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Response of customized fertilizer application on growth, yield and economics of potato (*Solanum tuberosum* L.) in eastern region of India

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Abstract
This study is based upon the assessment of performance of Customized Fertilizer (CF) on potato crop in Eastern region of India. The treatments were control (No fertilizer application), five different graded doses of customized fertilizers (50%, 75%, 100%, 125% and 150% CF dose) and recommended dose of fertilizer. Highest Plant height (54.6 cm) was recorded in treatment 125% CF dose followed by treatment 150% CF dose. Highest number of branches plant^{-1} (6.67) and number of effective branches plant^{-1} (5.50), tuber length (8.27), tuber plant^{-1} (9.03), tuber weight (163.23 g tuber^{-1}) and tuber yield (23445kg ha^{-1}) were recorded in 150% CF dose. Net return and B: C ratio was highest in 150% CF dose over all the treatments. Available N was significantly increased in the treatment 150% CF dose over initial. Available P_2O_5 was significantly increased in the treatment 125% CF dose while available K_2O was significantly increased at all application of customized fertilizer over initial.

Keywords: Customized fertilizers, balanced fertilization, potato growth, potato yield, soil characteristics

1. Introduction
Fertilizer application to crop had been to provide nutrients to plants and in turn enhanced or sustained optimal yield. Improvement of fertilizer use efficiency is required for optimizing nutrient uptake and crop yield (Kamble and Kathmale, 2015) [7]. Customized fertilizers are multi-nutrient carrier which contains macro and/or micronutrients, whose sources are from inorganic or organic, manufactured through systematic process of granulation and satisfy crop's nutritional demand, specific to area, and soil and growth stage of plant. The customized fertilizer provides site specific nutrient management for achieving maximum fertilizer use efficiency for the applied nutrient in a cost effective manner (Tiwari, 2014) [13]. Mudalagiriyappa *et al*., 2015 worked on the influence of customized fertilizer in the finger millet (*Eleusine Coracana* L.) in Alfisols of Southern India and reported positive impact of customized fertilizer on growth and yield of the crop. Kaleeswari, 2013 [6] conducted a field experiment on lowland rice ecosystem and observed that 100 % RDF in the form of CF II (N:P:K:Zn mixture) recorded the highest grain yield and increased yield attributing characters of the crop over the other treatments of CF and the blanket recommendation. Similarly, Dwivedi and Meshram, 2014 [2] reported that 150% dose of CF recorded the highest growth and yield attributing characters, viz. grain yield, harvest index (HI), and maximum net returns as well as B: C ratio over the other doses of fertilizer application in Mahamaya rice in Raipur, Chhattisgarh. Application of customized fertilizer is compatible with existing farmers system & hence, it will be comfortably accepted by the farmers.
The rising Indian human population and capita^{-1} income has pushed up the food feed demand and escalated prices of commodities. Potato crop can produces more edible energy and protein unit^{-1} area and time than many other food crops. Potato is the highly profitable cash crop for small and marginal farmers in Bihar. In India, potato is believed to have been introduced in the early 17th century most probably by the Portuguese traders of British missionaries. Potato is grown in India over 1.89 Million ha with an annual production of 39.66mt and yield of 20993 kg ha^{-1} (Directorate of Economics and statistics, Ministry of Agriculture, Government of India 2010-11). The country recorded an increase in area under potato from 0.24mha in 1950-51 to 1.89mha in 2010-11 with the corresponding increase in production from 1.66 to 39.66mt. The productivity of potato has also improved from 6.92 t ha^{-1} in 1950-51 to 20.9 t ha^{-1} in 2010-11. Bihar contributes 16.63% of total cultivated area and 14.59% of total production of the country. The productivity of potato in Bihar (18.4 t ha^{-1}) is low as when compared with productivity of the country. This is concern and need to improve the yield and productivity of the crop in the state and also country at global level.

Nutrient is the main limiting factor for low productivity in this crop. In different crops customized fertilizer has been found improve the yield in different soils of the various countries. But the information in relation to customized fertilizer is found scanty for Eastern region of India especially Bihar. This study imparts the performance and optimization of customized fertilizer on potato crop.

2. Materials and Methods

The field experiments were conducted at the experimental farm of Bihar Agricultural College Sabour farm during winter season (2010-12). Bihar Agricultural college, Sabour, a pioneer in the field at Agricultural research, is located 10km east of the Bhagalpur district headquarters (25°23′N latitude and 87°07′E longitude with an attitude of 37.19 m amsl). It is under sub-tropical climatic condition characterized with an average maximum temperature between 35 °C to 39 °C. January is the coldest month of the year with minimum temperature varies from 5 °C to 10 °C. The average annual rainfall at this around 1380 mm precipitating mostly between mid-junes to mid-October. During the cropping period i.e. December to March crop received an amount at 190.6mm of rainfall at Sabour. The center is location under Agro-climatic zone III-A; comprising six districts, viz., Bhagalpur, Banka, Munger, Jamui, Lakhisarai, and Sheikhpura, having diverse type of topography and soil classes.

Field experiments were conducted with potato crop. Two grade of NFCL Customized fertilizer viz-CF 39: 14, 17, 14, 5, 0.5 & 0.2 (N, P_2O_5, K_2O, S, Zn & B) and CF-40: 22, 00 & 10 (N, P_2O_5, K_2O) percent were used for Basal and Top dress. The variety for experimental purpose was taken as Kufri Ashoka, which is the common Potato variety. The study consists of seven treatments laid out in a Randomized Block Design with three replications. Detail of treatments used in was kept the experiment for presented in Table 1. The unit plot size was kept 4.2×4m^2 (16.8m^2) and spacing 60×15cm^2. Recommended package and practices for the crop were adopted as and when needed.

Observation on plant height was recorded at harvest. Five plants from each plot were selected randomly and tagged for recording progressive height. Mean values were then calculated. Yield attributing characters like number of branches plot^{-1}, tuber length in cm, tuber plant^{-1}, tuber weight, were recorded at harvest. Seed yield was taken from each plot excluding the border rows and converted into quintal ha^{-1}. After harvest of crop soil samples were collected, air-dried, processed and physicochemical characteristics of the soil was analyzed. The pH (1:2.5) and EC of soil were determined by pH meter and conductivity meter (Jackson, 1973) [5]. The soil samples were analyzed for oxidizable organic carbon by dichromate digestion method (Walkley and Black, 1934) [14], available N by the alkaline permanganate method (Subbiah and Asija, 1956) [12], available P (Olsen-P) by 0.5 M $NaHCO_3$ extraction (Olsen *et al*., 1954), available K (NH_4OAc method) by 1 N neutral NH_4OAc extraction on flame photometer (Knudsen *et al*., 1982) [8]. Mean data of two years are combined together and then analysis was performed.

The Statistical analysis was done using randomized block design and critical difference was computed at the 5 percent probability level (Panse and Sukhatme, 1985) [11].

3. Results and Discussion

The Customized Fertilizer had a significant effect on growth and yield attributing characters of Potato (Table 2). The plant height was increased significantly for all the treatments over the control. The highest plant height was observed at treatment T_5 i.e. 125% CF dose (54.6cm) among all the treatments. The treatments of customized fertilizer had shown better effect as compared to recommended dose of fertilizer. This shows that customized fertilizer improved the plant height. The improvement in plant height due to customized fertilizer application may be attributed to proper nourishment of the potato crop and optimum growth. Balanced fertilizer application improves the metabolic processes in the plant. Similar result was reported by Dwivedi and Meshram, 2014 [2] in rice crop and Mudalagiriyappa *et al*., 2015 in finger millet (*Eleusine Coracana* L.).

In case of number of branches plant^{-1} was increased significantly for all the treatments over the control. The maximum number of branches plant^{-1} was recorded for treatment T_6 i.e. 150% CF dose (6.67) among all the treatments. The treatments of customized fertilizer had shown better effect as compared to recommended dose of fertilizer. Similar trend of result was recorded in case of effective branches plant^{-1}, tuber length, tubers plant^{-1} and tuber weight. The maximum effective branches plant^{-1}, tuber length, tubers plant^{-1} and tuber weight was observed at treatment T_6 i.e. 150% CF dose which were 5.5, 8.27 cm, 9.03 and 163.23 g tuber^{-1}, respectively. The enhanced yield attributing characters due to increased nutrient supplying by the customized fertilizer may increase the translocation of photosynthates from vegetative to reproductive part. Similar results were reported by Irfan *et al*. (2015) [4] in potato crop at Faizabad, Goel *et al*. (2011) [3] in pomegranate, Kamble and Kathmale (2015) [7] in onion crop and Mudalagiriyappa *et al*., 2015 in finger millet (*Eleusine Coracana* L.). They reported positive response of customized fertilizer on growth and yield of the crop.

Customized fertilizers influenced the tuber yield of potato significantly among all the treatments over the control (Table 3). The customized fertilizer at higher dose shown higher yield as compared with treatment T_7 i.e. recommended dose of fertilizer. The highest tuber yield (23445kg ha^{-1}) was recorded in T_6 treatment, followed by T_5 treatment (21,091kg ha^{-1}). The highest percent increase in yield over control was recorded at treatment T_6 i.e. 150% CF dose. 30.97%, 58.32%, 89.23%, 110.64%, 134.15% and 72.98% increase in tuber potato yield was observed over control by CF 50% (T_2), CF 75% (T_3), CF 100% (T_4), CF 125% (T_5), CF 150% (T_6), and recommended dose of fertilizer (150:90:100) (T_7), respectively. 9.39%, 21.76% and 35.35% increase in tuber potato yield was observed over recommended dose of fertilizer by CF 100% (T_4), CF 125% (T_5) and CF 150% (T_6), respectively. The application of customized fertilizer increased the total dry matter production in the crop. The variations in yield due to treatments could be attributed to the variations in the yield attributing parameters.

Table 4 represented the net return and B: C ratio of customized fertilizer experiment on potato crop. The highest net return and B: C ratio was recorded at treatment T_6 i.e. 150% CF dose among all the treatments over control. The net return for the treatment T_6 was ` 44, 066 ha^{-1} and B: C ratio was 0.88.

Soil health study before and after harvesting crop showed that there is to some extent positive impact on soil. Table 5 represents the effect of customized fertilizer on chemical properties after harvest of crop. Among all the treatments there was non-significant change on soil pH, EC and organic carbon in the soil over initial status of the soil but there was significant change on available N, Available P_2O_5 and

available K_2O at higher dose of customized fertilizer dose as compared with initial status of the soil. In case of available N significant increase in the treatment T_6 i.e. 150% CF dose was observed. In case of available P_2O_5 significant increase in the treatment T_5 i.e. 125% CF dose over initial status was recorded while available K_2O was significantly increased at all application of customized fertilizer. When control (no fertilizer application) was compared with initial status of the soil there was overall decline in the nutrient status. Similar results were reported by Kamble and Kathmale (2015) [7] in onion crop. Here, the quantification of short term effect of customized fertilizer on soil quality/health was not observed much difference. The amendment of different organics in the recommendations can control the ill effects of intensive inorganic fertilizer application on soil quality/soil health.

Table 1: Detail of treatments in the experiment

Treatments	Basal grade CF-39. (kg ha^{-1})	First top dress CF-40 (kg ha^{-1})	Second top dress Source- Urea (N kg ha^{-1})
T_1-Control	0.0	0.0	0.0
T_2: 50% CF dose	250.0	125.0	54.0
T_3: 75% CF dose	375.0	187.5	54.0
T_4: 100% CF dose	500.0	250.0	54.0
T_5: 125% CF dose	625.0	312.5	54.0
T_6: 150% CF dose	750.0	375.0	54.0
T_7: Blanket recommendation as package^{-1} of practice*	-	-	-

* In T_7 treatment i.e. Blanket recommendation as package^{-1} of practice at Sabour 150kg N, 90kg P_2O_5 & 100kg K_2O ha^{-1} were applied. The source of N was DAP & Urea, for P_2O_5-DAP and K_2O-MOP.

Table 2: Effect of customized fertilizer (CF) on yield attributes of potato crop

Treatments	Plant height (cm)	Branches plant^{-1}	Effective branches plant^{-1}	Tuber length (cm)	Tubers plant^{-1}	Tuber weight (g tuber^{-1})
T_1-control (No fertilizer)	28.5	2.0	1.5	2.57	3.57	53.63
T_2-50% CF dose	37.7	2.7	2.0	3.63	4.2	70.00
T_3-75% CF dose	40.5	3.5	3.0	4.07	4.70	81.27
T_4-100% CF dose	46.5	4.5	3.8	5.23	6.03	99.67
T_5-125% CF dose	54.6	5.3	4.7	6.30	7.73	118.7
T_6-150% CF dose	46.8	6.7	5.5	8.27	9.03	163.23
T_7-Recommended dose of fertilizer (150:90:100)	44.5	4.2	3.7	4.60	5.07	85.2
CD (p=0.05)	4.05	0.48	0.35	0.57	0.54	10.68

Table 3: Effect of Customized Fertilizers (CF) on tuber yield of potato

Treatment	Tuber yield (kg ha^{-1})	Increase in yield over control		Increase in yield over recommended dose of fertilizer	
		kg ha^{-1}	% Increase	kg ha^{-1}	% Increase
T_1: Control (No fertilizer)	10013	-	-	-	-
T_2: 50% CF dose	13115	3102	31	-	-
T_3: 75% CF dose,	15853	5840	58	-	-
T_4: 100% CF dose	18948	8935	89	1627	9
T_5: 125% CF dose	21091	11078	111	3770	22
T_6: 150% CF dose	23445	13432	134	6124	35
T_7: Recommended dose of fertilizer	17321	7308	73	-	-
CD (p=0.05)	2279				

Table 4: B: C ratio, Cost of cultivation and Net return (` ha^{-1}) of Customized Fertilizer (CF-39 & CF-40) experiment on Potato crop

Treatment	Cost of Cultivation (` ha^{-1})	Gross return (` ha^{-1})	Net return (` ha^{-1})	B:C ratio
T_1: Control	39,453	40,732	1,279	0.03
T_2: 50% CF dose	43,432	52,460	9,028	0.21
T_3: 75% CF dose	45,070	63,412	18,342	0.41
T_4: 100% CF dose	46,707	75,792	29,085	0.62
T_5: 125% CF dose	48,345	84,364	36,019	0.75
T_6: 150% CF dose	49,982	94,048	44,066	0.88
T_7: Recommended dose of Fertilizer (150:90:100)	44,456	69,284	24,828	0.55

Table 5: Effect of customized fertilizer on chemical properties after harvest of Potato

Treatment	pH	EC	Org. C (%)	Av. N (kg ha^{-1})	Av. P_2O_5 (kg ha^{-1})	Av. K_2O (kg ha^{-1})
T_1: Control	7.38	0.26	0.51	186.3	18.5	151.3
T_2: 50% CF dose	7.30	0.26	0.52	199.8	19.8	172.5
T_3: 75% CF dose	7.30	0.27	0.50	195.6	20.5	194.5
T_4: 100% CF dose	7.25	0.25	0.53	201.5	26.8	214.7
T_5: 125% CF dose	7.24	0.26	0.50	200.4	41.6	220.5
T_6: 150% CF dose	7.20	0.25	0.47	231.6	52.5	233.5
T_7: Recommended dose of Fertilizer (150:90:100)	7.30	0.24	0.48	204.8	42.6	204.2

Initial status	7.40	0.25	0.50	198.5	22.5	159.4
CD (p=0.05)	NS	NS	NS	20.4	30.3	21.7

4. Conclusion

Customized fertilizer provides improvement in fertilizer use efficiency resulting optimal yield. It supplies macro as well micronutrient for the growth and yield development of the crop. Potato is a nutrient loving crop. Its production and productivity majorly depends upon the soil nutrient status. Customized fertilizer provide sustainable environment for the better performance of potato crop. The treatment supplied with 150% CF dose has shown highest production and profitability for the grown potato crop and hence, can be recommended for sustainable yield.

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