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Effect of Eco-acid (78% Organic Acid) Product on Growth, Development and Yield Contributing Parameters on Potato (*Solanum tuberosum*)

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ABSTRACT

To counter the requirement of nutrient demand by the potato crop, the experimental field trial was conducted at Lovely Professional University, Agriculture Research Farm in Punjab, India. The experiment was carried out using the randomized block design (RBD) with three replications and seven treatments. The treatments were; T_1: Control, T_2: 100% recommended dosage of fertilizers (RDF), T_3: 50% RDF + orthophosphoric acid, T_4: 50% RDF+ 85% humic acid), T_5: 50% RDF + Eco-acid (78% organic acid) @ 1.0 l/ acre, T_6: 50% RDF + Eco-acid (78% organic acid) @ 2.0 l/ acre and T_7: 50% RDF + Eco-acid (78% organic acid) @ 4.0 l/acre. Morphological and physiological parameters were analyzed. T_6: 50 % RDF + Eco-acid (78% organic acid) @ 2.0 l/acre was one of the most effective treatments for plant height, number of leaves, fresh weight, dry weight and chlorophyll content (using SPAD), leaf area index (LAI) in different time intervals viz., 30, 60, 90 DAP, and even in the number of tubers, starch content and yield. Contrarily, T_1: Control was the least performing in all the parameters where neither fertilizer nor any organic acid was used.

Key words: Organic acid, foliar application, crop growth and development, sustainability, crop production, potato

INTRODUCTION

One of the most significant food crops in the world is the potato crop. More than a billion people depend on it as a staple meal, and it is farmed in more than 100 different nations. Carbohydrates, vitamin C, potassium and other nutrients are abundant in potatoes. Cooking techniques include boiling, baking, frying and mashing. The potato (*Solanum tuberosum*) is a tuber crop and one of the most cultivated crops in the world. Peru is considered the center of origin. It belongs to the family Solanaceae. It was introduced in India by Portuguese sailors in the early 17th century, but generally, potatoes are native to the South American continent (Hussain, 2016). Depending on the location, potatoes are often planted in the late winter or early spring. Either tuber pieces or seed potatoes can be used for planting. Whole or sliced potatoes with sprouts or eyes are known as seed potatoes. Small chunks of tubers.

The vegetative and tuberization phases of the potato crop are distinct. The potato plant's leaves, stems, and roots grow during the vegetative phase. The potato plants produce underground tubers, or potatoes, during the tuberization period. Various climatic conditions influence the process of tuberization (Dutt *et al.,* 2017). The type of potato and the surrounding environment affect the duration of these phases. The onset of the tuberization phase is accompanied by a reduction in temperature and day length.

During the initial days, around 38 varieties were cultivated. Potatoes are a highly starch-containing crop. Potatoes contain around 16% carbohydrates, 2% protein and 1% minerals. It's a wholesome food with additional vitamin C and antioxidants. In northern India, potato is generally called ba-tata or aloo, and all over India, potato is consumed in various forms ranging from boiled to cooked types (Hussain, 2016). It's herbaceous plant with a short stem. Cultivation of potatoes is done by using TPS (true potato seeds) or tubers for the sake of cultivation. These tubers have different structures, ranging from oval to round. Potato tubers are the harvestable product of the potato. In the world production scenario, few major producers are China, India, Russia, Ukraine, USA, Germany, Bangladesh, Poland and France (Campos and Ortiz, 2019), with yields ranging from 17.04, 20.54, 15.31, 16.58, 49.02, 44.42, 19.91, 28.47 and 39.00 kg/ha, respectively.

In India, major potato-producing states are Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, Punjab, Assam, Jharkhand, Haryana and Chhattisgarh, with 15.81, 13.2, 9.04 t, 3.89, 3.57, 2.95, 2.95, 0.99, 0.77, 0.81 and 0.61 mmt (million metric tonnes), respectively. It's one of the perishable vegetables and is generally grown in *rabi* in the northern part of the country. Sowing is done in the months of October fortnightly to the first week of November, and harvesting is done in the months of February to March, depending on the variety of the crop. The optimum temperature for the sake of potato cultivation is 14-25° (Pradel *et al.,* 2019), with a rainfall of 300-500 mm. The optimal soil condition ranges from pH 6.5 to 7, and the preferred texture of the soil is loamy to sandy loamy soil. The few major varieties used for cultivation that are majorly produced by the Central Potato Research Institute (C. P. R. I.) are Kufri Alankar, Kufri Ashoka and Kufri Badshah, which increase yield with supplementation of nutrients (Rana *et al.,* 2020), Kufri Bahar, Kufri Chamatkar and Kufri Pukhraj. These varieties are resistant to frost, late blight and early blight of potatoes.

Pests, diseases, weeds and climate change are just a few of the difficulties facing the potato crop. Potato plants are frequently attacked by pests such as aphids, Colorado potato beetles, wireworms and nematodes. Aphids are one of the most dangerous pests in the potato crop (Xu and Gray, 2020). The diseases blackleg, scab, late blight and early blight are a few that frequently damage potato plants. Potato plants frequently face competition from weeds, including quack grass, pigweed and nightshade. Even though various chemical fertilizers are used for weed control, such as metribuzin and pendimethalin, weeds are still a major issue in potato crops. By changing the temperature, rainfall, frost and drought patterns, climate change can have an impact on the potato crop.

Orthophosphoric acid is a tribasic acid, meaning that it can donate three protons in an aqueous solution. The three dissociation constants of orthophosphoric acid are 2.14, 7.20 and 12.37 at 25°C, corresponding to the formation of dihydrogen phosphate, hydrogen phosphate and phosphate ions, respectively. Orthophosphoric acid may be combined with alcohols to create esters known as organophosphates, which have a variety of uses in industry, medicine and agriculture.

The term "humic acid" refers to a category of organic molecules that are created during the breakdown of plants and other living things. Microorganisms acting on organic substances over an extended period of time eventually produce humic acid. Humic acid is a complicated blend of numerous distinct compounds with interconnected properties and roles (Ekin, 2019). Humic acid forms in water with an acidic pH, while it is soluble in water with a neutral or alkaline pH. Humic acid has a large molecular weight having dark brown colour. Humic acid is crucial for soil fertility, plant development, water quality and the restoration of the environment. The physical and chemical characteristics of soil, such as water retention, nutrient availability, cation exchange capacity and pH buffering, can be improved by humic acid. Humic acid can also promote the uptake and metabolism of minerals and organic chemicals by plants, as well as drive their growth and development. Additionally, heavy metals, pesticides and hydrocarbons can be bound by humic acid in soil and water, which diminishes their toxicity and mobility.

Carbon-based substances with acidic characteristics are called organic acids, which are weak acids and do not dissolve completely in water (Adeleke *et al.,* 2017). Organic acids have also been proven to help in the development of soil microbes and improve the nutrition and metabolism of soil flora and fungal life. They are frequently used in agriculture as plant growth regulators, soil amendments and fertilizers. Potatoes are one of the crops that can profit from the application of organic acids. Through promoting nutrient uptake, increasing soil microbial activity, decreasing soil pH and controlling soil-borne diseases, organic acids can enhance the quality and productivity of potato tubers (Selladurai and Purakayastha, 2016). The type, concentration and timing of the application of organic acid, as well as the soil and environmental conditions, all play a role in how organic acid affects potato crops. To maximise the advantages of organic acids and minimise any potential disadvantages, it is crucial to carry out field trials and soil studies before applying them to potato crops.

MATERIALS AND MATHODS

The field trial was conducted at the Agriculture Research Farm, Lovely Professional University, Phagwara, Kapurthala district, Punjab, during the *rabi* season of the year 2022-23. In one of the six agro-climatic zones of Punjab, a state that lies in the north-west region of India, an area lies in the central plains section of geographical location with coordinates of 31.24 North longitude and 75.6909 East latitude, where soil conditions range from sandy loamy to clay-textured soil with a pH of 7.5 to 8. The research trials consisted of seven treatments and three replications set up in a randomized block design (RBD). The potato variety Khufri Badshah was opted for the trial i.e. foliar application of the treatments. Eco-acid was the testing product with various concentrations: 1, 2 and 4 l/acre. Orthophosphoric acid and humic acid were the reference products and the recommended dosage of chemical was applied. Treatments were: T_1: Control, T_2: 100% recommended dosage of fertilizers (RDF), T_3: 50% RDF + orthophosphoric acid, T_4: 50% RDF+ 85% humic acid), T_5: 50% RDF + Eco-acid (78% organic acid) @ 1.0 l/acre, T_6: 50% RDF + Eco-acid (78% organic acid) @ 2.0 l/ acre and T_7: 50% RDF + Eco-acid (78% organic acid) @ 4.0 l/acre. The packages of practices of Punjab Agricultural University (P. A. U.) were followed in the field trials. The potato crop was harvested after the complete drying up of the stolon (upper part of the plant above the soil) and fully developed tubers below the ground. Harvested tubers were weighed and sun-dried for hardening of the layer around the tubers. Growth and yield parameters were estimated along with morphological parameters [plant height (30, 60 and 90 days after planting: DAP), number of leaves (30, 60 and 90 DAP), fresh weight of the plant (30, 60 and 90 DAP), dry weight of the plant (30, 60 and 90 DAP), chlorophyll content (using SPAD) in the plant leaves (30, 60 and 90 DAP)]. Three plants were randomly selected to compute mean for following parameters at the time of harvest: the number of tubers per plant per plot and the overall yield. The data were analyzed using both OPSTAT and SPSS software, where interpretation for the variance of the collected data was done using OPSTAT software, and means comparison was performed for all the respective treatments using SPSS software. The Duncan multiple range test (DMRT) was used to determine significance.

RESULTS AND DISCUSSION

The study revealed a considerable association between Eco-acid (78% organic acid) with different concentrations and other reference products such as 85% humic acid, the recommended dosage of orthophosphoric acid and the recommended dosage of fertilizer on potato. At 30 days after planting (DAP), the highest and lowest plant heights were recorded as 15.2 and 9.4 cm in T_6 (Eco-acid with a concentration of 2 l/acre + 50% RDF) and T_1 (Control). At 60 DAP, the highest and lowest plant heights were recorded as 28.7 and 19.5 cm in T_7 (Eco-acid @ 4 l/acre + 50% RDF) and T_1 (Control). Finally, at 90 DAP, T_6 (Eco-acid @ 2 l/acre + 50% RDF) recorded the highest plant height as 55.9 cm, while T_1 (Control) recorded the least height of 25 cm (Table 1). The scrutiny of the variance revealed that plant height was affected by the application of T_6 (Eco-acid with a concentration of 2 l/acre + 50% RDF). The maximum height was obtained with the application of Eco-acid + 50% RDF with various concentrations T_6 @ 2 l/acre and T_7 @ 4 l/acre) along with the 50% recommended dose of fertilizer when compared with other treatments, and the least height was observed in the T_1 treatment. The experimental results were similar to the trials performed by Wang *et al.* (2022).

The number of leaves per plant ranged from 9 to 38 in T_1 (Control) and T_7 (Eco-acid @ 4 l/acre + 50% RDF) at 30 DAP and similarly at 60 DAP. T_6 treatment (Eco-acid @ 2 l/acre + 50% RDF) recorded the highest number of leaves as 46, and the least was recorded in T_1 treatment (Control) with 21. Finally, even at 90 DAP, T_6 treatment (Eco-acid @ 2 l/acre + 50% RDF) performed well with the highest number of leaves i.e. 52. Followed by T_7 (Eco-acid @ 4 l/ acre + 50 % RDF) with 50 leaves. Contrarily, T_1 (Control) was low performing with 29 leaves. However, other treatments such asT_2, T_3, T_4 and T_5 were at par with each other. At 60 and 90 days, the application of T_6 treatment i.e. (Eco-acid @ 2 l/acre + 50% RDF), showed more leaves than T_1 (Control) plants per plot, which

Table 1. Effect of eco-acid (78% organic acid) on plant height, number of leaves/plant, fresh and dry weight of potato crop

Treatment	Plant height (cm)	No. of leaves/ plant	Fresh weight (g/plant)	Dry weight (g/plant)
T_1 (Absolute control)	25^{e}±1.45717	29^{f} ±2.00000	22.8^{e}±1.08056	3.2^{e}±0.13454
T_2 (100% recommended dosage of fertilizer (RDF)	30.1^{d}± 2.68180	36.6^{e}±1.52753	30.2^{d}±1.36442	3.9^{d}±0.21008
T_3 (50% RDF+Orthophosphoric acid)	34.9^{cd}±2.26780	42.3^{d}±2.51661	34.8^{c}±0.80914	4.4^{cd}±0.06658
T_4 (50% RDF+85% humic acid)	38.3^{c}±1.81530	45.0^{cd}±1.00000	36.8^{c}±0.97110	4.7^{c}±0.14177
T_5 (50% RDF+Eco-acid (78% organic acid) @ 1.0 l/acre	44.8^{b}±3.14643	47.3^{bc}±1.15470	42.1^{b}±1.96013	6.03b±0.6658
T_6 (50% RDF+Eco-acid (78% organic acid) @ 2.0 l/acre	55.9^{a}±4.30000	51.6^{a}±2.51661	47.8^{a}±1.02000	6.6^{ab}±0.30892
T_7 (50% RDF+Eco-acid (78% organic acid) @ 4.0 l/acre	54.7^{a}±2.95691	50^{ab}±1.00000	46.8^{a}±1.01796	6.7^{a}±0.79002
S. Em±	1.537	0.842	0.510	0.163
C. D. (P=0.05)	4.787	2.623	1.590	0.509

had fewer leaves. The obtained results are in accordance with the work done by Xin *et al.* (2017).

At the 30 DAP, maximum dry weight was recorded as 1.51 g/per plant in treatment T_6 (Eco-acid @ 2 l/acre + 50% RDF) and lowest was detected in T_1 (Control), which was 0.78 g/plant. Similarly, treatment T_6 showed maximum dry weight at 60 and 90 DAP followed by treatment T_7 (Eco-acid @ 4 l/acre + 50% RDF) in all the three-time intervals i.e. 30, 60 and 90 DAP. Treatment T_1 (Control) performed very poorly. An increase in dry weight by integrated use of humic acid and biofertilizer also ensured higher productivity of potatoes (Ekin, 2019).

Fresh weight ranged from 9.6 g/plant (T_1: Control) to 28.7 g/plant (T_6: Eco-acid @ 2 l/acre + 50% RDF) at 30 days. The lowest and highest fresh weights were observed at 60 days, from 19.1 g/plant (T_1: Control) to 35.4 gm/plant (T_7: Eco-acid @ 4 l/acre + 50% RDF). Similarly, the lowest and highest fresh weights were from 22.8 g/plant (T_1: Control) to 47.8 g/plant (T_6: Eco-acid @ 2 l/acre + 50% RDF) at 90 days, (Table 1). Due to the application of Eco-acid, there was a significant difference between these treatments among humic acid, orthophosphoric acid and the recommended dosage of fertilizer. The conclusions are consistent with research trials performed by Naghdi *et al.* (2022).

The SPAD-520 meter was utilized for the estimation of chlorophyll concentration. At 30 DAP, the maximum chlorophyll content reading was observed in T_6 (Eco-acid @ 2 l/acre + 50% RDF), which was 39.43, and the minimum was observed in T_1 (Control) with 13.63. At 60 DAP, the highest recording was observed from T_6 (Eco-acid @ 2 l/acre + 50% RDF) i.e. 43.09, and the least recording was from T_1 (Control) i.e. 21.54. However, at 90 DAP, T_7 (Eco-acid @ 4 l/acre + 50% RDF) with a 45.3 SPAD reading was the highest, and T_6 (Eco-xcid @ 4 l/acre + 50% RDF) was second highest with a 44.93 SPAD reading, and the lowest SPAD recording was observed from T_1 (Control). Similar results were screened by Azamshah *et al.* (2016).

Leaf area index (LAI) is one of the important parameters, where it gives information regarding the area of the leaf, which is directly proportional to the amount of photosynthesis that occurs in the leaf, which helps plants to perform well. LAI was calculated by taking the plant leaves from five plants and placed in the leaf area meter. The highest leaf area at 30 days was observed in treatment T_6 (Eco-acid @ 2 l/acre + 50% RDF) with 1.41 cm and the lowest was observed in T_1 (Control) with 0.523 cm. T_6 proved to have good results even at 60 and 90 days with values 6.36 and 5.82 cm, whereas T_1 (Control) was low performing with values of 3.84 and 4.05 (Table 2).

The number of tubers per plant was calculated by taking five plants randomly from each plot with the treatments and means were calculated. The highest number of tubers was observed in treatment T_6 (Eco-acid @ 2 l/acre + 50% RDF) with nine tubers per plant, and the lowest number of tubers was observed in Treatment T_1 (Control) with five tubers per plant.

For starch content of the potato, a random sample of potato tubers was taken and the amount of starch present (in grams) per 100 g of potato i.e. (starch content in g/100 g of potato) was calculated. The highest amount of starch content was detected in T_6 (Eco-acid @ 2 l/acre + 50% RDF) with 15.27 g of starch/ 100 m of potato tubers and least amount of starch content was observed in T_1 (Control) i.e 7.8 m of starch/100 m of potato tubers.

Table 2. Effect of eco-acid (78% organic acid) on chlorophyll, leaf area index, number of tubers, starch content and yield

Treatment	Chlorophyll	Leaf area index (cm)	No. of tubers/ plant	Starch content (g)	Yield (t/ha)
T_1 (Absolute control)	28.1c±1.68226	4.05e±0.03	5.0c±1.00000	7.8d±0.35	7.1d ±0.28618
T_2 (100% recommended dosage of fertilizer (RDF)	36.3b±1.44222	4.28de±0.15	6.3bc±1.52753	11c±1.00	23.7c±0.50478
T_3 (50% RDF+orthophosphoric acid)	35.1b±5.13258	4.41d±0.03	6.0bc±1.00000	11.67c±1.53	24.2c±1.55388
T_4 (50% RDF+85% humic acid)	35.0b±0.30000	4.6cd±0.15	6.3bc±0.57735	13.43b±0.51	25.4bc±0.59518
T_5 (50% RDF+Eco-acid (78% organic acid) @ 1.0 l/acre	44.1a±1.58745	4.89c±0.03	7.6ab±0.57735	14.53ab±0.50	27.5ab±1.21006
T_6 (50% RDF+Eco-acid (78% organic acid) @ 2.0 l/acre	44.9a±2.25019	5.82a±0.02	8.6a±0.57735	15.27a±0.64	29.6a±2.35086
T_7 (50% RDF+Eco-acid (78% organic acid) @ 4.0 l/acre	45.3a±1.96977	5.22b±0.03	7.0ab±1.00000	14.87ab±0.15	26.8b±0.83355
S. Em±	1.509	0.195	0.586	0.418	0.756
C. D. (P=0.05%)	4.7	0.609	1.827	1.301	2.355

The total yield of potato (t/ha) was found highest at 29 t/ha in treatment T_6 (Eco-acid @ 2 l/acre + 50% RDF), followed by T_7 (Eco-acid @ 4 l/acre + 50% RDF) and T_3 (50% RDF + orthophosphoric acid) and the least yield was found in T_1 (Control). The upsurge in yield may have resulted from the enhanced growth characteristics of the plant due to the application of Eco-acid in various concentrations. Chen *et al.* (2017) also reported similar results.

CONCLUSION

Organic acids play a crucial role in increasing nutrient availability and helping to maintain the sustainability of agricultural practices, in addition to the recommended dosage of fertilizer provide access to all of the essential nutrients required for plant growth and development. Plant growth, productivity and yield are affected by the application of organic acids. The performed experimental trials concluded that the application of the Eco-acid with different concentrations along with the 50% RDF had a substantial influence on the growth, development and yield parameters of the potato crop. The best growth, development and yield were displayed by T_6 (Eco-acid @ 2 l/acre + 50% RDF). Similarly, T_7 (Eco-acid @ 4 l/acre + 50% RDF) was the second most effective treatment among the other treatments involving orthophosphoric acid, humic acid and the sole recommended dosage of fertilizer. The T_1 (Control) treatment, where neither organic acids nor the recommended dosage of fertilizer was utilized, showed the least efficiency in the growth, development and yield parameters. Hence, it was suggested that the application of Eco-acid @ 2 l/acre along with 50% of the recommended dose of fertilizer was effective in terms of both production and yield.

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