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Effect of integrated nutrient management on growth and tuber yield of potato (*Solanum tuberosum* L.) under red and lateritic belt of West Bengal

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Abstract
A field experiment was conducted to study the effect of integrated nutrient management on growth and tuber yield of potato (*Solanum tuberosum* L.) under red and lateritic belt of West Bengal. The study was laid out during 2014-15 and 2015-16 at Bahadurpur, Birbhum district of west Bengal which consists of 14 treatments and carried out in randomized block design with three replications. The results revealed that treatment T_{10}: 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer exhibited highest growth attributes i.e. plant height (43.3 cm), leaf area index (4.42), dry matter accumulation (583.45 g m^{-2}) and crop growth rate (18.38 g m^{-2} day^{-1}**)** followed by treatment T_{11}: 80% RDN through chemical fertilizer + 20% through mustard oil cake + biofertilizer and T_9: 80% RDN through chemical fertilizer + 20% through FYM + biofertilizer. This treatment T_{10}: 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer also showed highest total number of tubers per plant (9.05 tubers $plant^{-1}$), tuber weight per plant (517.8 gm) and tuber yield (32.05 t ha^{-1}) of potato and the tubers yield was 55% higher over 100% RDN through chemical fertilizer (T_1). The higher tuber yield achieved in 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer might be due to the integration of inorganic, organic and biofertilizers might have improved the physico-chemical conditions of the soil.

Keywords: INM, vermicompost, biofertilizer, potato, growth and tuber yield.

Introduction
Potato (*Solanum tuberosum* L.*)* popularly known as 'The king of vegetables', is one of the four major food crops of the world. Globally, it ranks fourth in importance among food crops i.e., after rice, wheat and maize. India ranks 4th in area and 3rd in production in the world (Anonymous, 2015) [3]. In India, the potato is grown in tropics as well as subtropics during the cool season, as influenced by favorable combination of latitude and altitude. Potato is an economical food and it provides a source of low cost energy to the human diet. Potato is the rich source of starch, vitamin B and minerals. Potato contains lysine and because of this, potato can supplement the diets limiting lysine content. It is a source of vitamin C. Potato also contains considerable quantities of niacin, thiamine, pyridoxine and its derivatives (Andre *et al*. 2014) [2]. Thus potato is considered as a whole some and nutritious food for human being. 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 tonnes. In India, the potato production during the year 2014-15 was estimated to be around 480.0 lakh MT from the area of 20.76 lakh ha. It is cultivated on a large scale in Uttar Pradesh, West Bengal, Bihar and Punjab. In West Bengal, the potato production during the year 2014-15 was estimated to be around 120.3 lakh MT from the area of 4.12 lakh ha (Agricultural statistics at a glance, 2015) [1]. Potato crop is a heavy feeder of nutrients, it requires high dose of nitrogen, phosphorus and potassium. Inorganic fertilizers are the main source of nutrients used for potato crop. However, continuous dependence on inorganic fertilizers causes nutritional imbalance and adverse effects on physico-chemical and biological properties of the soil. Vermicompost is a rich source of nutrients, plant growth regulators, vitamins, enzymes and other plant growth-influencing materials produced by microorganisms. The high porosity, aeration, water-holding capacity and microbial activity which are stabilized by interactions between earthworms and microorganisms in a non-thermophilic process which improves the moisture-holding capacity of soils, temperature regulation and pH buffering capacity and increasing crop yields (Shambhavi and Sharma, 2011) [16]. 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.

Fertilizer being a costly input, PSB (Phosphorus Solubilizing Bacteria) could supplement the nutrient requirement of the potato crop especially the phosphorus and thereby boosting the yield (Barman, *et al*., 2018) [4]. 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) [17]. Hence, an attempt has been made to study the growth and yield variation in potato as affected by the integrated use of chemical fertilizer and organic manure with biofertilizer.

Materials and methods

A field experiment was conducted on sandy loam and lateritic soil to study the effect of integrated nutrient management on growth and tuber yield 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 23º 4' N latitude and 87º 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. Crop was planted with a spacing of 50 x 15 cm with variety Kufri Surya. The analysis of variance of (Cochran and Cox, 1977) [6] was followed for statistical analysis for various data.

Results and discussion

Growth attributes

Most of the plant growth attributes of potato was significantly influenced by different sources of organic manure, inorganic and biofertlizer. Result showed that a positive effect of application of nutrients from organic and inorganic sources and biofertilizer on plant height, Leaf Area Index (LAI), Dry matter production and Crop Growth Rate (CGR) of potato (Table 1). The height of plant increased gradually in all the treatments. At 60 day after planting (DAP), application of treatment T_{10}: 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer recorded the highest (43.10 cm) during first year, where a non-significant response was found by different nutrient management. In second year, the plant height varies significantly and was recorded highest (43.5 cm) with treatment T_{10}. The pooled data of two years showed that maximum plant height of 43.30 cm with treatment T_{10} followed by the treatment T_{11} (41.88 cm) and minimum (32.05 cm) with treatment T_1-100% RDN through chemical fertilizer. This result was in accordance with Parmar *et al.* (2007) [13] who observed that application of organic, inorganic and biofertilizers (PSB + Azotobacter) showed significant response on plant height (81.53 cm). Indiresh *et al*. (2003) [7] reported that biofertilizers increased the efficiency of nutrients in the soil and increased the plant height when applied in combination with fertilizers. With regard to leaf area index (LAI) in potato, significant response was noticed by integrated nutrient management practices at 60 DAP crop growth stage. At 60 day after planting, treatment T_{10}:80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer recorded the maximum LAI (4.43) during the first year. Whereas, the maximum LAI (4.42) was observed with the treatment T_{11} in second year. Pooled analysis over the years also revealed that highest LAI (4.42) was observed with the treatment T_{10} which was statistically at par to treatments T_{11} (4.41) and T_9 (4.26). The results showed that LAI increased up to certain stage of crop growth thereafter it decreased. This declining of LAI occurred due to leaf senescence at the later stages of crop growth as reported by Sarkar *et al*. (2011) [15].

Table 1: Effect of Integrated Nutrient Management on growth attributes of potato

Treatments	Plant height (cm) at 60 DAP			Leaf Area Index (LAI) at 60 DAP			Dry matter accumulation (g m^{-2}) at 60 DAP			CGR (g m^{-2} day^{-1}) at 45-60 DAP		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	33.20	30.90	32.05	3.25	3.01	3.13	396.50	392.30	394.40	12.49	12.39	12.44
T_2	39.75	40.60	40.18	3.90	4.11	4.01	489.10	507.40	498.25	15.60	16.07	15.84
T_3	40.90	41.20	41.05	4.11	4.22	4.17	504.70	527.40	516.05	15.73	16.83	16.28
T_4	39.95	40.35	40.15	4.00	4.17	4.09	478.80	493.80	486.30	15.50	15.64	15.57
T_5	39.80	39.10	39.45	3.80	3.59	3.70	459.00	457.10	458.05	14.95	14.49	14.72
T_6	39.70	40.50	40.10	4.20	3.90	4.05	473.80	480.00	476.90	15.71	15.49	15.60
T_7	39.50	39.30	39.40	3.50	3.81	3.66	469.90	478.10	474.00	15.11	15.50	15.31
T_8	36.40	35.90	36.15	3.38	3.26	3.32	418.10	417.40	417.75	12.85	13.17	13.01
T_9	40.20	40.72	40.46	4.32	4.20	4.26	520.70	559.70	540.20	15.93	17.73	16.83
T_{10}	43.10	43.50	43.30	4.43	4.40	4.42	571.20	595.70	583.45	18.09	18.67	18.38
T_{11}	40.85	42.90	41.88	4.40	4.42	4.41	536.30	581.10	558.70	17.37	18.31	17.84
T_{12}	40.00	39.80	39.90	3.85	3.96	3.91	468.10	469.10	468.60	15.07	14.68	14.88
T_{13}	38.86	41.85	40.36	4.10	4.05	4.08	479.90	493.50	486.70	15.72	16.16	15.94
T_{14}	39.45	40.70	40.08	3.78	4.00	3.89	472.80	488.30	480.55	15.43	15.98	15.71
SEm(±)	1.59	1.55	1.29	0.17	0.20	0.17	18.74	24.63	17.74	1.31	1.23	0.87
CD at 5%	NS	4.52	3.75	0.49	0.57	0.50	54.46	71.60	51.57	NS	3.57	2.52

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}.

The total dry matter production of potato plants progressively increased as the growth of the crop progressed up to a certain stage. This occurred due to continued photosynthesis which took place throughout the growth period. At 60 DAP, the maximum dry matter accumulation of (583.45 g m^{-2}) was recorded under treatment T_{10}:80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer. This result showed due to the organic matter with PSB and *Azotobacter* which made the availability of nutrients and ultimately increases dry matter accumulation of the crop. This result is in accordance with Jaipaul *et al*. (2011) [8] who observed the application of 150 kg N with 80 kg P_2O_5 ha^{-1} and application Azotobactor and PSB culture were found beneficial in increasing dry matter accumulation. During 45-60 DAP, non-significant response of CGR was found, where the maximum (18.09 g m^{-2} day^{-1}) was recorded by T_{10}: 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer) during year 2014-15. In the year 2015-16 and in pooled data, significant effect was observed with different integrated nutrient management, where highest CGR of 18.67 g m^{-2} day^{-1} and 18.38 g m^{-2} day^{-1}, respectively was recorded with treatment T_{10}:80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer. This highest crop growth rate at 45-60 DAP mainly due to faster dry matter accumulation at 60 DAP *i.e.* after tuberization of potato. Nongmaithem *et al*. (2011) [12] reported that vermicompost with biofertilizer showed positive effect on crop growth rate. Application of treatment T_{10}, T_{11} and T_9 showed superior over rest of the treatments which attributed to the beneficial effect of combined use of chemical fertilizers, organic manures and biofertilizers in right proportions that led to increased nutrient availability through enhanced microbial activity, conversion from unavailable to available forms of essential nutrients to improved the growth attribute of potato.

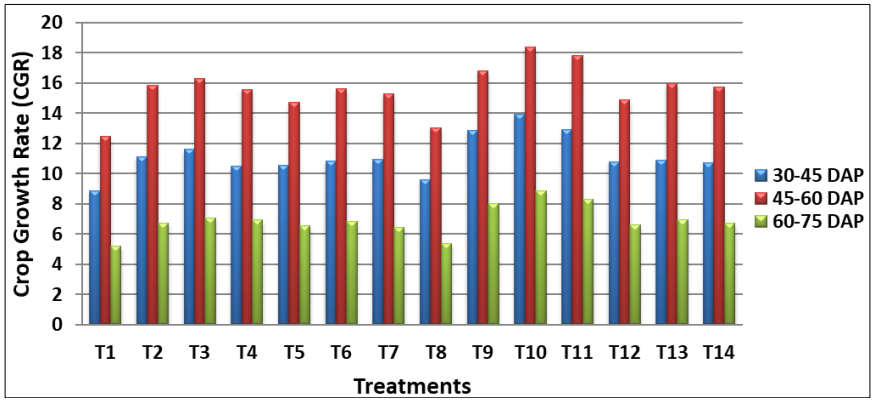

Fig 1: Effect of Integrated Nutrient Management on Crop Growth Rate (CGR) (g m^{-2} day^{-1}) of potato (pooled data)

Yield attributes and Yield

The tuber number is an important attributing character of tuber yield. It is evident from the data (Table 2) that effect of integrated nutrient management were found significant on producing numbers of tubers $plant^{-1}$ during 2014-15 and treatment T_{10} gave the highest number of tubers (8.9 tubers $plant^{-1}$). In the year 2015-16 and in pooled data, non-significant response was found in case of numbers of tubers $plant^{-1}$, where treatment T_{10}:80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer showed highest value of 9.20 and 9.05 tubers $plant^{-1}$, respectively. The increased numbers of tubers $plant^{-1}$ with in the 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. Narayan **(**2010) [11] revealed that the application of 75% Recommended Dose of Fertilizer with 8t ha^{-1} vermicompost + *Azotobacter* and *PSB* (T_6) significantly increased the number of tubers $plant^{-1}$ over other nutrition management treatments. Jaipaul *et al*. (2011) reported that the organic fertilizers with biofertilizers resulted in highest number of tubers $plant^{-1}$ (7.5 $plant^{-1}$). Maximum (517.8 g) total tuber weight $plant^{-1}$ was also recorded with treatment T_{10} which was statistically at par with treatments T_{11} (492.70 g) and T_9 (477.95 g). The total tuber yield of potato was influenced significantly due to different inorganic, organic treatments and biofertilizer. Application of treatment T_{10} recorded the highest total tuber yield of 31.39 t ha^{-1} with 49.6% high yield compared to tuber yield of 20.98 t ha^{-1} with treatment T_1:100% RDN through chemical fertilizer during first year. Maximum total tuber yield (32.70 and 32.05 t ha^{-1} in the second year and in pooled data, respectively) of potato was also recorded with treatment T_{10} which was statistically at par with treatments T_{11} (32.48 and 31.61 t ha^{-1} in the second year and in pooled data, respectively), T_9 (30.17 and 29.98 t ha^{-1} in the second year and in pooled data, respectively) and T_3 (31.23 and 30.79 t ha^{-1} in the second year 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. The increase in tuber yield might be due to improved soil fertility, growth and better nitrogen uptake by potato tuber which resulted in better

growth of photosynthetic organs, translocation of nutrients and photosynthates to developing plant parts. This result was conformity with earlier researcher Rajiv (2014) [14] 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}. Choudhary *et al.* (2010) [5] who observed that application of vermicompost doses @ 20 or 30 t ha^{-1} as well as bio-fertilizers alone or in combination with biofertilizers increased tuber yield. These results are in line with finding of Meena *et al.* (2013) [9], Singh (2013) [18] and Mohammed *et al.* (2018) [10].

Table 2: Effect of Integrated Nutrient Management on yield attributes and yields of potato

Treatments	No. of tubers plant^{-1}			Tuber weight plant^{-1} (g)			Tuber yield (t ha^{-1})		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	5.80	6.10	5.95	334.17	315.47	324.82	20.98	20.35	20.67
T_2	6.50	6.70	6.60	420.77	434.57	427.67	27.60	28.20	27.90
T_3	7.20	6.90	7.05	436.60	447.80	442.20	30.35	31.23	30.79
T_4	7.70	7.90	7.80	413.97	440.93	427.45	28.94	29.10	29.02
T_5	6.70	7.40	7.05	374.10	398.17	386.13	25.39	25.63	25.51
T_6	6.00	6.50	6.25	371.90	411.97	391.93	27.00	27.40	27.20
T_7	7.10	6.80	6.95	368.80	388.73	378.77	25.50	26.70	26.10
T_8	6.30	6.20	6.25	367.53	341.93	354.73	21.50	21.11	21.31
T_9	7.80	8.10	7.95	466.93	488.97	477.95	29.79	30.17	29.98
T_{10}	8.90	9.20	9.05	508.30	527.30	517.80	31.39	32.70	32.05
T_{11}	8.20	8.50	8.35	480.00	505.40	492.70	30.74	32.48	31.61
T_{12}	6.40	6.70	6.55	407.03	417.80	412.42	26.25	27.05	26.65
T_{13}	7.00	7.30	7.15	412.10	434.30	423.20	28.70	29.25	28.98
T_{14}	6.80	7.50	7.15	402.57	428.43	415.50	27.43	27.90	27.67
SEm(±)	0.60	0.73	0.62	17.24	19.83	17.46	1.06	1.13	0.92
CD at 5%	1.74	NS	NS	50.13	57.64	50.76	3.09	3.29	2.67

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}.

Conclusion

From the present study it may be concluded as integrated nutrient management gave significant result on improving the growth, yield and economics of potato. Application of biofertilizer and vermicompost provide the additional benefits on soil health and proved better in the productivity of potato under red and lateritic condition of West Bengal. The treatment 80% RDN through chemical fertilizer + 20% through vermicompost + biofertilizer may be recommended for the enhancement of growth, tuber yield and sustainability.

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