Research Article

# Iron and Sulfur Foliar application: The Key to Enhance Peach (*Prunus persica* L.) Fruit Yield and Quality

**Faizan Fida[1], Irshad Ali Khan[2]*, Mehran Gul[2], Sidra Ahmad[3], Nayab Ahmad[3], Gajian Saleem[1], Abdul Moaiz[1], Ayesha Alam[4], Sajid Ali[1] and Abdur Rehman[5]**

*[1]Department of Horticulture, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; [2]Department of Agriculture, The University of Swabi, Khyber Pakhtunkhwa, Pakistan; [3]Institute of Biotechnology and Genetic Engineering, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; [4]Department of Botany, Government Post Graduate College Dargai, Malakand, Pakistan; [5]Department of Soil and Environmental Sciences, ARI, Tarnab, Peshawar, Khyber Pakhtunkhwa, Pakistan.*

**Abstract** | Peach growers often struggle with low productivity and poor fruit quality which can have a significant impact on the profitability of their operations. These issues are of major concern for the peach fruit industry on commercial basis. For improving the production and quality of peach, the experiment was conducted at Horticulture Farm, The University of Agriculture, Peshawar Pakistan, during 2021. Randomized Complete Block Design (RCBD) was used in the experiment with 3 replications. Peach trees were sprayed with 12 concentrations of Iron and Sulfur (0+0, 100+0, 300+0, 0+500, 0+1000, 0+1500, 100+500, 100+1000, 100+1500, 300+500, 300+1000 and 300+1500 ppm) after 10 days of fruit set. Peach trees treated with Iron and Sulfur at the rate of 100+1500 ppm reported maximum leaf area (50.54 $cm^2$), leaf chlorophyll content (42.66 SPAD), fruit weight (160.90 g), fruit volume (160.07 $cm^3$), fruit yield $tree^{-1}$ (86.33 kg), fruit firmness (6.20 kg $cm^{-2}$), Total Soluble Solids (TSS) (12.40 °Brix), titratable acidity (0.73%) and less percent of infected fruits (15.15%). While maximum fruit juice pH (4.97) and fruit ascorbic acid content (5.60 mg $100g^{-1}$) were recorded in fruits sprayed with iron and sulfur were applied at the rate of 100+1000 ppm in combination. It can be concluded from the present research that iron and sulfur applied at the rate of 100+1500 ppm enhances the productivity and quality of peach.

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***Correspondence** | Irshad Ali Khan, Department of Agriculture, The University of Swabi, Khyber Pakhtunkhwa, Pakistan; **Email:** irshad_1242000@yahoo.com
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## Introduction

Peach growers frequently encounter pre harvest problems such as fruit drop, disease attack, leaf chlorosis and pest infestation. Peaches can be affected by a variety of diseases including viral and fungal infections. These diseases can potentially lead to the destruction of an entire peach plantation (Hartman, 2007). Nutrient deficiency is a common cause of reduced fruit production and poor fruit quality in peaches. It is essential to maintain a balanced nutrient level in order to successfully grow and produce high quality peaches. Peach (*Prunus persical* L.) is one of the stone fruit belongs to family Rosaceae. Peach is originated from China. Peach history goes back to 4000 BC (Ahmed *et al*., 2022). In terms of nutritive value peach is very important fruit having fats (0.3 g), proteins (0.9 g), vitamins C (6.6 mg), carbohydrates (9.5 g), iron (0.25 mg) and potassium (190 mg) (USDA Nutrient Database, 2011).

In Pakistan, peaches are the second most important fruit in the stone category, after plums. Total area under peach production in Pakistan is 15.2 thousand hectares with 52.6 thousand tons of peach fruit. In Khyber Pakhtunkhwa province, area under peach production is 5.6 thousand hectares with 30.8 thousand tons of fruits (MINFA, 2019). Pakistan is to produce very few peaches as compared to other major peach-producing nations. Deficit in certain nutrients is one of the factors causing the output gap. In deficient nutrients iron is one of the most limiting nutrient in plants. Iron is deficient due to little solubility of the oxidized form (Zuo and Zhang, 2011). Symptoms of insufficient iron in plants are the under developed roots and yellowing of young leaves. In waterlogged soils, due to low redox potential iron concentration may rise. In crop plants iron deficiency is a common nutritional disorder which causing poor nutritional value and reduced yield. Iron is important for preservation of chloroplast structure and function, and is involved in chlorophyll synthesis. High amount of iron is present in the lithosphere, it also present in soil but its bio availability in neutral pH is not sufficient. Excessive amount of iron is toxic for plants. Root acidity or blackening are the symptoms of plants receiving excess amount of iron (Snigdha *et al*., 2021). In soil iron exists in $Fe^{3+}$ chelate form. Therefore, in many physiological conditions like high soil pH plants cannot absorb it. Consequently, the plants grown in high soil pH has problems in the development of chlorophyll, and resulting reduced growth and poor yields (Cesco *et al*., 2010).

Along with iron, sulfur is another essential element which immensely affects the fruit quality and production. Sulfur is essential for plant growth and development (Bonato and Silva, 2003). Sulfur scarcity is reported in most of the soils, although 90% sulfur present in soil as in organic form. Mostly sulfur is losses from the soil due to volatilization (Oliveira *et al*. 2014). Crops grown in sulfur deficient soils shows reduced growth, yield and quality (Schonhof *et al*., 2007). Mainly sulphate ($SO_4^{-2}$) is the available form of sulfur in soil. Sulfur can also be taken from the leaves in the form of foliar spray (Zenda *et al*., 2021). If sulfur is sufficiently provided to plants, then plants are able to prevent pathogen attack with the help of releasing hydrogen sulphide through leaves (Salac *et al*., 2005). Application of nutrients through foliar spray is beneficial for fulfilling plant nutritional requirements and it also increases plant growth and development (Inglese *et al*., 2002). It also interacts with phytochemical constituents of plant and can increase their properties (Rahman *et al*., 2022; Ahmad *et al*., 2024). For correcting nutrient deficiencies in plants foliar spray is the fastest method and an easy way to provide high soluble fertilizers in a very little amount (Saykhul *et al*., 2014). Hence, the study aimed to assess the impact of iron and sulfur, both individually and in combination, on the production and quality of the peach variety Early Grand.

## Materials and Methods

*Experimental site*

The present study was carried out at the Horticulture Research Farm of the University of Agriculture Peshawar, which is located in the Peshawar Valley of Pakistan. The climate of the region is classified as semiarid and sub-tropical, with hot, prolonged summers and severe winters. March is the wettest month, averaging 78mm of rainfall, while June is the driest at 7mm (Sajid *et al*., 2022; Gilani *et al*., 2021). The region's subsoil consists of boulders, gravels, and layers of sand, clay, and silt, with valley deposits of sand, silt, and pebbles from recent geological times. The maximum wind speed in the area reaches 35 km/h (Basit *et al*., 2022).

*Experimental design and plant material*

The research trail was carried out using Randomized Complete Block Design (RCBD) with one factor having 3 replications. Peach plants was sprayed with different combination of iron and sulfur along with a single control. Different iron levels contain (100 and 300 ppm) and sulfur levels contain (500, 1000 an 1500 ppm).

*Parameters studied*

Leaf area was measured by selecting 5 randomly leaves in each treatment and area was measured with the help of leaf area meter (SYSTRONICS, Leaf Area Meter-211). Leaf chlorophyll content was measured by selecting 5 randomly leaves in each treatment and chlorophyll was measured with the help of Soil Plant Analysis Development chlorophyll meter (SPAD) (Ahmed *et al*., 2022). For finding fruit weight the weight of 5 randomly selected fruits were measured by digital weight balance in grams and then averaged. Fruit volume was measured by selecting 5 randomly fruits in each treatment and volume was measured with the help of water displacement method. Water was taken in one liter graduated beaker and the selected fruits were dipped in the beaker. Water displaced from the beaker was used to calculate volume of the fruit with the following formula.

$$Fruit\ volume\ = Final\ reading\ - Initial\ reading$$

Fruit yield tree$^{-1}$ was find out with the help of balance from selected trees in each treatment and then their averages were taken. A specific protocol was used to determine fruit firmness provided by Pocharski *et al*. (2000). Pressure tester (Penetrometer) was used. 5 fruits were taken from each treatment randomly. A little part of peel was removed from peach with the help of peeler then penetrometer was inserted in the fruit. Reading was noted when the tip of penetrometer was reached to the soft tissue of the fruit. Hand refractometer (Kernco, Instruments Co. Texas) was used to measure Total soluble solids (TSS) of peach fruits. 5 fruits from each treatment was selected for finding TSS. A drop of peach juice was placed on the glass prism of refractometer and reading was noted. For each reading glass prism was cleaned with the help of tissue paper. Fruit juice pH was measured with the help of pH meter. 5 fruits from each treatment was selected for finding pH of peach fruits. Juice was prepared from peach fruits of each treatment and pH meter was placed in it and reading was taken. For each reading tip of pH meter was properly cleaned. To find the titratable acidity, the typical analyzed procedure of Feldsine *et al*. (2002) (now called AOAC international was used.

Percent titratable acidity was measured with the help of given formula.

$$\text{Titratable acidity (\%)} = \frac{\text{FxTxNx100}}{\text{SxD}} \text{ x 100}$$

Whereas; F= Constant acid factor 0.067 (in case of citrus acid), T= Titration reading, N=Normality of NaoH (0.1), S=Volume (ml) of diluted taken sample for titration (10ml), D= Volume (ml) of taken sample for dilution (10ml), To find ascorbic acid content, dye method was used (Vahid, 2012). Vitamin C was calculated by using the following formula.

$$\text{Ascorbic Acid contents} = \frac{\text{T x F x 100}}{\text{D x S}} \text{ x 100}$$

Whereas; T= Dye solution utilized from burette (ml), F= Constant dye factor (0.11), D=Taken fruit juice for dilution (10ml), S= Taken diluted sample for titration (10ml).

The percent disease fruit was visually examined in each replication for every treatment in a way that fruits shows symptom of disease, and its percent was noted and calculated against total fruit harvest.

$$\text{\% diseases fruits} = \frac{number\ of\ diseased\ fruits}{Total\ number\ of\ fruits} \times 100$$

*Data analysis*

Data were analyzed using Statistix 8.1 software, following the Randomized Complete Block Design (RCBD) as outlined by Hossam *et al*. (2022). The least significant difference (LSD) test at 1% and 5% significance levels was employed for mean comparisons when differences were significant (Steel and Torrie, 1980).

## Results and Discussion

The experiment evaluated the effects of iron and sulfur on the production and quality of peach (*Prunus persica* L). All experimental data were recorded, and results were discussed with possible clarifications provided under specific headings.

*Leaf area and chlorophyll content*

Foliar application of Fe and S significantly influenced the leaf area and chlorophyll content of peach (Figure 1). However, plants sprayed with Fe and S in combination @ 100 and 1500 ppm showed maximum leaf area (50.54 cm$^2$) and chlorophyll content (42.66 SPAD). Whereas the minimum leaf area (36.86 cm$^2$) was recorded in peach plants sprayed with Fe (100 ppm) and lowest leaf chlorophyll content (32.46 SPAD) was observed in leaves of control treatment.

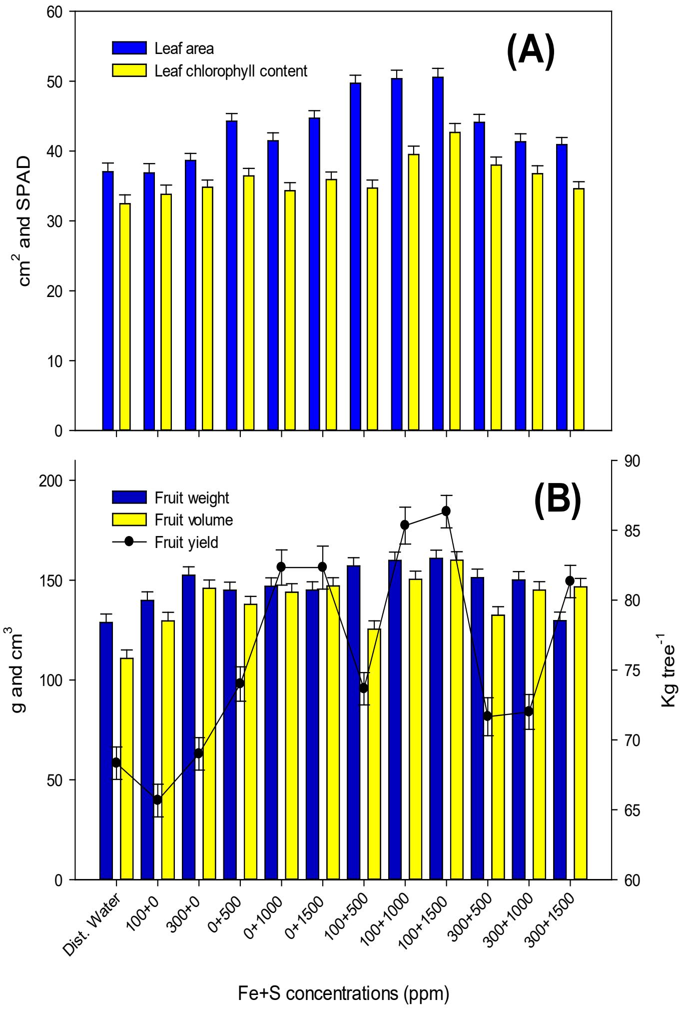


**Figure 1:** *Leaf area (cm$^2$), leaf chlorophyll content (SPAD), fruit weight (g), fruit volume (cm$^3$) and fruit yield tree$^{-1}$ (kg) of peach as affected by foliar application of iron (Fe) and sulfur (S).*

Increase in iron and sulfur increased the leaf area of the plants, this might be due to the role of these elements as a cofactor in a variety of proteins. Iron is a vital mineral for plants, as a result iron availability has a substantial impact on plant growth and yield (Balk and Pilon, 2011). In plant cells, the chloroplasts and mitochondria require the most of the iron (Forieri *et al*., 2013). Iron application improved the leaf area in peach trees as compared to control treatments (El-Jendoubi *et al*., 2014). After nitrogen, phosphorus and potassium, sulfur (S) is a macro element that is necessary to plants and is regarded as the fourth most important element (Lewandowska and Sirko, 2008). Plants need sulfur to make S-containing amino acids like cysteine, cystine, and methionine, which are important components of protein and account for over 90% of sulfur in plants (Jassim *et al*., 2020). So, due of the presence of sulfur, plants may have more nutrients availability, which could explain why they have more leaf area. Sulfur application significantly increased N, P, K, and S in the peach leaves (Al-Aareji *et al*., 2009). The present results are supported by (Mostafa, 2008) who stated that leaf area is the most significantly noted data regarding the growth and vigor of the vines by using sulfur.

Iron is required for the regular functioning of metabolic processes including electron transport, respiration and photosynthesis, as well as chlorophyll biosynthesis, in terms of metabolic functions (Gyana and Sahoo, 2015; Ahmad *et al*., 2024). Many people believe that iron is an essential cofactor in the formation of chlorophyll since iron shortage in plants causes severe chlorosis of the leaves (Roosta *et al*., 2017). Iron plays a vital role in the chlorophyll biosynthesis pathway. Iron deficiency may reduce fruit yield (Guo *et al*., 2020). Micro-nutrients such as iron, zinc and boron, are important for improving tree production and fruit quality (Suman *et al*., 2017). Sulfur deficiency reduced photosynthesis by lowering the rate of photosynthesis per unit chlorophyll and decreasing the chlorophyll content which declined linearly with leaf sulfur. Because of the strong link between sulfur and nitrogen, sulfur shortage will disrupt nitrogen metabolism (Paula *et al*., 2022). Leaf chlorophyll content was increased by applying micronutrients containing iron in peach fruits (El-Sheikh *et al*., 2007). Leaf chlorophyll concentration is strongly connected with iron floral concentration as well as K, Zn, and Na leaf concentrations in peaches (Zarraek *et al*., 2005).

*Growth and yield attributes of peach fruit*

Iron and sulfur foliar application significantly influenced fruit weight, volume and yield per tree of peach (Figure 1). Maximum fruit weight (160.90 g), fruit volume (160.07 cm$^3$) and fruit yield tree$^{-1}$ (86.33 kg) were noted in trees sprayed with iron and sulfur in combination at the rate of 100+1500 ppm. Whereas minimum fruit weight (128.8g), fruit volume (110.77 cm$^3$) and fruit yield tree$^{-1}$ (65.66 kg) were noted in trees of control treatment.

Iron, which is involved in respiration, photosynthesis and the electron transport chain could be one of the reasons for the increase in peach fruit weight (Kroh and Pilon, 2020). Iron is necessary for chloroplast structure and function and plays a crucial role in chlorophyll production (Rout and Sahoo, 2015). Iron deficiency has negative impact on plant growth which reduces plant production. Iron deficiency causes a decrease in peach fruit quality and output (Fernandez et al., 2003). Foliar application of iron enhanced strawberry fruit weight considerably (Bakshi et al., 2013). Sulfur essential for the synthesis of protein, enzymes, vitamins and chlorophyll could be a reason to increase in the fruit weight of peach (Soetan et al., 2010). Sulfur requirements vary widely among plant species ensuring enough and balanced sulfur nutrition is critical for their productivity, quality and health (Zhao et al., 2008). Sulfur is essential for plant metabolism, as it is found in the amino acids cysteine and methionine, and in glutathione, which helps eliminate free radicals and inactivate heavy metals (Colovic et al., 2018). The present findings confirmed the results of Pathak and Mitra (2008) who observed that plant treated with sulfur produced maximum fruit weight as compared to control or untreated one. Foliar application of iron enhances the concentration of micronutrients which may be the reason for high fruit weight (El-Sheikh et al., 2007).

Iron plays a crucial part in plant growth acting as a cofactor for over 140 enzymes and being involved in chlorophyll synthesis, thylakoid development and chloroplast development (Marschner, 2012). Fruits serve as a powerful sink absorbing more photosynthetic elements than other plant organs from the source (mostly leaves). Iron help to increase the photo assimilates production during photosynthesis process thereby increase the fruit size (Talaie, 2008). Foliar application of nutrients such as Fe and sulpur is effective in meeting plant requirements and in promoting plant growth and development (Inglese et al., 2002; Hossain et al., 2024). The use of sulfur and iron expressively improved fruit volume in peach fruits (Jassim et al., 2020). Sulfur application at the rate of 1500 ppm significantly increased the fruit size of olive fruits (Ali et al., 2020). Foliar application of sulfur also increased the fruit size of pecan and increased its productivity (Wells, 2014). Berry volume was increased by the application of iron sulphate in grapes. It might increase the chlorophyll content in leaf which is associated with high production of photosynthates in plant (Ali et al., 2021).

Iron fertilization positively impacts fruit yield due to its essential roles in processes such as chlorophyll biosynthesis, protein synthesis, nitrogen fixation, electron transport, and enzyme structure for nitrate absorption (Marschner, 2012; Al-Bamarny et al., 2010; Hamouda et al., 2016). Enhanced photosynthesis rates in plants lead to increased fruit production. The above-mentioned roles of Fe in plants as well as its availability in appropriate quantities by foliar spray may be contributing factors to increased yield (Abdi and Hedayat, 2010; Shahid et al., 2023). Use of sulfur and iron expressively improved fruit yield tree$^{-1}$, especially at 750gm sulpur tree$^{-1}$ and 100 mg Fe L$^{-1}$ in comparison to control (Jassim et al., 2020). Many researchers described the significance of sulfur in increasing growth and yield of various grapevine cultivars (El-Akkad, 2004).

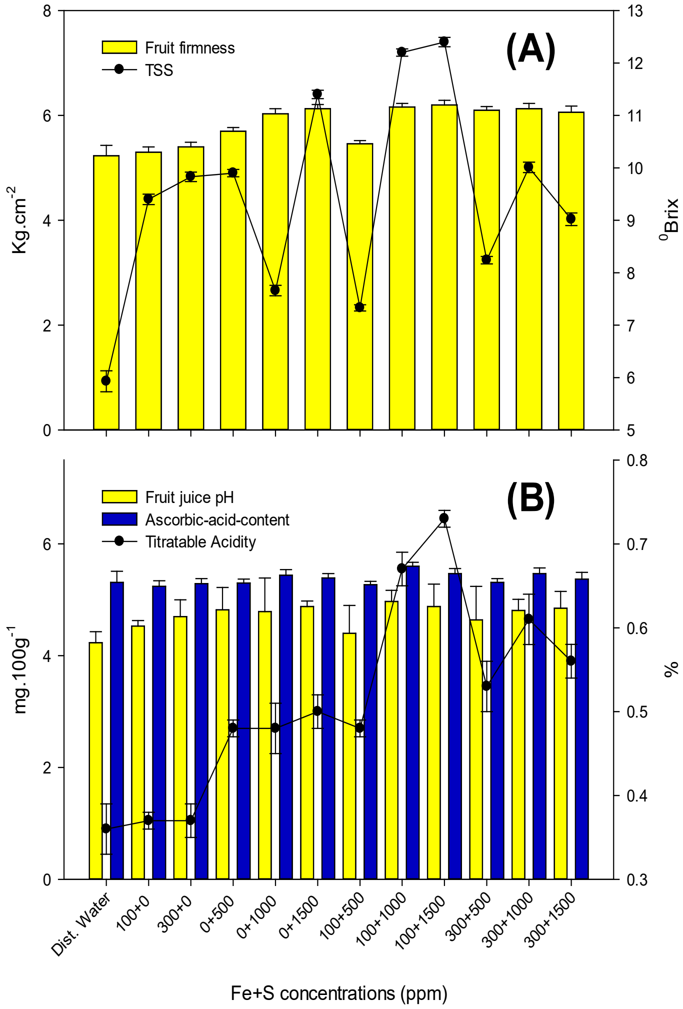


**Figure 2:** *Fruit firmness (kg cm$^{-2}$), Total soluble solids ($^{0}$Brix), Fruit juice pH, Titratable Acidity (%), Ascorbic-acid-content (mg 100g$^{-1}$) of peach as affected by foliar application of Iron (Fe) and Sulfur (S).*

*Biochemical attributes*

Fruit firmness, total soluble solids, fruit juice pH, titratable acidity and ascorbic acid content were significantly influenced by foliar application of iron and sulfur (Figure 2). However, maximum fruit firmness (6.20 kg cm$^{-2}$), total soluble solids (12.40 °Brix) and titratable acidity (0.73%) were recorded in peach trees sprayed with iron and sulfur in combination at the rate of 100+1500 ppm while highest fruit juice pH (4.97) and ascorbic acid content (5.60 mg 100g$^{-1}$)

were noted in peach trees which were sprayed with iron and sulfur application at the rate of 100 and 1000 ppm respectively which were statistically at par with fruit juice pH and ascorbic acid content of peach plants sprayed with Fe +S at 100+1500 ppm. Whereas minimum fruit firmness (5.23 kg $cm^{-2}$), total soluble solids (5.93 °Brix), fruit juice pH (4.23) and titratable acidity (0.36%) were observed in fruits of peach trees which were kept as control treatment and minimum ascorbic acid content (5.24 mg 100 $g^{-1}$) was recorded in peach trees sprayed with Fe (100 ppm).

The improved internal physiology of the developing fruit in terms of water, nutrients, and other compounds important for their appropriate growth and development may have contributed to the increase in fruit firmness as a result of foliar application of micronutrients (Dutta and Banik, 2007). Iron sulphate application improved the yield and quality of peach fruit (El-Sheikh *et al*., 2007). Iron and zinc application significantly increased the fruit firmness and lycopene content in cucumber (Kazemi, 2013). Improved fruit firmness of peach fruits may be due to the role of Sulfur in the synthesis of vitamins, enzymes, proteins and chlorophyll content (Soetan *et al*., 2010). Balanced Sulfur nutrition is required for better production, quality and health of peach (Zhao *et al*., 2008).

The increase in TSS after Fe applications could be attributed to adequate Fe provided by foliar spraying resulted in an increased photosynthesis rate. Because sugars are the primary products of photosynthesis which increased TSS resulted from increased photosynthesis (Abdi and Hedayat, 2010). The reason for the increase in total soluble solids when sprayed these elements could be due to their role in increased cell division and chlorophyll content. Because of their role in photosynthesis efficiency increasing manufactured elements in leaves move to the fruit may increase the components and improve their properties (Eiada *et al*., 2013). TSS may have increased due to changes in pectins and starches, as well as the formation of simple sugars during ripening when different enzymes were active (Hussain *et al*., 2019). Sulfur treatments enhanced total soluble solids and lowered total acidity in grapevine berries (Mostafa, 2008).

Fruit juice pH of peach is enhanced with the application of iron and sulfur because these elements play a vital role in the metabolic activities. Iron is essential for carbohydrate metabolism and fruit quality (Gyana and Sahoo, 2015) as it enhances cell division, chlorophyll content, and photosynthesis. This leads to an increase in the materials produced in leaves, which improves fruit components and properties (Eiada *et al*., 2013). Iron application increased the fruit juice pH, total soluble solids and percent acidity in tomato fruits (Kazime, 2013). Judicious use of Sulfur according to the requirements of the plant improves the growth as well as quality parameters. Sulfur increases the photosynthesis in plants ultimately improving the plants quality and growth (Zhao *et al*., 2008).

Iron fertilization enhances juice titratable acidity by increasing the juice ascorbic and citric acid (Hamouda *et al*., 2016). Iron and sulfur sprays may increase titratable acidity due to their effects on various enzymes which are involved in the formation of proteins, acids, and sugars (Zenda *et al*., 2021; Gyana and Sahoo, 2015). These nutrients play a role in the synthesis of tryptophan, a precursor for the synthesis of indole acetic acid, which is involved in the fruit's growth and development (Kazemi, 2013). Sulfur availability increases the rate of photosynthesis which might be the reason for more titratable acidity. The application of micronutrients containing iron and sulfur improved the percent acidity, total soluble solids, and TSS/acid ratio in olive (Hassan, 2000). The increase in titratable acidity from Fe fertilization aligns with previous studies (El-Shewy and Abdel-Khalek, 2014; Mirzapour and Khoshgoftarmanesh, 2013; Ghayekhloo and Sedaghatpoor, 2015).

The rise in ascorbic acid content is linked to Fe's role in supporting protein and enzyme functions necessary for pigment biosynthesis and photosynthesis (Mohammadi *et al*., 2018). Foliar application of these nutrients may enhance their absorption and translocation, thereby aiding cellular activity and promoting chlorophyll formation, which boosts photosynthesis (Khayatnezhad *et al*., 2021). Thus, better quality of peach may be due to the greater supply of food and more cellular activity. Iron and sulfur application significantly increased the ascorbic acid content, TSS and total sugar content of Kinnow (Kazi *et al*., 2012). Iron sulphate and zinc sulphate increased growth and quality parameters of strawberry including ascorbic acid content (Chaturvedi *et al*., 2005).

*Percent infected fruits*

The statistical analysis of the data showed a significant variation for percent infected fruits of peach by foliar application of Fe and S (Table 1). Minimum percent infected fruits (15.15%) were recorded in the trees which were sprayed at Fe and S @ 100 and 1500 ppm which were which were statistically at par with percent infected fruits (18.96%) of peach plants sprayed with Fe +S at 100+1000 ppm. While maximum percent infected fruits (29.64%) was observed in trees of control treatment. Decrease in percent infected fruits may be due to the contribution of iron and sulfur in improving fruit quality parameters. Iron is vital for the enzymes catalase and peroxidase, which participate in oxidation-reduction reactions (Singh, 2003; Havlin *et al*., 2005). It plays a crucial role in various enzymes that activate physiological processes in plant cells (Marschner, 2012). Sulfur helps manage certain diseases and pests and enhances plant resistance to heavy metals (Zekri and Obreza, 2013). Together, these elements boost photosynthesis and growth. However, iron deficiency negatively impacts fruit quality, yield, and can even result in tree death (Dawood, 2008; Kessel, 2006).

**Table 1:** *Percent infected fruits of peach as affected by foliar application of iron (Fe) and sulfur (S).*

| Foliar application of Fe & S (ppm) | Percent infected fruits |
|---|---|
| Dist. water spray | 29.64 A |
| 100 | 27.61 AB |
| 300 | 27.46 AB |
| 500 | 23.60 ABC |
| 1000 | 20.28 CD |
| 1500 | 19.20 CD |
| 100+500 | 21.65 BCD |
| 100+1000 | 18.96 CD |
| 100+1500 | 15.15 D |
| 300+500 | 19.56 CD |
| 300+1000 | 24.50 ABC |
| 300+1500 | 22.47 BC |
| $LSD_{\alpha\ 0.01}$ | 6.5454 |
| $LSD_{\alpha\ 0.05}$ | -- |

*Means within a table followed by the same letter are not significantly different by LSD test (P < 0.01 and 0.05).*

## Conclusions and Recommendations

The experiment confirmed that the combined foliar application of iron and sulfur improves the production and quality of peach (*Prunus persica* L.). Combine application of iron and sulfur @ 100 and 1500 ppm respectively improves leaf area ($cm^2$), leaf chlorophyll content (SPAD), fruit weight (g), fruit volume ($cm^3$), fruit yield tree$^{-1}$ (kg), fruit firmness (kg cm$^{-2}$), total soluble solids (TSS) (°Brix), titratable acidity%, fruit juice pH, ascorbic acid content (mg 100g$^{-1}$) and percent infected fruits therefore it is concluded from the significant results of the present research that iron and sulfur should be applied in a combination of 100 and 1500 ppm to improve growth, production and quality of peach.

## Novelty Statement

This study uniquely demonstrates the synergistic effect of foliar-applied iron and sulfur on enhancing both yield and fruit quality traits in peach under field conditions in Pakistan. It identifies the optimal concentration (100+1500 ppm) for significantly improving physiological and biochemical parameters, providing a practical solution for commercial peach growers.

## Author's Contribution

**Faizan Fida**: Conceived the idea, designed the methodology, and wrote the first draft.
**Irshad Ali Khan**: Supervised the research work.
Mehran Gul and Abdul Moaiz: Contributed to data analysis.
**Ayesha Alam and Sajid Ali**: Assisted in writing the initial draft.
**Sidra Ahmad and Nayab Ahmad**: Performed proofreading and editing.
**Gajian Saleem**: Critically revised the manuscript.
**Abdur Rehman**: Contributed to language editing.
All authors reviewed and approved the final version of the manuscript.

*Generative AI or AI-assisted Technology Statement*

The author(s) declare that no Genrative AI was used in the creation of this manuscript.

*Conflict of interest*

The authors have declared no competing interests.

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