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Response of potato (*Solanum tuberosum* L.) to integrated nutrient management in alluvial plains of northern Bihar

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Abstract
A field experiment was conducted during the *Rabi* season of the year 2018-19 at Research farm of Tirhut college of Agriculture Dhoil, Muzaffarpur (Bihar), to study the "Response of Potato (*Solanum tuberosum* L.) to Integrated Nutrient Management" with variety *Kufri* Ashoka. Treatments consisted of five levels of RDF (0, 75, 100, 125, 150%) and two sources of organic manures (farm yard manure @ 20.0 t/ha and spent mushroom substrate @ 4.0 t/ha). The results revealed that there was a significant difference in various plant growth and yield parameters like plant height, number of shoots, number of leaves per plant, dry matter accumulation, bulking rate of tubers, yield attributes and fresh yield of tubers due to various treatment applied in the experimentation. The outcome of the research trial revealed that treatments T_5-100% RDF (150: 90: 100 N, P_2O_5 K_2O kg/ha) + FYM 20.0 t/ha and T_6-100% RDF (150: 90: 100 N, P_2O_5 K_2O kg/ha) + SMS 4.0 t/ha gave (252.11 q/ha) and (248.15 q/ha) yield of tubers, respectively, which was found statistically at par to treatments T_7-125% RDF + FYM 20.0 t/ha, T_8-125% RDF + SMS 4.0 t/ha, T_9-150% RDF + FYM 20.0 t/ha and T_{10}-150% RDF + SMS 4.0 t/ha. A similar result was observed with respect to other crop growth attributes, dry matter accumulation, and yield attributes of potato. Keeping the fact of sustainable crop production as well as improving soil fertility status, the application of 100% RDF + 20 t/ha farm yard manure or 100% RDF + 4.0 t/ha spent mushroom substrate is recommended for potato cultivation.

Keywords: Spent mushroom substrate (SMS), recommended dose of fertilizer, sustainable agriculture, North Bihar

Introduction
Potato is cultivating around the globe and secures the fourth position in food production after rice, wheat and maize. In 2050 potato demand in India is estimated to be 122 million tons, compared to 48.60 million tons, almost 2.5 times the current production. To satisfy this requirement, the productivity of potatoes need to be improved. Among the various factors limiting potato production, nutrient management play a key role. But current fertilization approaches are inadequate to sustain high yields and to replenish nutrient removal by the potato crop. (Imas and Bansal, 1999) [7]. Improved nutrient management techniques alone boost the production of potato by 50 per cent (Grewal *et al*., 1980) [4]. Hence, nutrient application through fertilizers becomes essential. However, continuous dependence on chemical fertilizer causes nutritional imbalance and adverse effects on the physico-chemicals and biological properties of soil. Higher and sustainable yields can be achieved through the application of optimal NPK doses along with organics in a balanced proportion. (Wuest and Fahy, 1991) [13] explained that the compost released after the harvest of one full crop of mushroom, beyond which extension of the crop becomes unremunerative is called the 'spent mushroom substrate' (SMS). The SMS has been found to be a good nutrient source for agriculture mainly because of its rich nutrients status, high cation exchange capacity (CEC) and slow mineralization rate which retain its quality as an organic matter. Keeping the above facts in view the present investigation was carried out to study the effect of organic manures and fertilizer levels on growth and yield parameters of potato and nutrient uptake as well NPK status of post-harvest soil.

Materials and Methods
The present study entitled "Response of Potato (*Solanum tuberosum* L.) to Integrated Nutrient Management" was performed during *rabi* season of the year 2018-19 at the Research Farm of Tirhut College of Agriculture, Dholi (Muzaffarpur), a campus of Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar.

The experimental soil was sandy loam in texture, slight alkaline in reaction (pH 7.9), low in organic carbon (0.47%), available N (224.60 kg/ha) and K_2O (138.01 kg/ha) and medium with respect to available P_2O_5 (23.55 kg/ha). Four levels of fertilizers i,e 75, 100, 125, 150 percent of Recommended Dose of Fertilizer (RDF) were integrated with farm yard manure (@ 20.0 t/ha) and spent mushroom compost (@ 4.0 t/ha) separately. These treatments were compared with 100% RDF (150, 90 and 100 kg N, P_2O_5 and K_2O) by fertilizers and absolute control. Potato cultivar 'Kufri Ashoka' was planted during 26th November in the gross plot of 4.8×4.0metres with spacing 60×20 cm and harvested in the first week of March. Well-decomposed farm yard manure and spent mushroom substrate were gathered from a nearby farm and mushroom research center respectively. In accordance with the treatments, organic manures collected were applied to the plots. The recommended dose of N, P_2O_5, and K_2O was taken as 150, 90 and 100 kg/ha for potato. Nitrogen, phosphorus and potassium, respectively, were applied as urea, DAP and MOP. Half of N and whole of phosphate and potash were applied at the planting of the crop. The remaining half of the nitrogen was applied as a top dressing at the time of earthing up according to treatment. Recommended package and practice for disease and insect management in the region for potato crop was followed. To support a smooth harvest, haulm cutting was executed at 10 days prior to harvesting. Observations on various growth and yield attributing characters were recorded by randomly selecting five competitive plants of each treatment in a replication, which were tagged properly. The growth and yield parameters of the crop during the experimental duration were recorded at regular intervals, in order to assess the probable relationship between growth attributes and the final yield. Five representative plants were not dehaulmed, as the data of vine yield and dry matter yield is essential at the time of harvest for the purpose of research studies. The significance of the treatment impact was examined by the F test. Standard errors of variances were calculated and recorded simultaneously with the summary results. Critical differences for various groups of treatments at a 5% level of significance were computed.

Results and Discussion

The growth attributes of potato were recorded at 45, 60, 75 DAP and at harvest. The data presented in Table. 2 indicate that potato crop raised under various treatments had a significant response on growth attributes. Among different treatments, Treatment T_9 registered higher plant height (48.80 cm), number of shoots (5.87/plant), number of leaves (62.22/plant), dry matter production (70.16 g/plant) and bulking rate (10.34 g/plant/day), was found statistically at par with treatments T_5, T_6, T_7, T_8, T_{10} and significantly superior over rest of the treatments. The increment in plant height, number of shoots and leaves per plant with an increase in fertilizers dosage coupled with organic manures could clearly indicate that application of organic manures to the soil in concurrence with mineral fertilizers, which could have significantly enhanced the nutrient availability, leading to beneficial impact on growth parameters as indicated by (Youtrchi *et al.,* 2013) [15]. The addition of organic manures has led in enhanced organic carbon content, the availability of macro and micro nutrients, beneficial microorganism activity and release of nutrients during the entire crop growth period, synthesis of growth promoting substances such as vitamin B_{12}, auxins, cytokinins, etc., which could have caused cell division and elongation due to increase in meristematic activity promoting rapid initiation and boost in plant height, number of shoots, leaves per plant, leaf area and duration contributing to higher chlorophyll synthesis resulted in greater quantity of dry matter production in plant parts. In accordance with this result, (Hossain *et al.*, 2007) [16] found the highest stem height of potato with the application of cattle manure in conjunction with mineral NPK fertilizers. (HabtamSetu, 2012) [5] who reported that an increase in the bulking rate of the crop in response to the high rate of application of nutrients was might be due to increased dry matter production and its distribution in plant parts. The results of this research were consistent with the findings of Bose *et al.* (2008) [3], Raghav *et al.* (2008) [10], Yassen *et al.* (2011) [14] and Meena *et al.* (2016) [9].

A perusal of the mean data presented in Table 3 revealed that different nutrient management practices had a significant impact on yield attributes of potato. The highest fresh yield of tuber per plant,(359.63 g/plant), total tuber yield (265.29 q/ha), vines yield (113.83 q/ha) and biomass yield(379.11 q/ha), was observed in Treatment T_9, it was found statistically at par with treatments T_5, T_6, T_7, T_8, T_{10} and significantly superior over rest of the treatments. Similarly, treatment T_9 recorded the highest tuber to vine ratio (2.33) and harvest index (69.97%) which was significantly superior over treatment Control (T_1) and statistically at par with remaining treatments. The higher yield achieved by applying a higher fertilizer dose (NPK) may be due to the positive reaction of potato crop to nutrients such as nitrogen, phosphorus and potash. In general N, P and K had a profound effect on the size of tuber. N and P influenced tuber formation in potato by influencing the activity and phytohormone balance of the plant especially, on gibberellin, abscisic acid and cytokinin levels. Potassium application promotes the activation of a number of enzymes involved in photosynthesis, carbohydrate, protein metabolism and helps to translocation carbohydrates from leaves to tubers. Organic manure in the soil improves nitrogen mineralization, plant absorption of phosphorus, by promoting carbonic acid production the acid that increases the solubility of phosphate compounds. Organic manures also supply micro nutrients and enhance the soil physico-chemical characteristics resulting in enhanced nutrient uptake that would have increased the yield of large sized tubers. The FYM has been found to be superior than SMS because it is bulky in nature and provides more quantities of available macro and micro nutrients. The FYM nutrient release was faster than SMS since the rate of mineralization of SMS was slow. These experimental results are in close agreement with the findings of Alam *et al.* (2007) [1], Sarkar *et al.* (2011) [11], Baishya *et al.* (2013) [2], Sharma and Kumar (2014) [12] and Kumar *et al*. (2017) [8].

Although the highest tuber yield was observed in 150% RDF + 20.0 t/ha FYM treatment, it was found statistically at par with treatments T_5-100% RDF + 20.0 t/ha FYM and T_6-100% RDF + 4.0 t/ha SMS. The overall conclusion is that the application of 100% RDF + 20 t/ha farm yard manure or 100% RDF + 4.0 t/ha spent mushroom substrate are recommended for sustainable potato crop production as well as enhancing the soil nutrient status under calcareous soil of northern Bihar.

Table 1: Treatments details

T_1	-	Control
T_2	-	100% RDF
T_3	-	75% RDF + 20.0 t/ha Farm Yard Manure
T_4	-	75% RDF + 4.0 t/ha Spent Mushroom Substrate
T_5	-	100% RDF + 20.0 t/ha Farm Yard Manure
T_6	-	100% RDF + 4.0 t/ha Spent Mushroom Substrate
T_7	-	125% RDF + 20.0 t/ha Farm Yard Manure
T_8	-	125% RDF + 4.0 t/ha Spent Mushroom Substrate
T_9	-	150% RDF+ 20.0 t/ha Farm Yard Manure
T_{10}	-	150% RDF + 4.0 t/ha Spent Mushroom Substrate

Table 2: Effect of different treatments on growth attributes of potato.

Treatments	Plant height	Number of shoots per plant	Number of leaves per plant	Dry matter accumulation (g/plant)	Bulking rate (g/day/plant) 60 - 75DAP
T_1 – Control	31.48	3.33	41.24	41.20	2.75
T_2 - 100% RDF	39.57	4.87	49.80	57.50	8.75
T_3 -75 % RDF + 20.0 t/ha FYM	38.83	4.80	50.84	56.12	8.27
T_4 -75 % RDF + 4.0 t/ha SMS	38.52	4.67	48.81	54.81	8.20
T_5 -100 % RDF + 20.0 t/ha FYM	44.26	5.33	57.43	65.45	10.17
T_6 -100% RDF + 4.0 t/ha SMS	44.49	5.30	54.74	64.80	10.10
T_7 -125 % RDF + 20.0 t/ha FYM	47.59	5.73	60.63	68.24	10.23
T_8 -125% RDF + 4.0 t/ha SMS	46.37	5.67	59.19	67.35	10.20
T_9 -150% RDF+ 20.0 t/ha FYM	48.80	5.87	62.22	70.16	10.34
T_{10} -150%RDF + 4.0 t/ha SMS	47.75	5.80	61.71	69.73	10.28
SEm(±)	2.01	0.18	2.67	1.76	0.57
CD (*p=0.05*)	6.44	0.58	8.55	5.63	1.81

Table 3: Effect of different treatments on fresh tuber yield (q/ha) and yield attributes of potato.

Treatment	Tuber yield (g/plant)	Fresh Yield of Tubers (q/ha)	Yield of Vines (q/ha)	Biomass Yield (q/ha)	Tuber: Vine Ratio	Harvest Index (%)
T_1 – Control	151.34	110.48	72.42	182.89	1.53	60.39
T_2 - 100% RDF	279.19	225.95	103.39	329.34	2.18	68.60
T_3 -75 % RDF + 20.0 t/ha FYM	276.27	229.56	102.75	332.31	2.24	69.08
T_4 -75 % RDF + 4.0 t/ha SMS	265.43	228.21	102.27	330.48	2.23	69.05
T_5 -100 % RDF + 20.0 t/ha FYM	340.92	252.11	108.90	361.01	2.32	69.83
T_6 -100% RDF + 4.0 t/ha SMS	336.35	248.15	108.63	356.78	2.29	69.54
T_7 -125 % RDF + 20.0 t/ha FYM	350.88	260.29	112.02	372.32	2.33	69.89
T_8 -125% RDF + 4.0 t/ha SMS	345.43	258.11	111.79	369.90	2.31	69.78
T_9 -150% RDF+ 20.0 t/ha FYM	359.63	265.29	113.83	379.11	2.33	69.97
T_{10} -150%RDF + 4.0 t/ha SMS	351.96	261.72	112.80	374.52	2.32	69.87
SEm(±)	7.41	5.54	3.09	10.12	0.06	0.56
CD (*p=0.05*)	23.70	17.72	9.90	32.38	0.19	1.80

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