# SURVEY OF APPLE ORCHARDS FOR ASSESSING DISORDERS AND NUTRIENT STATUS IN SOIL, LEAVES, AND FRUITS

Nasra Begum* and Abdul Mateen Khattak
Department of Horticulture, The University of Agriculture Peshawar
* **Corresponding author**: Nasra Begum

## ABSTRACT

Apple growers may suffer up to 90% yield losses from various physiological disorders if orchards are not managed properly. Thus, the incidence of pre and postharvest physiological disorders is a major concern worldwide. Therefore, the present study was conducted to assess the apple orchards of Swat, Pakistan for disorders and nutrient status in soil, leaves, and fruits of different apple cultivars. Soil samples of two different locatities (Kalam and Matta) of Swat and plant tissues (leaves and fruits) of 6 apple cultivars (Treco Gala, Jonica, Gala Must, Jonagored, Golden Smoothee, and Pink Lady) were examined to establish the occurrence of disorders and to relate them with the nutritional status of apple trees. The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times. The results showed that soil, leaf, and fruit calcium content, and fruit yield in Kalam were lower than Matta location. All the cultivars varied significantly in terms of leaf and fruit calcium content, as well as fruit yield. Regarding the means for locations, leaf and fruit calcium content and fruit yield with lower prevalence of physiological disorder i.e. bitter pit, internal browning, internal breakdown, water core and lenticels breakdown was recorded in Matta as compared to Kalam valley. Moreover, among the cultivars, apple cultivar Golden Smoothee was found to be the most prone and susceptible cultivar with maximum bitter pit incidence, internal browning, internal breakdown, water core and lenticles breakdown with minimum leaf and fruit calcium content. Minimum fruit yield, maximum leaf and fruit calcium content with least incidence of physiological disorders was recorded in cultivar Pink Lady. Maximum fruit yield was observed in cultivar Jonica. It is concluded that orchards of cultivar Pink Lady and Jonica need to be established in Kalam locations to obtain better yield and minimum physiological disorders of apple. While treatments need to be applied to minimize physiological disorders with maximum yield in apple cultivar Golden Smoothee.

**Key words:** Apple cultivars, locations, nutrientional status, physiological disorders, yield.

## Introduction

Apple trees grow well in a broad range of soil types. However, soils with a texture of sandy loam to a sandy clay loam are preferred. Proper soil drainage is critical for successful apple production. The desirable soil pH for the cultivation of apple trees is around 6.4. Waterlogged soils, raised water tables to the root zone, soils with hardpan, and shallow soils are not favorable for the growth and development of apple trees (Chaudhary 1994). Several disorders threaten the quality of apple fruit, especially in storage. The most important among these are bitter pit, brown heart, cork spot, scald, water core, and fruit drop. These disorders result in significant losses both in quality and quantity during storage. Apple growers may suffer up to 90% yield losses from bitter pit if orchards are not managed properly (Beckerman et al. 2015). Thus, the incidence of postharvest physiological disorders is a major concern worldwide. Among the disorders, the bitter pit reduces the fruits' market values to a large extent. Bitter pit appears as small brown spots of 3-8 mm in diameter. In this case, the tissue beneath the fruit skin becomes dark. Normally, in the beginning, it's invisible. However, over time, the affected areas become depressed making spots on the surface during storage. It can be prevented through the foliar application of calcium well before harvest (Khan 2015). Brown heart is a disorder associated with large and full-grown fruits and occurs when the ambient carbon dioxide concentration rises above 1%. Brown symptoms appear with clear borders and dehydrated holes because of dryness (Weber 2009). Cork spot is another disorder of apple fruits where the primary signs appear in the red area of the fruit. The affected tissue is usually much more rigid than the normal tissue (Weber 2009). Scald is also a major concern of apple growers. It varies in appearance and characteristics according to the atmosphere, cultural practices, and variety of apple. This disorder also develops due to not enough aeration in storage rooms or packaging materials (Mitropoulos et al. 2004). Another disorder of apple fruit is water core, which mostly occurs in mature fruits and appears as water-soaked regions in the tissue around the seed. The fruits should be harvested before the development of the water core. The fruits with water core signs should not be stored but urgently marketed. The proper time of harvest is the most effective way to control the incidence of water core (Brackmann et al. 2010). Fruit drop is one other problem for apple growers. Nutrient content in apple leaves is specific to cultivars. However, it can also be influenced by the rootstock, soil structure, climatic conditions, phase of vegetation, and orchard management practices, such as irrigation and fertilization (Peck et al. 2006). Apple fruit needs an optimum level of calcium. Lower levels of calcium in fruit bring about several disorders during storage. Apple fruit can not get enough calcium from the soil because, depending upon pH, calcium is not fully mobile from the roots to the leaves and fruit (Yamane 2014). Apple fruits grown with calcium deficiency tend to loose more weight during storage (Weibel et al. 2000). High calcium content is essential for successful storage (Sindha et al. 2018). In apples, calcium can be increased by various management practices (Droby, 2006). Keeping in view the significance of apple cultivars' susceptibility to diseases and their link with nutrient deficiencies especially calcium, the current study was conducted with the objectives to determine the nutritional status of the soil of apple orchards in the Swat region. To collect plant tissues (leaves and fruits) from selected orchards and determine their nutrient status, especially calcium and to find apple cultivars that are most sensitive to physiological disorders and further study them to extend their fruit shelf life.

## Materials and Methods

### Experimental site and plant material

The experiment was conducted in two locations (Kalam and Matta) in the district of Swat, Pakistan in 2017. Kalam and Matta are located at altitudes of 1800 m and 1500 m above sea level respectively. The swat region has a cool climate in winter and pleasing to hot in the summer. Mean annual rainfall ranged from 480-650 mm during the experimental period of 2017 with slight summer dominance. The soils of experimental sites were calcareous and silty clay loam in Kalam and Matta, respectively. These soils were low in pH having little organic matter and low to medium calcium content. Different cultivars of apple were selected in established orchards in Kalam and Matta.

### Experimental Design and treatment combinations

The experiment was laid out in Randomized Complete Block Design with two factors replicated three times. Two apple orchards in Kalam and Matta were evaluated for soil and plant tissues (leaves and fruits) to know the nutritional status of apple trees. Six apple cultivars i.e. Treco Gala, Jonica, Gala Must, Jonagored, Golden Smoothee, and Pink Lady were evaluated in both the orchards of Kalam and Matta. There were 12 treatments combination in the experiment and the total experimental units were 36.

### Soil analyses

At the start of the experiment, composite soil samples were collected and analyzed for various soil physico-chemical properties. Eighteen soil samples were collected from the orchards on 15 June 2016 for analyses. The soil samples were taken from depths of 0-30 cm from each plot to know the physical and chemical properties of the orchard's soils. The collected soil samples were brought to the soil testing laboratory, Agriculture Research Institute (ARI) Mingora for further evaluation. Soil analyses were performed according to the methods used by Glover et al. (2000) to determine the soil nutrient status of the apple orchards. The detail of physico-chemical analysis is given in the results section.

For the determination of soil texture, 10ml 1N $Na_2CO_3$ was added to 50g soil as a dispersing agent and mechanically shaken for 10 minutes and the reading for soil texture was taken after 40 seconds as determined by Moodie et al. (1959).

For the analysis of soil pH, 10g of air-dried soil was taken in a plastic bottle and 50ml of distilled water was added to it. Then it was agitated on a shaker for 30 minutes. After adjustment of the pH meter with standard buffer solutions of pH 4, 7, and 10, the samples readings were recorded as described by Mclean (1982).

Electrical conductivity was measured in $dSm^{-1}$ as described by Rhoades (1996). From collected soil samples, 10g of each was mixed with 50 ml of water (at a 1:5 ratio) in a 100ml size bottle and shaken for 60 minutes. After shaking, the suspension was left overnight to allow the soil to settle down. A pipette-type conductivity cell was filled with the supernatant. For the determination of soil organic matter, 1g air-dried soil was taken in a 500 ml beaker and 10 ml potassium dichromate solution was added followed by 20 ml concentrated sulfuric acid. The samples were left for 30 minutes and 200 ml distilled water and 10 ml concentrated orthosphosphoric acid were added. After that, 15 drops of diphenylamine indicator were added and the solution was then titrated with 0.5 M ferrous ammonium sulfate for organic matter (Nelson and Sommers, 1982)

For nitrogen content, a 0.2 g soil sample was digested with 3 ml of concentrated $H_2SO_4$ in the presence of a digestion mixture containing $K_2SO_4$, $CuSO_4$, and Se (100:10:1) on a block digester for about 4 hours. The digestion started at 50ºC and the temperature was raised gradually from 100 to 350ºC for 1 hour. After cooling, 20 ml of the digest was distilled in the presence of 5 ml of 40% NaOH solution and 5 ml of boric acid mixed indicator solution. The distillate was titrated against standard 0.005 M HCl and then N was calculated and also a blank reading was taken at the same time.

For the determination of phosphorous, a 10 g soil sample was mixed with 20 ml AB-DTPA extractant solution in an open flask and shaken for 15 minutes. The suspension was then filtered through Whatman No. 42 filter paper. From the filtrate, a 5 ml sample was taken and a 10 ml color reagent (0.4 g ascorbic acid and 100 ml ammonium molybdate solution) was added and the volume was made up to 50 ml in a volumetric flask with distilled water. Then extractable Phosphorus in the soil sample was determined (Soltanpour, 1985).

For AB-DTPA (Ammonium Bicarbonate- Diethylene Triamine Penta Acetic acid) potassium determination, AB-DTPA extractable potassium was extracted in solution by AB-DTPA in a flame photometer as described by Sultanpour (1985). Standard solution of K as 20, 40, 60, 80, and 100 mg $L^{-1}$ was tested. One blank was also run in start on the machine with AB-DTPA extract only (without the sample). Extractable K was determined using the formula;

$$\text{AB} - \text{DTPA extractable K (mg/kg)} = \frac{(I.R. - blank) \times volume \times D.F.(if\ any)}{Factor\ \times weight\ of\ sample}$$

Where

R = Initial Reading

D.F. = Dilution factor

**Meterological data of both the location**

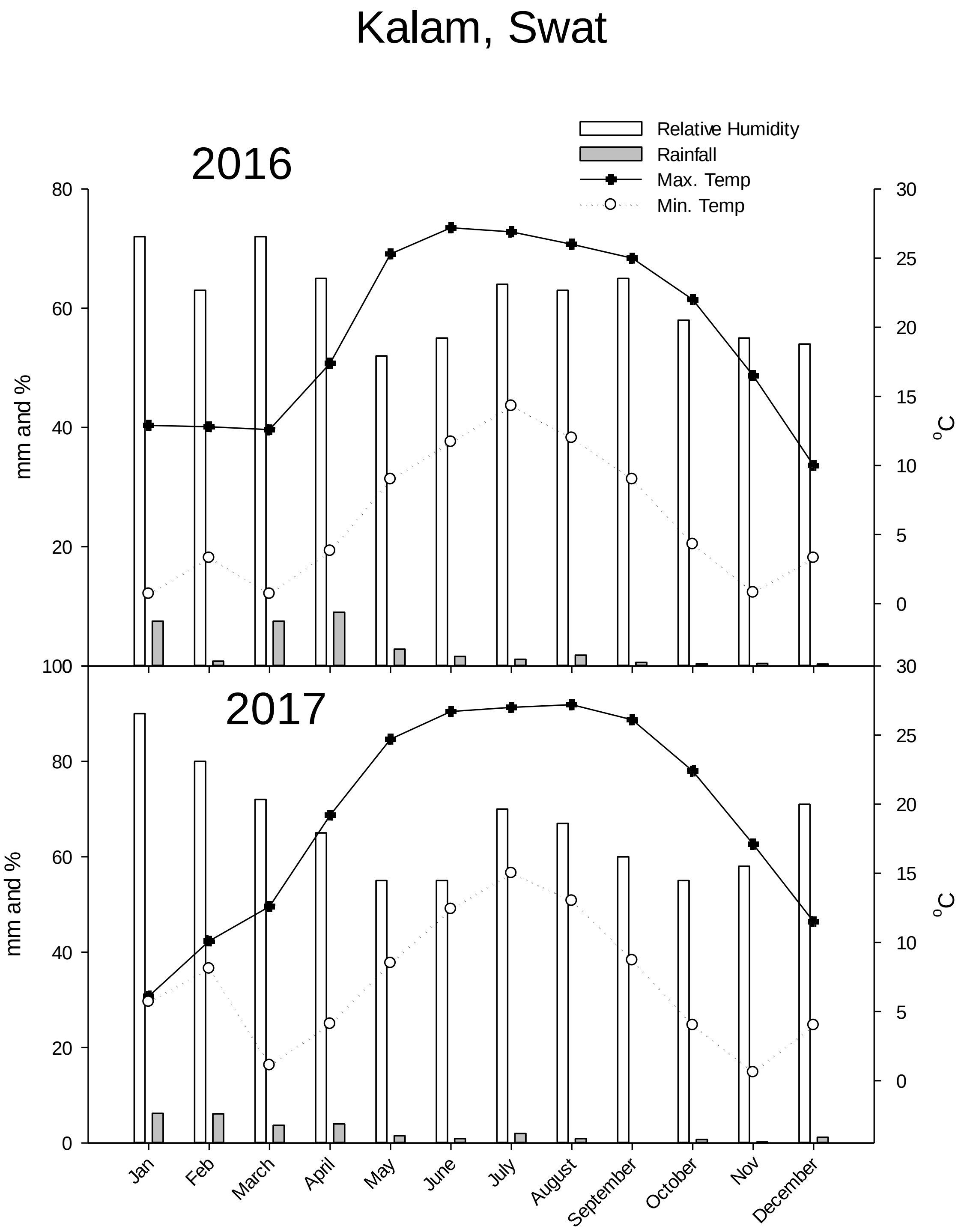


**Fig. 1 Rainfall, relative humidity, maximum and minimum temperature of Kalam Swat.**

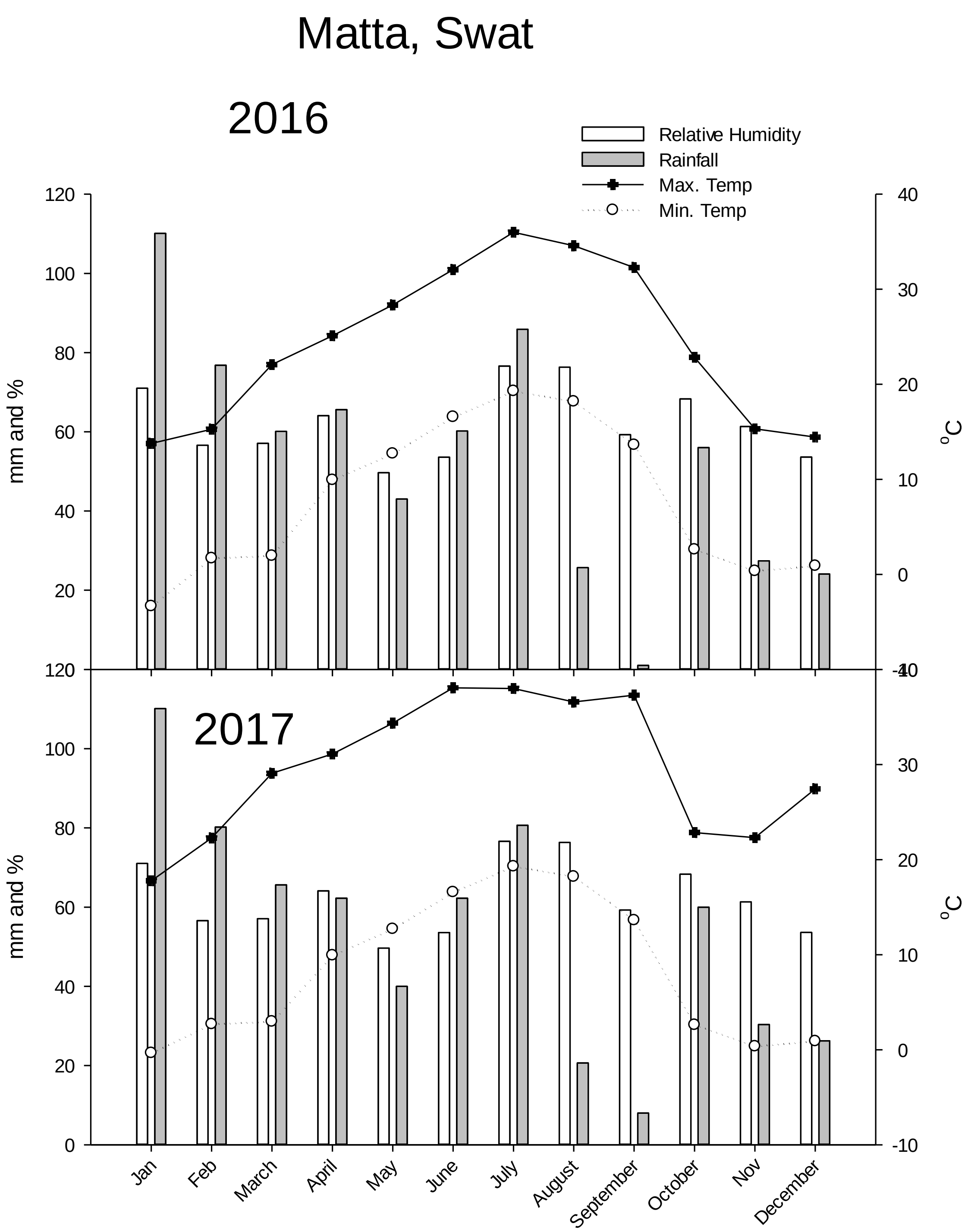


**Fig. 2. Rainfall, relative humidity, maximum and minimum temperature of Matta, Swat.**

## Attributes studied

### Leaf and fruit calcium content (%)

Leaf calcium concentrations were recorded from 54 leaves randomly selected from each tree taken from mid-awning height. Fruit calcium concentrations were taken for 18 fruits from each tree. Leaf and fruit calcium contents were recorded following the procedure of Isaac and Kerber (1971). Both leaf and fruit calcium samples were collected two weeks before harvest to know the calcium status in leaf and fruit tissues. The sample was first pulverized to a particle size of 1 mm and 1 g of plant sample was taken in a digestion flask. It was left overnight after adding 10 ml $HNO_3$. After that, 4 ml perchloric acid ($HClO_4$) was added and heated for 20 minutes and thus the solution became colorless. After cooling the sample was transferred to a volumetric flask and the volume was made to the mark. This solution was used for recording the calcium content in leaves and fruits.

### Fruit Yield (Kg tree$^{-1}$)

Apple fruits harvested from each cultivar were weighed with electronic balance and the total yield tree$^{-1}$ for each cultivar was calculated.

### Identification of disorders

The harvested fruits from each cultivar were stored at room temperature for one month to observe disorders. During storage, apple fruits were regularly examined and checked for various physiological disorders described below.

Bitter pit incidence in apple was determined when dark depressions on the fruit surface associated with the collapse of flesh cells below the peel, were observed (Amarante et al. 2013). The apples were cut equatorially to check the incidence of internal browning (Kittemann et al. 2015). The internal breakdown was determined when the internal tissues were broken down and became spongy (Martins et al. 2013). Water core was measured when water-soaked areas appeared on the cortex, which caused the tissue to become translucent (Baranowski et al. 2008). Lenticels breakdown was measured when sunken circles around lenticels were observed (Curry et al. 2008). Percentages for each physiological disorder were measured using the following formula

$$Percent\ infected\ fruits = \frac{No. of\ infected\ fruits}{Total\ no. of\ fruits} \times 100$$

### Statistical analysis

The recorded data were arranged according to randomized complete block design (RCBD) and subjected to analysis of variance technique as given by **Jan et al. (2009)**. It was then analyzed using statistical software (Statistix 8.1, 2003). In case the data were found significant, the least significant difference (LSD) test was applied for individual means comparisons.

## Results and Discussion

### Soil Status of Sites

The data concerning physico-chemical properties of soil are shown in Table 3.3.1. In Kalam, the soil was calcareous having 5.83 pH, 0.62 ds/cm electrical conductivity, 0.89% organic matter, 6.50% calcium, 16.4 mg $kg^{-1}$ nitrogen, 7.8 mg $kg^{-1}$phosphorous, and 132 mg $kg^{-1}$ potassium. The Matta orchard soil was silty clay loam having 6.52 pH, 0.55 ds/cm electrical conductivity, 0.96% organic matter, 9.73% calcium, 18.2 mg $kg^{-1}$ nitrogen, 11.8 mg $kg^{-1}$ phosphorous, and 133 mg $kg^{-1}$ potassium. The soil pH and organic matter in Kalam were lesser than those of Matta. The fertility status of the Kalam orchard soil was also lower than that of Matta soil. In addition, the soil calcium of the Matta orchard was higher than the Kalam one (Table 1).

Soil physicochemical properties depend largely on the size, shape, arrangement, and mineral composition of the soil. High soil fertility in organic systems improves soil biological properties, which influence nitrogen availability to plants (Rocha et al. 2001). Orchard management influences fruit resistance to bitter pit and internal browning and fruit decay can be decreased by adjusting the cultural practices and proper nutrition (Ferguson et al. 1999). Calcium spray plays an important role in increasing crop yield (Fageria et al., 2009). Soil or foliar application of chemical fertilizer is important for nutrient management in apple orchards. Some growers often apply too many fertilizers to their orchards to ensure maximum productivity. However, the overdose of chemicals not only increases production costs but may also adversely affect the produce quality. Foliar fertilizer application, especially calcium is beneficial for improving the nutritional status of apple plants, which in turn increases fruit set, productivity, and quality (Fornes et al. 2002).

**Table 1 Physico-chemical properties of soil at both locations.**

| Properties | Locations | |
|---|---|---|
| | Kalam | Matta |
| Soil texture | Silty clay loam | Silty clay loam |
| pH | 5.83 | 6.52 |
| EC | 0.62 ds/cm | 0.55 ds/cm |
| Organic matter | 0.89% | 0.96% |
| Calcium carbonate | 2.9% | 3.1% |
| Total N | 16.4 mg $kg^{-1}$ | 18.2 mg $kg^{-1}$ |
| AB-DTPA phosphorus | 7.8 mg $kg^{-1}$ | 11.5 mg $kg^{-1}$ |
| AB-DTPA potassium | 132 mg $kg^{-1}$ | 133 mg $kg^{-1}$ |

**Leaf Calcium Content (%)**

Table 2 depicts considerable variation in leaf calcium content in both the locations ($P \leq 0.01$) as well as apple cultivars ($P \leq 0.01$). However, the interaction between locations and apple cultivars was non significant. Regarding the means for locations, maximum (1.30%) leaf calcium content was recorded in the apples of Matta while it was minimum (0.85%) in the case of Kalam apples. Among the cultivars, maximum leaf calcium content (1.25%) was recorded in cultivar Pink Lady, followed by GalaMust and Treco Gala exhibiting leaf calcium contents of 1.14 and 1.10 % respectively. The lowest leaf calcium content (0.66%) was recorded in cultivar Golden Smoothee.

More Leaf calcium content of apple was recorded in Matta as compared to Kalam which may be because calcium content in the soils of Matta (9.73%) was more than that of Kalam (6.50%) as evident from the soil analysis of both the areas (Table

1). The availability of more calcium in the soil would have resulted in more absorption by plants and hence more accumulation in the leaves. Furthermore, more leaf calcium content in the cultivar Pink Lady might be due to its genetic makeup of having an efficient root system that could absorb nutrients from the soil more efficiently as compared to other cultivars.

**Fruit Calcium Content (%)**

Significant differences in fruit calcium content were recorded for locations as well as apple cultivars. The interaction between locations and cultivars was found non significant (Table 2). More fruit calcium content (0.048%) was recorded in Matta while less fruit calcium content (0.030%) was observed in Kalam. Regarding the means for apple cultivars, the maximum fruit calcium content (0.039%) was recorded in cultivar Pink Lady, followed by fruit calcium content (0.031%) in Jonagored. Cultivar Golden Smoothee was found to be the lowest in fruit calcium content (0.018%).

Mineral analysis of leaf and fruit tissues has commonly been used to optimize mineral nutrition in fruit trees; Similarly, fruit analysis is more useful to estimate quality (Fallahi et al. 1985). Moreover, there is a great link between postharvest quality and pre-harvest mineral nutrients along with orchard practices (Sharples, 1980). Fruit calcium content of apple was recorded higher in Matta region as compared to Kalam valley which may be due to the availability of calcium content in excess in Matta region as compared to Kalam (Table 1). More calcium content in the soil results in better absorption of nutrients especially calcium by the plants and translocated to the leaf and fruit portion where it has accumulated in access. Furthermore, more leaf calcium content in the cultivar pink Lady might be due to its capability to absorb nutrients from the soil more efficiently (may be due to an efficient root system) as compared to other cultivars. An efficient and strong root system and better absorption of the nutrients from the soil by the Pink Lady cultivar of apple may be one of the reasons for increased calcium content in its fruits as compared to other cultivars under the study.

**Fruit Yield (kg tree$^{-1}$)**

Significant differences in fruit yields were observed among the cultivars as well as the locations. The interaction between locations and cultivars was non-significant (Table 2). Fruit yield (118.9 Kg tree$^{-1}$) of Kalam was considerably lower than that of Matta (133.2 Kg tree$^{-1}$) location. Among the apple cultivars, maximum fruit yield (148.8 Kg tree$^{-1}$) was recorded in cultivar Jonica, followed by cultivar Treco Gala with a yield of 133.2 Kg tree$^{-1}$). Cultivar Pink Lady produced minimum fruit yield (108 Kg tree$^{-1}$).

The reason for the higher yield in Matta might be due to the favourable environmental conditions as well as the better nutrient availability in the area as supported by table 1. Although the environmental condition of both locations favour apple production, they are slightly different. Moreover, the fertility status of Matta soil was better than that of Kalam, which resulted in the yield difference. The increased nutrient status of the Matta soil led to the translocation of more nutrients to the plant, which in turn increased yield considerably compared to Kalam. Moreover, maximum fruit yield was produced by cultivar Jonica compared to the other studied cultivars. It may be due to the genetic makeup of the cultivar that produced more yield as compared to other cultivars, though all of them were provided with similar growing conditions. It seems that cultivar Jonica utilized the environmental conditions and the available resources more efficiently and hence produced more fruit. In addition, cultivar Jonica showed more tolerance to physiological disorders compared to the others that were sensitive to such disorders. This may be another reason for the better fruit yield shown by this cultivar. The present results are in close conformity with Kucuker et al. (2015) who also observed significant differences in fruit yield of apple cultivars.

**Table 2 Leaf calcium content, fruit calcium content, and fruit yield collected from various apple cultivars at Kalam and Matta orchards, district Swat, Pakistan.**

| **Locations (L)** | **Leaf Calcium content (%)** | **Fruit calcium content (%)** | **Fruit yield (kg tree$^{-1}$)** |
|---|---|---|---|
| Kalam | 0.85 B | 0.021 B | 118.9 B |
| Matta | 1.30 A | 0.033 A | 133.2 A |
| *Significance* | *** | *** | *** |
| **Apple Cultivars (Cv)** | | | |
| Treco Gala | 1.10 BC | 0.024 C | 133.2 B |
| Jonica | 1.00 D | 0.029 B | 148.8 A |
| GalaMust | 1.14 B | 0.020 D | 116.0 D |
| Jonagored | 1.03 CD | 0.031 B | 123.5 CD |
| Golden Smoothee | 0.91 E | 0.018 D | 126.7 BC |
| Pink Lady | 1.25 A | 0.039 A | 108.0 E |
| *LSD value* | 0.66 | 0.0025 | 7.97 |
| **Interaction (L×Cv)** | | | - |
| *Significance* | NS | NS | NS |

Means followed by the same letter(s) in the respective columns, do not differ significantly from each other

***: Significant at P≤0.01, *,**: Significant at P≤0.05

**Disorders in Apple Orchards at Swat**

**Bitter Pit Incidence (%)**

Significant differences were observed among the cultivars as well as the locations. However, the interaction between the growing locations and the cultivars was non significant (Table 3). In Kalam, apple fruits were mostly affected by bitter pit (17%) compared to Matta location, where the incidence of bitter pit was 13%. Among the cultivars, Golden Smoothee had the highest (22%) bitter pit incidence, followed by Treco Gala (16.17%), Jonica and Gala Must (14.67%). Cultivar Pink Lady showed the least (9%) bitter pit incidence.

The incidence of postharvest physiological disorders is a major concern worldwide. Bitter pit was the most serious and prevalent disorder of apple fruits. Apple growers can experience up to 90% yield losses from bitter pit if orchards are not managed properly (Beckerman et al. 2015). Bitter pit and internal breakdown are calcium-related disorders that cause 5% to 10% postharvest losses every year. Calcium and other plant nutrients are key factors that influence fruit quality and storability (Conway et al. 1991), especially in fleshy crops, such as apples (White and Broadley, 2003; De-Freitas and Mitcham, 2012). Comparing both the experimental sites, the soils of Kalam were mostly low in nutrients that showed different physiological disorders compared to the soils of Matta (Table 1). Bitter pit is closely associated with calcium and according to the soil analysis of both locations, Matta soil is richer in calcium content than that of Kalam. Thus the availability of more calcium in Matta soil may have reduced the incidence of bitter pit compared to Kalam apples. Moreover, Frasnelli and Casera (1996) reported that orchards located in areas where vegetative growth is high and yield is low, tend to have more secondary infections, thereby incurring more losses due to bitter pit. Furthermore, apple trees grown at low fertility have low productivity and up to 65% of damage is caused by different physiological disorders, especially bitter pit (Tough et al. 1998). Cultivar Pink Lady was relatively more resistant to various disorders as compared to other cultivars. Cultivar Golden Smoothee was susceptible to a range of disorders. This might be due to the genetic variability in sensitivity and its inability to extract the proper amount of calcium and other essential nutrients from the soil to increase its vigor and resist the influence of diseases and disorders, especially the occurrence of bitter pit (Volz et al. 2006). Another reason for more susceptibility of different cultivars to bitter pit might be that these cultivars lose xylem functionality at various fruit growth stages (Miqueloto et al. 2014). As calcium ions move through the xylem (Saure, 2005), a lower amount of calcium is provided to the leaf and fruit, thus resulting in the susceptibility of these cultivars to the incidence of bitter pit (Miqueloto et al. 2014).

**Internal Browning (%)**

Significant variations were observed for internal browning among the cultivars and locations. However, their interaction was non significant (Table 3). The incidence of internal browning was maximum (8.44%) in Kalam, while minimum (5.50%) in Matta apples. Among the cultivars, Golden Smoothee was greatly affected by internal browning (14.50%), followed by Jonagored where the disorder was 7.83%. Pink Lady was the least affected cultivar with internal browning of 3.33%.

Many physiological disorders of apples are due to the lack of calcium in the soil or its availability to the plant (Amarante et al. 2010). In Kalam, among the apple cultivars, Golden Smoothee had a high incidence of physiological disorders where bitter pit and internal browning were the most prevalent. In Matta, apple cultivars were less susceptible to physiological disorders including bitter pit and internal browning. Cultivar Golden Smoothee was mostly affected by bitter pit and internal browning. Bitter pit damaged cultivars Treco Gala, Jonica, Jonagored, and GalaMust more than the others. Cultivar Pink Lady was more resistant to bitter pit, internal browning, internal breakdown, water core, and lenticels breakdown (Table 3). susceptibility of cultivars to bitter pit and internal browning may be an inherent defect among the cultivars because they extract lesser amounts of calcium from the soil (Conway et al. 1991). The susceptibility to flesh browning also increases with advancement in fruit maturity (Herremans et al. 2013). Internal browning of apples is possibly more related to fruit ripening and senescence processes (Kittemann et al. 2015).

**Internal breakdown (%)**

Significant differences were observed between the locations, as well as, among the cultivars in terms of internal breakdown. However, their interaction was found non significant (Table 3). In Kalam, apple trees were more affected by the internal breakdown (7.22%) compared to Matta, where the damage was 5.78%. Concerning the cultivars, Golden Smoothee was highly affected by the internal breakdown (14.17%). Cultivar Treco Gala was slightly affected with an internal breakdown incidence of 3.58%.

Apple production is greatly affected by biological and physiological disorders (Martins et al. 2013). Information regarding the nutrient status of calcium in apple trees is important to observe the accurate rationale of the issue. Peck et al. (2006) stated that the main reason for the decrease in apple production and quality is the deficiency of nutrients. The fruits remain small, abnormal, and suffer from various disorders. These disorders are characterized by the breakdown of the flesh on one side of the fruit or the whole fruit. The flesh becomes off-white to yellow, then brown, soft, and mealy. Sometimes, an outer narrow margin between the skin and the affected area stays sound. The skin is also discolored, becomes dull, and the fruit cracks. The internal breakdown is also associated with old age where strong respiration and calcium deficiency become limiting factors, which can be cured by pre-harvest calcium treatment (Raese et al 1993; Kays, 1999). In the present study, cultivar Golden Smoothee showed these symptoms and had the highest incidence of internal breakdown while cultivar Treco Gala was competent in internal breakdown and water core.. The reasons for the difference in the internal breakdown incidence in the studied locations might be due to the nutritional status and poor soil management strategies which led to the vulnerability of plants to the incidence of pests, diseases, and physiological disorders (Martins et al. 2013). This is also confirmed by the soil analysis of the studied location where less calcium was found in the soils of Kalam as compared to Matta (Table 1). Frank et al. (2007) stated that calcium sprays in mid-July are effective to increase fruit calcium concentration, which is the most important mineral element determining fruit quality and incidence of physiological disorders, especially internal breakdown. Hafez and Haggag (2007) and Amarante et al. (2008) observed that apple fruits from the orchard harvested at commercial maturity had more yellowish skin backdrop color and firmness than fruits from the conventional orchard. Haq and Rab (2012) observed that foliar application of calcium and borax significantly increased the fruit calcium content, thereby reducing the incidence of physiological disorders. Danner et al. (2015) reported that calcium applied to the soil can replace the leaf application frequently used in apple orchards to reduce production costs. Doryanizadeh et al. (2017) stated that the measurement of fruit mineral composition before and during harvest time might be a plan for predicting postharvest issues of apple fruits (bitter pit and internal breakdown) during cold storage.

**Water core (%)**

Considerable variations were observed for water core between the locations and cultivars. The interaction between the locations and the cultivars was found non significant (Table 3). In Kalam, apple fruits were more affected by the water core (4.77%) compared to Matta, where the incidence was 3.92%. Among the cultivars, Golden Smoothee had the highest water core (8.15%). Cultivar Treco Gala was the least affected with a water core incidence of 2.17% .

Water core is another serious disorder associated with dysfunction in carbohydrate physiology, low calcium levels, and advanced maturity (Brown and Watkins, 1997). It is characterized by water-soaked areas near and around the core of the apple flesh, which later develop into hard and glassy areas. The affected fruits are heavier than sound fruits and may be isolated by measuring light transmittance through intact fruits. Heat, drought, sunlight, calcium deficiency, and over-maturity are some of the factors that promote this disorder (Brown and Watkins, 1997). In the present study, the water core was more pronounced in Kalam as compared to Matta. The reason for the higher incidence in Kalam might be due to the environmental conditions favourable for the occurrence of water core. Another reason for this might be that the apple orchards are exposed to high temperatures, which cause water core in fruits (Roper, 1999). Moreover, water core is also associated with calcium deficiency and it is evident from the soil analysis that Kalam soils have calcium as compared to Matta soils, which indicates the occurrence of this disorder at a high rate. Cultivar Treco Gala was competent in water core. The difference in water core among the cultivars might be due to their genetic characteristics (Khan, 2015). Roper (1999) also reported that some cultivars are far more susceptible to water core than others. He was also of the opinion that the age of trees also had a role in the incidence of water core. He observed that larger apples produced on young trees had a higher incidence of water core. The present results are in line with Neuwald et al. (2014) who observed the incidence of water core in Fuji apples. Moreover, Brackmann et al. (2001) reported that the incidence of water core was cultivar and season dependent.

**Lenticels breakdown (%)**

Significant differences were observed among the cultivars as well as the locations. However, the interaction between the locations and the cultivars was found non significant (Table 3). In Kalam, the incidence of lenticels breakdown in apple fruits was 7.39%, which was significantly higher than that of Matta (4.81%). Among the cultivars, Golden Smoothee had the highest (8.72%) incidence of lenticels breakdown, whereas, Gala Must was the least affected cultivar having 4.64% lenticels breakdown.

Lenticel breakdown and other lenticel-related disorders can be serious quality defects in apple. Lenticel breakdown appears after postharvest handling but the damage starts at the pre-harvest stage. During the rapid fruit development, micro-cracks appear in the fruit cuticle thereby exposing the epidermis and skin to desiccation that results in cell death and pits around the lenticels. Fruits with more incidence of lenticel breakdown are of poor quality (Blakey, 2018). The symptoms of lenticel breakdown appear to be darkened pits, centered on a lenticel, ranging from 1 to 8 mm in diameter (Curry et al. 2008). Expansion in the fruit cuticle is undertaken by shearing and cracking as the fruits proceed to enlargement (Faust and Shear, 1972; Meyer, 1944). Enlargement is also due to the stretching of the hypodermal cells by the process of mitosis (Curry, 2003), thereby appearing the symptoms of lenticel breakdown. Lenticels are often the source of multiple microcracks that may further stress or induce injury to underlying cells, leading to desiccation pre- and postharvest (Maguire et al.

1999). The variability in the incidence of lenticel breakdown might be due to differences in environmental and cultural factors (Curry, 2005). In addition, the difference in surface wax morphology and chemical composition of the cultivars also have a significant role in lenticel breakdown (Veraverbeke et al. 2001). Characteristics and composition of apple cuticular wax also change in response to chemicals (Curry, 2008), as well as environmental stresses such as rain acidity (Rinallo and Mori, 1996), temperature (Lurie et al. 1996), and radiation (Kasperbauer and Wilkinson, 1995) that lead to the occurrence of lenticel breakdown injury.

**Table 3.3.3 Bitter pit, internal browning, internal breakdown, water core, and lenticels breakdown identified in apple orchards at Kalam and Matta locations of district Swat, Pakistan.**

| **Locations (L)** | **Bitter pit (%)** | **Internal Browing (%)** | **Internal Breakdown (%)** | **Water Core (%)** | **Lenticels Breakdown (%)** |
|---|---|---|---|---|---|
| Kalam | 17.00 A | 8.44 A | 7.22 A | 4.77 A | 7.39 A |
| Matta | 13.00 B | 5.50 B | 5.78 B | 3.92 B | 4.81 B |
| *Significance* | *** | *** | *** | *** | *** |
| **Apple Cultivars (Cv)** | | | | | |
| Treco Gala | 16.17 B | 5.17 C | 3.58 C | 2.17 D | 6.28B |
| Jonica | 14.67 B | 5.33 C | 5.25 B | 2.97 CD | 6.42 B |
| GalaMust | 13.83 B | 5.67 BC | 5.53 B | 4.30 BC | 4.64 C |
| Jonagored | 14.67 B | 7.83 B | 5.40 B | 5.33 B | 5.60 BC |
| Golden Smoothee | 22.00 A | 14.50 A | 14.17 A | 8.15 A | 8.72 A |
| Pink Lady | 9.00 C | 3.33 C | 5.08 BC | 3.17 CD | 4.95 C |
| *LSD value* | *2.60* | *2.36* | *1.57* | *1.55* | *1.19* |
| **Interaction (L×Cv)** | | | | | |
| *Significance* | NS | NS | NS | NS | NS |

Means followed by the same letter(s) in their respective columns, do not differ significantly at 5% (lower case) and 1% (upper case) from each other

***: Significant at P≤0.01, *,**: Significant at P≤0.05

## Conclusions

The leaves and fruits of the cultivar Pink Lady were rich in calcium, while the lowest amount of calcium was observed in the leaves and fruits of cultivar Golden Smoothee at both locations. The fruit yield of cultivar Pink Lady was the lowest among all other cultivars in both locations. Cultivar Golden Smoothee was extremely susceptible to disorders such as bitter pit and internal breakdown.

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