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Research Article

Impact of different mycorrhizal species and leaf extracts on nutrient content, fruit yield, and quality of Satluj Purple plum (*Prunus salicina* Lindl.)

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Abstract
Mycorrhizal fungi are symbiotic associations between plants and fungi that are a wonderful advantage to horticulturists. They enhance nutrient assimilation and promote overall plant growth, evaluating the impact of combining different mycorrhizal species and leaf extracts on fruit nutrients and plum quality. The present study sought to evaluate the impact of various mycorrhizal species- *Oidiodendron echinulatum* (MTCC No. 1356) (Oe), *Rhizophagus irregularis* (Strain no. MUCL57021) (Ri) and *Rhizophagus fasciculatus* (Strain no. OR563927) (Rf) in combination with leaf extracts (LE) on nutrient composition and quality factors of Satluj Purple plum. The study design employed a Randomized Block Design factorial arrangement with eight treatments (Control, LE- custard apple, citrus and guava leaf extracts @0.5%, Oe, OeLE, Ri, RiLE, Rf, RfLE) that had three replications. Among eight various treatments, Rf with custard apple, citrus, and guava leaf extracts (RfLE) had a beneficial effect on nutritional parameters, fruiting traits, yield, and quality traits of Satluj purple plum. Additionally, Oe with custard apple, citrus, and guava leaf extracts (OeLE) was significant following RfLE for fruit nutrient, yield, and quality determination. These mycorrhizal fungi and leaf extracts (RfLE) combinations showed enhanced nitrogen (2.83%), phosphorus (0.45%), and potassium (3.26%) absorption, indicating superior quality and nutrient content. Pearson's correlation also quantified the strength and direction of single treatments and variables, which indicated the direct and indirect effects of variables. Thus, the dual use of RfLE and leaf extract is useful not just for alleviating the nutritional value but also for enhancing the calibre of fruit quality of plum fruit.

Keywords: Fruit-quality, Leaf extract, Mycorrhiza, Nutrient uptake, *Prunus salicina*, Yield

INTRODUCTION

A temperate and subtropical world, stone fruit plums are members of the Rosaceae family, subfamily Amygdaloideae, order Rosales, and genus Prunus. Among all the stone fruits, it is the second most economically important fruit after peaches. It is a deciduous fruit crop that is grown in areas with hot winters and summers (Kaul *et al.,* 2024). Whereas 19–40 plum species occur worldwide, the European plum (*Prunus domestica* L.) and Japanese plum (*Prunus salicina* Lindl.) are the two commonly cultivated plums for commercial utilization. Chilling periods and ploidy levels required by the two Prunus species differ. Unlike the hexaploid (2n=6x=48) European plum, the Japanese plum is diploid (2n=2x=16). It is assumed that European plums originated from Asia Minor, while Japanese plums originated in China. Plum-producing areas are primarily found in China, the United States, the European Union, Serbia, Chile, and Romania (Tasneem *et al.,* 2024). Though being grown mainly in subtropical and temperate areas, a temperate-zone fruit crop, plums, is regarded. The nutritional value of these fruits includes vitamins K, C, and A, as well as potassium, antioxidant dietary fibre, and other essential minerals. Other bioactive agents like quercetin, tryptophan, and sorbitol also assist in supporting the physiological processes of the body (Xu *et al.,* 2024).

The extensive application of chemical fertilizers contaminates the environment and deteriorates the soil. Therefore, the application of new management methods has changed the global policy for establishing a sustainable agriculture system. Therefore, particular attention has to be paid to biological and integrated systems, especially biofertilizers, to meet the nutrient requirements of plants and reduce the application of chemical fertilizers (Agarwal *et al.,* 2018). Fungal mycorrhizae (AMF) and leaf extracts are of potential worth since they are organic, environmentally friendly, cheap, and also a source of macro- and microelements, vitamins, pro-enzymes, and growth regulators, and therefore play a vital role in sustainable soil fertility (Rasouli *et al.,* 2022).

Arbuscular mycorrhizal fungi like *Rhizophagus irregularis* (RI) and *Rhizophagus fasciculatus* (RF, formerly known as Glomus fasciculatum) establish vast symbiotic associations primarily with vascular plant roots to the benefit of both the partner organisms. They have acquired fixed carbon from their plant hosts, which is the product of photosynthesis. As a contribution, they provide mineral nutrients, viz., phosphorus and nitrogen, to stimulate an increase in the growth of the plant (Genre *et al.,* 2020 and Kokkoris *et al.,* 2024). A form of ericoid mycorrhizal fungus, *Oidiodendron echinulatum* (OE), is reported to stimulate growth in Ericaceae family plants (Bizabani *et al.,* 2016). One key role of ErM fungi is to help furnish nutrients to host plants and to reduce land poisoning (Leopold, 2016 and Baba et al., 2021). Such microbes play a vital part in plant nutrition, mainly in humus-poor soils that lack N, P, and other nutrients. They allow plants to mobilize phosphorus (P) that is unavailable and not absorbed in the growth medium. (Cobb, 2016). Generally, mycorrhizal symbiosis can be held accountable for the fertility of the soil and stabilization of soil structure when promoting plant water absorption, quality, and yield (Bona *et al*., 2017). Therefore, the quantity and quality of fruit crops can be enhanced by the application of bio-fertilizers.

Leaf extracts of custard apple, guava, and citrus crops find application in augmenting fruit crop yields since they contain secondary metabolites like flavonoids, alkyl ketones, and sesquiterpenes. Plants are treated with bioactive-enriched custard apple leaf extract, which is rich in antioxidants, to enhance their nutrient composition, thereby improving pest and disease resistance mechanisms and promoting increased growth with improved fruit quality (Zhu *et al*., 2020). Citrus leaf extract contains components such as essential oils (EOs), ascorbic acid, sugars, carotenoids, flavonoids, dietary fibre, polyphenols, and other microelements, which enhance its antimicrobial activity and help protect crops against fungal and bacterial infections (Maqbool *et al*., 2023). The extracts produce eco-friendly and sustainable approaches for enhancing the productivity of fruit crops and reducing their dependence on artificial chemicals. Natural biopesticide attributes of guava leaf extract are derived from its flavonoids and tannin compounds that can function without necessitating chemical application. The compound enhances both soil health and biological functions that lead to enhanced nutrient efficiency and enhanced crop production levels (Jamphol *et al.,* 2012). Most of the studies documented the effect of mycorrhizae on fruit growth and production, while others emphasized leaf extracts to enhance fruit quality. However, there are no findings in the literature on the use of mycorrhizal fungi combined with various leaf extracts to enhance the biochemical qualities of plum. In this regard, the present study aimed to evaluate the effects of a unique leaf extract (CCG, comprising custard apple, citrus, and guava) and mycorrhizal fungi species on the nutrient and biochemical profiles of plum.

MATERIALS AND METHODS

Experiment site

The study was conducted in October 2023 at the Government Garden and Nursery in Jalandhar Cantt, Punjab. A deep sandy loam soil exists at the site because of alluvial deposition, while slightly alkaline conditions with a pH of 7.9 feature moderate drainage. According to the data provided by the Meteorological Department of Lovely Professional University, the region has a hot, humid climate with cool winters and a hot, humid summer. In summer, temperatures range between 35°C and 39°C, occasionally exceeding 42°C in May and June, while winter brings the temperature down to 4°C–6°C during December and February. The region receives an average annual rainfall of about 703 mm with an elevation of 232 meters at the experimental location situated near 31.9 °N latitude and 75.6°E longitude. The study design utilized a Randomized Block Design factorial setup, including eight treatments, which had three replications, including a control group. The study was conducted on 24 five-year-old Satluj Purple plum plants to ensure reliable and consistent results.

Treatment details

The investigation included the soil application of three different mycorrhizal species (*Oidiodendron echinulatum*, *Rhizophagus irregularis*, and *Rhizophagus fasciculatus*) and foliar application of 0.5% concentration of leaf extracts of custard apple, citrus, and guava combined at a ratio of 1:1:1. The mycorrhizae *Oidiodendron echinulatum* (MTCC No. 1356) were collected from the Research Institute,Microbial Ty pe Culture Collection and Gene Bank (MTCC), Chandigarh and the stains of

Table 1. Treatment details of different mycorrhizal species and leaf extracts

Treatments	Notation	Quantity/plant
Control	C	No mycorrhiza and leaf extract
Custard apple, citrus and guava leaf extracts (CCG@0.5%)	LE	80 ml LE
Oidiodendron echinulatum	Oe	20g mycorrhiza
Oidiodendron echinulatum + CCG@0.5%	OeLE	20g mycorrhiza + 80 ml LE
Rhizophagus irregularis	Ri	20g mycorrhiza
Rhizophagus irregularis + CCG@0.5%	RiLE	20g mycorrhiza + 80 ml LE
Rhizophagus fasciculatus	Rf	20g mycorrhiza
Rhizophagus fasciculatus + CCG@0.5%	RfLE	20g mycorrhiza + 80 ml LE

Rhizophagus fasciculatus (OR563927) and *Rhizophagus irregularis* (MUCL57021) were collected from Seed2Plant and SOM Phytopharma Ltd., India, respectively.., India, respectively. An amount of 20g of mycorrhiza with a subordinate of 10kg of cow dung was applied to each plant in the orchard (Table 1). It was applied by removing the weeds and making a trench around the trees by digging soil up to 6 inches (Razouk *et al.,* 2016). The orchard had a spacing of 10ft ´10ft between plants and rows). Adequate water was supplied to the field after the mycorrhizal application.

Leaf extract preparation

For the preparation of leaf extracts, the leaves were washed with distilled water, then parched in an oven at 60°C and ground into a crude powder with a diameter of around 1 mm. Extraction was executed utilizing the maceration method in 96% ethanol solvent for 48 hours, employing the "intermittent shaking" method to get an extract. A rotary evaporator was applied to evaporate the extract at 50 rpm and 40°C until a concentrated extract was obtained. The concentrated extract was then laid down in a glass beaker, covered with aluminium foil, and stored in a refrigerator at 4°C to protect it from damage. The solvent used was Sodium carboxymethyl cellulose (CMC Na) with 1% concentration to obtain the extract with several concentrations (Solikhah *et al.,* 2020).

Observations

To evaluate the trees, the experimental ones were carefully marked in the field, and observations were made on fruit drop, quality, and yield. For the quality assessment, ten ripe fruits were randomly selected from each tree. The data on various characteristics, such as fruit set (%), fruit retention (%), fruit weight (g), fruit yield (kg/tree), ascorbic acid (mg/100g), anthocyanin content (mg/100g), total soluble solids (°B), titratable acidity (%) and total sugar (%) were recorded. The observations on fruit nutrient content (Nitrogen, Phosphorus, and Potassium) were also recorded and expressed in %. This comprehensive approach ensured a detailed analysis of the fruit's characteristics.

Fruit set %

Fruitlets (developed fruits) on the tagged branches were counted several weeks after pollination, often around 5 weeks or 10-14 days after bloom. The total fruit set of the plant was counted by multiplying the fruit set on a tagged branch by the total number of branches on the plant. (Deng *et al.,* 2022).

$$\text{Fruit set (\%)} = \frac{\text{Number of fruits set}}{\text{Total number of flowers}} \times 100 \quad \text{(Eq. 1)}$$

Fruit retention %

The number of fruits harvested at maturity per tagged branch was counted, and the total number of harvested fruits is calculated by multiplying the harvested fruits on a tagged branch by the total number of branches on the plant (Singh *et al.,* 2023).

$$\text{Fruit retention (\%)} = \frac{\text{Number of fruits harvested}}{\text{Number of fruit set}} \times 100 \quad \text{(Eq. 2)}$$

Fruit weight (g)

A digital balance with 0.001g accuracy was used to determine the fruit weight (Cerri *et al.,* 2019).

Fruit yield (kg/tree)

Plum fruits were harvested during the first week of June. The harvested fruits from the selected trees were weighed using a digital weighing balance and expressed in kg/tree (Kaur *et al.,* 2021).

Yield (kg/tree) = Total number of fruits x Average fruit weight (Eq. 3)

Fruit nutrient content

Mineral nutrition analysis was performed by thoroughly washing ripe fruits in tap water, using a labolene wash, and then rinsing with distilled water. The fruits were washed, air-dried overnight on newspapers, and subsequently oven-dried at 60°C. The materials were air-dried and then ground in a stainless steel blender and stored in polythene bags to be analyzed in more detail. The vanado-molybdo phosphoric yellow colour method was employed to identify phosphorus, and a double-beam ultraviolet-visible spectrophotometer was employed to measure the intensity of color at 440 nm. A Flame Photometer 130 (Systronics) was used to detect potassium. The micro-Kjeldahl method was employed to quantify nitrogen, which was further expressed as a percentage (Dar *et al.,* 2018).

$$N\% = \frac{14.01 \times 0.1N \times (\text{Titre Value} - \text{Blank Value})}{\text{Sample Weight} \times 1000} \times 100 \quad \text{(Eq. 4)}$$

Where,
14.01- Ammonia's Molecular Weight
0.1N- Titration Solution's Normality

Fruit biochemical attributes

TSS (total soluble solids), TA (titratable acidity), AA (ascorbic acid), and TS (total sugar) content of fruits were measured using Latimer's (2019) standard protocols. The determination of the anthocyanin content (AC) was performed as per method provided by Taghavi et al. (2022). The AA content was measured using the 2,6-dichloroindophenol titration method. TSS was assessed by placing 1–2 drops of plum juice on the prism of a digital refractometer. TA was determined by titrating the fruit pulp against 0.1N NaOH, with the results expressed as a percentage of acid. These methods provided accurate and reliable measurements of the fruit's key quality attributes. Owing to the dominance of malic acid in plum fruits, TA was estimated on the basis of the equivalent weight of malic acid (Xiao *et al.,* 2024). To measure TS, we added citric acid to the sample, then boiled the solution to ensure complete sucrose inversion (Dongariyal *et al.,* 2024).

Statistical analysis

The healthy samples of fruit were statistically analyzed using a significance of $p<0.05$. Statistical software OPSTAT and R Studio were used to analyze. Variations in treatments were also assessed using Tukey's HSD Test for their significance. Pearson's correlation coefficient was further computed to examine the correlation among different traits and how they influenced yield. Principal Component Analysis (PCA) was also run to further elucidate the data and determine primary patterns.

RESULTS AND DISCUSSION

The combination of leaf extracts of custard apple, citrus, and guava, along with mycorrhiza, has shown promising results towards the nutrient content and fruit quality of plum. The central hypothesis of the study was that mycorrhizal fungi inoculation in combination with custard apple, citrus and guava (CCG) leaf extracts would enhance the nutrient quality, yield, and biochemical characteristics of plum. The leaf extracts were rich in nutrients and also had bioactive compounds, which turned out to be beneficial for the plum plant. Moreover, mycorrhiza improved the overall quality of fruit trees by intensifying the ingestion of mineral nutrients.

Fruiting and yield parameters

Mycorrhizal and a combination of leaf extract applications have a significant impact on fruiting parameters. The highest fruit set percentage (46.43%) and fruit retention (67.51%) were found to be significant and highest in RfLE, closely followed by OeLE at 46.07% and 67.29%, respectively (Table 2). Mycorrhizal inoculation improved the overall quality of fruit trees by enhancing the uptake of mineral nutrients. This increase in nutrient absorption likely contributed to better fruit set and retention, ultimately reducing pre-harvest fruit drop (Ortas, 2017). The use of mycorrhizal inoculants boosted the Siam oranges produced during the low season. This improvement was attributed to an increase in the percentage of fruit set and the number of fruits per tree (Astiari *et al.,* 2019). The nutrients mainly N, P, K present in leaf extract enhance fruiting in plum through enhanced vegetative growth and floral development, since increasing doses of nitrogen have been used to substantially improve fruit set percentages in guava and other tree fruits. The leaf extract enhances plum fruit retention by minimizing fruit drop, likely through improved nutrition and health levels in the plants, as seen in guava, where higher NPK levels correlate with increased fruit retention (Popova *et al.,* 2020). Moreover, fruit weight was significant and approximately similar among RfLE, OeLE, and RiLE, but the highest fruit weight was attained in RfLE (35 g). Also, fruit yield was found to be significant in RfLE and OeLE, while the highest was observed in RfLE (68.52 kg/tree). Florida Prince peach treated with mycorrhiza showed a significant increase in nutrient content, weight, and yield of fruit (Soliman *et al*., 2017 and Alarcon-Zayas *et al.*, 2024). The NPK content in leaf extract improved fruit weight due to elevation of nutrient acquisition and translocation, resulting in higher synthesis of metabolites and dry matter buildup. Fruit yield is enormously improved by nutrient content, mainly NPK, to provide regular nutrition and encourage higher fruit output, as reported in plums and fruit crops in multiple research studies (Parameshwari *et al.,* 2022).

Nutrient content

The application of mycorrhiza and leaf extracts of custard apple, citrus, and guava has a significant impact on the nutritional content, particularly NPK (nitrogen, phosphorus, potassium) of plum fruits. NPK content of plum fruit as influenced by different treatments showed that nitrogen in plum fruit ranged from 1.36% to 2.83%. Nitrogen content was significant and found maximum (2.83%) in RfLE, while minimum nitrogen content of

Table 2. Impact of different treatments on fruiting and yield parameters of the plum plant

Treatments	Fruit set %	Fruit retention %	Fruit weight (g)	Fruit yield (kg/ tree)
C	36.82±0.17^{e}	57.42±0.35^{d}	31.82±0.27^{c}	34.99±0.15^{f}
LE	37.22±0.23^{e}	60.10±0.42^{cd}	32.00±0.26^{c}	37.87±0.19^{e}
Oe	38.27±0.20^{d}	61.61±0.57^{bc}	32.65±0.14^{bc}	42.59±0.26^{cd}
OeLE	46.07±0.16^{a}	67.29±0.35^{a}	34.92±0.29^{a}	66.80±0.32^{a}
Ri	37.91±0.16^{d}	60.68±0.49^{c}	32.18±0.23^{bc}	40.26±0.46^{de}
RiLE	42.73±0.23^{b}	63.41±0.49^{b}	34.12±0.14^{a}	55.12±0.25^{b}
Rf	39.54±0.22^{c}	61.74±0.50^{bc}	33.00±0.32^{b}	44.58±0.41^{c}
RfLE	46.43±0.17^{a}	67.51±1.56^{a}	35.00±0.22^{a}	68.52±1.60^{a}

All values of the parameters are the mean and error of three replications. The superscript letters represent the significance of the mean values at p<0.05; Abbreviations: Refer to Table 1

1.36% was recorded in the control treatment (Fig. 1). Phosphorus (P) levels was significant and approximately similar in OeLE, RiLE and RfLE in the fruit flesh of plum ranged from 0.13% to 0.45%, maximum P content was obtained in treatment RfLE treatment. The highest potassium content, 3.26%, was found significant in RfLE (Fig. 1), followed by OeLE (3.20%), while the minimum potassium content was obtained in C (2.00%). The application of leaf extracts positively influences NPK accumulation in fruits due to soil fertility enhancement by microbial activity and nutrient availability, root absorption efficiency for nutrients due to phosphorus, and efficient nutrient translocation from roots to plants by potassium (Kumar et al, 2021, and Tahir *et al.,* 2023). Mycorrhizal inoculation improved the overall quality of fruit trees by enhancing the uptake of mineral nutrients (Ortas, 2017). Florida Prince peach administered with mycorrhiza revealed a significant increment in nutrient content, weight, and yield of fruit (Soliman *et al.,* 2017).

The symbiotic fungi that grow with plant roots enable them to obtain essential soil nutrients, specifically phosphorus, which aids root growth and nutrient distribution within the plant. The use of mycorrhizal inoculation methods results in substantial percentage increases of nitrogen, phosphorus, and potassium levels (Lu *et al*., 2023 and Wu *et al*., 2023). The leaf extracts from custard apple, citrus, and guava plants contain bioactive components that contribute to enhancing nutrient availability within the soil. The extracts activate soil microorganisms while improving soil fertility, which results in better nutrient availability for plants (Kumar *et al*., 2021). Guava leaf extracts are also known to enhance phosphorus availability due to their high nutrient content (Singh and Singh, 2022; Galvez *et al.,* 2015). The combined application of mycorrhizae and these leaf extracts not only boosts the NPK levels in the plum plant but also promotes better growth.

Biochemical parameters

The content of AA, AC, TSS, TA, and TS in the fruit juice was determined at ripening. Different treatments were applied to influence the optimization of fruit flavour characteristics by improving some of the attributes of fruit quality, like AA, AC, TSS, and TS, combined with a drop in TA. The maximum AA (15.67 mg/100g) in fruit juice was significantly influenced by RfLE, while the minimum (10.67 mg/100g) was found in untreated fruit juice. The AC in fruit juice was significant and found maximum (126.20 mg/100g) in RfLE-treated fruits, followed by OeLE-treated fruits (126 mg/100g), while it was found to be the lowest AC content (122.68 mg/100g) in untreated fruits (Table 3). Mycorrhizal fungi enhanced anthocyanin accumulation in strawberry because of improvement in uptake of plant nutrients and modulating hormonal pathways, suggesting that mycorrhizal symbiosis could indirectly promote anthocyanin biosynthesis in plum through expression of key biosynthetic genes and enzyme activities (Chiomento *et al.,* 2021 and Niu *et al.,* 2017). The nutrients present in leaf extract may increase anthocyanin content in plum by promoting plant metabolic activities and enzyme processes involved in pigment biosynthesis, as observed through higher total soluble solids and better quality in corresponding fruit crops (Priya *et al.,* 2022).

TSS content of fruit juice was significant and approximately similar in RfLE (17.15°B) and OeLE treated fruits (16.20°B) which was significantly higher than the TSS content in C (8.45°B). TA was detected to be significantly lower in RfLE treated fruits (0.47%) that OeLE followed treated fruits (0.52%) compared with 1.05% of untreated fruits (Table 3). Melon fruit that was treated with *Rhizophagus sp*. contained the highest amounts of TSS and TA reduction (Benkebboura *et al*., 2024). The nutrient in leaf extracts, mainly K (potassium), is critical for sugar metabolism and translocation as K promotes enzymatic activity (e.g., invertase) that hydrolyzes su-

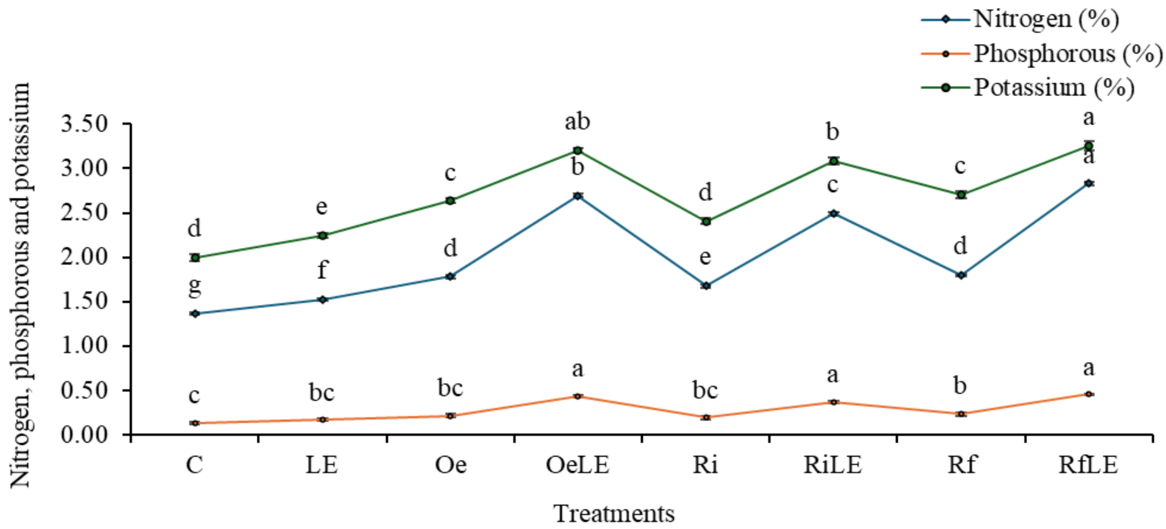

Fig. 1. *Impact of different treatments on fruit nutrient content of plum; Abbreviations: Refer to Table 1*

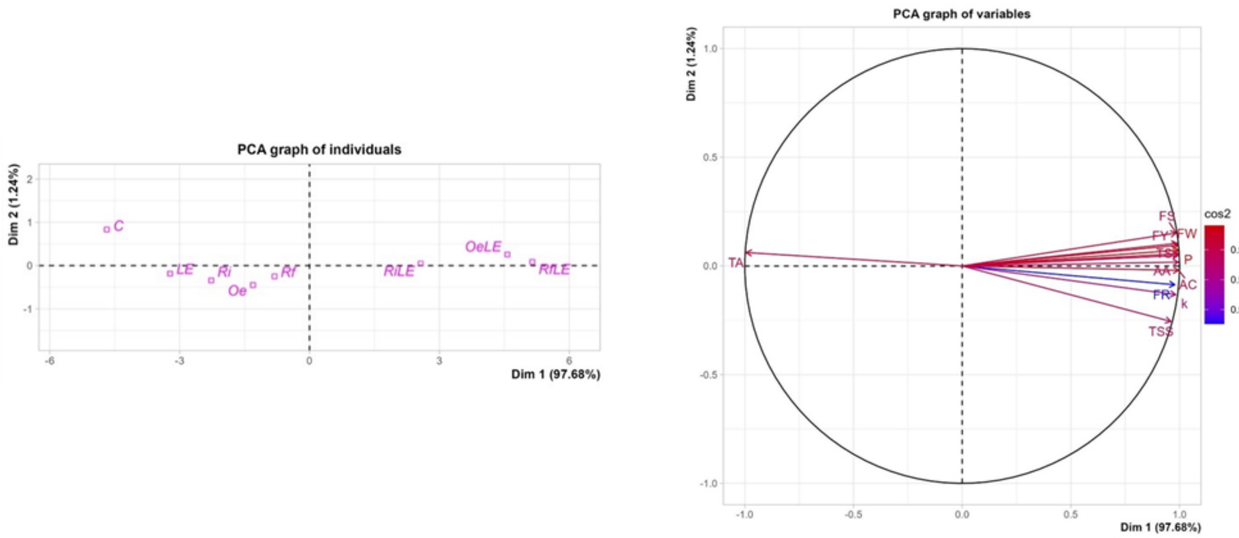

Fig. 2. *Principal component analysis of variables (observations) and individuals (treatment combinations). [N: Nitrogen (%); P: Phosphorous (%); K: Potassium (%); FS: Fruit set (%); FR: Fruit retention (%); FW: Fruit weight (g); FY: Fruit yield (kg/tree); AA: Ascorbic acid (mg/100g); AC: Anthocyanin content (mg/100g); TSS: Total soluble solids (^{o}B); TA: Titratable acidity (%); TS: Total sugar (%); C: No treatment; LE: No mycorrhiza + Custard apple, Citrus and Guava leaf extracts; Oe: Oidiodendron echinulatum + No leaf extract; OeLE: Oidiodendron echinulatum + Custard apple, Citrus and Guava leaf extracts; Ri: Rhizophagus irregularis + No leaf extract; RiLE: Rhizophagus irregularis + Custard apple, Citrus and Guava leaf extracts; Rf: Rhizophagus fasciculatus + No leaf extract; RfLE: Rhizophagus fasciculatus + Custard apple, Citrus and Guava leaf extracts]*

crose into glucose and fructose, elevating TSS. Thus, leaf extracts significantly increased TSS and RI by enhancing sugar accumulation and neutralizing organic acid by converting it to sugars (Priya *et al.,* 2022 and Tabassum *et al*., 2018). The TS content in fruit juice was notably impacted by the application of various treatments (Table 3). The utmost content of total sugar (7.63%) was observed with the fruit juice treated with RfLE treatment (Table 3), being closely followed by OeLE0.5 (7.57%), and recorded minimum in C fruits (6.17%). The inoculation of AM (arbuscular mycorrhiza) fungi in papaya significantly improved TS (Martin *et al*., 2017). Nutrients present in leaf extracts, mainly N, enhance chlorophyll synthesis and photosynthetic efficiency, increase carbohydrate production, and lead to an improvement in total sugar accumulation (Souza *et al*., 2024).

Principal component analysis

The Principal Component Analysis (PCA) output reflects a strong clustering of variables and individuals. The PCA plot of individuals shows distinct separation between various treatments, where principal component 1 (Dim 1) accounts for 97.68% of the variation,

Table 3. Impact of different treatments on biochemical parameters of plum

Treatments	Ascorbic acid (mg/100g)	Anthocyanin content (mg/100g)	TSS (°B)	Titratable acidity (%)	Total sugar (%)
C	10.67±0.60^{e}	122.68±0.17^{f}	8.45±0.17^{d}	1.05±0.17^{a}	6.17±0.17^{e}
LE	11.00±0.52^{de}	123.07±0.23^{e}	11.75±0.23^{c}	0.97±0.23^{ab}	6.38±0.23^{de}
Oe	12.50±0.66^{c}	124.03±0.20^{c}	12.80±0.20^{c}	0.81±0.20^{cd}	6.59±0.20^{cd}
OeLE	15.33±0.73^{ab}	126.00±0.16^{a}	16.20±0.16^{a}	0.52±0.16^{ef}	7.57±0.16^{ab}
Ri	11.67±0.51^{d}	123.52±0.16^{d}	12.55±0.16^{c}	0.89±0.16^{bc}	6.52±0.16^{cd}
RiLE	14.67±0.94^{b}	125.40±0.23^{b}	14.80±0.23^{b}	0.58±0.23^{e}	7.37±0.23^{b}
Rf	12.67±0.65^{c}	124.30±0.22^{c}	12.85±0.22^{c}	0.79±0.22^{d}	6.63±0.22^{c}
RfLE	15.67±0.65^{a}	126.20±0.17^{a}	17.15±0.17^{a}	0.47±0.17^{f}	7.63±0.17^{a}

All values of the parameters are the mean and error of three replications. The superscript letters represent the significance of the mean values at $p<0.05$; Abbreviations: Refer to Table 1

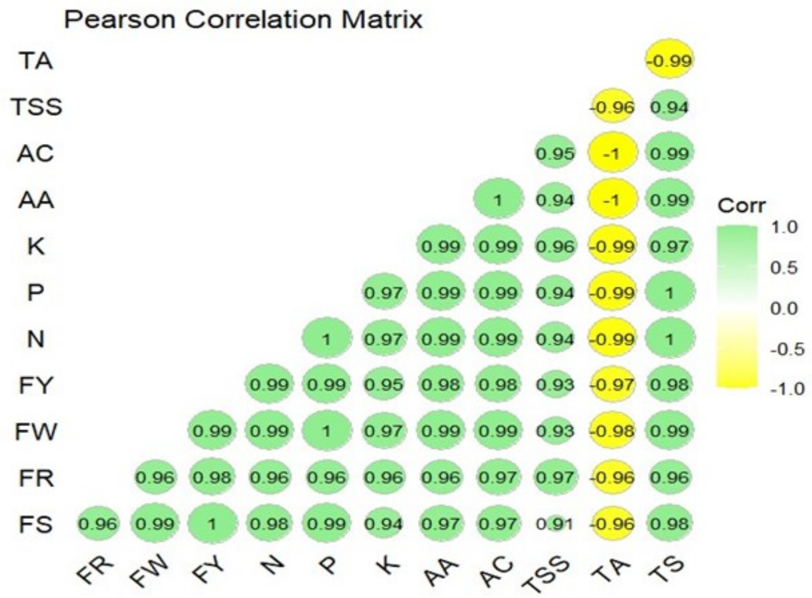

Fig. 3. *Pearson's correlation matrix [N: Nitrogen (%); P: Phosphorous (%); K: Potassium (%); FS: Fruit set (%); FR: Fruit retention (%); FW: Fruit weight (g); FY: Fruit yield (kg/tree); AA: Ascorbic acid (mg/100g); AC: Anthocyanin content (mg/100g); TSS: Total soluble solids (^{o}B); TA: Titratable acidity (%); TS: Total sugar (%)]*

and Dim 2 only contributes 1.24%. Labels reflect varying groupings of treatments based on their principal component values. PCA graph of variables indicates high correlations between variables like fruit set (FS), fruit yield (FY), fruit weight (FW), total soluble solids (TSS), phosphorous (P), anthocyanin (AC), and other biochemical parameters, which are predominantly along Dim 1, reflecting their major contribution to variability. Titratable acidity (TA) is uniquely located along the negative axis of Dim 1, reflecting its negative correlation with other variables. The large cos2 values show that the majority of variables are well explained in the first principal component (Fig. 2). Combined, these findings indicate that Dim 1 is the main driver of variation in individuals and variables, explaining almost all the information in the data set.

Pearson's correlation

The Pearson correlation matrix shows the correlation between different physiological and biochemical strawberry parameters. All variables have strong positive correlations (nearly 1), which indicates that the rise in one parameter is linked with the rise in others. Parameters related to fruit like fruit set (FS), fruit yield (FY), fruit weight (FW), and fruit retention (FR) have nearly perfect correlations among themselves, reflecting their mutual dependence in fruit productivity determination (Fig. 3)). In the same vein, biochemical characteristics like total soluble solids (TSS), anthocyanin (AC), and ascorbic acid (AA) also have strong positive correlations, mirroring their cumulative effect on fruit quality. However, titratable acidity (TA) exhibits strong negative correlations with all variables except for TA itself (e.g., -0.99 with TSS and -1 with AA and AC), indicating that higher acidity levels are associated with lower sweetness and anthocyanin levels. These results are consistent with the PCA results, further validating that major variables that contribute to fruit yield and quality are grouped, whereas TA is a contrasting variable in the dataset.

Conclusion

The present study highlighted the significant role of mycorrhizal inoculation (*Oidiodendron echinulatum*, *Rhizophagus irregularis* and *Rhizophagus fasciculatus*) and leaf extracts in enriching the chemical content, yield, and nutritional value of Satluj Purple plum, particularly in sub-tropical areas where environmental stress limits productivity. Synergistic combination of the most effective *Rhizophagus fasciculatus* + custard apple, citrus, and guava leaf extracts resulted in maximum nutrient uptake (NPK), yield, and fruit quality, thereby improving the fruit palatability. These positive effects are caused by enhanced water and nutrient acquisition, which is important to maintain productivity under water-deficient and low-fertility conditions. The research confirms the hypothesis that mycorrhizal fungi and leaf extract combinations improve plum yield, nutrient concentration, biochemical attributes, and marketability. More studies would be required to determine the best combinations of mycorrhizal species and leaf extracts to be applied on a commercial basis.

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Conflict of interests

The authors of this paper disclose that they have no competing interests.

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