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Shubha AS
Research Scholar, Department of Vegetable Science , College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

Srinivasa V
Professor and Head, Department of Vegetable Science , College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

Devaraju
Assistant Professor, Department of Vegetable Science, College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

Shivaprasad M
Associate Director of Research, ZAHRS, Mudigere, Karnataka, India

Nandish MS
Assistant Professor, Department of Agricultural Microbiology, College of Agriculture, Shivamogga, Karnataka, India

Lavanya KS
Research Scholar, Department of Vegetable Science , College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

Yogaraju M
Research Scholar,Department of Vegetable Science , College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

Shanwaz A
Research Scholar, Department of Vegetable Science , College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

Correspondence
Shubha AS
Research Scholar, Department of Vegetable Science , College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

Effect of integrated nutrient management on growth, yield and economics of potato (*Solanum tuberosum* L.) under hill zone of Karnataka

Shubha AS, Srinivasa V, Devaraju, Shivaprasad M, Nandish MS, Lavanya KS, Yogaraju M and Shanwaz A

Abstract
In order to know the effect of INM on growth, yield and quality parameters and economics of potato, this study was undertaken at department of vegetable science, College of Horticulture, Mudigere. The experiment was undertaken in RCBD design and the experiment consisted of 14 treatments. The results revealed that the combination of 75% RDF + *Azotobacter* + PSB + KSB + $MgSO_4$ + Micronutrient mixture resulted in the maximum sprouting (99.33%), plant height (59.33 cm), number of leaves (298), plant spread (45 and 47.33 cm, North-South and East-West, respectively), number of stems (4.79), leaf area (6296.55 cm^2). AGR (0.75 g/plant/day), CGR (1.37 $g/m^2/day$), RGR (0.00808 g/g/day), NAR (0.002100×10^{-2} $g/dm^2/day$). Yield parameters like number of tubers per plot (118.33), tuber weight (88.67), yield per hectare (21.50 t/ha), dry matter (22%) were found maximum in the same treatment. The treatment with the combination of 75% RDF + *Azotobacter* + PSB + KSB + $MgSO_4$ + Micronutrient mixture produced maximum gross income (Rs. 426530) and net income (Rs. 303638) and B:C ratio (2.47).

Keywords: Potato, nutrients, biofertilizers, growth, yield and quality

Introduction
Potato (*Solanum tuberosum* L) 2n=4n=48 is native to tropical South America and one of the most efficient food crop which produces more dry matter, dietary fibre, quality protein, minerals, vitamins and richest source of energy. Potato is an annual, herbaceous, dicotyledonous and self-pollinated crop. Potato is cultivated in diverse climatic zones including temperate regions, subtropics and tropics and as both a lowland and highland crop. The area and production of potato in the country is estimated around 20.85 lakh hectares and 480.96 lakh million tonnes, respectively with the productivity of 23.07 tonnes per hectare (Anon., 2015) [3].

The possibility for the use of organic fertilizer alone or in combination with inorganic fertilizer is to be explored in order to maintain soil health and crop productivity. There are many organic sources of nitrogen, phosphorus and potassium among them Farm Yard Manure (FYM) is most popular. Integrated supply of nutrients through organic, inorganic and bio fertilizers is the need of the hour for sustainable productivity and to maintain better soil health (Jagadeesh *et al.*, 1994) [11]. Besides the major nutrients, micronutrients also have a good role in plant growth. Micronutrients like iron, zinc and boron are necessary for plant development and metabolism. Foliar spray of micronutrients facilitates efficient consumption of nutrients straightly through leaves, the effect of which can show its importance soon (Tawab *et al*., 2015) [17]. The production and productivity of the potato crop are far below in the country due to lack of proper management practices. Among which balanced nutrition is one of the most important factor that affecting the growth and productivity of potato. Therefore, present study was conducted to ensure the nutrient requirement of the crop by integration of organic, inorganic and biofertilizers which helps not only to increase the yield but also maintains the soil health and ecofriendly environment. Keeping this is mind the experiment is carried out with the objectives to detect the impact of INM on growth, yield and quality parameters.

Materials and Methods
The present investigation was carried out at College of Horticulture, Mudigere during 2017-18 to test the potentiality of bio inoculants on potato namely *Azotobacter*, PSB, KSB, along with

$MgSo_4$ and micronutrient mixture. The experiment was laid out in randomized complete block design (RCBD) with three replications and 14 treatments. The tubers of Kufri Jyothi were sown in ridge and furrow method at spacing of 60 x 20 cm. recommended dose of fertilizers were applied at the time of sowing. Vermicompost and biofertilizers were applied ten days after application of basal dose of fertilizers. Observations on growth, yield and quality parameters were recorded. The treatments list is shown in Table 1.The growth parameters like AGR, CGR, RGR and NAR were worked out with the help of respective formulas given by Briggs *et al*. (1920) [7], Watson (1952) [19], Gregory (1926) [10] and Blackman (1919) [6].

The data was collected on different parameters like sprouting, plant height, number of leaves, plant spread, number of stem, leaf area and yield parameters. Germination is worked out by the formula Sprouting percentage=Number of tubers sprouted/ Total number of tubers sown × 100. Leaf area is calculated by using leaf area meter (LICOR portable leaf area meter).

Results and Discussion

Different INM treatments recorded significant difference among the sprouting percentage in potato shown in fig 1. The maximum sprouting percentage T_{13} (99.33%) was recorded with the combination of *Azotobacter* + PSB + KSB + 75% RDF + $MgSO_4$ + Micronutrient mixture (T_{13}) which was on par with T_{11}, T_{14} and T_{12} compared to RDF (T_1) when compared to the control. Chopra *et al*. (2006) [8] and Banjare (2012) [5] observed similar results in potato.

Plant height recorded significant difference among the INM treatments (Table 2). The maximum plant height of about 59.33 cm was recorded in the treatment supplied with the combination of 75% RDF + *Azotobacter* + PSB + KSB + $MgSO_4$ + Micronutrient mixture (T_{13}), which was onpar with T_{11} (56 cm). The reason is because, the combination of organic manure, inorganic fertilizers and biofertilizers facilitate in better availability and uptake of nutrients by the plants. *Azotobacter* and Phosphobacteria could produce bio-active substances having similar effect as that of growth hormones which promotes better vegetative growth. Biofertilizers like, PSB and KSB helps in converting the unavailable form of P and K respectively into available form in soil condition hence better nutrient uptake by the plants which inturn stimulates the vegetative growth and yield attributing traits. Similar work done by Nag (2006) [14] and Verma *et al.* (2011) [18].

The number of leaves per plant (298) and plant spread (45 cm N-S, 47.33 cm E-W) differed significantly during the potato crop growth as influenced by different integrated nutrient management practices (Table 2). In the present study, the maximum number of leaves per plant (298) was found with the application of 75% RDF + *Azotobacter* + PSB + KSB + $MgSO_4$ + Micronutrient mixture (T_{13}) and the lowest was found in the control (200). Increase in the number of leaves could be attributed to increased plant height which is due to balanced nutrition and easy availability of nitrogen, which helped in increasing chlorophyll content in leaf and better synthesis of carbohydrate in the plants and which is utilized in the building of new cells. Thus it leads to production of more number of leaves per plant and also helped in better canopy synthesis in plants. These results are in conformity with the findings of Patel (2013) [16] and Amarananjundeshwara *et al*. (2018) [2].

The number of stems per plant were also influenced significantly by integrated nutrient management practices at different stages of crop growth (Table 2). The maximum number of stems per plant (4.79) at the time of harvest was registered in the plants which received *Azotobacter* + PSB + KSB + 75% RDF + $MgSO_4$ + Micronutrient mixture (T_{13}) which was *on par* with T_{11}, T_{14} and T_{12}. The increased number of stems in these treatments could be attributed to better growth, balanced C: N ratio and availability of nutrients from the soil. Similar results were observed by Nandekar *et al.* (2006) [15]. The maximum leaf area (6296.55 cm^2) was recorded with application of *Azotobacter* + PSB + KSB + 75% RDF + $MgSO_4$ + Micronutrient mixture (T_{13}) compared to RDF (T_1) (Table 2). The size of the leaf or leaf area plays an important role in photosynthetic activity as it intercepts more of solar energy. Leaf area decides the efficiency of photosynthetic activity and contributes towards better growth and yield of the crop. Al Moshileh *et al.* 2005 [1], reported that there was significant increase in the leaf area with the application of 450 kg/ha potassium and 300 kg/ha nitrogen when split into three equal doses.

The absolute growth rate, crop growth rate, relative growth rate and net assimilation rate differed significantly during the crop growth stage (Table 3). The maximum AGR (0.75 g/plant/day between 60-90 DAS), CGR (1.37 g/m^2/day between 60-90 DAS), RGR of the plant (0.00808 g/g/day between 60-90 DAS) and NAR (0.00002100 g/dm^2/day between 60-90 DAS) were recorded in treatment *Azotobacter* + PSB + KSB + 75% RDF + $MgSO_4$ + Micronutrient mixture (T_{13}). This might be due to increase in the dry weight because of higher number of leaves, plant biomass and leaf surface area induced by the combined application of inorganic fertilizers, nitrogen fixing biofertilizer, phosphate solubilizing bacteria and potassium solubilizing bacteria. The results are in conformity with the findings of Duragannavar *et al.* (2013) [9] in chilli who reported maximum total dry matter production and yield of chilli due to higher LA, LAI, LAD, AGR, RGR, NAR and CGR.

The highest number of tubers per plot (118.33), weight of the tubers per plant (88.67g) and yield per hectare (21.50 t/ha) were recorded with the combination of *Azotobacter* + PSB + KSB + $MgSO_4$ + Micro nutrient mixture + 75% RDF (T_{13}) (Table 4). The increase in number of tubers per plot and weight of the tubers could be attributed to increased vegetative growth observed due to balanced nutrient levels, which stimulated initiation of more stolons, thus increasing the number of tubers per plant as well as plot and weight and to increased yield. Further the higher number of tubers per plant in T_{13} may also be attributed to the synergistic interactions between vermicompost, biofertilizers, FYM and inorganic fertilizers which in turn helps in improvement of soil physical conditions and in turn helps to increase the yield. These findings are in line with Baishya *et al.* (2010) [4] who reported that the number of tubers/plant in potato increased significantly due to the use of 75% RDF + 25% recommended dose of N (RDN) through FYM. Jaipaul *et al.* (2011) [12] reported that higher tuber yield under integrated use of inorganics + organics and chicken manure + biofertilizer probably reflect the greater nutrients availability under these treatments.

Tuber dry matter accumulation was significantly influenced by integrated nutrient management practices. The maximum tuber dry matter accumulation (22%) was recorded with the combination of *Azotobacter* + PSB + KSB + $MgSO_4$ + Micro nutrient mixture + 75% RDF (T_{13}) which was statistically on par with T_{11}, T_{14} ,T_{12} and T_{10} (Table 4). Increased dry matter accumulation is also related to better uptake of nutrients due to the influence of biofertilizers supplied along with chemical fertilizers and organic manures. The better absorption and accumulation of nutrients promotes growth and metabolism. This inturn resulted in production of more dry matter accumulation. Similar results were also reported by Manoj *et al*. (2011) [13] who stated the maximum tuber dry matter (20.29%) was observed with the application of 50% of NPK through inorganic sources.

The maximum gross returns (Rs. 426530), net returns (Rs. 303638) and B:C ratio (2.47) was recorded in plants received *Azotobacter* + PSB + KSB + 75 per cent RDF + $MgSO_4$ + Micronutrient mixture (T_{13}) which was followed by T_{11} and minimum net returns was registered in T_1 (Table 5). The highest net returns in T_{13} might be due to increased yield and relatively higher gross income compared to other treatments. Jaipaul *et al.* (2011) [12] reported that conjoint use of inorganic, organic and bio-fertilizer resulted in higher yield and B: C ratio.

Table 1: Treatment Details

T_1	Control (RDF)(125 :100:125 kg NPK/ha + FYM(25t)
T_2	75% RDF + Vermicompost (2.5 t/ha)
T_3	75% RDF + Vermicompost + *Azotobacter*
T_4	100% RDF + *Azotobacter*
T_5	75% N + RD of P and K +*Azotobacter*
T_6	100% RDF +PSB
T_7	75% P+ RD of N and K + PSB
T_8	100% RDF +KSB
T_9	75% K + RD of N and P + KSB
T_{10}	50% RDF+ VC+ *Azotobacter* +PSB +KSB
T_{11}	T_{10}+$MgSO_4$ + Micronutrient mixture
T_{12}	75% RDF + *Azotobacter*+ PSB + KSB
T_{13}	T_{12}+ $MgSO_4$+ Micronutrient mixture
T_{14}	RDF +$MgSO_4$ + Micronutrient mixture

RDF: 125:100: 125 Kg NPK/ha.
Bio: Inoculants like *Azosipirillum*, PSB and KSB
$MgSO_4$: 12.5 kg/Acre Micronutrient mixture-5kg/Acre.
PSB: Phosphorous solubilizing bacteria (*Pseudomonas striata*)
KSB: Potassium solubilizing bacteria (*Bacillus mucilaginosus*).

Table 2: Effect of INM on plant height, number of leaves, plant spread, number of stem and leaf area in potato

Treatments	**Plant Height (cm)**	**Number of leaves**	**Plant spread (cm) N-S**	**Plant spread (cm) E-W**	**Number of stem**	**Leaf area (cm^2)**
T_1	35.00	200.00	25.00	31.00	2.70	2293.12
T_2	37.33	216.67	27.00	32.00	2.72	2725.26
T_3	39.67	250.00	29.00	33.00	2.75	3372.38
T_4	43.00	277.33	33.33	36.33	3.50	4407.24
T_5	42.33	275.43	32.88	35.83	3.45	4189.25
T_6	42.60	275.47	32.89	35.93	3.52	4169.25
T_7	42.29	273.00	31.33	35.33	3.10	4020.67
T_8	42.41	273.48	32.99	36.03	3.29	4146.37
T_9	40.33	270.17	30.33	34.33	3.03	3878.67
T_{10}	43.00	280.00	33.13	37.00	3.60	4624.30
T_{11}	56.00	287.00	43.67	46.00	4.23	5789.43
T_{12}	51.33	279.67	40.67	44.33	4.08	5627.17
T_{13}	59.33	298.00	45.00	47.33	4.79	6296.55
T_{14}	55.67	286.67	42.67	45.33	4.10	5737.62
S. E m±	2.73	15.89	2.95	2.55	0.27	519.70
CD @5%	7.94	46.19	8.58	7.41	0.79	1510.74

Table 3: Effect of INM on AGR, CGR, RGR and NAR in potato

Treatments	**AGR (g/plant/day)**	**CGR (g/m^2/day)**	**RGR (g/g/day)**	**NAR (g/dm^2/day) × 10^{-2}**
	60-90 Days	**60-90 Days**	**60-90 Days**	**60-90 Days**
T_1	0.37	0.85	0.00563	0.001290
T_2	0.44	1.03	0.00610	0.001360
T_3	0.45	1.10	0.00619	0.001367
T_4	0.50	1.16	0.00650	0.001523
T_5	0.49	1.15	0.00583	0.001390
T_6	0.48	1.16	0.00514	0.001400
T_7	0.47	1.13	0.00504	0.001397
T_8	0.46	1.14	0.00525	0.001393
T_9	0.45	1.11	0.00522	0.001390
T_{10}	0.58	1.19	0.00646	0.001507
T_{11}	0.66	1.27	0.00798	0.002043
T_{12}	0.62	1.20	0.00716	0.002000
T_{13}	0.75	1.37	0.00808	0.002100
T_{14}	0.63	1.26	0.00780	0.002010
S. E m±	0.037	0.04	0.000423	0.0001
CD @5%	0.107	0.11	0.001229	0.0003

Table 4: Effect of INM on yield attributes in potato

Treatments	Number of tubers/plot	Tuber weight(g)	Yield per hectare (t)	Dry matter (%)
T_1	91.07	70.00	13.52	16.00
T_2	94.53	72.33	14.33	16.23
T_3	99.12	72.85	15.07	16.73
T_4	106.47	73.33	16.50	18.00
T_5	100.90	72.83	15.33	17.55
T_6	108.93	74.23	18.52	18.50
T_7	108.64	74.20	18.18	18.00
T_8	104.20	71.67	15.36	17.54
T_9	99.67	71.88	14.93	17.00
T_{10}	105.40	74.33	16.63	20.00
T_{11}	111.13	88.00	20.74	21.50
T_{12}	109.65	87.00	20.00	21.00
T_{13}	118.33	88.67	21.50	22.00
T_{14}	110.00	87.67	20.25	21.30
S. E m±	4.16	4.16	1.21	1.15
CD @ 5%	12.10	12.10	3.51	3.33

Table 5: Effect of INM on cost economics in potato

Treatments	Cost of cultivation (Rs)	Marketable yield (t)	Gross returns (Rs)	Net returns (Rs)	B:C ratio
T_1	111060	7.45	201550	90490	1.01
T_2	117092	7.97	222040	104948	1.04
T_3	119092	8.01	240196	121104	1.02
T_4	113060	9.13	274008	160948	1.42
T_5	111060	8.43	253000	141940	1.28
T_6	113060	9.72	291612	178552	1.58
T_7	110521	9.47	284200	173679	1.57
T_8	113060	8.45	253584	140524	1.24
T_9	110717	7.93	237758	127041	1.15
T_{10}	120415	9.81	294360	173945	1.44
T_{11}	121215	13.08	392512	271297	2.24
T_{12}	115092	12.31	369210	254118	2.21
T_{13}	122892	14.22	426530	303638	2.47
T_{14}	114860	12.71	381213	266353	2.32

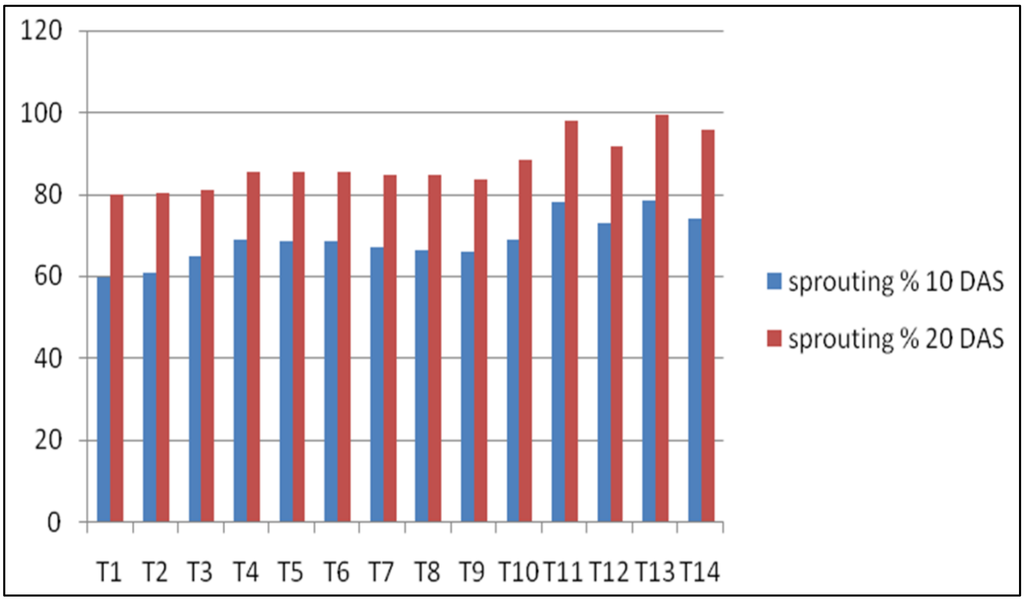

Fig 1: Effect of INM on sprouting percentage in potato

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