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Productivity and economic potentials of tuber treatments supplemented with N and P fertilization in potato (*Solanum tuberosum* L.) in Eastern Bihar plains

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ABSTRACT
Experiment involving tuber treatments supplemented with N and P fertilization in potato (*Solanum tuberosum* L.) was conducted in Eastern Bihar plains to study its productive and economic potential in terms of benefits in yield and economy in fertilizer use with other contributions viz., soil fertility and nutrient removal. The study under reference was undertaken on potato cv. Kufri Jyoti during *rabi* 1999-00 and 2000-01 in a sandy clay loam soil, low in O.C. & N, and medium in P & K. Results revealed that dipping of planting materials (tubers) with 1% each of urea and sodium bicarbonate along with tuber treatment with both *Azotobacter* and *Azophos* resulted in highest productivity and greater economic benefits both in fertilizer use and net return. Newer strain of *Bacillus* viz., *B. cereus* was found to be more effective in nutrient mobilization, crop growth, tuber productivity with more economic benefits in comparison to its counterpart i,e., *B. subtilis.* Although higher productivity was realized with higher NPK combinations yet the combined application of the followings viz., tuber dipping in 1% urea and sodium carbonate along with *Azotobacter* and *Azophos* supplemented with low NPK might be the cost saving proposition. The present findings suggests that dipping of tubers with 1% each of urea and $NaHCO_3$ along with tuber treatment with both *Azotobacter* and *Azophos* supplemented with 25 % reduction in normal requirement of N & P may be essential for realization of optimum productivity and economic potential in the potato crop in Bihar plains.

Key words : Potato, Tuber treatments, N & P fertilizers, *Azotobacter*, *Azophos* , *Bacillus,* Yield, Nutrient uptake, Economics, Soil fertility.

INTRODUCTION

Recognition of potato (*Solanum tuberosum L.)* as a nutritionally fourth valuable food crop of the world after rice, wheat and maize, has facilitated to sustain and diversify the food production in this new millennium. In the developing country like India, the crop has substantially contributed to sustaining the food productions over the last five decades; and its nutritionally superiority with favorable protein-carbohydrate balance and high quality protein have made the crop more wholesome in its consumption and raised the demand for the crop both within and outside the country. Figures in 2004 reveals that India's production touched to 25 m tonnes of potatoes only from 1.40 m hectares with the productivity of 178.6 q/ha (Pandey and Sarkar, 2005). Keeping in view its importance in food security and the ever increasing demand for the commodity, both the production and productivity have to be raised at the growth rate of 3.10 and 1.89 % respectively towards 2020 with the target of 37.3 m tonnes from nearly the same area with productivity of 259 q/ha. In addition, with escalating cost of inputs that eats out the margins in production, newer challenges/limitations are emerging in for maintaining the tempo of sustaining both its production & productivity, and making the commodity more remunerative.

One of the major limitation in our effort to sustain the performance of the crop is agro-technological that includes the twin problems viz., lack of availability of good quality planting materials and poor crop management including that of input and its cost. Therefore, in presence of goods quality seeds, emphasis on low cost sustainable technologies vis-a-vis use of alternative biological sources for inorganic fertilizers provides necessary impetus so as to make the crop more competitive and productive with regard to both input cost and profit margin. Simple techniques of seed treatments involving very low costs but virulent microbes along with initial nourishments of planting materials *in situ* might sustain both productivity and economic viability via. enhanced nutrient solubility and mobilization. More critically, the benefits accruing from the use of such environmentally friendly microbes viz.,*Azotobacter, Azophos* and *Bacillus* supplemented with N & P nutrition of the crop will ease the stress in cost of cultivation besides accruing gain in output quality and quantity (Sharma et al. 1997). Thus, extrapolating such a benefit further, study was conducted to ascertain the productivity and economic potentials of tuber treatments supplemented with N and P fertilization in potato (*Solanum tuberosum* L.) in relatively untapped regions of Bihar plains under Eastern Indo-Gangetic Plains.

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MATERIALS AND METHODS

Field experiment with *Azotobacter* for nitrogen & *Azophos* for phosphorus and growth promoting (PGB) bacteria (*Bacillus subtilis* and *Bacillus cereus*) along with urea and single super phosphate as common sources for N & P, was conducted using potato cv. Kufri Jyoti for two years during *rabi,* 1999-00 and 2000-01 at Central Potato research Station, Patna under South Bihar alluvial plain sub-region of Bihar. The experimental sandy clay loam soils was low in O.C. (0.31%), total N (387 ppm) & available N (109 ppm), and medium in available P (9.4 ppm) & K (121 ppm) and was slightly alkaline (pH of 7.9).

The treatment combinations comprising of five different tuber treatments and two levels of N & P fertilizer combinations were tried in factorial R.B.D. with four replications. Tuber treatments include control (sprouted tubers planted as such, $\mathbf{T_1}$), dipping in solutions containing 1 % urea and 1% sodium bicarbonate ($NaHCO_3$) for 5 minutes ($\mathbf{T_2}$), dipping as in T_2 along with tuber treatment of both *Azotobacter* sp. and *Azophos* sp. (IARI strains,$\mathbf{T_3}$), application of *Bacillus subtilis* (strain B5, $\mathbf{T_4}$) and application of *Bacillus cereus* ($\mathbf{T_5}$, strain B4; both B_4 & B_5 were CPRIC, Modipuram strains). The N & P applications included variable N & P fertilizers viz., 100 % recommended dose, for N & P (**NP**) i.e., 180 kg Urea-N & and 60 kg SSP-P_2O_5) and 75 % of recommended dose for N & P (**75 % NP**). Potassium @ 100 kg/ha in terms of MOP-K_2O was applied uniformly in all the plots at planting along with whole quantity of Phosphorus. Only nitrogen was applied as half at planting and half at earthing up.

Method for tuber treatments

The required planting material i.e., healthy tubers (40 g each) of cv. Kufri Jyoti with sprouts of 2-3 mm, was divided into 5 lots. One lot of seed materials was kept as such without any treatment (control, $\mathbf{T_1}$). The second lot of tubers was dipped and allowed to soak in 1 % each of urea and $NaHCO_3$ solution (400 g each of the chemical dissolved in 40 litres of potable water) for 5 minutes and allowed to dry in shade ($\mathbf{T_2}$). The third lot of tubers was subjected to similar treatment as in T_2 but was partially dried in the shade. For tuber treatment with *Azotobacter and Azophos*, 200 g of each of above ash-based bio-formulations (sufficient for one acre) were added to a *jaggery* solution (100 g of *jaggery / gur* in one litre of water) and the solution was spread on this 3rd lot of tubers soaked with urea & $NaHCO_3$ and was mixed thoroughly and finally these tubers are also allowed to dry in shade (**T_3**) .

For *Bacillus* inoculation, half kg each of *Bacillus* (@10^6 colony forming units (CFU)/ml) culture (viz. *Bacillus subtilis*, strain B5 (**T_4**) and *Bacillus cereus* strain B4 (**T_5**) were suspended in 40 liters of water separately and to each of these a *jaggery* slurry (prepared by boiling 2 kg of *jaggery* in one litre of water) was added after cooling. The tubers of 4th lot (**T_4**) and 5th lot (**T_5**) were dipped for 30 minutes in the above solution prepared separately with different strains of *Bacillus* and dried in the shade (Kumar Vivel et al., 2001).

All the seed lots after required treatments were planted in the designated plots in the earmarked field immediately as per treatments at a row spacing of 60 x 20 cm during 2nd week of October every year without changing the lay out. There was no pest problem except that for minor incidence of leaf spot caused by *Macrophomina* species and the crop received normal rainfall and temperature regimes in both the years and thus, its growth and development were normal. The tubers were harvested during 3rd week of March every year at harvest maturity of the tuber (with soft but firm skin). Data on plant biometrics at 75 DAS, harvest attributes, soil fertility status and nutrient removal based on nutrient concentration and dry matter of potato tuber at harvest were analyzed year wise and the data was subjected to statistical analysis following the normal procedures (Gomej and Gomez, 1984). The economics of potato production was calculated following current whole sale prices. The details of the year wise whole data on various parameters along with interaction effect if any was depicted in Table 1-3.

RESULTS AND DISCUSSION

Tuber yield

Both the tuber treatments and fertilizer levels influenced the tuber yield significantly over the years (Table-1). An additional tuber yields to the tune of 11.7 and 21.0 q/ha was realized with full dose of N & P over that in 75 % N & P in the 1st and 2nd year respectively. Similarly tuber dipping in both urea and $NaHCO_3$ along with *Azophos* and *Azotobacter* (T_3) produced maximum mean yield of fresh tubers and was significantly higher over that in control during both the years. Additional tuber treatment with above bioinoculants (T_3) over and above the dipping in chemicals (T_2) produced higher yields in the both years and even the difference in yield between the two was significant in 1st year and thus, the former has an edge over dipping. Tuber yields obtained under newly introduced *B. cereus (*T_5) was also statistically on par with that in tuber dipping in chemicals combined with bio-inoculants (T_3) during both years, thereby signifying the potential role of the new strain (*B.* cereus) on the performance of the crop.

It is also apparent that application of suitable starter chemical along with bioinoculants for N & P (T_3), or a virulent PGP like *Bacillus cereus* (T_5) may prove its potential for promoting plant growth and consequently influencing on the tuber yield. Introducing new strain has also contributed to effect the underground tuber production by competing with the native strains and establishing an effective rhizospheric association with the potato plants (Sunaina et al., 2001). Thus, the decreasing trend in yield realization was observed in treatments involving dipping in chemicals plus bioinoculants (T_3) followed by tuber treatment with *B. cereus* only (T_5) and dipping in chemicals only (T_2).

Marwaha, 1995 and Bhattacharyya et al., 2000 cited that the increases in tuber yield can be ascribed to N supplementation by *Azotobactor* through biological N fixation, production of hormones like IAA, gibbrellins and vitamins like biotin, folic acid & different B group vitamins and greater availability by phosphorous by *Azophos*. Moreover, use of new PGP bioagents like *Bacillus cereus* may act as a potential bioagent for its exploitation in improving plant growth & yield of the crop (Sunaina et al. 2001).

Table 1 : Tuber fresh weight, harvest attributes and biometric of cv. Kufri Jyothi as influenced by interacting influence of tuber treatments and inorganic fertilizations.

Treatments	Tuber Yield (q/ha)		Haulm dry wt. (q/ha)		Tuber dry wt. (%)		Plant height (cm.)		Primary stems/hill		Leaves/ hill	
	I	II	I	II	I	II	I	II	I	II	I	II
i) 75 % NP												
T_1 : Control	255	231.1	11.1	9.1	18.8	19.7	39.0	40.2	4.0	3.7	33.0	30.6
T_2 : Urea + $NaHCO_3$	272	251.7	12.3	10.9	19.2	19.8	42.0	42.8	5.0	4.4	34.7	33.0
T_3 : Urea + $NaHCO_3$ + *Azophos* + *Azotobacter*	296	255.9	14.9	12.2	19.9	20.0	44.0	43.5	6.1	4.9	35.9	33.5
T_4 : *B. subtilis*	274	239.1	12.9	11.3	19.1	20.3	41.6	41.5	5.0	4.5	34.9	31.8
T_5 : *B. cereus*	276	250.6	13.4	11.3	19.0	18.8	42.0	41.8	5.0	4.6	35.7	32.9
Mean	274.6	245.7	12.9	10.9	19.2	19.7	41.7	42.0	5.02	4.4	34.8	32.4
ii) NP												
T_1 : Control	254.0	260.2	13.7	12.2	18.7	18.5	40.0	42.2	4.0	4.20	35.0	33.7
T_2 : Urea + $NaHCO_3$	288.0	270.8	15.6	14.3	18.4	17.6	43.0	43.7	5.1	4.50	37.0	35.2
T_3 : Urea + $NaHCO_3$ + *Azophos* + *Azotobacter*	304.0	274.3	16.5	15.0	18.8	18.6	45.0	46.7	6.0	5.10	37.9	35.6
T_4 : *B. subtilis*	286.3	263.0	15.3	13.5	18.8	19.0	42.7	43.3	5.0	4.60	36.5	34.3
T_5 : *B. cereus*	299.0	265.0	15.4	13.7	18.9	18.5	43.0	43.5	5.1	4.70	36.2	34.6
Mean	286.3	266.7	15.3	13.7	18.7	18.4	42.8	43.9	5.04	4.60	36.5	34.7
C.D. (0.05)#(levels)												
Fertilizer levels (2)	10.7	8.5	1.31	1.00	NS	1.05	1.08	NS	NS	NS	1.37	0.81
Tuber treatments (5)	15.7	13.4	1.77	1.59	NS	NS	1.57	NS	1.64	NS	1.76	0.29
Interaction (10)	23.5	18.9	NS	NS	NS	NS	3.20	NS	NS	NS	NS	NS

I for 1styour and II for 2nd year

While making comparisons for determining the combined (interaction) effects, the yield response of potato to N & P fertilizer was pertinent only up to 135 kg N and 45 kg/ha P_2O_5 per hectare (i.e. 75 % N & P) along with bioinoculants and chemicals (T_3) in the current study for both the years. Thus, the most important observation in the present study is the saving in nutrient application to the tune of 25 % (for getting the same yields as that under 100 % N & P) by the combined tuber treatments involving dipping plus bioinoculants supplemented with 75 % of inorganic N & P fertilizers applied during plant growth since interacting influence of these on the tuber yield was significant in both the years (Table-1). Evidently, although highest tuber yields were recorded under *Azotobacter and Azophos* inoculation supplemented with tuber dipping with 1 % each of urea and $NaHCO_3$ (T_3) along with 100 % N & P yet it is statistically on par with that treatment along with 75 % N & P. This effects of bio-inoculants on enhancing yield may be attributed to in enhancing nutrient solubility in the rhizosphere (Sood and Sharma, 2001) since their action starts with formation of colonies on developing potato roots and remaining active in plant rhizosphere-soil interfaces for more than 60 days and promotes crop growth and development (Sunaina et al. 2001).

Harvest attributes and growth parameters

Dry weight of haulms after harvest was significantly influenced by the treatments and was consistently higher in both the years with full dose of inorganic nutrients and with tuber dipped in chemicals plus bioinoculants both for N & P (T_3). Again the interaction effect involving tuber treatments and N& P fertilization was not significant thereby indicating the similar biomass under T_3 at both the nutrient levels. Both the species of *Bacillus* also showed similar dry weight improvements on par with that in above combined treatment (T_3). Similarly, tuber dry weights were not affected by the treatments except some weight gain following higher dose of N & P during the second year only (Table-2).

Crop growth parameters acting as a regulator of ultimate expression of yields following constraints application, responded little to both nutrient and tuber treatments (Table-1) and not much variation was evident following application of higher dose of N & P although significantly taller plants (in 1st year) and more number of leaves/hill (during both the years) were observed under it in comparison to that in lower dose. In contrast, dipping in the chemicals integrated with bioinoculants for N & P (T_3) resulted in tallest plant, highest number of stems and leaves/hill in both the years (Sood and Sharma, 2001) followed by tuber treated with *Bacillus cereus*. The interaction effect of inorganic fertilization and tuber treatments was not significant in respect of all the parameters (except that for plant height during 1st year).

Thus, it is inferred from the growth and harvest parameters that tuber dipping in chemicals followed by bioinoculation, and *Bacillus* might enabled higher nutrient solubility and consequently improved the attributes of growth and yield resulting in significantly higher yield in both the years. Similar effect of bio-inoculants (*Azotobacter* and *Azophos*) and bio-agents (*Bacillus*) in enhancing nutrient solubility in the rhizosphere, root growth and tuber yield through change in rhizosphere soil micro-flora and enhanced root proliferation is demonstrated by Van der Zaag,1994 and Sood and Sharma, 2001. It is reported that significant increases in yield along with tuber mass and root volume were recorded by treating the seed potatoes with suspension of PGP *Bacillus* spp. viz., *cereus* & *subtilis* prior to planting in the field (Sunaina et al., 2001). The action of these microbes starts with the formation of colonies on developing potato roots and remaining active in plant rhizosphere-soil interfaces for more than 60 days and promotes crop growth and development.

Nutrient uptake

Nutrient removal by the crop as a direct indication of nutrient mobility and subsequent distribution and utilization within the plant has manifold role in growth, development and ultimate yield of the

Table 2 : Plant N, P & K uptake and economics of potato (cv. Kufri Jyothi) under interacting influence of various treatments.

Treatments	N uptake (Kg./ha)		P uptake (Kg./ha)		K uptake (Kg./ha)		Cost of cultivation (Rs/ha)		Net return (Rs/ha)		B:C ratio	
	I	II	I	II	I	II	I	II	I	II	I	II
i) 75 % NP												
T_1 : Control	81.6	71.6	12.2	10.9	89.2	83.2	29632	29694	46838	39727	2.58	2.34
T_2 : Urea + $NaHCO_3$	87.0	78.0	13.1	11.8	95.2	90.6	30232	30294	51428	45325	2.70	2.50
T_3 : Urea + $NaHCO_3$ + *Azophos* + *Azotobacter*	94.7	79.3	14.2	12.0	103.6	92.1	30432	30494	58308	46398	2.92	2.52
T_4 : *B. subtilis*	87.8	74.1	13.1	11.2	96.7	86.1	30157	30394	52294	41449	2.74	2.36
T_5 : *B. cereus*	88.3	77.7	13.2	11.8	96.6	90.2	30332	30394	52588	44899	2.73	2.48
Mean	87.9	76.1	13.2	11.5	96.3	88.4	30157	30254	52291	43560	2.73	2.44
ii) NP												
T_1 : Control	81.3	80.7	12.2	12.2	88.9	93.7	30376	30346	45674	47836	2.50	2.58
T_2 : Urea + $NaHCO_3$	92.2	83.9	13.8	12.7	100.8	97.5	30976	30946	55484	50437	2.79	2.63
T_3 : Urea + $NaHCO_3$ + *Azophos* + *Azotobacter*	97.3	85.0	14.6	12.9	106.4	98.7	31176	31146	60084	51294	2.93	2.65
T_4 : *B. subtilis*	91.5	81.5	13.8	12.4	100.4	94.7	31076	31046	54897	47989	2.76	2.55
T_5 : *B. cereus*	95.7	82.1	14.4	12.5	104.6	95.4	31076	31046	58504	48591	2.88	2.57
Mean	91.6	82.7	13.8	12.5	100.2	96.0	30936	30906	54928	49229	2.77	2.60
C.D. (0.05)#(levels)												
Fertilizer levels (2)	3.57	2.24	0.55	0.30	3.86	2.54	NS	NS	NS	2108	NS	0.07
Tuber treatments (5)	5.65	3.54	0.87	0.48	6.10	4.01	NS	NS	5190	3331	0.17	NS
Interaction (10)	8.51	5.31	1.30	0.76	9.15	6.05	NS	NS	7941	5062	0.26	0.19

I for 1st your and II for 2nd year

crop. Because of biomass increase under normal dose of nutrient (NP), significantly higher nutrient (N, P & K) uptake by the tubers was analyzed over that in lower dose (Table-2) following greater mobility, assimilation of nutrient and consequently higher biomass/ yields under it. Similarly, higher yield realization and relatively increased biomass (haulm weight) under the combined application of chemicals and bioinoculants (T_3) resulted in highest nutrient uptake under it and is statistically significant over that in control, dipping alone and *B. subtilis* treated one. Incidentally, similar nutrient uptakes analyzed under above combined application (T_3) and *Bacillus cereus* (T_5) alone depicts the comparability and potential usefulness of the newer strains in crop production. Shanmugasundaram and Savithri, 2000 reported that increasing N levels correspondingly enhanced the N content and uptake in plant haulm and tuber which confirms the above findings. Yet increases in nutrient uptake in these treatments under normal N & P fertilization could not influence the final yield over that in lower dose (75 % N & P).

Economics of production

Potato, being a commercial cash crop, both the seed cost and cost of cultivation are equally high. Investment on fertilizer application is usually high with higher dose of the nutrients and similar is the case in the current study although the mean difference of Rs. 715/- in the cost of cultivation between the two is statistically nonsignificant (Table-2). Moreover, additional expenditure of Rs.800/- so as to dip the seed tubers in the chemicals followed by bioinoculation could maximize the returns by an additional mean net returns of Rs.12940/ - & Rs.5065/- and additional mean benefit cost ratios of 0.38 and 0.12 over control during the 1st and 2nd year respectively. Similarly, an amount of Rs 700/- invested on *B. cereus* produced the mean net return of Rs. 9290/- & Rs.2964/- and mean B:C ratio of 0.26 and 0.06 over control during the same period respectively. It is also evident that tuber treatment with both bioinoculants and inorganic chemicals (T_3) gave similar returns and B:C ratios under both the nutrient levels. Although investment on inorganic fertilizer gives higher dividends i.e., more with NP, yet fertilizer economy (through reduction in N & P) in the wake of a cost saving bio-inoculation/ bacterization can be an appropriate and effective measure for realization of higher yield and profit in the sustainable manner (Praharaj et al, 2002). Therefore, the combined application of all these viz., tuber dipping along with treatment of tubers with *Azotobacter* and *Azophos* supplemented with low NPK (75 % N& P) might be the cost saving proposition.

Soil fertility status

Fertility status analyzed after two years of cropping revealed no significant changes in organic carbon (OC), total N, available P & K status in the soil following application of inorganic nutrients (Table-3). However, tuber treatments did affect the organic carbon status of the soils and significantly highest mean OC was analyzed under tuber dipping combined with bioinoculation (T_3) over that in control followed by that under *B. cereus*. Similar is the case for total N and available P & K although statistically nonsignificant differences were observed in case of the former one (total N). Evidently, because of better mobilization and crop uptake at lower nutrition (75 % NP), the soil fertility status under integration of chemical and bioinoculation (T_3) and bacterization with *B. cereus* were similar both under NP and 75 % NP. Similar observations were recorded by Sood and Sharma, 2001. Thus the present findings indicate that dipping of potato tubers with 1% each of urea and $NaHCO_3$ along with tuber treatment with both *Azotobacter* and *Azophos* resulted in significantly highest productivity with greater economy in fertilizer use. New strain like *Bacillus cereus* was found to be more effective in nutrient mobilization, for better crop growth, tuber productivity and higher economy. Although higher productivity was realized with higher N & P combinations yet the combined application of the followings viz., tuber dipping in urea and sodium bicarbonate along with *Azotobacter* and *Azophos* supplemented with low NPK might be the cost saving proposition.

Table 3 : Soil fertility status at the end of the season as influenced by tuber treatments, inorganic fertilization and their interaction

Treatments	Organic carbon (%)	Total N (PPM)	Avail P (PPM)	Avail K (PPM)
Initial Status	0.31	387.0	9.4	121.0
i) 75 % NP				
T_1 : Control	0.20	353	7.1	95
T_2 : Urea + $NaHCO_3$	0.22	351	7.5	107
T_3 : Urea + $NaHCO_3$ + *Azophos* + *Azotobacter*	0.28	360	8.3	113
T_4 : *B. subtilis*	0.26	354	7.7	108
T_5 : *B. cereus*	0.26	358	8.2	110
Mean	0.24	355	7.8	106.6
ii) NP				
T_1 : Control	0.21	348	7.4	97
T_2 : Urea + $NaHCO_3$	0.23	343	7.6	108
T_3 : Urea + $NaHCO_3$ + *Azophos* + *Azotobacter*	0.29	357	8.4	115
T_4 : *B. subtilis*	0.26	347	7.9	106
T_5 : *B. cereus*	0.27	351	8.4	113
Mean	0.25	349	7.9	107.8
C.D. (0.05)#(levels)				
Fertilizer levels (2)	NS	NS	NS	NS
Tuber treatments (5)	0.03	NS	0.73	3.81
Interaction (10)	NS	NS	NS	6.02

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