Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(4): 1454-1456
Received: 22-05-2020
Accepted: 24-06-2020

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Effect of vermicompost and phosphate solubilizing bacteria on growth and yield of potato (*Solanum tuberosum L.*)

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Abstract
Field investigation was carried out to study the effect of organic and biofertilizers on growth and yield parameters in potato cultivar Kufri Chipsona-3 at School of Agriculture and Environmental Sciences, Shobhit University, Gangoh Saharanpur, Uttar Pradesh condition during 2016-2017 and 2017-2018. The experiment was laid out in a randomized block design with four nutrient management practices vermicompost (VC), and their combinations with biofertilizers (PSB). Growth parameters like plant height, number of compound leaves per plant, number of shoots per plant, diameter of stem and number of stolon per plant, number of branches per plant, fresh and dry weight of shoot and yield attributing parameters like fresh and dry weight of tubers per plant, number of tuber per plant, diameter of tuber per plant and total yield per hectare increased with the application of vermicompost in different combination rates with biofertilizers was much better than applying of vermicompost one and the using of phosphate solubilizing bacteria with them in tries combinations were the most effective treatments comparing with the others. However, highest values for number of tuber per plant and per plot as well as tuber yield per plot and per hectare was recorded on application of Vermicompost @ 6 t/ha + PSB @ 10 kg/ha was the most effective treatment both the years followed by Vermicompost @ 6 t/ha, respectively.

Keywords: Vermicompost, biofertilizers, phosphate solubilizing bacteria

Introduction
Potato (*Solanum tuberosum* L.) belongs to Solanaceae family which is major world vegetable crop in terms of quantities produced and consumed worldwide. Potato (*Solanum tuberosum* L.) plays a crucial role in food security for ever elongate world population (Thiele *et al.,* 2010 and Scott and Sourez, 2012) [17, 14]. It is popularly known as the "Vegetable King". It is the world's most fruitful vegetables crop a major source of income to many population and summation, and edible protein makes it of good nutritional quality (Swaminathan 2014) [16]. Potato provides a source of low cost potency to the human aliment and it is the ample source of trehala, vitamin C and B and minerals (Kumar *et al.,* 2013 and Lokendrajit *et al.,* 2013) [6, 7];
The use of phosphate solubilizing bacteria as inoculants cumulatively increases P uptake by the plant and crop yield. The main function of mineral phosphate solubilization is the production of biological acids, and acid phosphates play a key role in the mineralization of organic form of phosphorous in soil. Hence, inherited manipulate of phospho-solubilizing bacteria to retouch their capability for improvement of plant enhancement may involve cloning genes including both mineral and organic phospho solubilization, followed by their manifestation in selected rhizobacterial strains. (Rodríguez *et al.,* 1999) [12]. Using of vermicompost is now a universal movement for the second greeny revolution that emphasis on composting. This mixture is made by earthworm's activities which are necessary for soil improvement and farm production, raw materials and various microorganisms which decompose organic wastes and convert them into suitable nutritional elements particularly NPK. As the researchers stated the application of recommended dose of fertilizers and vermicompost noticed higher yield in Potato (Patil, 1995, Saikia and Rajkhowa, 1998, Asumus and Gorlitz, 1986) [10, 15, 2].

Material and methods
During Rabi season 2016-2017 and 2017-2018 a potato experiment with two organic sources was established on an experimental farm of the School of Agriculture and Environmental Sciences, Shobhit University, Gangoh Saharanpur, Uttar Pradesh, India. The study area lies in the north western plains sub-region of Upper Gangatic Plains. The experiment was set up in four treatments replicated four times with each plot (12.6m^2) in a randomized block design. Healthy seed tubers with uniform size of about 40-45g in weight were sowing according to the

norm of 2.5 t ha^{-1}. The domestic early to medium 'Kufri Chipsona- 3 potato cultivar was used. Seed tubers were sown in mid-November and harvested in the month of March. And as well as seed tubers was sown the same process next year's same field. The soil of the experimental farm is sandy loam (pH 6.12). The nutrient management was done as per treatments. The organic fertilizers were also used as per treatments. In treatment T_1 - Vermicompost @ 6 t/ha, T_2 – Vermicompost @ 6 t/ha + PSB @ 10 kg/ha, T_3 - PSB @ 10 kg/ha, T_4 – without manure and fertilizer i.e. control were treated *(*Ansari 2008 and Ram *et al*., 2017) [3, 11]. It was applied in ridges and furrow area then tuber lets were immediately sown in the field at spacing of 40 X 30cm. All the necessary cultural practices and plant protection measures were followed uniformly for all the treatments during the entire period of experimentation.

Growth and yield parameters

For the growth and yield parameters, five plants in each plot were tagged randomly in the second row of either north or south side in the field. Plant height, number of compound leaves $plant^{-1}$, number of shoots $plant^{-1}$, diameter of stem and number of stolon $plant^{-1}$ after 90 days of sowing, number of branches $plant^{-1}$ recorded at the harvest time, fresh and dry weight of shoot and tubers at maturity stage were recorded. At harvest time, all tubers of each plot were harvested to record total yield kg $plot^{-1}$, total yield $hectare^{-1}$ and diameter of tuber $plant^{-1}$.

Results and discussion

The present investigation has been carried out to find out the appropriate relative amount of vermicompost and biofertilizers for improving plant growth and yield parameters to response of potato *(Solanum tuberosum* L.). The experimental findings obtained in present studies due to application of vermicompost and phosphate solubilizing bacteria in table.1, 2 and 3.

Table 1: Effect of vermicompost and phosphate solubilizing bacteria on growth attributes of potato

Treatments	Plant height (cm) 201,6 2017	Number of compound leave/plant 2016, 2017	Number of shoot/plant 2016, 2017	Diameter of stem/plant (cm) 2016, 2017	Number of stolon /plant 2016, 2017
T_1	46.55 49.42	44.49 45.73	4.65 5.40	1.93 1.94	13.38 14.29
T_2	49.38 51.52	46.57 49.45	5.38 6.33	2.55 2.57	13.64 14.41
T_3	45.04 48.44	42.68 44.84	4.63 5.31	1.83 1.84	12.38 13.18
T_4	29.71 32.31	37.13 38.25	4.25 4.54	1.13 1.32	10.17 10.27

***** T_1 - Vermicompost @ 6 t/ha, T_2 – Vermicompost @ 6 t/ha + PSB @ 10 kg/ha, T_3 - PSB @ 10 kg/ha, T_4 – control.

Table 2: Effect of vermicompost and phosphate solubilizing bacteria on number of branches $plant^{-1}$ at harvest, fresh and dry weight of shoot and tubers of potato.

Treatments	Number of branches/plant 2016, 2017	Fresh weight of shoot /plant (gm) 2016, 2017	Dry weight of shoot /plant (gm) 2016, 2017	Fresh weight of tuber /plant (gm) 2016, 2017	Dry weight of tuber /plant (gm) 2016, 2017
T_1	4.60 5.46	84.42 87.00	10.78 12.39	199.08 204.21	32.94 31.28
T_2	5.29 6.43	88.76 91.05	11.67 13.65	213.40 218.00	35.26 33.84
T_3	4.43 5.42	81.14 83.69	10.34 12.59	196.84 201.43	32.32 31.73
T_4	2.95 3.40	52.56 54.92	5.87 8.18	102.66 105.99	31.84 31.10

***** T_1 - Vermicompost @ 6 t/ha, T_2 – Vermicompost @ 6 t/ha + PSB @ 10 kg/ha, T_3 - PSB @ 10 kg/ha, T_4 – control.

Table 3: Effect of vermicompost and phosphate solubilizing bacteria on number of tubers, diameter of tuber and yield of potato.

Treatments	Number of tubers /plant 2016 2017	Number of tubers /plot 2016 2017	Diameter of tuber /plant 2016 2017	Total yield (kg $plot^{-1}$) 2016 2017	Total yield (q ha^{-1}) 2016 2017
T_1	7.06 7.63	740.78 745.34	4.14 4.57	14.96 15.07	118.73 119.78
T_2	8.10 8.23	850.76 819.33	4.28 4.80	16.31 17.13	129.40 135.93
T_3	6.50 7.42	682.76 696.42	4.20 4.52	13.41 14.21	106.43 112.77
T_4	3.85 4.49	403.99 446.90	3.08 3.23	7.61 7.62	60.35 60.49

***** T_1 - Vermicompost @ 6 t/ha, T_2 – Vermicompost @ 6 t/ha + PSB @ 10 kg/ha, T_3 - PSB @ 10 kg/ha, T_4 – control.

Plant height, number of compound leaves and number of shoot $plant^{-1}$ were significantly improved with the treatments of vermicompost and bio fertilizers in Rabi season. The reason for such beneficial response might be due to the fact that large amount of vermicompost improved the soil structure and soil aeration. Vermicompost favorably affects soil pH, microbial population and soil enzyme activities (Maheswarappa *et al*., 1999) [8]. Vermicompost resulted in better plant growth in comparison to other treatments. Application of treatment T_2 (Vermicompost + PSB) recorded higher diameter of stems $plant^{-1}$ and lower diameter of stems $plant^{-1}$ was noticed under the treatment T_4 (Control) both year. The application of treatment T_2 provided sufficient nutrients for better growth of stems. Application of treatment T_2 (Vermicompost + PSB) gave maximum plant height, number of compound leaves, number of shoot and number of stolon $plant^{-1}$ and minimum growth parameters was under the treatment T_4 (Control) both years. The similar finding was also recorded by (Yeptho *et al.* 2012) [18].

The total yield of tubers was significantly affected by application of various organic and biofertilizers sources of nutrients. The maximum total yield of tubers q/ha (129.40 and 135.93) were obtained with treatments T_2 (Vermicompost +PSB). The minimum total yield q/ha under the treatment T_4 (60.35 and 60.49.) during 2016 and 2017 both years. The another scientific explanation for achieving higher yield of tubers might be due to vermicompost alone and other nutrients provided through combination of Phosphate solubilizing bacteria & vermicompost. The present findings are in conformity to (Choudhary *et al*., 2010) [4].

The maximum fresh weight and dry weight of tuber $plant^{-1}$ was recorded with the application of treatment

(Vermicompost + PSB) while the minimum fresh weight and dry weight of tuber plant^{-1} was recorded under the treatment (Control) during both years. Maximum fresh weight and dry weight of shoot plant^{-1} was recorded with the application of treatment T_2 and minimum fresh weight and dry weight of shoot plant^{-1} was observed under the treatment T_4 both years. Similar findings are also reported by (Nag 2006 and Alam *et al.*, 2007) [9, 1].

Maximum number of tuber per plant was obtained with the application of treatment (PSB +Vermicompost) compared to treatment (vermicompost) and (control) during both years 2016 and 2017. With the result reported by (Jaipaul *et al.*, 2011) [5].

The highest diameter of tuber (4.28 cm) was recorded in treatment T_2 (PSB + vermicompost) and found to be statistically significant over the other treatments both years. The lowest diameter of tuber (3.08 cm) was recorded in control. The maximum number of branch per plant (5.29) was recorded with the application of treatment T_2 (Vermicompost + PSB) and the lowest number of branch per plant (2.95) was recorded with the application of treatment T_4 (control) during both years.

Conclusion

Based on the two-year data it may be concluded that potato requires adequate nutrition under North Indian condition that may be achieved by judicious and balanced use of vermicompost and biofertilizers sources of nutrients. The applications of Vermicompost + Phosphate solubilizing bacteria are recommendable practices for higher growth characters and tuber yield. A significant effect of the using vermicompost as compared to Phosphate solubilizing bacteria is shown both years of 2016 and 2017.

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