**Effect of Foliar Application with Potassium Nitrate and Copper Sulfate on Fruit Yield and Quality of Pear (Pyrus communis L.) Trees**

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**ABSTRACT**

Influence of foliar application of potassium nitrate and copper sulfate on the production and quality of Pear cv. Le Conte was carried out at Horticulture Research Farm and Postharvest Laboratory, The University of Agriculture Peshawar-Pakistan, during the year 2018–19. The aim of the study was to get quality pear production with minimal disease incidence. The research was carried out in a randomized complete block design with three replications. The study contained two factors, i.e., different concentrations of potassium nitrate (0%, 1%, 2%, and 3%) as Factor A, while different levels of copper sulfate (0%, 0.2%, 0.4%, 0.6%, and 0.8%) as factor B and the treatments were applied in spring season at the fruit set stage. The application of 2% potassium nitrate to the pear plants resulted in heaviest fruit (188.30 g), maximum fruit volume (203.80 cm$^3$), fruit yield tree$^{-1}$ (60.13 kg) with minimum fruit drop (8.52%) and disease incidence (5.28%), while maximum fruit firmness (7.66 kg.cm$^{-2}$), total soluble solids (12.40 °Brix), fruit juice pH (5.38), ascorbic acid content (5.56 mg.100 g$^{-1}$) while minimum Titratable acidity (0.41%) were noted in fruits of plants sprayed with 3% potassium nitrate solution. However, the maximum fruit weight (192.04 g), fruit yield tree$^{-1}$ (59.06 kg), minimum fruit drop (6.75%), and disease incidences (3.54%) were recorded in pear plants applied with 0.6% foliar copper sulfate solution. However, maximum fruit firmness (7.53 kg.cm$^{-2}$), total soluble solids (12.38 °Brix), fruit juice pH (5.31), ascorbic acid content (5.22 mg.100 g$^{-1}$) with minimum Titratable acidity (0.42%) were noted in the plants sprayed with 0.8% copper sulfate solution. This study will provide a basis for high yield and quality fruit production, which will affect the storability of pear and other important fruit crops. Further studies should be conducted to optimize the dose, timing, and method of application of these fungicides for other pome fruits.

**KEYWORDS**

Pear; foliar spray; potassium nitrate; growth; stress tolerance; copper sulfate; pear scab; post-harvest quality

**Introduction**

Pear (Pyrus communis L.) is one of the most important crops of Rosaceae family. It is a pome fruit, which is grown in districts of the temperate climatic conditions. Pear trees are mostly multiplied through Whip and cleft grafting techniques on the rootstock of wild Batangi cultivar in Pakistan. Quince is used as worldwide rootstock for its multiplication (Chaudhary, 2009). China’s annual pear production is more than any other country in the world (Statista, 2021). In the case of Pakistan, surprisingly, pear production is not that much as compared to other countries. It is commercially

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grown on an area of 1697 hectares with 15.642 thousand tons production year\(^{-1}\) (MNSFR, 2018-19). Pear fruit contains 15.46 g carbohydrates, 0.12 g fats, 0.38 g proteins, 9.80 g sugars, 83.71% water, 4.20 mg vitamin C, 119 mg potassium, 11 mg magnesium, 7 mg iron, and 0.10 mg zinc (USDA, 2011).

Adequate soil nutrients in the soil play an important role for the healthy pear trees and quality pear fruit production. Nitrogen is essential for vegetative and floral growth of pear trees. Similarly, phosphorus is required for the normal cell division, growth, and establishment of sugar-phosphate molecules. Potassium is indispensable for increasing resistance to different pathogens and insect pests; it also regulates water uptake and improves fruit quality. The optimal quantity of macro and micro nutrients in soil is the basic requirement for quality pear production (Saleem et al., 2018). In Pakistan, established pear trees of 10 years or above are fertilized FYM 25 kg tree\(^{-1}\), N 500 g, and 1 kg each of P and K per bearing tree/year for maximum fruit yield. However, micro nutrients are seldom applied. Moreover, excessive fertilization causes damage to trees and exposes pear trees to fungal diseases that severely affect their yield and production worldwide. Pear scab (Venturia pirina) is the most common and lethal pathogen which severely declines fruit yield and quality (Hibberd et al., 1996; Percival and Boyle, 2005; Sabri et al., 1997; Villalta et al., 2004). To avoid such fungal diseases of pears, regular utilization of fungicides is mandatory to sustain commercial pear production to meet the needs of consumers (Percival et al., 2009). Many commercial fungicides such as lime sulfur, captan, wettable sulfur, and Bordeaux mixture are used to get rid of pear diseases. However, these applications are hazardous to human health. Therefore, alternate sources of fungicides are necessary to discover to get rid of the pear diseases and to increase quality pear production with minimal use of synthetic fungicides (Agostini et al., 2003; Gozzo, 2003; Percival and Haynes, 2008; Schnabel and Parisi, 1997; Schneider et al., 1996; Stanis and Jones, 1985).

Application of potassium and copper-based fertilizers can serve as an alternative to synthetic fungicides and can help in quality fruit production of pear without having adverse effects on the environment. Foliar application of potassium nitrate significantly promoted yield and quality in stone fruits (Lester et al., 2006). Spray of potassium in peach caused noticeable improvement in the total soluble solids content and fruit appearance (Mimoun et al., 2008). Potassium nitrate also promotes and expands the fruit size by causing cell expansion and increase in fruit weight by adjusting the osmosis phenomena (Ruiz, 2005). Potassium nitrate has an important role in plant assimilate preparation and its transportation to the different tissues of plant and hence straightly affiliated to fruit setting and adjusting fruit ratio (Harhash and Abdel-Nasser, 2010; Khayyat et al., 2012; Shahin, 2007). Copper plays an important role in the photosynthesis, functioning of several enzymes, seed development, and production of lignin, which gives physical strength to stem and shoots (Ram and Bose, 2000). Copper is an antimicrobial agent and is effective against the common foodborne disease-causing bacteria, such as Salmonella enterica and Campylobacter jejuni (Faúndez et al., 2004). Copper also has antagonistic effects against food deteriorating microorganisms, such as yeast and molds (Weaver et al., 2010).

The present study aimed to investigate the effect of foliar application with potassium nitrate and copper sulfate to improve the yield and fruit quality of pear trees. The main objectives of the research were to increase quality pear production and minimize the injurious effects of synthetic fungicides. Our study will provide basis and insights for further research in other pome fruits species.

Materials and Methods

Experimental Site

The present study was carried out during 2018 and 2019 spring seasons at Horticulture Research Farm (34.0206° N, 71.4814° E) and Post-Harvest laboratory, Department of Horticulture, The University of
Agriculture Peshawar. Ten-year old trees of pear cv. Le Conte budded on Batangi (Pyrus pashia) rootstock used in this study. Soil samples were collected randomly from 15 cm deep core for nutrient analysis.

Physio-chemical properties of soil taken at a depth of 15 cm.

| Determination                  | Attributes   |
|--------------------------------|--------------|
| Nitrogen (%)                   | 0.054        |
| Phosphorous (mg kg⁻¹)          | 9.00         |
| Potassium (mg kg⁻¹)            | 110          |
| Organic matter (%)             | 0.83         |
| pH                             | 7.3          |
| Texture class                  | Clay loam    |

**Experimental Procedure**

The experiment was laid out in randomized complete block design (RCBD) with factorial arrangement having two factors, replicated three times. Pear trees were sprayed with four levels of potassium nitrate (0%, 1%, 2%, and 3%) and five levels (0%, 0.2%, 0.4%, 0.6%, and 0.8%) of copper sulfate after fruit set stage (berry size fruits) in the spring, and in the control treatments, the pear trees were treated with distilled water. The foliar application was done by using a carbon dioxide propelled spray pump having TJ 60–8002VS flat fan nozzles (TeeJet Technologies, Wheaton, IL, USA) at the rate of 240 L ha⁻¹. Other cultural practices such as irrigation and fertilization were kept uniform for all treatments. Total numbers of treatments were 60. The fruits were harvested in the first week of August, and the following parameters were studied:

**Physical and Chemical Characteristics**

**Fruit Weight (G) and Fruit Yield Tree⁻¹ (kg)**

The fruit after harvesting from each tree was weighted with a digital balance, in the same way, for single fruit weight, it was measured by using digital balance with random fruit selection for each treatment and replication, and then, means were calculated.

**Percent Fruit Drop Percentage (%)**

It was calculated by relating the total number of fruits that were harvested with the fruits harvested initially by using the equation.

\[
\text{Fruit drop} \% = \frac{\text{No. of initial fruits} - \text{No of final harvested fruits}}{\text{Total no. of initial fruits}} \times 100
\]

**Disease Incidence (%)**

The diseased fruits were counted in each replication for each treatment, and their percentage was taken out against total harvested fruits by using the relation

\[
\text{Disease incidence} \% = \frac{\text{No. of affected fruits}}{\text{Total no. of fruits}} \times 100
\]

**pH**

The juice was extracted from each treatment in each replication then the pH was determined by the standard method of AOAC (2012) by using pH meter.
**Fruit Volume (cm³)**
The volume of each pear fruit was measured using the water displacement method. Each fruit was submerged in a container full of water, and the volume of displaced water was directly measured using a 250 cm³ graduated cylinder. Water temperature during measurements was maintained at 25°C.

**Fruit Firmness (kg.cm⁻²)**
It was measured with the help of Penetrometer. A small section of fruit peel was removed, and penetrometer nob was inserted gently into the fruit and the value was recorded. The process was repeated three times, and the averages were taken.

**Total Soluble Solids (°brix)**
The total soluble solids (TSS) were measured by the standard method of AOAC (2012). Briefly, the TSS was determined through hand refractometer. The refractometer prism surface was cleaned with distilled water and dried with tissue paper. A drop of juice was put on prism, and the reading was taken by looking through the eyepiece, and the soluble sugar was expressed in °Brix.

**Titratable Acidity (TA)**
Titratable acidity was determined by the standard method of AOAC (2012), where juice samples were titrated against 0.01 N NaOH and reading was recorded when color change to light pink.

**Ascorbic Acid Content (mg.100 g⁻¹)**
The standard method of AOAC, (2012) was used to determine the ascorbic acid of pear fruits. The titration was started against dye, and the reading was recorded when the sample changed into pink light color.

**Statistical Analysis**
The data collected were analyzed through a statistical software named Statistix 8.1, and the least significant differences were calculated at 5% level of significance (P ≤ .05) (Jan et al., 2009).

**Results and Discussion**

**Single Fruit Weight (g)**
Data analysis revealed that application of potassium nitrate and copper sulfate significantly affected the fruit weight of pear, while their interaction showed a non-significant difference (Table 1). Fruit weight showed that fruit tree sprayed with 2% potassium nitrate recorded maximum fruit weight (188.30 g), closely followed by (187.20 g) found in fruit tree sprayed with 3% potassium nitrate, while the minimum fruit weight (153.67 g) was recorded in 0% potassium nitrate (control) treatment. Mean values in the case of copper sulfate levels also showed significant differences. Pear fruit plants supplied with 0.6% copper sulfate concentration recorded maximum fruit weight (192.04 g), followed by fruit weight (185.71 g) in pear trees supplied with 0.8% copper sulfate concentration, while minimum fruit weight (156.71 g) was recorded in control pear fruit plants. The increase in fruit weight may be due to potassium availability, which enhanced the stream of sucrose to the apoplast resulting in increased sugar transportation to the sink tissues and hence promoted the fruit growth (Taiz and Zeiger, 2004). A similar finding was also reported by Gill et al. (2012) in pear who reported that fruit weight was enhanced by foliar sprays of potassium nutrient. Copper sulfate is required for photosynthesis as it was involved in electron transport chain. So, the plants deficient in copper have less enzymatic activities, which results in low carbon fixation and hence show stunted growth and less yield in pear fruits (Bergmann, 1992).
Table 1. Fruit weight, fruit yield tree\(^{-1}\), fruit drop, and fruit juice pH as affected by potassium nitrate and copper sulfate levels.

| Treatments                      | Fruit weight (g) | Fruit yield tree\(^{-1}\) (kg) | Fruit drop (%) | Fruit juice pH |
|--------------------------------|------------------|--------------------------------|-----------------|---------------|
| Copper sulfate levels (%)      |                  |                                |                 |               |
| 0% (control)                   | 156.71c          | 46.51c                         | 11.97 a         | 4.88d         |
| 0.20%                          | 166.04bc         | 50.55 bc                       | 11.17ab         | 5.06c         |
| 0.40%                          | 175.96ab         | 54.78ab                        | 10.21b          | 5.15 bc       |
| 0.60%                          | 192.04a          | 59.06a                         | 6.75c           | 5.22 ab       |
| 0.80%                          | 185.71a          | 57.86a                         | 7.36c           | 5.31a         |
| LSD at 5%                      | 4.88             | 1.87                           | 0.29            | 0.03          |
| Potassium nitrate levels (%)   |                  |                                |                 |               |
| 0% (control)                   | 153.67 c         | 44.43c                         | 11.02a          | 4.86d         |
| 2%                             | 188.30 a         | 67.13a                         | 8.52c           | 5.23 b        |
| 3%                             | 187.20 a         | 58.72a                         | 8.63c           | 5.38 a        |
| LSD at 5%                      | 3.90             | 1.50                           | 0.23            | 0.02          |
| Interaction                    | CS X P. N        | NS                             | NS              | NS           |

Mean values followed by different alphabets are significantly different at \(P \leq 0.05\), NS stands for non-significant.

**Fruit Yield Tree\(^{-1}\)(kg)**

Fruit yield per tree\(^{-1}\) in pear was significantly affected by foliar application of potassium nitrate and copper sulfate, while their interaction showed a non-significant difference. The data regarding pear fruit yield tree\(^{-1}\) are presented in Table 1, which publicized that highest fruit yield tree\(^{-1}\) (60.13 kg) was recorded in fruit trees sprayed with 2% potassium nitrate followed by fruit yield (58.72 kg) tree\(^{-1}\) sprayed with 3% potassium nitrate. However, the lowest fruit yield (44.43 kg) tree\(^{-1}\) was noted in the control plants. Mean data regarding copper sulfate levels revealed that highest fruit yield (59.06 kg) tree\(^{-1}\) was recorded in plants sprayed with 0.6% copper sulfate followed by the fruit yield (57.86 kg) tree\(^{-1}\) with 0.8% copper sulfate application, while the lowest fruit yield (46.51 kg) tree\(^{-1}\) was recorded in untreated pear fruit trees. These findings are also in agreement with those of Oosthuysse (1996) who pointed out that KNO$_3$ sprayed at 2% and 4% increased yield with increase in fruit retention. The increase in fruit yield might be due to the increase in fruit weight and fruit volume. The application of KNO$_3$ significantly increased the fruit yield in ber (Yadav et al., 2014). It was pointed out that application of copper sulfate, boric acid, and zinc sulfate either alone or in combination enhanced the yield and yield-related attributes.

**Fruit Drop Percentage (%)**

The data in Table 1 regarding fruit drop (%) showed that foliar application of potassium nitrate KNO$_3$ and copper sulfate significantly affected \((P < .05)\) the fruit drop (%) in pear fruits, while their interaction was found non-significant. The mean data in Table 1 regarding fruit drops (%) clearly exposed that the highest fruit drop (%) was noticed in both control treated fruits, which were (11.02%) and (11.97%), respectively. In KNO$_3$ applications the 2% KNO$_3$ treated pear fruit trees showed a minimum fruit drop (8.52%) which was statistically at par (8.63%) in plants treated with 3% potassium nitrate. In the case of copper sulfate levels the lowest fruit drop (6.75%) were noted with 0.6% copper sulfate foliar spray, closely followed by fruit drop (7.36%) in pear trees sprayed with 0.8% copper sulfate. Higher fruit retention at higher KNO$_3$ concentration might be due to higher photosynthetic activity and higher carbohydrate transportation to fruits due to sufficient availability of K (Hawkesford et al., 2012). Application of copper resulted in increased fruit set, fruit retention, and reduced fruit drop, and hence, the total number of guava fruits was increased. The present results are in agreement with the findings of Tiwari and Shant (2014) in guava, Nitin et al. (2012) in guava, Sajid et al. (2010) in citrus, and Ghosh (1986) in guava.


**pH**

Fruit juice pH was significantly (P < .05) affected by potassium nitrate and copper sulfate applications while their interaction was found non-significant. In Table 1, the data regarding copper sulfate means clearly declared that maximum fruit juice pH (5.38) was recorded at 3% potassium nitrate application, while minimum pH (4.86) was recorded in control treatment. The mean data regarding copper sulfate levels showed that the highest pH (5.31) was observed in fruits treated with 0.8% copper sulfate, which was closely followed by pH (5.22) found in fruits treated with 0.6% copper sulfate concentration. However, the lowest pH (4.88) was noted in control treated fruits. The percent acidity and pH are complementary to each other. As percent acidity increases, the fruit pH increases and vice versa, while in the case of potassium, pH gets increased because of the fact that potassium is known as electro neutrality maintenance element of organic acid in tomato fruit (Dong et al., 2001). Water absorption capacity of plants increases when potassium doses are applied to plant and pH goes higher (Lawlor, 2004).

**Fruit Firmness (kg.cm⁻²)**

Analysis of variance of the data regarding fruit firmness illustrated that Potassium nitrate (KNO₃) and copper sulfate significantly (P < .05%) affected the fruit firmness, while their interaction was declared as non-significant (Table 2). The KNO₃ mean data with 3% application showed the maximum fruit firmness (7.66 kg.cm⁻²), while the minimum fruit firmness (5.26 kg.cm⁻²) was noted in control treated fruits. Copper sulfate concentration with 0.8% indicated maximum fruit firmness (7.53 kg.cm⁻²), closely pursued by (7.11 kg.cm⁻²) in pear trees receiving 0.6% copper sulfate, while the minimum fruit firmness (5.29 kg.cm⁻²) was detected in control treated fruit. Potassium regulates the opening and closing of stomata in leaves, which increases the water absorption capacity of the plants, and as a result, fruit firmness increases. Application with Potassium accelerates osmoregulation of cell vacuoles and maintained the equilibrium, which results in firm fruits. The application of Cu + chitosan improved the firmness in tomato fruits by 9% (Bouazizi et al., 2011).

**Total Soluble Solids (°brix)**

Total soluble solid (TSS) was significantly affected by potassium nitrate and copper sulfate concentration, while their combination showed a non-significant difference (Table 2). Maximum TSS (12.40° Brix) was noted with 3% concentration of potassium nitrate, which was closely pursued by (11.60°

| Treatments                      | Fruit firmness (kg.cm⁻²) | Total soluble solid (°Brix) | Titratable acidity (%) | Ascorbic acid content (mg.100 g⁻¹) | Disease incidence (%) |
|---------------------------------|--------------------------|----------------------------|------------------------|-----------------------------------|----------------------|
| Copper sulfate level (%)        |                          |                            |                        |                                   |                      |
| 0% (control)                    | 5.29d                    | 9.94d                      | 0.74a                  | 4.71e                             | 7.99 a               |
| 0.20%                           | 6.13c                    | 10.64c                     | 0.54b                  | 4.80d                             | 7.26 b               |
| 0.40%                           | 6.96b                    | 10.83c                     | 0.51c                  | 4.91c                             | 6.32 c               |
| 0.60%                           | 7.11ab                   | 11.52b                     | 0.46d                  | 5.10b                             | 3.54 d               |
| 0.80%                           | 7.53a                    | 12.38a                     | 0.42e                  | 5.22a                             | 3.99 d               |
| LSD at 5%                        | 0.12                     | 0.17                       | 0.009                  | 0.02                              |                      |
| Potassium nitrate level (%)     |                          |                            |                        |                                   |                      |
| 0% (control)                    | 5.26d                    | 9.79d                      | 0.66a                  | 4.47d                             | 6.63a                |
| 1%                              | 6.34c                    | 10.46c                     | 0.57b                  | 4.73c                             | 5.97 b               |
| 2%                              | 7.15b                    | 11.60b                     | 0.50c                  | 5.05b                             | 5.28 c               |
| 3%                              | 7.66a                    | 12.40a                     | 0.41d                  | 5.56a                             | 5.39 c               |
| LSD at 5%                        | 0.10                     | 0.13                       | 0.007                  | 0.02                              |                      |
| Interaction                     |                          |                            |                        |                                   |                      |
| C.S X P. N                      | NS                       | NS                         | NS                     | NS                                | NS                   |

Mean values followed by different alphabets are significantly different at P ≤ 0.05, NS stands for nonsignificant.
Brix) in fruit trees sprayed with 2% potassium nitrate. However, the lowest TSS (9.79°Brix) was recorded in control treatment. Meanwhile, the maximum TSS (12.38°Brix) was recorded in the fruit trees treated with 0.8% copper sulfate spray, followed by (11.52°Brix) in the fruits sprayed with 0.6% copper sulfate, and the minimum TSS (9.94°Brix) was observed in control (untreated) fruits. KNO₃ application improved TSS of mango fruits (Patel et al., 2016). The improvement in TSS content with foliar application of potassium might be due to the fact that potassium enhanced the translocation of sugars from leaves to fruits. Potassium foliar applications have an important role in nutrient translocation from source to sink which results in better quality produce having maximum quantity of TSS. These results are also in favor with the findings of Shirzadeh and Kazemi (2011) in apple, Mahajan et al. (2008) in plum, Mahajan et al. (2005) in pear, and Siddiqui and Bangerth (1995) in ber fruit.

**Titratable Acidity (%)**

Results in Table 2 showed that the titratable acidity (%) was significantly (P < .05) influenced by foliar application of potassium nitrate and copper sulfate. The highest titratable acidity (0.66%) was noted in control fruits, while the lowest (0.41%) was detected with 3% of potassium nitrate application pursued by (0.50%) and (0.57%) titratable acidity in pear fruit trees introduced with 2% and 1%, respectively. In copper sulfate treatments, the decreasing trend of titratable acidity was recorded similar to potassium nitrate in which the highest titratable acidity (0.74%) was obtained in control fruits, while the lowest titratable acidity (0.42%) was achieved by (0.8%) copper sulfate sprayed followed by (0.46%), (0.51%), (0.54%) titratable acidity sprayed with 0.6%, 0.4%, 0.2% copper sulfate, respectively. Results of mango control treatment showed higher acidity than those of KNO₃ treated fruits (Sarker and Rahim, 2013). Increased KNO₃ application to fruits always recorded a declining trend in titratable acidity of fruits. The decline in acidity under potassium treatment might be owed to high TSS of the fruits (Prasad et al., 2015).

**Ascorbic Acid (mg.100 g⁻¹)**

Results in Table 2 showed that application of potassium nitrate and copper sulfate had significantly (P < .05) influenced the ascorbic acid content in pear fruits, but their interaction was found non-significant. The increasing trend was seen with the increased concentration of potassium nitrate, the highest ascorbic acid (5.56 mg.100 g⁻¹) was detected with 3% KNO₃ spray, and the lowest ascorbic acid (4.47 mg. 100 g⁻¹) was recorded in the control treatment. In the case of copper sulfate, the Vitamin C content also exhibited an increasing trend with increasing copper sulfate concentration, and the highest vitamin C (5.22 mg.100 g⁻¹) was noted with 0.8% copper sulfate treatment, while the lowest vitamin C (4.71 mg.100 g⁻¹) was found in control treatment. The pre-harvest treated pear fruits with potassium nitrate exhibited higher ascorbic acid than the control treatment (Prasad et al., 2015). An increase in ascorbic acid content with foliation of potassium nitrate was also observed in cherry by Bhat et al. (2012).

**Disease Incidence (%)**

Results in Table 2 showed that application of potassium nitrate and copper sulfate significantly (p < .05) affected the disease incidence (%) in the pear fruit trees as shown in Table 2. However, their interaction was found non-significant. Fruit supplied with 2% potassium nitrate showed less disease incidence (3.54%) which was statistically at par (5.39%) in plants supplied with 3% potassium nitrate. However, the highest percent disease incidence (6.63%) was recorded in control treatment pear plants. Copper sulfate treatments resulted in the lowest disease incidence (3.54%) was observed in plants treated with 0.6% copper sulfate treatment, which was followed by (3.99%) sprayed with copper sulfate at 0.8%. The highest disease incidence (7.99%) was observed in control (untreated) plants. Potassium had a very vital role in the refugence of biotic stresses, which damage the plants, as it plays a key role in the synthesis of high-molecular-weight compounds such as proteins, starch, and cellulose.
and reduces the collection of soluble sugars, organic acids, and amides on which pathogens feed (Hawkesford et al., 2012). On the other hand, copper application helps in accelerating lignification in plants to develop plants central defense mechanism against fungal infestation (Marschner, 2011). Evans et al. (2007) studied the effect of copper application to improve the lignin formation, who found that lower fungal diseases in most plant species. Brown et al. (1995) explained the influence of copper in enhancing the cross linking of cell wall components and controlling fungal diseases. Copper as a fungicide may denature the spores and conidia of fungus, which subsequently stops spore germination (Montag et al., 2006).

**Conclusion**

This experiment was carried out by foliarly applying two salts, i.e. potassium nitrate, as a source of essential plant nutrients, and copper sulfate, as a potential fungicide for higher yield and quality pear fruits of pear through minimal losses and damages. It concluded that foliar application of potassium nitrate and copper sulfate at 2% and 0.6% resulted in maximum fruit weight (192.04 g), fruit volume (207.67 cm³), fruit yield (59.06 kg) tree⁻¹, minimum fruit drop (6.75%), and disease incidence (3.54%). Similar results were observed for quality attributes such as maximum fruit firmness (7.53 kg.cm⁻²), total soluble solids (12.38 °Brix), fruit juice pH (5.31%), ascorbic acid content (5.22 mg.100 g⁻¹), with minimum titratable acidity (0.42%). Further studies should be conducted to optimize the dose, timing, and method of application of these fungicides for other pome fruits.

**Disclosure Statement**

No potential conflict of interest was reported by the author(s).

**References**

Agostini, J.P., P.M. Bushong, and L.W. Timmer. 2003. Greenhouse evaluation of products that induce host resistance for control of scab, melanose, and Alternaria brown spot of citrus. Plant Dis. 87:69–74. doi: 10.1094/PDIS.2003.87.1.69.

Association of official analytical chemists. 2012. International official methods of analyses. 19th ed. AOAC, USA.

Bergmann, W. 1992. Nutritional disorders of plants: Visual and analytical diagnosis.

Bhat, M.Y., H. Ahsan, F.A. Banday, M.A. Dar, A.I. Wani, and G.I. Hassan. 2012. Effect of harvest dates, pre harvest calcium sprays and storage period on physico-chemical characteristics of pear cv. Bartlett. J. Agric. Res. Dev. 2:101–106.

Bouazizi, H., H. Jouili, A. Geitmann, and E. El Ferjani. 2011. Cell wall accumulation of Cu ions and modulation of lignifying enzymes in primary leaves of bean seedlings exposed to excess copper. Biol. Trace Elem. Res. 139:97–107. doi: 10.1007/s12011-010-8642-0.

Brown, N.L., S.R. Barrett, J. Camakaris, B.T.O. Lee, and D.A. Rouch. 1995. Molecular genetics and transport analysis of the copper-resistance determinant (pco) from *Escherichia coli* plasmid pRJ1004. Mol. Microbiol. 17:1153–1166. doi: 10.1111/j.1365-2958.1995.mmi_17061153.x.

Chaudhary, M.I. 2009. A text book of horticulture by Mahmood N. Malik, Managing author Elena Bashir and Robyn Bantel, Editors. 472–474.

Dong, L., H.-W. Zhou, L. Son ego, A. Lers, and S. Lurie. 2001. Ripening of Red Rosa’plums: Effect of ethylene and 1-methylcyclopentene. Funct. Plant Biol. 28:1039–1045. doi: 10.1071/FP00149.

Evans, S.E., M.A. Mendez, K.B. Turner, L.R. Keating, R.T. Grimes, S. Melchoir, and V.A. Szalai. 2007. End-stacking of copper cationic porphyrins on parallel-stranded guanine quadruplexes. JBC J. Biol. Inorg. Chem. 12:1235–1249. doi: 10.1007/s00775-007-0292-0.

Faitínez, G., M. Troncoso, P. Navarrete, and G. Figueroa. 2004. Antimicrobial activity of copper surfaces against suspensions of *Salmonella enterica* and *Campylobacter jejuni*. BMC Microbiol. 4:1–7. doi: 10.1186/1471-2180-4-19.

Ghosh, S.N. 1986. Effect of magnesium, zinc and manganese on yield and fruit quality of guava. South Indian. Hort. 34:327–330.

Gill, P.P.S., M.Y. Ganaie, W.S. Dhillon, and N.P. Singh. 2012. Effect of foliar sprays of potassium on fruit size and quality of ‘Patharnak’ pear. Indian J. Hortic. 69:512–516.

Gozzo, F. 2003. Systemic acquired resistance in crop protection: From nature to a chemical approach. J. Agric. Food Chem. 51:4487–4503. doi: 10.1021/jf030025s.
Harhash, M.M., and G. Abdel-Nasser. 2010. Improving of fruit set, yield and fruit quality of “Khalas” tissue culture derived date palm through bunches spraying with potassium and/or boron. Aust. J. Basic Appl. Sci. 4:4164–4172.

Hawkesford, M., W. Horst, T. Kichey, H. Lambers, J. Schjoerring, I.S. Møller, and P. White. 2012. Functions of macronutrients, p. 135–189. In: Marschner’s mineral nutrition of higher plants. (3rd Edition). New York: Elsevier.

Hibberd, J.M., P. Richardson, R. Whitbread, and J.F. Farrar. 1996. Effects of leaf age, basal meristem and infection with powdery mildew on photosynthesis in barley grown in 700 μmol mol−1 CO2. New Phytol. 134:317–325. doi: 10.1111/j.1469-8137.1996.tb0436x.

Jan, M.T., P. Shah, P.A. Hollington, M.J. Khan, and Q. Sohail. 2009. Agriculture research: design and analysis. Dept. of Agronomy, KPK Agric. Uni. Peshawar, Pakistan.

Khayyat, M., A. Tehranifar, M. Zaree, Z. Karimian, M.H. Aminifard, M.R. Vazifeshenas, S. Amini, Y. Noori, and M. Shakeri. 2012. Effects of potassium nitrate spraying on fruit characteristics of ‘Malas Yazdi’pomegranate. J. Plant Nutr. 35:1387–1393. doi: 10.1080/01904167.2012.684130.

Lawlor, D.W. 2004. In: K. Mengel and E.A. Kirkby (eds.). Principles of plant nutrition. Annals of Botany, 93(4), 479–480. https://doi.org/10.1093/aob/mch063

Lester, G.E., J.L. Jifon, and D.J. Makus. 2006. Supplemental foliar potassium applications with or without a surfactant can enhance netted muskmelon quality. HortSci. 41:741–744. doi: 10.21273/HORTSCI.41.3.741.

Mahajan, S., S. Mahajan, and N. Tuteja. 2005. Cold, salinity and drought stresses: An overview. Arch. Biochem. Biophys. 444:139–158. doi: 10.1016/j.abb.2005.10.018.

Mahajan, B.V.C., J.S. Randhawa, H. Kaur, and A.S. Dhatt. 2008. Effect of post-harvest application of calcium nitrate and gibberellic acid on the storage life of plum. Indian J. Hortic. 65:94–96.

Marschner, H. 2011. Marschner’s mineral nutrition of higher plants. Academic press.

Mimoun, M.B., M. Ghrab, M. Ghanem, and O. Elloumi. 2008. III effects of potassium foliar spray on olive, peach and plum. Part 2: Peach and Plum experiments. Peach 23:73.

MNSFR (Ministry of National Food Security and Research). 201819. Fruits, vegetables and condiments, statistics of Pakistan.

Montag, J., L. Schreiber, and J. Schönherr. 2006. An in vitro study of the nature of protective activities of copper sulphate, copper hydroxide and copper oxide against conidia of Venturia inaequalis. J. Phytopathol. 154:474–481. doi: 10.1111/j.1439-0434.2006.01132.x.

Nitin, T., S. Devi, B. Vijay, V.M. Prasad, and J.P. Collis. 2012. Effect of foliar application of zinc and boron on yield and fruit quality of guava (Psidium guajava L.). HortFlora Res. Spectr. 1:281–283.

Oosthuysie, S.A., 1996. Effect of KNO3 sprays to flowering mango trees on fruit retention, fruit size, tree yield, and fruit quality, in: V International Symposium Mango 455. pp. 359–366.

Patel, G.D., B.N. Patel, K.D. Desai, N.K. Patel, and B.B. Patel. 2016. Influence of paclobutrazol for earliness in mango cv. Alphonso. Int. J. Sci. Envi. Tech 5(5):2713–2718.

Percival, G.C., and S. Boyle. 2005. Evaluation of microcapsule trunk injections for the control of apple scab and powdery mildew. Ann. Appl. Biol. 147:119–127. doi: 10.1111/j.1744-7348.2005.00019.x.

Percival, G.C., and I. Haynes. 2008. The influence of systemic inducing resistance chemicals for the control of oak powdery mildew (Microsphaera albitoides) applied as a therapeutic treatment. Urban For. 34:271–279.

Percival, G.C., K. Novis, and I. Haynes. 2009. Field evaluation of systemic inducing resistance chemicals at different growth stages for the control of apple (Venturia inaequalis) and pear (Venturia pirina) scab. Crop Prot. 28:629–633. doi: 10.1016/j.cropro.2009.03.010.

Prasad, B., D.C. Dimiri, and L. Bora. 2015. Effect of pre-harvest SOL spray of calcium and potassium on fruit quality of Pear cv. Paternakh. Sci. Res. Essays. 10:376–380. doi: 10.5897/SRE2015.6246.

Ram, R.A., and T.K. Bose. 2000. Effect of foliar application of magnesium and micro-nutrients on growth, yield and fruit quality of mandarin Orange (Citrus reticulata Blanco). Indian J. Hortic. 57:215–220.

Ruiz, R., 2005. Effects of different potassium fertilizers on yield, fruit quality and nutritional status of Fairlane nectarine trees and on soil fertility, in: V International Symposium on Mineral Nutrition of Fruit Plants 721. pp. 185–190.

Sabri, N., P.J. Dominy, and D.D. Clarke. 1997. The relative tolerances of wild and cultivated oats to infection by Erysiphe graminis. sp.avenae: II. The effects of infection on photosynthesis and respiration. Physiol. Mol. Plant Pathol. 50:321–335. doi: 10.1006/pmpp.1997.0095.

Sajid, M., A. Rab, N. Ali, M. Arif, L. Ferguson, and M. Ahmed. 2010. Effect of foliar application of Zn and B on fruit production and physiological disorders in sweet Orange cv. Blood Orange. Sarhad J. Agric. 26:355–360.

Saleem, M., S.M. Saddudin, A.W. Bhatti, and I. Gandahi. 2018. Status of soil macronutrients in apple orchards of district Killa Saifullah Balochistan. Pak. J. Agric. Agril. Engg. Vet. Sci. 34(1):22–30.

Sarker, B.C., and M.A. Rahim. 2013. Yield and quality of Mango (Mangifera indica L.) as influenced by foliar application of potassium nitrate and urea. Bangladesh J. Agric. Res. 38:145–154. doi: 10.3329/bjar.v38i1.15201.

Schnabel, G., and L. Parisi. 1997. Sensitivity of Venturia inaequalis to five DMF fungicides, including the new triazole fludioxonil, and to pyrimethanil/Sensitivität von Venturia inaequalis gegenüber fünf DMF Fungiziden, einschließlich dem neuen Triazol Fludioxonil, und gegenüber P. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz/Journal Plant Dis. Prot. 104 (1): 36–46.
Schneider, C., L. Sepp-Lorenzino, E. Nimesegern, O. Ouerfelli, S. Danishefsky, N. Rosen, and F.U. Hartl. 1996. Pharmacologic shifting of a balance between protein refolding and degradation mediated by Hsp90. Proc. Natl. Acad. Sci. 93:14536–14541. doi: 10.1073/pnas.93.25.14536.

Shahin, M., 2007. Effect of potassium fertilization on growth, leaves nutrient content, and yield of "Khalas" date palm in Al-Hassa Oasis (KSA), in: The Fourth Symposium on Date Palm in Saudi Arabia (Challenges of Processing, Marketing, and Pests Control), Date Palm Research Center, King Faisal University, Al-Hassa. pp. 5–8.

Shirzadeh, E., and M. Kazemi. 2011. Effect of malic acid and calcium treatments on quality characteristics of apple fruits during storage. Am. J. Plant Physiol. 6:176–182. doi: 10.3923/ajpp.2011.176.182.

Siddiqui, S., and F. Bangerth. 1995. Effect of pre-harvest application of calcium on flesh firmness and cell-wall composition of apples—influence of fruit size. J. Hortic. Sci. 70:263–269. doi: 10.1080/14620316.1995.11515296.

Stanis, V.F., and A.L. Jones. 1985. Reduced sensitivity to sterol-inhibiting fungicides in field isolates of Venturia inaequalis. Phytopathology. 75:1098–1101. doi: 10.1094/Phyto-75-1098.

Statista. 2021. Global leading pear producing countries in 2020/2021 (in 1,000 metric tons). https://www.statista.com/statistics/739168/global-top-pear-producing-countries/

Taiz, Z., and E. Zeiger. 2004. Fisioloia Vegetal. Armed, Porto Alegre, 719.

Tiwari, J.P., and L. Shant. 2014. Effect of foliar application of zinc and boron on fruit yield and quality of winter season guava (Psidium guajava) cv. Pant Prabhat. Ann. Agri. Bio. Res. 19:105–108.

USDA. 2011. Economic National Nutrition Database for Standard References. Available at: http://www.nal.usda.gov. Accessed on 25th August.

Villalta, O.N., W.S. Washington, and G. McGregor. 2004. Susceptibility of European and Asian pears to pear scab. Plant Prot. Q. 19:1.

Weaver, L., H.T. Michels, and C.W. Keevil. 2010. Potential for preventing spread of fungi in air-conditioning systems constructed using copper instead of aluminium. Lett. Appl. Microbiol. 50:18–23. doi: 10.1111/j.1472-765X.2009.02753.x.

Yadav, D., S.P. Singh, and S. Singh. 2014. Effect of foliar application of potassium compounds on yield and quality of ber (Zizyphus mauritiana) cv. Banarasi Karaka. Int. J. Res. Applied, Nat. Soc. Sci. 2:89–92.