9	19.82	19.49	19.65
T_8 -50% RDF as CF+50% RDF as *neem* cake	11.20	11.89	11.55	62.13	58.72	60.43	235.02	237.21	236.12	19.75	19.52	19.64
SE(m) ±	0.69	0.59	0.46	1.29	1.78	1.10	6.35	5.69	4.65	0.21	0.27	0.39
CD (P=0.05)	2.02	1.74	1.29	3.79	5.22	3.11	19.54	16.69	13.14	0.87	0.89	1.09

RDF: Recommended dose of nitrogen, CF: chemical fertilizer, DAP: days after planting, VC: vermicompost, FYM: farmyard manure

Table 2 Effect of integrated nutrient management on N, P and K uptake of potato (pooled data of two years)

Treatment details	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Tuber	Haulm	Total	Tuber	Haulm	Total	Tuber	Haulm	Total
T_1-Control (no manure and fertilizer)	20.24	25.32	45.56	2.97	3.37	6.34	28.09	27.80	55.89
T_2-100% RDF as chemical fertilizer (CF)	50.73	49.17	99.91	6.01	6.09	12.10	51.78	51.54	103.32
T_3-75% RDF as CF+25% RDF as FYM	52.21	53.46	105.47	6.66	7.95	14.61	54.50	55.88	110.68
T_4-75% RDF as CF+25% RDF as vermicompost (VC)	52.73	52.80	105.53	6.79	7.74	14.54	54.76	54.97	109.73
T_5-75% RDF as CF+25% RDF as *neem* cake	52.65	53.75	106.40	6.70	7.76	14.46	54.52	54.09	108.61
T_6-50% RDF as CF+50% RDF as FYM	68.64	62.16	130.80	8.76	8.13	16.92	77.68	58.68	136.36
T_7-50% RDF as CF+50% RDF as vermicompost	67.95	58.01	125.96	8.59	8.05	16.64	75.47	57.88	133.35
T_8-50% RDF as CF+50% RDF as *neem* cake	68.56	61.78	130.34	8.73	7.94	16.67	73.24	59.84	133.08
SE(m) ±	0.50	1.45	2.12	0.15	0.13	0.20	1.03	1.05	1.60
CD (P=0.05)	1.40	4.10	5.99	0.43	0.36	0.57	3.07	2.96	4.67

RDF: Recommended dose of nitrogen, CF: chemical fertilizer, DAP: days after planting, VC: vermicompost, FYM: farmyard manure

account of leaching and fixation, respectively (Singh and Gupta 2005 and Rajwade *et al*. 2000). The lowest yield of potato tubers was noticed in the control plot (T_1) which implied that fertilization had a direct impact on crop growth of potato (Malik 2000). The combined application of organic and inorganic sources of nitrogen had an advantageous effect on the growth and yield of potato tubers, though 100% RDF through inorganic mode was not far behind which may be due to quick availability of plant nutrients to the crop (Singh *et al*. 2007). Substitution of 50% RDF either through FYM or VC or *neem* cake produced the highest weight of tubers per plant which were significantly greater than 75% RDF supplied through inorganic mode + 25% RDF through the above organic sources and also the use of 100% RDF through chemical fertilizer. Higher tuber growth and bulking rate and also tuber weight per plant were mainly responsible for higher and ultimately higher tuber yield (Table 1). Beneficial effect of integrated use of organic and inorganic sources of plant nutrients in improving the soil physical condition and higher availability of nutrients which, in turn, resulted to higher tuber yield (Khanda *et al.* 2005).

Nutrient (N, P and K) uptake

The highest uptake of N, P and K by tuber and haulm (Table 2) was noticed with the application of 50% RDF through inorganic fertilizers and remaining 50% through FYM which was significantly higher than that of other treatments in the test, but it was statistically at par with those obtained from the crop receiving 50% RDF through inorganic fertilizers and remaining 50% RDF through neem cake or vermicompost during both the years of experimentation. This might be ascribed to the fact that organic manures (FYM, VC or *neem* cake) in conjunction with inorganic fertilizers might have provided additional nutrients other than N, P and K in addition to an added advantage of improvement in physical condition of the soil, and thus the nutrients became readily available to the crop (Mondal and Roy 2001). Replacement of 50% RDF through VC or *neem* cake resulted in higher uptake of N, P and K by the potato crop which were next best treatments and significantly superior to sole use of 100% RDF given through inorganic source. Pathak *et al.* (2005) reported that the use of organic source of fertilizers not only release profuse amount of N, P and K to the available soil pool but also checks leaching and deep percolation losses of N by improving the physical condition of the soil. Mohapatra *et al.* (2008) opined that prolific development of root system by balanced nutrition, leading to better absorption of water and nutrients**.** Application of 50 % RDF each from inorganic and organic (FYM, VC or *neem* cake) sources were also found significantly superior in recording higher uptake of K than that of other treatments during both the years.

Available soil nutrient status of the experimental soil

The available OC, N, P and K in the soil increased gradually after each year due to the application of recommended dose of nutrients through integrated application of inorganic fertilizers and organic manures. The plots receiving 50% RDF through inorganic fertilizers and remaining 50% RDF through FYM (T_6) registered the highest available OC, N, P and K status in the soil and it was closely followed by the plots receiving 50% RDF through inorganic fertilizers and remaining 50% RDF through VC or *neem* cake (T_7 and T_8), but was markedly higher than those of the plots receiving 75% RDF through inorganic fertilizers and remaining 25% RDF through FYM, VC or *neem* cake (T_3, T_4 and T_5), 100% RDF through inorganic fertilizers (T_2) and control plots (T_1) during both the years of experimentation (Table 3). Application of 75% RDF through inorganic fertilizers and remaining 25% RDF through FYM, VC or *neem* cake (T_3, T_4 and T_5) being

Table 3 Effect of integrated nutrient management on available nutrients status of soil after harvest of potato during 2007- 08 and 2008-09 cropping seasons

Treatment	2007-08				2008-09			
	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1-Control (no manure and fertilizer)	0.477	103	15.8	107	0.461	94	15.7	101
T_2-100% RDF as CF	0.478	229	17.8	114	0.473	232	17.9	112
T_3-75% RDF as CF+25% RDF as FYM	0.503	252	18.1	116	0.508	255	18.6	119
T_4-75% RDF as CF+25% RDF as vermicompost	0.502	250	18.0	114	0.507	251	18.1	117
T_5-75% RDF as CF+25% RDF as *neem* cake	0.494	251	18.3	115	0.502	253	18.5	118
T_6-50% RDF as CF+50% RDF as FYM	0.517	260	19.4	128	0.527	264	19.6	132
T_7-50% RDF as CF+50% RDF as vermicompost	0.514	259	19.1	126	0.521	263	19.4	130
T_8-50% RDF as CF+50% RDF as *neem* cake	0.515	258	19.0	125	0.519	261	19.1	131
SEm (±)	0.007	2.52	0.36	1.63	0.008	2.84	0.30	1.56
CD (P=0.05)	0.021	7.33	1.05	5.07	0.024	6.32	0.89	4.54
Initial status	0.481	228.00	18.00	122.00				

RDF: Recommended dose of nitrogen, CF: chemical fertilizer, DAP: days after planting, VC: vermicompost, FYM: farmyard manure

Table 4 Effect of integrated nutrient management on economics of potato (mean data of two years)

Treatment	Gross return (₹/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	B: C ratio (Return/Reinvestment)
T_1-Control (no manure and fertilizer)	49 850	42 074	7776	1.02
T_2-100% RDF as CF	104 100	55 944	48 156	1.86
T_3-75% RDF as CF+25% RDF as FYM	110 520	56 590	53 930	1.95
T_4-75% RDF as CF+25% RDF as vermicompost	109 180	58 239	50 941	1.87
T_5-75% RDF as CF+25% RDF as *neem* Cake	110 638	59 065	51 573	1.87
T_6-50% RDF as CF+50% RDF as FYM	117 940	59 157	58 783	1.99
T_7-50% RDF as CF+50% RDF as vermicompost	117 943	61 202	56 741	1.93
T_8-50% RDF as CF+50% RDF as *neem* cake	117 840	62 385	55 455	1.89

Sales price: INR 6000/t of potato tubers. RDF: recommended dose of nitrogen, CF: chemical fertilizer, DAP: days after planting, VC: vermicompost, FYM: farm yard manure

statistically at par among themselves, also exhibited the higher availability of OC, N, P and K status in the soil than those obtained under 100% RDF through inorganic fertilizers (T_2) and control plots (T_1). Results also indicated that the treatments, viz. T_6, T_7 and T_8 improved the available OC, N, P and K status in the soil over their initial values, whereas, available OC, N, P and K status in the soil decreased gradually over the years in control plots. The results emphasized the need for integrated nutrient management practices through inorganic fertilizers and organic manures for enhancing the available OC, N, P and K status in the soil. Similar favourable effects of integrated nutrient management involving inorganic fertilizers and organic manures on increasing the available OC, N, P and K contents in soil after harvest of the crop have also been noticed by Kumar *et al.* (2008) and Zaman *et al.* (2011).

Economics

Two years mean data on economics of different treatments have been presented in Table 4. The gross returns (₹ 117 943/ha), cost of cultivation (₹ 62 385/ha) and net returns (₹ 58 743/ha) although were higher in T_7, T_8 and T_6 as compared with other treatments, but the highest net returns, among other treatments, was obtained with the application of 50% RDF as inorganic fertilizers and rest 50% RDF through FYM (T_6). Higher purchasing cost of VC and *neem* cake organic manures appeared to be the key factor in lowering the net returns (₹ 56 741 and 55 455/ha) although produced almost similar tuber yield to that of FYM as discussed earlier. It was noticed that the cost of cultivation was higher in the integrated nutrient management treatments as compared to 100 % RDF treatment owing to higher cost of organic inputs. The highest B: C ratio (1.99) was obtained where 50% RDF was replenished by FYM (T_6), which followed closely with 75% RDF through inorganic fertilizers + 25% RDF through FYM (T_3) (1.95) owing to less cost of cultivation on account of reduced quantity of FYM. The crop at control plot (T_1) exhibited very less gross and net returns and also B: C ratio mainly due to low tuber yield of potato.

CONCLUSION

Potato requires adequate nutrition under slightly acidic soils of Odisha state in east coast climatic conditions of India which may be achieved by judicious and balanced application of organic and inorganic sources of plant

nutrients. The application of 50% RDF through inorganic fertilizers and remaining 50% RDF through FYM, VC or *neem* cake are recommendable practices for higher tubers productivity and enhanced uptake of OC, N, P and K besides providing higher returns as compared to 100% N, P and K application through inorganic fertilizers alone. Application of organic manures in conjunction with inorganic fertilizers improved fertility status of soil over the years. Thus, this should be a part of the agronomic practices for potato cultivation in Odisha state under east coast climatic conditions of India.

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