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Studies on integrated nutrient management in productivity and economics of potato (*Solanum tuberosum* L.) under red and lateritic belt of West Bengal

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Abstract
Field experiment was conducted with potato (*Solanum tuberosum* L.) during winter (rabi) seasons of 2014-15 and 2015-16 to study on integrated nutrient management in productivity and economics of potato under red and lateritic belt of West Bengal. The study was laid out at Bahadurpur, Birbhum district of west Bengal which consists of 14 treatments and carried out in randomized block design with three replications. Among all the treatments, maximum yield (12.85 t ha^{-1} and 14.15 t ha^{-1}, respectively) of larger size tubers *i.e.* grade A (>100 g) tubers and medium size *i.e.* grade B (50-99 g) tubers was recorded with treatment T_{10}-80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer. However, maximum (8.79 t ha-1) yield of grade C (<50 g) tubers was recorded with the treatment T_2-80% RDN through chemical fertilizer + 20% through Farm Yard Manure (FYM). Crop receiving treatment T_{10} also showed highest total tuber yield (32.05 t ha-1) of potato. The higher tuber yield with T_{10} treatment could be attributed to increased availability of nutrients including micro nutrients in the soil which led to enhanced absorption of nutrients by the crop resulting in increased tuber production. An increase in tuber yield with the combined application of vermicompost and biofertilizers might be positive impact of vermicompost due to its richness in both macro and micronutrients. Similarly gross return (224315 ₹ ha^{-1}), net return (132659 ₹ ha^{-1}) and return per rupee invested (₹ 2.45) was recorded highest with treatment T_{10} followed by treatment T_{11}, which was statistically at par with each other.

Keywords: INM, organic manure, FYM, inorganic fertilizer, potato, productivity, economics

Introduction
Potato (*Solanum tuberosum* L.*)* belongs to family Solanaceae and called as the "poor man's Friend" as it fulfils all the demand for a healthy food and offers a great potential for decreasing global food crisis. The potato plant originated in the Peru-Bolivian region in the Andes (South America). It is largely raised in cool regions where the mean temperatures during its growing season, do not usually exceed 18 ^{0}C. Potato is used as vegetable and in industries for manufacturing starch, alcoholic beverages and other processed products. Being, an important temperate crop, potato has been adopted well for cultivation under sub-tropical conditions. It is a nutritious food which contains all the essential dietary constituents. Potato contains about 20.6% carbohydrates, 2.1% protein, 0.3% fat, 1.1% crude fiber and 0.9% ash. It also contains a good amount of essential amino acids like leucine, tryptophane and isolucine (Khurana and Naik, 2003) [6, 7]. It also contains essential minerals like phosphorus, calcium and iron. Globally, potatoes are cultivated over an area of 19.3 million hectares in 150 countries of the world with a total production of 308 million tons. In India, the potato production during the year 2015-16 was to be around 434.2 lakh MT from the area of 21.34 lakh ha. In West Bengal, the potato production during the year 2015-16 was estimated to be around 84.27 lakh MT with productivity of 19.73 t ha-1. Uttar Pradesh showed highest area (6.07 lakh ha) and production (138.52 lakh MT) during 2015-16 (Agricultural statistics at a glance, 2016). Potato crop is a heavy feeder of nutrients, it requires high dose of nitrogen, phosphorus and potassium. Fertilizer requirement of potato is very high as compared to cereal crops and it responds well to applied fertilizers. Inorganic fertilizers are the main source of nutrients used for potato crop. High basal dose of straight nitrogenous fertilizer like urea has some detrimental effect on emergence of potato (Sahota and Sharma, 2005) [14]. Integrated nutrient management (INM) is a better approach for supplying nutrition to the crop by including organic and inorganic

sources of nutrients (Arora, 2008) [3]. Integrated nutrient management (INM) involving combination of organic manure and it is an essential factor for an exhaustive and responsive crop like potato. Biofertilizers also are important substances of organic sources in INM which contains living micro-organisms and play a major role in supplementing the crop nutrients through biological nitrogen. Biofertilizers like phosphorus solubilizing bacteria (PSB) and *Azotobactor* may be useful for improving P and N nutrition in potato. Integrated use of all sources of plant nutrients (Chemical fertilizer, organic manures, biofertilizer) to be important not only for increasing crop productivity but also for improving soil health essential for sustaining the crop productivity in a long term (Shubha *et al*., 2018) [16] and on the other hand a judicious combination of organic and inorganic sources of nutrient might be helpful to obtain a good economic return with strong soil health (Alam *et al.*, 2007) [2]. Hence, an attempt has been made to study the productivity and economics of potato as affected by the integrated use of chemical fertilizer and organic manure with biofertilizers.

Materials and Methods

A field experiment was conducted on sandy loam and lateritic soil to studies on integrated nutrient management in productivity and economics of potato (*Solanum tuberosum* L.) under red and lateritic belt of West Bengal. The study was carried out during winter (Rabi) season of 2014-15 and 2015-16 at Bahadurpur, Birbhum district. The experiment was laid out in Randomized Block Design with 3 replications and 14 treatments. The field is situated in the western lateritic part of West Bengal under semi-arid-sub humid zone in the western India at 23° 4' N latitude and 87° 37' E longitude with average latitude of 58.9 m above mean sea level. The treatments included T_1: 100% RDN through chemical fertilizer, T_2: 80% RDN through chemical fertilizer + 20% through Farm Yard Manure (FYM), T_3: 80% RDN through chemical fertilizer + 20% through vermicompost, T_4: 80% RDN through chemical fertilizer + 20% through mustard oil cake, T_5: 60% RDN through chemical fertilizer + 40% through FYM, T_6: 60% RDN through chemical fertilizer + 40% through vermicompost, T_7: 60% RDN through chemical fertilizer + 40% through mustard oil cake, T_8: 100% RDN through chemical fertilizer + biofertilizer, T_9: 80% RDN through chemical fertilizer + 20% through FYM + biofertilizer, T_{10}: 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer, T_{11}: 80% RDN through chemical fertilizer + 20% through mustard oil cake + biofertilizer, T_{12}: 60% RDN through chemical fertilizer + 40% through FYM + biofertilizer, T_{13}: 60% RDN through chemical fertilizer + 40% through vermicompost + biofertilizer, T_{14}: 60% RDN through chemical fertilizer + 40% through mustard oil cake + biofertilizer. Biofertilizer (Azotobactor + PSB) was applied to the soil after mixing it with soil at the time of last ploughing. The remaining dose of nitrogen was applied as top dressing at 30 days after sowing. Crop was planted with a spacing of 50 x 15 cm with variety Kufri Surya. The analysis of variance of (Cochran and Cox, 1977) was followed for statistical analysis for various data.

Results and Discussion

Yield

Gradewise and total tuber yield recorded during all the two years of experimentation had been significantly analyzed and presented in table 1. Maximum yield (12.50, 13.19 and 12.85 t ha-1 in both the years and in pooled data, respectively) of larger size tubers *i.e.* grade A (>100 g) tubers was recorded with treatment T_{10}-80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer which was statistically at par with treatments T_{11} (12.01, 13.38 and 12.70 t ha^{-1} in both the years and in pooled data, respectively), T_9 (11.03, 12.03 and 11.53 t ha^{-1} in both the years and in pooled data, respectively), T_3 (11.40, 11.98 and 11.69 t ha^{-1} in both the years and in pooled data, respectively) and T_{13} (11.50, 11.65 and 11.58 t ha^{-1} in both the years and in pooled data, respectively). The minimum grade A (>100 g) tubers was recorded (6.20, 6.31 and 6.26 t ha^{-1} in both the years and in pooled data, respectively) with treatment T_1-100% RDN through chemical fertilizer. The yield of grade B (50-99 g) tubers was recorded maximum (13.80, 14.50 and 14.15 t ha^{-1} in both the years and in pooled data, respectively) with treatment T_{10}-80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer. It was statistically at par with treatments T_{11} (13.00 t ha^{-1}), T_9 (12.44 t ha^{-1}), T_3 (12.10 t ha^{-1}) in 2014-15 and treatment T_{11} (13.00 t ha^{-1} and 13.00 t ha^{-1}) in 2015-16 and in pooled data, respectively. Maximum yield of grade C (<50 g) tubers was recorded (8.67, 8.90 and 8.79 t ha^{-1}, in both the years and in pooled data, respectively) with the treatment T_2-80% RDN through chemical fertilizer + 20% through Farm Yard Manure. It was statistically at par with treatment T_1 (7.47 t ha^{-1}) in 2014-15 and significantly superior over other treatments in 2015-16 and in pooled data. Minimum yield of grade C (<50 g) tubers was recorded (5.09, 5.01 and 5.05 t ha^{-1}, in both the years and in pooled data respectively) with treatment T_{10}-80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer. Similar results was also recorded by Narayan (2010) [10, 11] who found that 'A', 'B' and 'C' grade tubers were significantly higher with application of 75% recommended dose of fertilizer with 8 tons ha^{-1} vermicompost + *Azotobacter* and *PSB* (N_6) treatment. The highest percentage of 'A' grade tubers (22.04 and 25.07% in 2008 and 2009, respectively) was obtained with that N_6 treatment. The grade wise distribution of tubers and the increase in yield of large and medium sized tubers was due to the cumulative effect of both organic and inorganic sources of nutrients that improved soil microflora and physical condition. The results corroborate the findings of Raghav *et al.*, (2008) [12]. Besides more percentage of 'C' grade tubers recorded with treatment T_2 could be due to inadequate availability of nutrients to the crop. Mondal *et al.*, (2005) [9] also reported similar distribution of grade wise tubers. Maximum total tuber yield (31.39, 32.70 and 32.05 t ha^{-1}, in both the years and in pooled data respectively) of potato was also recorded with treatment T_{10}-80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer) which was statistically at par with treatments T_{11} (30.74, 32.48 and 31.61 t ha^{-1}, in both the years and in pooled data respectively), T_9 (29.79, 30.17 and 29.98 t ha^{-1}, in both the years and in pooled data respectively) and T_3 (30.35, 31.23 and 30.79 t ha^{-1}, in both the years and in pooled data respectively). The higher tuber yield achieved in T_{10}, T_{11} and T_9 might be due to the integration of inorganic, organic and bio fertilizers sources of nutrients that might have improved the physico-chemical conditions of the soil and nutrient availability to the plants. This result was conformity with earlier researcher Rajiv (2014) [13] who observed that application of 75% NPK through chemical fertilizers along with 5 t ha^{-1} vermicompost recorded the highest tuber yield of 336 q ha^{-1} and similar observation was recorded by several researchers like Meena *et al.*, (2013) [8] and Kumar *et al.*, (2011) [8, 12].

Table 1: Studies on integrated nutrient management on grade wise and total tuber yield of potato

Treatments	Tuber yield (t ha^{-1})											
	A			B			C			Total		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	6.20	6.31	6.26	7.31	7.06	7.19	7.47	6.98	7.23	20.98	20.35	20.67
T_2	8.80	10.52	9.66	10.13	8.78	9.46	8.67	8.90	8.79	27.60	28.20	27.90
T_3	11.40	11.98	11.69	12.10	12.60	12.35	6.85	6.65	6.75	30.35	31.23	30.79
T_4	11.23	11.50	11.37	10.55	10.10	10.33	7.16	7.50	7.33	28.94	29.10	29.02
T_5	9.80	10.90	10.35	10.41	9.50	9.96	5.18	5.23	5.21	25.39	25.63	25.51
T_6	10.65	10.60	10.63	9.44	10.02	9.73	6.91	6.78	6.85	27.00	27.40	27.20
T_7	10.76	11.10	10.93	7.62	8.27	7.95	7.12	7.33	7.23	25.50	26.70	26.10
T_8	6.90	6.50	6.70	7.26	7.20	7.23	7.34	7.41	7.38	21.50	21.11	21.31
T_9	11.03	12.03	11.53	12.44	11.58	12.01	6.32	6.56	6.44	29.79	30.17	29.98
T_{10}	12.50	13.19	12.85	13.80	14.50	14.15	5.09	5.01	5.05	31.39	32.70	32.05
T_{11}	12.01	13.38	12.70	13.00	13.00	13.00	5.73	6.10	5.92	30.74	32.48	31.61
T_{12}	10.22	10.98	10.60	9.78	9.65	9.72	6.25	6.42	6.34	26.25	27.05	26.65
T_{13}	11.50	11.65	11.58	10.90	11.71	11.31	6.30	5.89	6.10	28.70	29.25	28.98
T_{14}	9.89	10.60	10.25	10.40	10.07	10.24	7.14	7.23	7.19	27.43	27.90	27.67
S.Em(±)	0.54	0.60	0.49	0.68	0.60	0.46	0.44	0.47	0.31	1.06	1.13	0.92
CD at 5%	1.58	1.74	1.44	1.96	1.76	1.33	1.29	1.37	0.92	3.09	3.29	2.67

T1: 100% RDN through chemical fertilizer, T2: 80% RDN through chemical fertilizer + 20% through Farm Yard Manure (FYM), T3: 80% RDN through chemical fertilizer + 20% through vermicompost, T4: 80% RDN through chemical fertilizer + 20% through mustard oil cake, T5: 60% RDN through chemical fertilizer + 40% through FYM, T6: 60% RDN through chemical fertilizer + 40% through vermicompost, T7: 60% RDN through chemical fertilizer + 40% through mustard oil cake, T8: 100% RDN through chemical fertilizer + biofertilizer, T9: 80% RDN through chemical fertilizer + 20% through FYM + biofertilizer, T10: 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer, T11: 80% RDN through chemical fertilizer + 20% through mustard oil cake + biofertilizer, T12: 60% RDN through chemical fertilizer + 40% through FYM + biofertilizer, T13: 60% RDN through chemical fertilizer + 40% through vermicompost + biofertilizer, T14: 60% RDN through chemical fertilizer + 40% through mustard oil cake + biofertilizer. Biofertilizer (Azotobactor + PSB).* RDN-Recommended Dose of Nitrogen = 200:150:150 N-P2O5-K2O kg ha-1. *A = 100 g or above, B = 50 g to 99 g, C = below 50 g.

Economics

The economics of potato cultivation under the present investigation was calculated using the prevailing cost of inputs and market rate of the product. The data pertaining to gross return, net return and return per rupee invested are presented in Table 2 and showed significant difference among the treatment. Owing to the highest production of tuber in the treatment T_{10}-80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer resulted the highest (219730, 228900 & 224315 ₹ ha^{-1}, in both the years and in pooled data, respectively) gross return followed by T_{11} (215180, 227360 & 221270 ₹ ha^{-1}, in both the years and in pooled data, respectively). Due to higher gross return the highest net returns of 128679, 136639 & 132659 ₹ ha^{-1}, in both the years and in pooled data, respectively was observed with treatment (T_{10}). This finding was in accordance with Narayan *et al.*, (2013) [10, 11] observation who found that the application of 75%.

Table 2: Studies on integrated nutrient management on economics of potato production

Treatments	Gross return (₹ ha^{-1})			Net return (₹ ha^{-1})			Return per rupee invested (₹)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	146860	142450	144655	65370	59750	62560	1.80	1.72	1.76
T_2	193200	197400	195300	100232	103222	101727	2.08	2.10	2.09
T_3	212450	218610	215530	122149	127099	124624	2.35	2.39	2.37
T_4	202580	203700	203140	110074	109984	110029	2.19	2.17	2.18
T_5	177730	179410	178570	73284	73754	73519	1.70	1.70	1.70
T_6	189000	191800	190400	89888	91478	90683	1.91	1.91	1.91
T_7	178500	186900	182700	74978	82168	78573	1.72	1.78	1.75
T_8	150500	147770	149135	68260	64320	66290	1.83	1.77	1.80
T_9	208530	211190	209860	114812	116262	115537	2.23	2.22	2.22
T_{10}	219730	228900	224315	128679	136639	132659	2.41	2.48	2.45
T_{11}	215180	227360	221270	121924	132894	127409	2.31	2.41	2.36
T_{12}	183750	189350	186550	78554	82944	80749	1.75	1.78	1.76
T_{13}	200900	204750	202825	101038	103678	102358	2.01	2.03	2.02
T_{14}	192010	195300	193655	87738	89818	88778	1.84	1.85	1.85
S.Em(±)	7433	7927	6424	7433	7927	6424	0.08	0.09	0.07
CD at 5%	21607	23043	18673	21607	23043	18673	0.23	0.25	0.21

T_1: 100% RDN through chemical fertilizer, T_2: 80% RDN through chemical fertilizer + 20% through Farm Yard Manure (FYM), T_3: 80% RDN through chemical fertilizer + 20% through vermicompost, T_4: 80% RDN through chemical fertilizer + 20% through mustard oil cake, T_5: 60% RDN through chemical fertilizer + 40% through FYM, T_6: 60% RDN through chemical fertilizer + 40% through vermicompost, T_7: 60% RDN through chemical fertilizer + 40% through mustard oil cake, T_8: 100% RDN through chemical fertilizer + biofertilizer, T_9: 80% RDN through chemical fertilizer + 20% through FYM + biofertilizer, T_{10}: 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer, T_{11}: 80% RDN through chemical fertilizer + 20% through mustard oil cake + biofertilizer, T_{12}: 60% RDN through chemical fertilizer + 40% through FYM + biofertilizer, T_{13}: 60% RDN through chemical fertilizer + 40% through vermicompost + biofertilizer, T_{14}: 60% RDN through chemical fertilizer + 40% through mustard oil cake + biofertilizer. Biofertilizer (Azotobactor + PSB).* RDN-Recommended Dose of Nitrogen = 200:150:150 N-P_2O_5-K_2O kg ha^{-1}

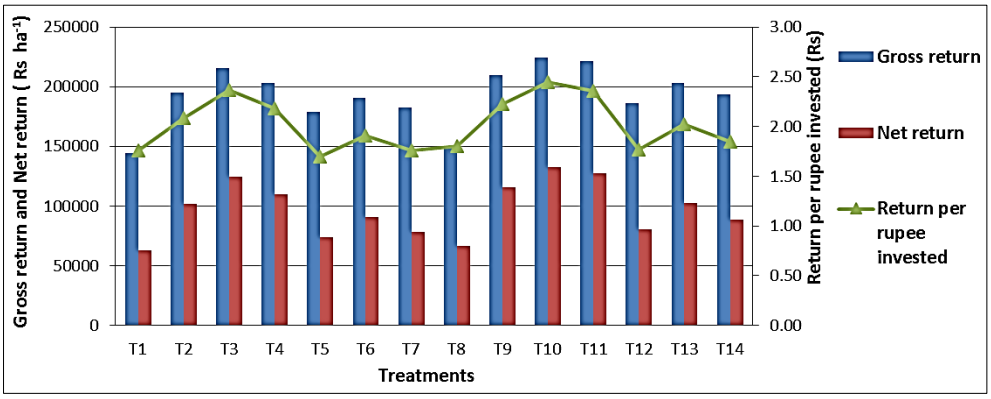

Fig 1: Studies on integrated nutrient management on economics of potato production (Pooled data)

Recommended Dose of Fertilizer with 8t ha^{-1} vermicompost + *Azotobacter* and PSB recorded highest gross (1, 92, 650.00 ₹ ha^{-1}) and net return (1, 29, 050.00 ₹ ha^{-1}). Due to higher net return, the return per rupee invested was also highest with the value of ₹ 2.41, ₹ 2.48 and ₹ 2.45, in both the years and in pooled data, respectively was obtained with treatment T_{10}. Choudhary *et al.*, (2010) [4] observed the highest gross (143050 ₹ ha^{-1}) and net returns (89025 ₹ ha^{-1}) in the treatment studded with vermicompost @ 30 t ha^{-1} along with PSB and *Azotobactor*. Yadav *et al.*, (2003) [4, 17] and Sahu *et al.*, (2014) [15] reported similar findings of higher net return and return per rupee invested in integrated nutrient management treatment.

Conclusion

The results of the field experimentation on integrated nutrient management in potato cultivars revealed that it gave significant result on productivity and economics of potato. Application of treatment T_{10}-80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer may be recommended for the enhancement of productivity and economics of potato under red and lateritic condition of West Bengal.

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