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Effect of integrated nutrient management on growth and yield of potato cv. Kufri Jyoti

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Abstract
A field experiment was conducted at the research field of Odisha University of Agriculture and Technology, Bhubaneswar during rabi, 2021- 22 to study the effect of integrated nutrient management practices on potato (*Solanum tuberosum* L.) cv Kufri Jyoti. The recommended dose of fertilizer was at 150:80:100 kg N: P_2O_5: K_2O/ha, 25 kg/ha of $ZnSO_4$ and 15 kg/ha of Borax were applied during the experiment. The maximum growth and yield attributing characters were observed at the application of 125% RDN through chemical fertilizer along with Zn and B which recorded the plant height (52.01 cm), number of shoots per plant (5.27), tuber length (5.71 cm), tuber circumference (14.45 cm), average tuber weight per plant (62.93 g), number of tubers per plant (10.87), harvest index (76.8%) and significantly higher yield (24.73 t/ha). From the perusal of the data with 16 different nutrient management practices, it was found that the application of 125% RDN along with Zinc and Boron significantly recorded the highest net return (Rs. 1,96,200) and B: C ratio of 2.31.

Keywords: *Solanum tuberosum* L., Kufri Jyoti, RDN, net return, yield, B: C ratio

Introduction
Potato (*Solanum tuberosum* L.) is an annual herbaceous plant of the Solanaceae family. The underground stem is the edible part of the plant. In the 17th century, the Portuguese transported the crop from South America to India and its cultivation was spread over North India by the British. Potato is one of the most commercially grown and profitable crops for producers owing to its great production potential in a short period of time. It is a high-energy crop that generates more food per unit of area and time than any other major food crop. India ranks third in potato cultivated area and second in production in the world after China. Uttar Pradesh, West Bengal, Bihar, Punjab and Gujarat are the major producing states in India. It is the fourth most important crop in our country that yields more dry matter, dietary fiber, and high-quality protein, minerals and vitamins and all important components of a healthy diet i.e., wheat, maize, and other cereal grains (FAO STAT, 2020) [9]. A balanced supply of essential nutrients is one of the most important factors in increasing yields of crops. Hence, knowledge of the interaction of N with other nutrients is an important factor in improving the efficiency of this element and consequently improving crop yields. By combining organic and inorganic sources of nutrients, integrated nutrient management (INM) is a superior technique for providing nutrition or food to the crop (Parihar *et al.*, 2015) [15]. As potato is a heavy feeder and highly responsive to nutrient input, the proper quantity and timing of nutrient supply is the most critical component in achieving high productivity in potato cultivation (Biswas *et al.*, 2020) [5]. Suitable nitrogen administration is one of the most important requirements to obtain high yields with superior potato quality (Vaezzadeh *et al*, 2012) [21]. An adequate early season N supply is remarkable to support vegetative growth, but too much soil N later in the season will suppress tuber initiation, decrease yields, and reduce the specific gravity in some cultivars (Jatav e*t al.*, 2018) [11]. Nitrogen is related to the structural constituent of cell walls that plays a pivotal role in many physiological and biochemical processes in plants. It is a component of many important organic compounds ranging from proteins, nucleic acids and constituent of the chlorophyll molecule, which plays an important role in plant photosynthesis. As no single source can supply the required quantity of nutrients, integrating all available resources is essential for supplying balanced nutrition to plants, which is aimed at increasing yield and improving soil fertility.
Micronutrients play an important role in the growth and development of potato. They are needed in small quantities.

Potato crop responds well to micronutrient (Zn and B) application and it has become difficult to get high yields without the application of micronutrients (Sarkar *et al*., 2018) [18]. Zinc plays a key role in chlorophyll production, carbohydrate metabolism and cell elongation, which impacts leaf size (Brady and Weil, 2002) [6]. Carbohydrate, protein and chlorophyll formation are significantly reduced in zinc-deficient plants. Boron plays a key role in a diverse range of plant functions including cell wall formation and stability, maintenance of structural and functional integrity of biological membranes, movement of sugar or energy into growing parts of plants and pollination and seed set (Zhao & Oosterhuis, 2002) [23]. According to reports, the micronutrients Zn and B have a special role in boosting potato productivity (Trehan and Grewal, 1989) [20].

Considering the importance of the crop and demand, it is crucial to comprehend the best tuber-producing methods to boost potato output and production through careful and balanced administration of micronutrients and macronutrients together with organic and inorganic sources of fertilizers.

Materials and Methods

The present experiment was conducted at the research field of Odisha University of Agriculture and Technology, Bhubaneswar during *Rabi*, 2021-22. The soil of the experimental field was sandy loam in texture, acidic in reaction (pH 5.24) and low in the status of available nitrogen (120.83 kg/ha), phosphorus (12.48 kg/ha), potassium (116.54 kg/ha) and organic carbon (0.23%). The experiment was conducted in randomized block design with three replications at four levels of nitrogen (100% RDN, 125% RDN, 75% RDN and 50% RDN) with sixteen treatment combinations of T_1 = 100% RDN, T_2 = 125% RDN, T_3 = 75% RDN through chemical fertilizer (RDNCF) + 25% RDN as FYM (RDNFYM), T_4 = 50% RDN through chemical fertilizer + 50% RDN as FYM, $T_5 = T_1$ + B as Borax, $T_6 = T_2$ + B, $T_7 = T_3$ + B, $T_8 = T_4$ + B, $T_9 = T_1$ + Zn as $ZnSO_4$, $T_{10} = T_2$ + Zn, $T_{11} = T_3$+ Zn, $T_{12} = T_4$ + Zn, $T_{13} = T_1$ + B + Zn, $T_{14} = T_2$ + B + Zn, $T_{15} = T_3$ + B + Zn and $T_{16} = T_4$ + B + Zn.

The potato variety 'Kufri Jyoti' was planted at 60 cm row spacing and 20 cm tuber-to-tuber spacing. Prior to planting, the field was prepared as per the standard procedure and the treated sprouted tubers were planted. The standard recommended fertilizer dose of 150: 80: 100 kg of N, P_2O_5 and K_2O/ha was applied. The total amount of phosphorous and 50% of potash and nitrogen were applied to the soil as basal dose before planting. The remaining nitrogen and potash were administered during the first top dressing, i.e., 25 days after planting. Nitrogen and phosphorous were applied in the form of urea and single superphosphate (SSP), respectively and potassium was in the form of Murate of potash (MOP). Plant and soil samples were analyzed for nutrient content as per the standard procedure. The results were statistically analyzed based on their sample means by Standard Error of Variance (ANOVA) test (Gomez and Gomez, 1984) [10]. The harvest index of different treatments was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100 \qquad (1)$$

where, economic yield = total tuber yield, biological yield = total tuber yield + total shoots yield

Results and Discussion

Different nitrogen levels were found to influence the plant height. Nitrogen application at various levels resulted in significant variations in potato plant height from 33.06 cm to 52.01 cm, with an average of 40.47 cm. The increase in nitrogen levels through chemical fertilization along with Zn and B was associated with an increase in plant height. The highest plant height was observed with 125% RDN with Zn and B (52.01 cm), followed by the application of 125% RDN along with the recommended doses of Zn (49.89 cm), from inorganic sources respectively. The lowest plant height was observed to be 33.06 cm under the application of 50% RDN CF + 50% RDN FYM (T_4). Treatments T_3, T_7, T_8, T_{12} and T_{16} were found at par for this character with T_4. This finding is supported by the results of Banjare *et al.* (2014) [3] and Banerjee *et al.* (2016) [2]. The number of shoots per plant ranges from 2.60 to 5.27 with a mean of 3.85. The application of nitrogen 125% RDNCF along with Zn and B (T_{14}) resulted in the maximum number of shoots per plant (5.27), the lowest number of shoots per plant was recorded in T_4. This type of result was also reported by Kumar *et al.* (2011) [12] and Dissoky and Abdel-Kader (2013) [8]. The increase in plant height and shoot with increasing nitrogen levels could be attributed to the fact that higher nitrogen concentrations stimulated carbohydrate and protein assimilation, which in turn increased cell division and tissue formation, resulting in increased vegetative growth of the plant (Mahata *et al.*, 2018) [14]. The application of Zn and B enhanced the cell division and the activity of indole acetic acid and the production of stem and axillary branches (Thomson *et al.*, 2020) [19] & (Das and Chakraborty, 2018) [7].

Tuber yield is a function of the interplay of various yield components such as the number of tubers per plant, tuber length, tuber circumference, and average tuber weight per plant. It is also the result of several growth-regulating factors, primarily genetic, environmental, and management factors that are intertwined to meet the crop's optimum needs at various stages of growth. The highest tuber length of 5.71 cm was obtained from the combined application of 125% RDN from chemical fertilizer with Zinc and Boron (T_{14}) followed by application with Zn which recorded tuber length of 5.63 cm (T_{10}), with B that recorded tuber length of 5.62 cm (T_6), and with the application of 100% RDN with Zn and B with tuber length of 5.45 cm (T_{13}). The lowest tuber length was found with the application of 50% RDN from chemical fertilizer + 50% RDN from FYM, T_4 (4.70 cm) followed by 50% RDN CF with 50% RDN FYM with boron in T_8 (4.92 cm) which were at par. The tuber circumference (cm) varied significantly among the treatments. An average range of 13.14 cm to 14.45 cm was observed in the tuber circumference. The highest tuber circumference was recorded with the application of 125% RDN from chemical fertilizer with Zinc and Boron in T_{14} (14.45 cm) which is at par with the application of 100% RDN from chemical fertilizer with Zn and B in T_{13} (14.44 cm). The lowest tuber circumference was observed in the treatment combination of 50% RDN from chemical fertilizer with 50% RDN from FYM alone in T_4 (13.14 cm) and with boron in T_8 (13.21 cm) which were at par. The variations in the average single tuber weight per plant (g) ranged from 49.63 g to 62.93 g were observed in the experiment. It revealed that the different integrated nutrient management practices and nitrogen levels caused marked variations in tuber weight at harvest. Maximum tuber weight was recorded with a treatment combination of 125% RDN from chemical fertilizer with Zinc and Boron in T_{14} (62.93 g) followed by the combination with Zn in T_{10} (61.35 g), with B in T_6 (60.62 g) and with 125% RDN application in T_2 (59.84 g). The lowest tuber weight was observed in treatment with 50% RDN from chemical fertilizer and 50% RDN from FYM i.e. in T_4 (49.63 g). The number of tubers per plant ranges between 7.27 to 10.87 with an average of 7.96. It was revealed that the application of 125% RDN from inorganic sources along with the application of Zn and B recorded the highest number of tubers per plant (10.87). This could be possibly due to better growth and photosynthates accumulation with the increased nitrogen availability and improved starch translocation through B application, inducing formation and growth of stolen with improved IAA activity by Zn application favoring the crop to express its optimum yield potential. The treatment T_4 recorded the lowest number of tubers per plant (7.27) which was at par with T_1, T_3, T_5 T_7, T_8, T_3, T_{12}, T_{15} and T_{16}. The results are in conformity with the earlier findings of Baghla *et al.* (2019) [1], Sarkar *et al.* (2017) [17] and Lenka and Das (2019) [13]. Significantly wide variation was observed for total yield (t/ha) from 16.27 to 24.73, with a mean of 20.13 t/ha. The highest total yield (24.73 t/ha) was recorded in T_{14} which was at par with T_6, T_9, T_{10} and T_{13}. Findings revealed that T_{14} recorded an increase of 38.38% in total tuber yield over T_1. The findings revealed that the treatments with the application of the controls (T_1, T_2, T_3, T_4) with Zinc resulted in a higher average yield of 21.34 t/ha (T_9, T_{10}, T_{11}, T_{12}) than the treatment combinations with Boron with an average yield of 19.66 t/ha (T_5, T_6, T_7, T_8) but were lower than the treatments which had both Zinc and Boron application with an average yield of 21.67 t/ha (T_{13}, T_{14}, T_{15}, T_{16}). The observations revealed that there was an increase in yield of 10.11% with the application of B with controls, 19.41% with the application of controls with Zinc, and 21.26% at the combination of controls with Zinc and Boron over the average yield of treatments T_1, T_2, T_3 and T_4. However, no significant difference in this character was found between the treatments T_6, T_9, T_{10} and T_{13}. The control (50% RDN through chemical fertilizer and 50% RDN through FYM) had the lowest total tuber yield (16.27 t/ha). Reiter *et al.* (2012) [16] found that significant amounts of inorganic N fertilizer are required for optimal production. Belanger *et al.* (2000) [4] reported that the application of appropriate quantity of nitrogen resulted in more beneficial effects than higher rates. Zelalem *et al.* (2009) [22] also reported that optimal nitrogen management was critical for higher tuber yield. The data pertaining to the harvest index i.e., the tuber dry weight over the total dry weight of the plant is influenced by different nutrient management practices and nitrogen levels recorded at harvest. The results revealed that among various integrated nutrient management practices, the highest harvest index (76.1%) was recorded under the application of 125% RDN from chemical fertilizer along with Zinc and Boron in T_{14} while, the lowest harvest index (70.3%) was recorded with the use of 100% RDN with Boron (T_5). Among the different nitrogen levels, the highest harvest index (76.1%) was reported with the application of 125% RDN from chemical fertilizer along with Zinc and Boron which was statistically similar with Zn (T_{10}), B (T_6) and with the application of 100% RDN with Zinc and Boron (T_{13}) and 75% RDN from chemical fertilizer + 25% RDN from FYM with Zinc and Boron (T_{15}). The economic evaluation of various treatments revealed that application at a rate of 187.5:80:100 kg N: P_2O_5: K_2O per ha along with the recommended dose of Zn and B yielded the highest net monetary return (Rs 196200 /ha) with a B: C ratio of (2.31), followed by 125% RDN along with Zn with B: C of 2.28. Treatments with 50% RDN through chemical fertilizer and 50% RDN through FYM (T_4) and the same combined with Boron (T_8) had the lowest net return (Rs 34294 /ha) and lowest B: C ratio (1.19).

Table 1: Effect of integrated nutrient management on growth and yield attributing parameters

Treatments	Plant Height (cm)	Shoots per plant	Tubers/plant	Tuber length (cm)	Tuber circumference (cm)	T Tuber weight (g)	Tot Total yield (t/ha)	Net return (Rs/ha)	B: C
T_1-100% RDN	39.45	3.4	7.41	4.93	13.63	55.51	17.87	82201	1.54
T_2-125% RDN	46.88	4.2	8.27	5.43	14.02	59.84	19.15	123550	1.85
T_3-75% RDN CF+25% RDN FYM	36.07	3	7.47	5.01	13.41	52.62	18.21	80926	1.5
T_4-50% RDN CF+50% RDN FYM	33.06	2.6	7.27	4.70	13.14	49.63	16.27	34294	1.19
T_5-T_1+B	39.47	3.93	7.41	5.23	13.94	56.23	17.87	100201	1.72
T6-T_2+B	47.13	5	8.67	5.62	14.04	60.62	23.49	181150	2.22
T_7-T_3+B	36.26	3.53	7.53	5.22	13.61	54.23	20.65	109153	1.67
T_8-T_4+B	33.96	2.87	7.33	4.92	13.21	50.14	16.64	34894	1.19
T_9-T_1+Zn	41.1	4.33	7.93	5.41	14.02	58.21	22.8	151421	1.99
T_{10}-T_2+Zn	49.89	5.2	8.93	5.63	14.37	61.35	23.96	188550	2.28
T_{11}-T_3+Zn	37.79	3.8	7.65	5.22	14.00	56.53	21.93	119696	1.71
T_{12}-T_4+Zn	36.19	3	7.33	4.93	13.52	50.72	16.65	39294	1.22
T_{13}-T_1+B+Zn	43.13	4.47	8.14	5.45	14.44	59.01	22.89	161021	2.12
T_{14}-T_2+B+Zn	52.01	5.27	10.87	5.71	14.45	62.93	24.73	196200	2.31
T_{15}-T_3+B+Zn	40.15	3.87	7.67	5.42	14.01	57.27	22.24	134696	1.81
T_{16}-T_4+B+Zn	35.03	3.2	7.63	5.24	13.83	53.07	16.82	36444	1.2
SEm ±	1.25	0.11	0.257	0.181	0.430	1.563	0.713	_	_
CD (P=0.05)	3.765	0.331	0.774	0.540	1.295	4.711	2.15	_	_

Table 2: Effect of integrated nutrient management on shoot DW, tuber DW, total DW, total yield and harvest index

Treatment	Shoot DW* (t/ha)	Tuber DW* (t/ha)	Total DW* (t/ha)	Total yield (t/ha)	Harvest Index (%)
T_1-100% RDN	1.09	3.140	4.235	17.87	74.1
T_2-125% RDN	1.18	3.610	4.788	19.15	75.4
T_3-75% RDN CF+25% RDN FYM	1.11	2.640	3.747	18.21	70.5
T_4-50% RDN CF+50% RDN FYM	0.95	2.560	3.511	16.27	72.9
T_5-T_1+B	1.11	2.620	3.727	17.87	70.3
T_6-T_2+B	1.23	3.970	5.197	23.49	76.4
T_7-T_3+B	1.14	3.440	4.581	20.65	75.1
T_8-T_4+B	1.06	2.580	3.637	16.64	70.9
T_9-T_1+Zn	1.24	3.830	5.067	22.8	75.6
T_{10}-T_2+Zn	1.24	3.980	5.221	23.96	76.2
T_{11}-T_3+Zn	1.19	3.480	4.667	21.93	74.6
T_{12}-T_4+Zn	1.06	2.590	3.647	16.65	71.0
T_{13}-T_1+B+Zn	1.22	3.880	5.097	22.89	76.1
T_{14}-T_2+B+Zn	1.28	4.200	5.477	24.73	76.8
T_{15}-T_3+B+Zn	1.19	3.760	4.947	22.24	76.0
T_{16}-T_4+B+Zn	1.10	2.610	3.707	16.82	70.4
SEm±	0.036	0.076	0.078	0.713	-
CD=P (0.05)	0.108	0.229	0.236	2.15	-

Conclusion
Based on field experimentation and perusal of the data from 16 treatments, it can be concluded that the potato variety Kufri Jyoti under nutrient management with the application of 125% RDN from chemical fertilizer along with Zinc and Boron was the best strategy for yield and yield attributing characters with the highest plant height, the number of shoots per plant, tuber number per plant, tuber length, tuber circumference, average tuber weight per plant and total yield of 24.73 t/ha whereas the application of 50% RDN from chemical fertilizer with 50% RDN from FYM reduced the yield of potato. The application of 125% RDN (187.5:80:100 kg N: P_2O_5: K_2O/ha) from chemical fertilizer along with Zinc and Boron in potato was also the most profitable and remunerative with the highest net return (Rs 196200 /ha) and B: C ratio of 2.31.

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