Australian Journal of Crop Science AJCS
Aust J Crop Sci. 19(03):258-265 (2025) | https://doi.org/10.21475/ajcs.25.19.03.p267 ISSN:1835-2707

Comparative analysis of nutrient uptake in *Solanum melongena* L. grown in sandy clay loamy soil mixed with different doses of Polyvinylpyrrolidone

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Received: 06/11/2024

Revised: 07/01/2025

Accepted: 06/02/2025

Abstract: Polyvinylpyrrolidone (PVP), a water-soluble polymer, is known to amend the soil's physicochemical properties and can also act as a potential soil conditioner while alanine, a non-polar and neutral amino acid, is a good source of nitrogen (N) for plants. The current study concluded that using PVP and alanine in balance improved essential nutrient uptake in eggplant (*Solanum melongena* L.) and fostered the plant growth. The experiment comprised 6 treatments in a randomized block design (RBD) in triplicate. The treatments were labeled as T0 (control; 0 mg PVP + 0 M alanine/kg soil), T1 (0 mg PVP + 0.1 M alanine/kg soil), T2 (250 mg PVP + 0.1 M alanine/kg soil), T3 (500 mg PVP + 0.1 M alanine/kg soil/Kg soil), T4 (750 mg PVP + 0.1 M alanine/kg soil) and T5 (1000 mg PVP + 0.1 M alanine/kg soil). The integrated use of PVP and alanine significantly increased the growth parameters, macronutrients, and micronutrient uptake in eggplant due to enhanced soil-amino acid interactions and the nutrients that are released as organic matter breaks down. Among different treatments, T5showed maximum growth of the plant which might be due to the highest uptake of nitrogen (N), magnesium (Mg), Iron (Fe), nickel (Ni), copper (Cu) and Zinc (Zn). Additionally, a change in sandy clay loamy soil's chemical properties was also observed during the study. From T0 to T5, the soil pH was decreased while electrical conductivity was increased. Scanning electron microscopy (SEM) was used to analyze the morphological changes in the soil's structure.

Keywords: Eggplant, nutrient uptake, organic polymer, polyvinylpyrrolidone, *Solanum melongena* L., soil conditioner.
Abbreviations: EC_electrical conductivity; EDS_Energy dispersive X-ray spectroscopy; PVP_polyvinylpyrrolidone; RBD_randomized block design; SEM_scanning electron microscopy.

Introduction

India was projected to produce 12.61 million metric tons of eggplant (*Solanum melongena* L.) in 2023 and now ranks second in the world to produce this crop behind China which accounts for over 68.7% of global output (Tiwari et al., 2023). Eggplant has become a profitable crop and grows in both the vegetative and reproductive phases at the same time thus it is important to provide the plant with nutrients throughout the whole growing season (Sharma and Brar, 2008). It is an economically important flowering plant of the Solanaceae family and farmed extensively in India, Pakistan, China, Bangladesh, and Philippines (Das and Barua, 2013; Uikey et al., 2018). The family has 75 genera and more than 2000 species (Biswas et al., 2018). The plant's various parts can treat cardiac debility, inflammatory diseases, neuralgias, cholera, nasal ulcers, asthma, and bronchitis (Mutalik et al., 2003; Igwe et al., 2003). Therefore, enhanced production of eggplant is ingreat demand in today's world and requires good-quality of soil. Macronutrients, such as nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca) are required by the plant in larger quantities as they boost crop output by activating enzymes involved in chlorophyll synthesis, growth, fruit ripening, and enzyme system maintenance (Nagar et al., 2024; De Bang et al., 2021). Many nutrient deficits have a significant detrimental impact on agricultural productivity leading to lower yields and lower quality of food (Frydenvang et al., 2015). Moreover, micronutrients like iron (Fe), copper (Cu), nickel (Ni), and zinc (Zn)also enhance nutrient absorption and balance other nutrients in plants as well. It has been demonstrated that free amino acid in soil is a significant source of nitrogen (N) for plants (Ruanet al., 2019). N promotes healthy crop productivity (Kodithuwakku et al.,2023). Alanine, due to its low molecular weight (89.09g/mol) and good solubility in water (16.7g/100ml) at 25°C, is a significant choice of amino acid for the present investigation as a nitrogen (N) source for eggplant. The molecular weight of amino acids plays a significant role in soil-amino acid interaction (Metges, 2000). Amino acids of larger molecular weight show poorer adsorption with the soil particles because of high steric hindrance (Dippold, 2014).

Additionally, the use of synthetic and organic polymers can modify the adsorption of amino acid via the soil bed which in turn influences the nitrogen (N) and other nutrients uptake in plants (Tewatia et al., 2024). Polymer when added to soil has several benefits including minimal dose requirements, consistent solidification results, excellent environmental protection, and the ability to stimulate plant development. A significant amount of polymer is released into the soil either directly through sewage discharge or indirectly through a wastewater treatment plant (WWTP) because of the increasing residential use of laundry detergents (Fig. 1). Literature showed that integrating the polymer with soil is the best and environment-friendly soil improvement method (Zhu et al.,2019). Polyacrylamide (PAM), polyurethane (PU), polyethylene glycol (PEG), polyvinylpyrrolidone (PVP), polyacrylates, resin, polyvinyl alcohol (PVA), polyvinyl acetate (PVAc) and methylene diphenyl di isocyanate (MDI) are few examples of synthetic organic polymers that were used as soil modifiers in the past (Al-Atroush and Sebaey 2021; Zhang et al., 2022; Rajabi et al., 2023). But, the consequence of polymer on plant's nutrient uptake is still a knowledge gap.

To fulfill this gap, the present investigation deals with the application of a water-soluble organic polymer, Polyvinylpyrrolidone (PVP)and alanine in a sandy clay loamy soil to improve the soil's agricultural properties. PVP is a polymeric lactam and poly N-vinyl amide that has amphoteric properties and an internal acid bond (Hood, 2021). This polymer finds application as a pigment dispersant, bonding agent, blood plasma extender, and hairspray film-former (Gawade et al., 2020). PVP, due to the established soil-amino acid interactions, increased the nutrient uptake in eggplant and therefore, improved the plant growth. The experiment includes6 treatments in a randomized block design (RBD) in triplicate, i.e., three sets of replications.

Results

Laboratory analysis of the soil

The soil was analyzed for the physicochemical properties before the investigation and various parameters were observed for it (Table 1). The texture of the soil was observed by using the hydrometer method where sand, silt, and clay percentage in the soil was recorded as 70%, 6%, and 24% respectively. Therefore, as per the United States Department of Agriculture (USDA) soil texture classification, the soil was classified under the "sandy clay loamy" texture. The soil's electrical conductivity (EC) was recorded as 3.0 dS/m and pH was observed as 7.50 for the soil before the mixing of PVP. The moisture percentage was noted as 26% of the wet soil. Exchangeable cations were also studied and recorded for Na^+, K^+, Ca^{2+}, and Mg^{2+} as 0.80, 0.95, 8.50, and 2.26 respectively. The soil was

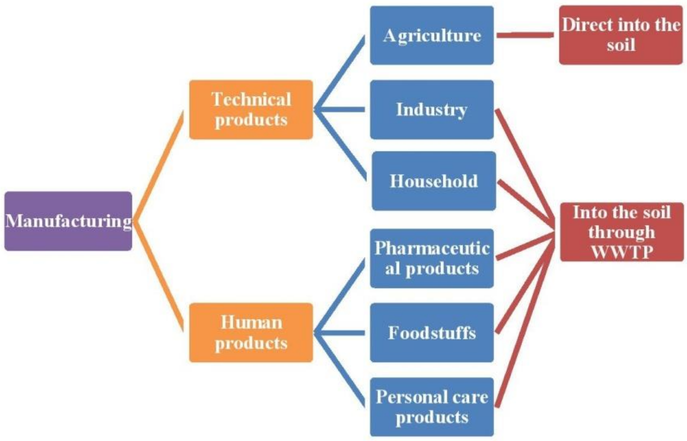

Fig. 1. Routes for potential transference of Poly vinyl pyrrolidone (PVP) into the soil.

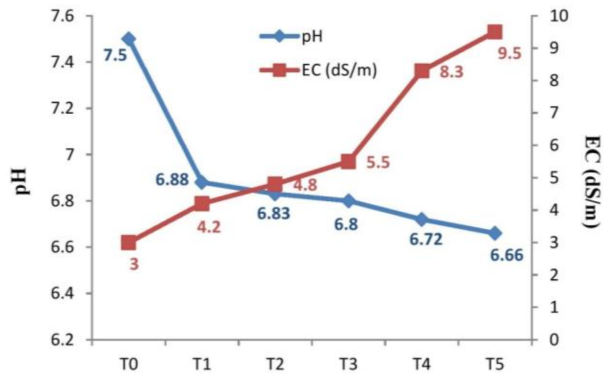

Fig. 2. Effect of pH and EC on sandy clay loamy soil amended with different concentrations of PVP.

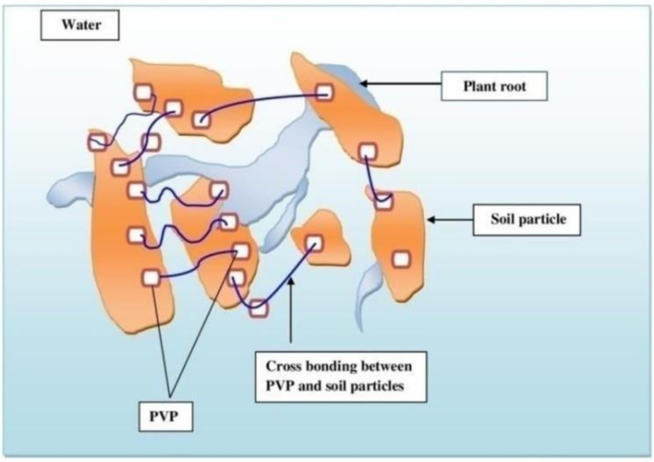

Fig. 3. Proposed interaction mechanism between PVP and soil particles.

mixed with different concentrations of PVP and alanine to conduct the experiment. Total six soil treatments, viz., T0 (control; 0 mg PVP + 0 M alanine/kg soil), T1 (0 mg PVP + 0.1 M alanine/kg soil), T2 (250 mg PVP + 0.1 M alanine/kg soil), T3 (500 mg PVP + 0.1 M alanine/kg soil/Kg soil), T4 (750 mg PVP + 0.1 M alanine/kg soil) and T5 (1000 mg PVP + 0.1 M alanine/kg soil) were studied. The variation in pH and EC were noted to record how the change in concentration of PVP in the soil affects the alkalinity and amount of dissolved salts in the soil. The data was summarized and demonstrated that the soil pH was determined as 7.50, 6.88, 6.83, 6.80, 6.72, and 6.66 for T0, T1, T2, T3, T4, and T5 respectively. However, the

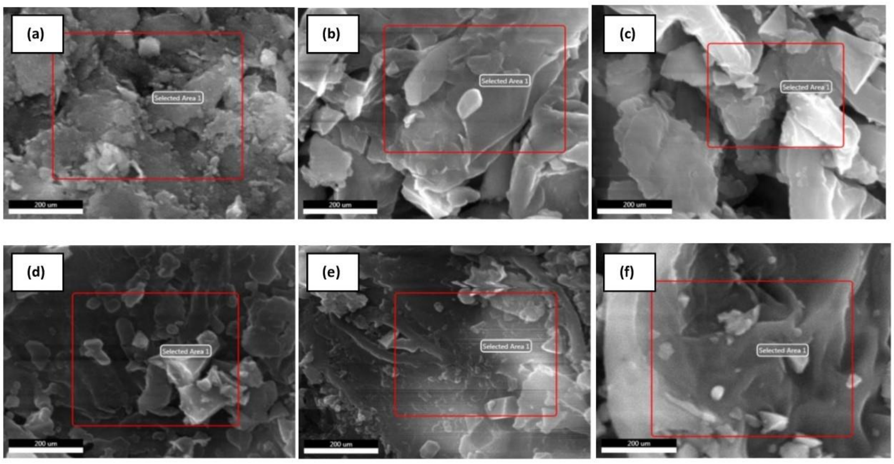

Fig 4. Images obtained in scanning electron microscopy analysisfor (a) T0 (control; 0 mg PVP + 0 M alanine/kg soil) (b) T1 (0 mg PVP + 0.1 M alanine/kg soil) (c)T2 (250 mg PVP + 0.1 M alanine/kg soil) (d) T3 (500 mg PVP + 0.1 M alanine/kg soil/Kg soil) (e) T4 (750 mg PVP + 0.1 M alanine/kg soil) (f) T5 (1000 mg PVP + 0.1 M alanine/kg soil).

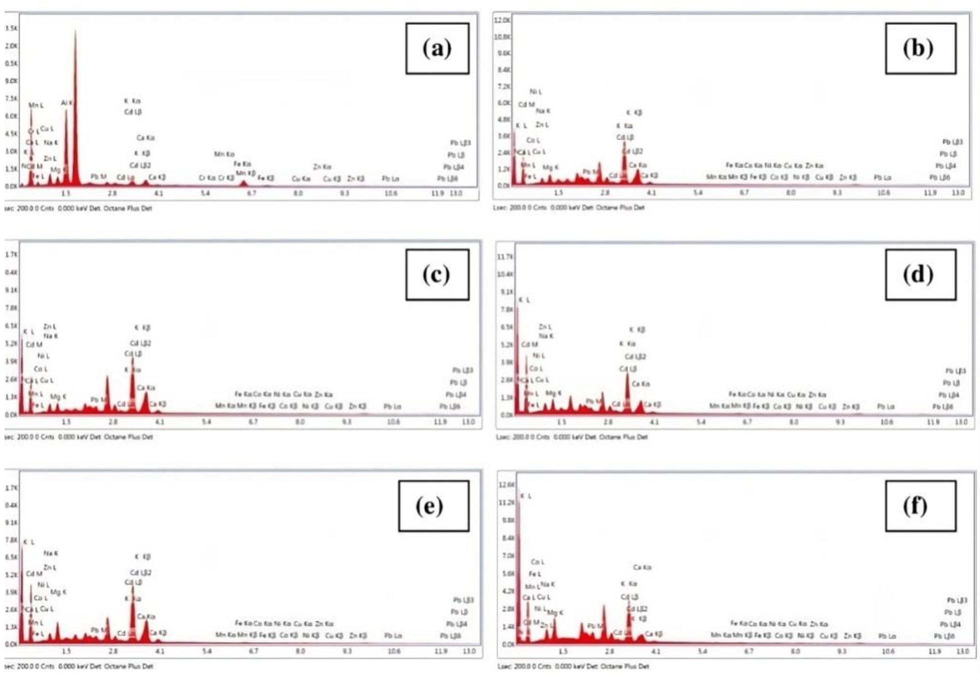

Fig. 5. Elemental analysis for (a) T0 (control; 0 mg PVP + 0 M alanine/kg soil) (b) T1 (0 mg PVP + 0.1 M alanine/kg soil) (c)T2 (250 mg PVP + 0.1 M alanine/kg soil) (d) T3 (500 mg PVP + 0.1 M alanine/kg soil/Kg soil) (e) T4 (750 mg PVP + 0.1 M alanine/kg soil) (f) T5 (1000 mg PVP + 0.1 M alanine/kg soil) obtained during energy-dispersive X-ray spectroscopy (EDS).

EC was recorded as 3.0, 4.2, 4.8,5.5, 8.3, and 9.5 respectively (Fig. 2). It can be concluded here that the soil was saline initially but the salinity was reduced after mixing PVP in the soil. Therefore, the control soil (T0) was obtained with the highest value of pH and the lowest value of EC. Interestingly, as the dose of PVP in the soil was increased, the soil pH was decreased while the EC was increased.

Study of soil-polymer interaction and characterization analysis

The established soil-polymer interaction contributed well towards the improved soil's agricultural properties. PVP with the hydrophilic amide group created a network that causes flocculation in soil particles. A mechanism of interaction between PVP and soil was also proposed (Fig.3). Such interactions proved to be beneficial for further elemental analysis and nutrient uptake in the plant. Adsorption of PVP on the soil carried a significant benefit for the plant growth. Energy-dispersive X-ray spectroscopy (EDS) and scanning electron microscopy (SEM) were used for the characterization analysis of the soil samples. SEM image obtained for control soil, T0, clearly indicated the presence of soil particles only and no evidence of the polymer was seen in the red-marked area (Fig.4a). However, the surface morphology for T1 illustrated the interaction between soil and polymer clearly (Fig.4b). Additionally, the changes in the morphological structure of soil can also be seen in T2, T3, T4, and T5.The adsorption of PVP on the soil surface can be well visualized with denser images obtained which were not obtained earlier for T0 (Fig. 4c-4f).Moreover, EDS was used successfully to find out the nutrients uptake in eggplant through various PVP-treated soil samples (Fig. 5).Nutrients value in the plant, grown in the soil with different doses of PVP, varied interestingly and tabulated in Table 3.

SPSS analysis

Effect of PVP-enriched sandy clay loamy soil on eggplant growth parameters

The experiment was conducted in three sets of replicates, therefore, three sets of results were obtained during the study. In terms of seed germination number, number of leaves, shoot length, and root length, as a result, a mean value was used for the result analysis (Table 2). The addition of PVP and alanine effectively increased the seed germination number, number of leaves, shoot length, and root length in eggplant ranged from 2 to 5, 4 to 12, 12.2 cm to 18 cm, and 7.3 cm to 14 cm respectively. T5 was observed with a significant and maximum plant height or shoot length (18 cm) thanT0 (12.2 cm). Thus, the treatment; T5significantly improved the plant height, whereas other treatments were statistically identical to the untreated one, T0. Similarly, the root length was obtained maximum in T5 (14 cm) followed by T4 (12 cm), and minimum in T0 (7.3 cm). The difference among all these treatments was statistically significant but with the exception of T1, T2, and T3. Moreover, the number of leaves was found to be maximum and statistically significant in T5 (12) when compared with T0 (4). Thus, the treatment T5 significantly increased the number of leaves, shoot length, and root length in eggplant. However, in the context of the seed germination number, the effect of PVP and alanine application was not significant.

Effect of PVP-enriched sandy clay loamy soil on nutrients uptake in eggplant

Table 3 demonstrated the effect of using PVP alone or with alanine on nutrient uptake in eggplant. The field examination data showed that three set of values were obtained for every nutrient and hence a mean value was calculated and used for the analysis. The nutritional value of various nutrients varied in a range. The study has some major findings. The maximum uptake of nitrogen (N) was observed inT5 (44.93%) which was significantly higher than the control; T0 (5.77%). Thus, the application of 1000 mg PVP + 0.1 M alanine(T5) significantly increased the N uptake, one of the main and essential macronutrients, in eggplant. Interestingly, other treatments were also found to be statistically significant with control. Likewise, Magnesium (Mg) was found to be highest in T5 (12.62%) and lowest in T1 (3.59%). The treatment T5 was significantly different from T0. Micronutrients like iron (Fe), copper (Cu), nickel (Ni), and Zinc (Zn) were found to be maximum in T5 (0.92%, 1.58%, 1.07%, and 1.18% respectively). Moreover, the differences were found to be statistically significant except for the case of Fe.

Discussion

Effect of PVP on sandy clay loamy soil's pH and EC

The decomposition of organic materials generates acids that react chemically with sparingly soluble salts, decreasing pH and increasing solubility (Blum and Eberl, 2004; El-Sharkawy et al., 2022). In this study, the addition of an organic polymer, PVP, combined with alanine, caused a decrease in soil pH due to the release of different acids, resulting in improved bioavailability of micronutrients as compared to using the amino acid alone in the soil. Moreover, the soil EC was increased from T0 to T5 which might be due to the increase of soluble or available salts in the soil as EC indicates the presence of salt in soil samples. However, the EC of soil was found to be negatively correlated with the soil pH. It could be observed from the result that soil pH affected the solubility of salts. The results were in close agreement with the previous research (Khan et al., 2021).

Effect of PVP-enrichedsandy clay loamy soil on eggplant growth and nutrient uptake

The addition of PVP to the soil had a positive impact on nutrient uptake and the plant growth, therefore significant increase of various nutrient uptake and other growth parameters was observed in T5 over the control (T0). The plant height was increased from T0 to T5, which might be due to the presence of high nitrogen (N) content in T5, which favored the vegetative growth of the plant (Nazar et al., 2015). The result of N uptake under various treatments were due to their diverse N content as well as the different rates of mineralization in the soil (Kuziemska et al., 2021). The polymer improved soil properties allowed the development of a greater root density which was responsible for the eggplant's nutrient-absorption capabilities and hence increased nutrient uptake in the plant (Wang et al., 2023). The N uptake in the plant, required for the plant growth, was also improved due to its involvement in different metabolic activities (Walia and Kler, 2010). As a vital component of plant physiology, nitrogen raises the plant's photosynthetic efficiency and, eventually, its production. Due to enhanced cell division and elongation, higher nitrogen levels cause plants to grow taller (Sharma and Brar, 2008). The highest value obtained for various growth parameters in T5wasalso possibly associated with the higher magnesium (Mg) content, whereas T0 showed the least plant growth as compared to the other treatments as Mg impacts various essential physiological and biochemical processes in higher plants, and its deficiency hinders the growth and development of plant (Xie et al., 2021).An interesting fact could be observed in this study that generally when the potassium (K) concentration increases, the magnesium (Mg) value decreases and vice versa. Because a high amount of K leads to inhibition in Mg uptake in plants (Tränkner et al.,2018).

The maximum uptake of micronutrients like iron (Fe), nickel (Ni), copper (Cu), and zinc (Zn) in T5 could be ascribed to the higher bioavailability of elements in soil, which improved their uptake in eggplant when compared to T0 (Saha et al., 2019). The breakdown of organic matter releases nutrients via several methods, increasing their availability in soil (Agbede, 2021). Ni and Cu are essential micronutrients for plants and significant for different physiological processes such as photosynthesis, seed germination, and plant growth. Many enzymes, including dehydrogenase, aldolase, isomerases, proteinase, peptidase, and phosphohydrolase require Zn as a necessary component (Mousavi, 2011). Fe contributes to the synthesis of enzymes and chlorophyll.

Fig. 6. Plant growth status (a) after 20 days (b) after 60 days of monitoring period.

Table 1. Physicochemical analysis of sandy clay loamy soilused in the investigation.

Parameters	**Value**
Sand	70%
Silt	6%
Clay	24%
Electrical conductivity (dS/m)	3.0
pH (1:5, soil: water)	7.50
Moisture percentage (wet soil)	26.00%
Exchangeable cations (Cmol/Kg soil)	
Na^+	0.80
K^+	0.95
Ca^{2+}	8.50
Mg^{2+}	2.26

Table 2. Effect of PVP-enriched sandy clay loamy soil on eggplant growth parameters.

Treatment	**seed germination number**	**number of leaves**	**shoot length (cm/plant)**	**root length (cm/plant)**
T0	2	4^{a}	12.2^{a}	7.3^{a}
T1	3	6^{ab}	13^{a}	9^{ab}
T2	3	8^{abc}	15^{ab}	10^{b}
T3	4	10^{bc}	15.5^{ab}	10.5^{bc}
T4	4	10^{bc}	16^{ab}	12^{c}
T5	5	12^{c}	18^{b}	14^{d}
Std. error (SE)	0.46	0.91	0.67	0.66
LSD (P=0.05)	7.98	3.58	3.97	1.10

In column, mean with a similar or dissimilar letter (s) was evaluated with the least significant difference (LSD) multiple range tests using a probability level of $p \leq 0.05$.T0 (control):0 mg PVP + 0 M alanine/kg soil, T1: 0 mg PVP + 0.1 M alanine/kg soil, T2: 250 mg PVP + 0.1 M alanine/kg soil, T3: 500 mg PVP + 0.1 M alanine/kg soil/Kg soil, T4: 750 mg PVP + 0.1 M alanine/kg soil and T5: 1000 mg PVP + 0.1 M alanine/kg soil.

The application of Zn and Fe significantly affects the plant height. As the micronutrient concentration increases from 0.3 to 0.5% the height of the plant increases generally. Zinc sulfate may affect plant height by influencing cell division, tissue activity, cell expansion, and cell wall development, in addition to chlorophyll synthesis (Basavarajeshwari et al., 2010). These findings are again in favor of enhanced plant growth in T5 and can also be correlated with the significant and maximum values obtained for the number of leaves, shoot length, and root length in T5.

Effect of soil-polymer interaction on eggplant growth

The analysis showed an established interaction between the polymer and the soil particles. The polymer increases soil pore connectivity and enhances aggregate stability by attaching itself to soil components through its molecules and cations like Ca^{2+}, Na^+, and Mg^{2+} (Mamedovet al., 2017). It is reinforced primarily through the reaction of hydroxyl groups or alkali nutrient ions in the soil with the polar amide groups on its long-chain macromolecules. This process decreases the width of the clay diffusion double layer and strengthens the bond between aggregate and soil particles (Fig. 3). Organic synthetic polymer modifiers with hydrophilic groups (such as hydroxyl, ether linkage, carboxyl, amino or amide) create a network that causes flocculation in soil particles (Huang et al.,2021). Such interactions prove to be beneficial for plant growth and nutrients uptake by plants (Lian et al., 2021). In this study also, the interaction between PVP and

Table 3. Effect of PVP-enriched sandy clay loamy soil on nutrient uptake (%) in eggplant.

Nutrient uptake (%)	Treatment							
	T0	T1	T2	T3	T4	T5	LSD (P = 0.05)	CV (%)
N	5.77^{a}	23.47^{b}	25.11^{c}	28.62^{d}	39.28^{e}	44.93^{f}	0.00	46.85
Mg	4.52^{c}	3.59^{b}	2.51^{a}	5.39^{d}	6.47^{e}	12.62^{f}	0.01	58.63
K	0.05^{a}	39.33^{f}	37.53^{e}	26.96^{b}	28.17^{c}	32.18^{d}	0.00	49.67
Ca	4.59^{a}	22.94^{e}	24.96^{f}	12.86^{c}	19.55^{d}	8.62^{b}	0.02	40.11
Mn	6.38c	0.15^{a}	0.47^{b}	0.33^{ab}	0.16^{a}	0.42^{ab}	2.62	179.66
Fe	0.74^{ab}	0.64^{ab}	0.68^{ab}	0.91^{b}	0.51^{a}	0.92^{b}	4.34	24.36
Ni	0^{a}	0.70^{c}	0.37^{b}	0.51^{bc}	0.33^{b}	1.07^{d}	1.06	71.07
Cu	0^{a}	1.31^{d}	1.38^{d}	0.28^{b}	0.58^{c}	1.58^{e}	0.24	73.27
Zn	0.82^{bc}	0.97^{d}	0.73^{b}	0.88^{cd}	0.25^{a}	1.18^{e}	0.43	37.12

In column, mean with a similar or dissimilar letter (s) was evaluated with the least significant difference (LSD) multiple range testsusing a probability level of $p \leq 0.05$. CV (%); coefficient of variation was calculated for all nutrients.T0 (control):0 mg PVP + 0 M alanine/kg soil, T1: 0 mg PVP + 0.1 M alanine/kg soil, T2: 250 mg PVP + 0.1 M alanine/kg soil, T3: 500 mg PVP + 0.1 M alanine/kg soil/Kg soil, T4: 750 mg PVP + 0.1 M alanine/kg soil and T5: 1000 mg PVP + 0.1 M alanine/kg soil.

soil carried a significant benefit for the plant and enhanced the essential nutrients uptake like nitrogen (N), magnesium (Mg), iron (Fe), nickel (Ni), copper (Cu) and zinc (Zn) along with the other plant growth parameters like seed germination number, number of leaves, shoot length, and root length (Aziz and Jawad, 2024).

Materials and methods

Site specifications and experimental design

The present investigation was conducted on soil collected from the location of village Dayalpur, Faridabad, Haryana (28° 30′ N,77° 38′ E and 247 m above mean sea level) from March to April 2024 (for 60 days). The region exhibited a semi-arid climate along with hot and pre-monsoon season. The experiment comprised 6 treatments in a randomized block design (RBD) in three sets of replications to study the effects of PVP and alanine on the growth of eggplant (*Solanum melongena* L.). Seeds of eggplant were bought from the certified "Bharat seeds and pesticides" of Faridabad district, Haryana, India. PVP K-30 was purchased from Sigma Aldrich (India). Alanine was bought from Central Drug House (P) Ltd., CDH (India). Initially, the soil's chemical properties were analyzed. Soil pH (soil: water, 1:5) was measured with an Ohaus pH meter model ST300-G bought from Sigma-Aldrich. Electrical conductivity (EC) of various soil samples (soil: water, 1:5) was determined using a conductivity cell (Hanna HI 8314, USA).

The soil was dried in a desiccator at room temperature, ground in a mortar, sieved through a 150µl sieve to maintain uniformity in particle size and finally, all the gardening pots, in three sets, were equally filled with 1 kg sandy clay loamy soil. Each set comprised of 6 pots labeled as T0 (control; 0 mg PVP + 0 M alanine/kg soil), T1 (0 mg PVP + 0.1 M alanine/kg soil), T2 (250 mg PVP + 0.1 M alanine/kg soil), T3 (500 mg PVP + 0.1 M alanine/kg soil/Kg soil), T4 (750 mg PVP + 0.1 M alanine/kg soil) and T5 (1000 mg PVP + 0.1 M alanine/kg soil) where 0.1 M alanine was prepared in pure distilled water. The pots were subsequently added with distilled water until around 60% of the soil could hold water. For every treatment, five dried and certified eggplant's seeds were sown. The pots were kept at 25-30°C and distilled water was added to regulate the moisture level regularly. After reaching the stipulated period of 60 days, the plants were manually harvested and rinsed with pure and distilled water thoroughly to remove any dust and dirt. One set of experiments has been demonstrated in Fig. 6. Later on, the soil and plant samples were collected for the further examination. In the current study, the physicochemical characteristics of sandy clay loamy soil such as pH, EC, sand, silt, clay percentage, exchangeable cations, uptake of N, Mg, K, Ca, Mn, Fe, Ni, Cu, and Zn by the plant were evaluated. The plant samples were also studied for growth parameters like seed germination number, number of leaves, shoot length, and root length manually.

Experimental characterization

Scanning electron microscopy (SEM) and Energy dispersive X-ray spectroscopy (EDS) were used to analyze the nutrient uptake and to perform the soil's morphological study respectively. The leaves from each pot, after the stipulated time, were dried for 2-3 days in natural sunlight and crushed in a mortar to make a fine powder before undergoing EDS and SEM studies. "JEOL Japan Mode: JSM 6610LV" of 1-30KV and x5 to x3, 00,000 magnification range was used for the investigation of soil's surface morphology and nutrients uptake with their weight percentage in the treated samples.

Statistical analysis

The experimental data was statistically analyzed using the Statistical Package for Social Science (SPSS) software version 16.0 (SPSS Inc., Chicago, USA) packages. Analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) were used in the study. The analysis determines whether the differences among the variables are significant or non-significant.

Conclusion

The use of PVP and alanine offered the double benefits of soil quality and plant growth, meeting the nutrients need of eggplant as well. The soil pH and EC were also varied with the application of organic polymer to the sandy clay loamy soil. From T0 to T5, the soil pH was decreased whereas the soil's EC was increased interestingly. Nutrient uptake for nitrogen (N), magnesium (Mg), iron

(Fe), nickel (Ni), copper (Cu), and zinc (Zn)was found to be maximum for T5. This treatment was also obtained with the highest values for seed germination number, number of leaves, shoot length and root length whereas these parameters were observed with the lowest values in case of T0. Overall, the soil treatment, T5, boosted the growth of roots, strengthened the shoot length, and promoted the photosynthetic rates thus improving the nutrient uptake in eggplant.

Acknowledgement
The authors are thankful to the department of Chemistry, Manav Rachna International Institute of Research and Studies, Faridabad, Haryana, India, for aiding the lab facilities for the research work.

Funding
The authors confirm that they did not receive any grants, funding or other forms of assistance for preparing this paper.

Ethical approval
The work has neither been published nor submitted in any other format or language elsewhere.

Competing Interests
The authors have no relevant financial or non-financial interests to disclose.

Authors' contributions
All authors contributed to the study's design and conception. Nisha Tewatia was in charge of material preparation, experimentation, and analysis. She also wrote the first draft of the manuscript. Dr. Shagufta Jabin has guided her throughout her efforts. She has also reviewed, edited, and finalized the manuscript for publication. Dr. Sona Gandhi and Dr. Jamal A. Khan assisted with the characterization and analysis of soil samples. All authors reviewed and approved the final manuscript.

Data availability
Data will be made available on request.

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