Research Article

Determination of Fruit Flies (Diptera: Tephritidae) infestation in various peach varieties in District Swat

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Abstract | Present study investigated the impact of fruit fly infestation in various peach varieties in District Swat. Data was collected on fruit fly infestation rates for four peach varieties. Results indicated that the Sharbati variety exhibited the highest infestation rates (30%) in Ningolai and Kabal, while Kanju showed the lowest (5%). Similarly, Shan e Punjab had the highest infestation in Ningolai (35%) and the lowest in Kanju (5%). The Red Sun variety had its highest infestation in Hazara (30%) and the lowest in Bara Bandai (10%). Sharbati fruits from Tree T2 showed the greatest weight (296.5g), T3 produced the longest fruits (96.7mm) and T1 had the frit with the largest diameter (82.3mm). Total Soluble Solids (TSS) levels were highest in T3 (13.7 Brix). For Red Sun peaches, Tree T1 yielded the heaviest fruits (206.5g), while T3 produced the longest fruits (93.5mm) and had the largest diameter (72.7mm). TSS was highest in T1 (15.0 Brix). Shan e Punjab trees from T1 had the highest fruit weight (235.7g), and T2 produced the longest fruits (91.1mm) and largest diameter (80.1mm). TSS levels were highest in T3 (14.0 Brix). The Khurmani variety showed the highest average weight in T3 (235.8g) and the longest fruits (83.5mm). T2 had the largest diameter (77.8mm) and TSS levels were highest in T1 and T3 (13.9 Brix). Stone weight and dimensions were relatively consistent within varieties, with T3 stones showing greater weights and lengths for the Red Sun and Khurmani varieties.

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Introduction

Fruit flies are notorious for targeting commercially important fruits, making them a significant economic pest on a global scale. They are a major nuisance both locally and worldwide and are classified as quarantine pests (Saeed *et al.*, 2022). These pests are ubiquitous and cause substantial damage wherever they infest their host plants. In Pakistan, fruit fly infestations result in estimated losses of

USD 200 million each year especially affecting small scale farmers who primarily grow highly susceptible crops like mangoes, cucurbits and peaches. These farmers struggle with the high costs of pest control measures (Munn *et al.*, 2003). The existence of fruit flies diminishes both the quality and quantity of fruit. Female flies use their ovipositors to lay eggs beneath the fruit's skin. The larvae develop inside the fruit. The extent of fruit loss varies with different fruit fly species and their host plants. The oriental fruit fly (*Bactrocera dorsalis*) is especially harmful, causing damage ranging from 5% to 100% of the fruit. The peach fruit fly is prevalent in Pakistan and can cause fruit losses from 3% to 100%. The Ber Fruit fly (*Carpomya vesuviana*) can inflect 90% to 100% damage to Ber Fruit (Kakar *et al.*, 2014). In Pakistan, *Bactrocera zonata* adults are active year, found in coastal areas but become dormant in winter, migrating north, their numbers peak from March to May, decline in June and July, and rise again in August, reaching their highest in September. The population is most abundant in July and August, with a seasonal peak from March to August (Ghanim, 2009).

In Pakistan, after plum peach is a significant stone fruit and is grown on 14,350 hectares producing an estimated 72,536 tons per year (Khan and Shaukat, 2006). According to province-specific statistics, peaches are produced on 36 hectares in Punjab, 9,013 hectares in Khyber Pakhtunkhwa, and 5,301 hectares in Balochistan. Production in these regions is 2,2256,776, and 15,538 tonnes, respectively (Memon *et al.*, 2015). Peach varieties have been thoroughly studied as peach fruits are valued by customers for their sweetness, flavour and juiciness. Cultivars, ripening circumstances, harvest time, processing method and storage conditions have all been found to affect the quantity and content of fruit volatile component (Evrendilek *et al.*, 2016). Sparkling peaches are high in potassium, fibre, and minerals A and C. A peach of average size has 7% of the daily needed dietary fibre, whereas the fruit contains over 80% water. Peaches are widely used in salads and milk shakes, despite their dietary value. The health benefits of peach fruit include treatment for obesity, blood stasis, cancer cholesterol, hypokalemia and neurological diseases. It also enhances cellular fitness, digestion, immune system and act as antioxidant having abundance of important minerals that are beneficial at different stages of pregnancy (Fateh *et al.*, 2020).

Peach cultivation in Pakistan spans regions such as Peshawar, Parachinar, Chitral, Hazara, Quetta, Pashin, Ziarat, Mastung, Skurdu, Hunza, Murree Hills, Chakwal and Swat (Khalil *et al.*, 2014). The horticultural sector has the potential to boost revenue, reduce socioeconomic troubles, end hunger and poverty. Malakand division of Khyber Pakhtunkhwa is ideal region for promotion of horticulture due to its varied topography, agro-climatic conditions, excellent irrigation water, and superior soil type (Ahmad *et al.*, 2013). The KP government in the Malakand division has undertaken several projects by domestic and international donors to advance horticulture and promotion of fruit cultivation. The Malakand fruit and Vegetable Development Project (MFVDP) and the Pak-Swiss Agreement for Horticulture Promotion are examples of these initiatives (Fahim, 2022).

Various peach varieties, such as Spring Crest, Elberta and Indian Blood (8-A) were cultivated in Malakand division, with special subsidies provided to small land-owners or landless farmers. The most auspicious peach cultivar groups have always been widely adapted and grown in the Malakand division, despite the fact that

these varieties are prone to pests and illnesses (Ayaz *et al*., 2001). Furthermore, widespread ignorance, mono-cropping, climate change, pests, frequent outbreaks of diseases, biotic and abiotic factors, pre- and post-harvest crop management such as incorrect storage, and poor supply chain have resulted in a peach quality decline and worsening productivity limitations in different regions of District Swat. (Ahmad *et al*., 2021; Fahim, 2022).

The objective of present study was to evaluate and compare fruit fly infestation rates among peach varieties across various locations in District Swat. Furthermore, analyse the relationship between physical and chemical characteristics of peaches and their susceptibility to fruit fly infestations.

2. Materials and Methods

2.1. Study area

District Swat is located in the Khyber Pakhtunkhwa province of Pakistan (Figure 1) and is renowned for its diverse agricultural produce, including a variety of fruit crops.

Figure 1: Khyber Pukhtunkhwa divisions

Its temperate climate and fertile soil make it an ideal region for cultivating peaches, among other fruits. However, the area's agricultural productivity is often challenged by pest infestations, particularly fruit flies, which pose a significant threat to peach crops. Addressing these challenges is crucial for enhancing fruit quality and ensuring sustainable agricultural practices in the region

2.2. Monitoring/Evaluation Survey

A comprehensive tracking/evaluation survey was performed within the locations in Swat from March, 2023 to June, 2023.

2.3. Identification of fruit fly

A stereo microscope was used for identification of fruit flies. Adult flies measured approximately five millimetres in length and were primarily orange to brownish in color. Fruit flies had a dark patch on the tip of their wings and a yellow dorsal protection. In the final larval stage, the maggots were large, ranging from white to creamy, and could reach a length of at least one centimeter (Figure 2).

Figure 2: Maggots of fruit fly inside peach fruit

2.4. Host plant

The peach fruit fly is capable of infesting a wide variety of fruits such as peach (*Prunus persica*), mango (*Mangifera indica*), and guava (*Psidium guajava*). Additionally, over fifty secondary host

plants were recognized, which could facilitate further infestation.

$$\text{Infestation Rate (\%)} = \frac{\text{Total Number of Fruits}}{\text{Number of Infested Fruits}} \times 100$$

2.5. Infestation and damage indicators

The fruit fly lays its eggs inside the fruit as a consequence the infected fruit is punctured. The flesh rots since the peach is harmed by the larvae's internal feeding. The widespread fruit damage can happen due to the larvae's eating habit long before symptoms and indicators become apparent from the outside. Damage indicators are difficult to find in the early stages of an infestation. The peach fruit fly only attacks the fruit, causing no damage to the root, trunk, branches, or leaves of the plant.

2.6. Peach morphometry

To conduct an accurate morphometric analysis, a representative sample of peaches was selected from each variety and location, ensuring a statistically significant sample size of 20-30 fruits per variety. The peaches were handled carefully to prevent bruising and were stored under appropriate conditions, such as a cool room temperature, until measurement.

2.6.1. Physical Measurements

For fruit morphometry, each peach was weighed individually using a precision digital scale and the weight was recorded in grams. The longest dimension of each peach from the stem end to the blossom end was measured with a caliper or ruler, and the length was recorded in millimeters. The fruit diameter at its widest point perpendicular to the length was also measured using a caliper or ruler, with the measurement recorded in millimeters. Stones were removed from the peaches, weighed individually with a precision scale, and the weight was recorded in grams. Finally, the length and width of each stone were measured with a caliper or ruler, and these dimensions were documented in millimeters.

2.6.2. Chemical Measurements

Total Soluble Solids (TSS) was measured by extracting juice from a sample of peaches using a juicer or press. A calibrated refractometer was then used to measure the TSS in degrees Brix (°Brix), ensuring that the refractometer was calibrated according to the manufacturer's instructions before use. The TSS levels were recorded in degrees Brix.

2.7. Data collection and analysis

Data was recorded by maintaining a detailed log of all measurements for each fruit, organized by variety, location, and individual fruit. For analysis, the average weight, length, diameter, stone weight, and Total Soluble Solids (TSS) were calculated for each peach variety. These metrics were compared across different varieties and locations, and statistical methods were applied to identify any significant differences or trends.

3. Results

The Sharbati variety experienced infestation rates ranging from 5% in Kuza Bandai to 30% in Ningolai. For the Shan e Punjab variety, Kabal had the highest infestation at 35%, while Kanju had the lowest at 5%. The Red Sun variety showed notable infestation rates, with Bara Bandai recording 30% and Hazara at 10%. Overall, the data underscores the varying susceptibility of peach varieties to fruit fly infestation in District swat.

Table 1: Fruit fly infestation rates by peach variety and location in District Swat, 2023

Peach Variety	Highest Infestation Location	Highest Infestation Percentage	Lowest Infestation Location	Lowest Infestation Percentage
Sharbati	Ningolai	30%	Kuza Bandai	5%
Shan e Punjab	Kabal	35%	Kanju	5%
Red Sun	Bara Bandai	30%	Hazara	10%

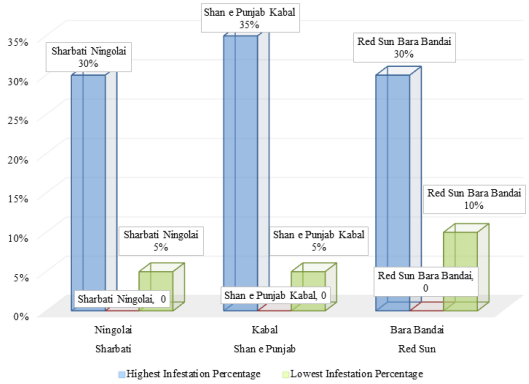


Figure 3: Fruit fly infestation rates by peach variety and location in District Swat, 2023

The data reveals that certain locations, such as Ningolai and Kuza Bandai, consistently exhibit high infestation rates across multiple peach varieties, indicating higher susceptibility in these areas. Conversely, locations like Hazara and Kanju generally show lower infestation rates. These findings highlight the importance of considering both the variety of peaches and the specific locality when developing targeted pest management strategies to effectively address fruit fly infestations.

Table 2: Fruit fly infestation rates by peach variety and location in District Swat, 2023

Location	Khurmani	Sharbati	Shan e Punjab	Red Sun
Ningolai	30%	30%	35%	24%
Kabal	15%	30%	35%	24%
Bara Bandai	30%	20%	20%	10%
Kuza Bandai	20%	30%	14%	30%
Kanju	15%	10%	10%	12%
Hazara	5%	5%	21%	24%

The analysis of Sharbati peach trees reveals distinct patterns across various parameters. Specifically, Tree T2 consistently yields heavier fruits compared to T1 and T3, while Fruit F2 generally surpasses F1 in weight across all trees.

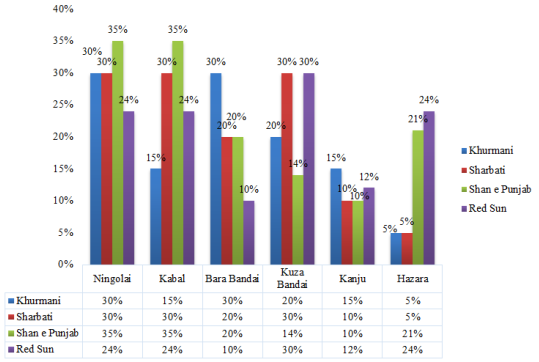
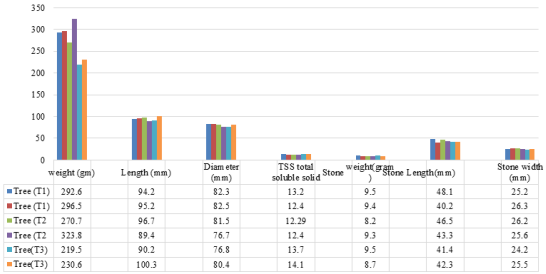


Figure 4: Fruit fly infestation rates by peach variety and location in District Swat, 2023

Regarding length, T3 consistently produces longer fruits for both F1 and F2 compared to T1 and T2, with F2 being longer overall. In terms of diameter, T1 and T2 typically produce larger fruits compared to T3, with T1 generally having a larger diameter than T2. TSS levels vary across trees, with T3 exhibiting higher values for both fruit types, and F2 consistently displaying higher TSS levels than F1. Stone weights remain relatively consistent across trees and fruit types. Notably, T2 produces shorter but wider stones compared to T1 and T3, and F1 stones tend to be longer and narrower than F2 stones. These comprehensive insights underscore the multifaceted nature of Sharbati peach tree characteristics, emphasizing the importance of considering multiple parameters for a thorough assessment of tree performance.

Table 3: Physical and chemical characteristics of Sharbati peach trees across different locations

Name of Parameter	Locations	Tree (T1)		Tree (T2)		Tree (T3)	
		F1	F2	F1	F2	F1	F2
Weight (g)	Ningolai	292.6	296.5	270.7	323.8	219.5	230.6
Length (mm)	Kabal	94.2	95.2	96.7	89.4	90.2	100.3
Diameter (mm)	Bara Bandai	82.3	82.5	81.5	76.7	76.8	80.4
TSS total soluble solid	Kuza Bandai	13.2	12.4	12.29	12.4	13.7	14.1
Stone weight (g)	Kanju	9.5	9.4	8.2	9.3	9.5	8.7
Stone length (mm)	Hazara	48.1	40.2	46.5	43.3	41.4	42.3
Stone width (mm)	Shamzao	25.2	26.3	26.2	25.6	24.2	25.5



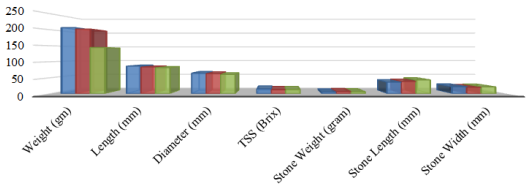
	weight (gm)	Length (mm)	Diameter (mm)	TSS total soluble solid	Stone weight (gram)	Stone Length(mm)	Stone width (mm)
Tree (T1)	292.6	94.2	82.3	13.2	9.5	48.1	25.2
Tree (T1)	296.5	95.2	82.5	12.4	9.4	40.2	26.3
Tree (T2	270.7	96.7	81.5	12.29	8.2	46.5	26.2
Tree (T2	323.8	89.4	76.7	12.4	9.3	43.3	25.6
Tree(T3)	219.5	90.2	76.8	13.7	9.5	41.4	24.2
Tree(T3)	230.6	100.3	80.4	14.1	8.7	42.3	25.5

Figure 5: Fruit fly infestation rates by peach variety and location in District Swat, 2023

The analysis of Red Sun peach trees highlights several key observations across various parameters. Firstly, Tree T1 consistently yields the heaviest fruits for both F1 and F2, while F1 generally outweighs F2 across all trees. Regarding length, T3 consistently produces longer fruits for both F1 and F2, with F1 typically longer except for T2. In terms of diameter, T1 and T2 generally produce larger fruits compared to T3, with T1 having a larger diameter than T3. TSS levels vary across trees, with T1 displaying the highest values for both F1 and F2, and F2 consistently showing lower TSS levels than F1. Stone weights remain relatively consistent across trees and fruit types. Notably, T2 produces longer but narrower stones compared to T1 and T3, with F1 stones generally longer and narrower than F2 stones. These comprehensive insights underscore the importance of considering multiple parameters for a thorough assessment of Red Sun peach tree performance

Table 4: Physical and chemical characteristics of Red Sun peach trees across different locations

Name of Parameter	Areas	Tree (T1)	Tree (T2)	Tree (T3)
Weight (g)	Ningolai	206.5	202.3	144.4
Length (mm)	Kabal	86.1	83.3	81.4
Diameter (mm)	Bara Bandai	64.2	63.1	60.2
TSS (Brix)	Kuza Bandai	15.0	12.8	13.0
Stone weight (g)	Kanju	5.1	6.3	5.7
Stone length (mm)	Hazara	36.2	38.3	42.9
Stone width (mm)	Shamzo	21.7	20.1	21.3



	Weight (gm)	Length (mm)	Diameter (mm)	TSS (Brix)	Stone Weight (gram)	Stone Length (mm)	Stone Width (mm)
Tree (T1)	206.5	86.1	64.2	15	5.1	36.2	21.7
Tree (T2)	202.3	83.3	63.1	12.8	6.3	38.3	20.1
Tree (T3)	144.4	81.4	60.2	13	5.7	42.9	21.3

Figure 6: Physical and chemical characteristics of peach trees across different areas

The analysis of Shan e Punjab peach trees reveals significant variations across various parameters. Firstly, Tree T1 consistently produces the heaviest fruits for both F1 and F2, while T3 consistently exhibits the lowest fruit weight. F1 generally outweighs F2 across all trees. In terms of length, T2 consistently yields longer fruits for both F1 and F2, with F2 tending to be longer than F1 across all trees. Regarding diameter, T2 and T3 generally produce larger fruits compared to T1, with T1 typically having a smaller diameter. TSS levels vary across trees, with T3 showing the highest values for both F1 and F2, while F2 consistently exhibits slightly higher levels compared to F1. Stone weights remain relatively consistent across trees and fruit types. Notably, T1 and T3 produce longer but narrower stones compared to T2, with F1 stones generally longer and narrower than F2 stones. These comprehensive insights underscore the need for a thorough assessment when evaluating Shan e Punjab peach tree performance, considering multiple parameters for a holistic understanding.

Each tree's characteristics are represented by alternating features, F1 and F2. This dataset offers ample opportunity for analysis to uncover patterns, correlations, and differences among the trees. For instance, relationships between tree weight

Table 5: Physical and chemical characteristics of Shan e Punjab peach trees across different areas

Name of Parameter	Areas	Tree (T1)	Tree (T2)	Tree (T3)
Weight (g)	Ningolai	235.7	210.1	213.4
Length (mm)	Kabal	79.2	69.2	72.9
Diameter (mm)	Bara Bandai	70.1	80.1	63.5
TSS (Brix)	Kuza Bandai	11.8	12.5	13.8
Stone weight (g)	Kanju	7.0	6.3	7.3
Stone length (mm)	Hazara	42.7	29.9	40.2
Stone width (mm)	Shamzo	24.8	24.1	23.9

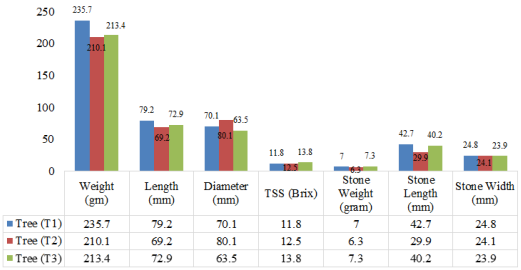


Figure 7: Physical and chemical characteristics of Shan e Punjab peach trees across different areas

Table 6: Physical and chemical characteristics of Khurmani peach trees across different areas

Parameter	Areas	Tree (T1)	Tree (T2)	Tree (T3)
Weight (g)	Ningolai	183.9 (F1)	162.4 (F2)	147.3 (F1)
Length (mm)	Kabal	70.1 (F1)	72.5 (F2)	76.3 (F1)
Diameter (mm)	Bara Bandai	70.1 (F1)	73.2 (F2)	70.7 (F1)
TSS (Brix)	Kuza Bandai	13.9 (F1)	13.3 (F2)	14.0 (F1)
Stone weight (g)	Kanju	6.2 (F1)	5.9 (F2)	7.1 (F1)
Stone length (mm)	Hazara	40.1 (F1)	39.1 (F2)	39.5 (F1)
Stone width (mm)	Shamzo	20.6 (F1)	19.3 (F2)	20.1 (F1)

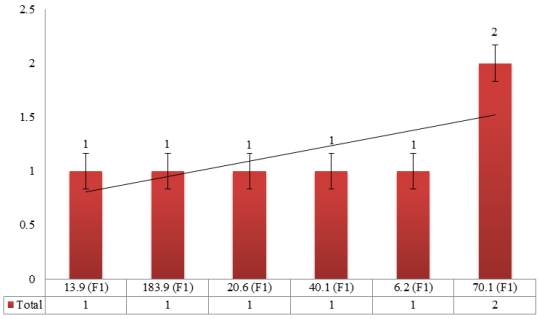


Figure 8: Physical and chemical characteristics of Khrmani peach trees across different areas

and stone weight could be explored, or variations in TSS (Brix) levels among the trees could be investigated. Visualizations such as graphs or charts could enhance understanding and interpretation of the data, facilitating insights into the characteristics of each tree and its associated stones.

4. Discussion

The data from current 2023 study provides crucial insights into fruit fly infestations across different peach varieties and locations in District Swat. The findings emphasize the need for a nuanced approach to pest management that considers both peach variety and specific locality.

The fruit fly infestation rates reveal that locations such as Ningolai and Kuza Bandai consistently show high infestation rates across multiple peach varieties, suggesting a higher susceptibility in these areas. For instance, Ningolai exhibits an infestation rate of 30% for Khurmani and Sharbati varieties and up to 35% for Shan e Punjab (Table 2 and Figure 4). Kuza Bandai shows a similar trend with an overall 30% infestation rate for Red Sun and 14% for Shan e Punjab, indicating variable susceptibility among peach varieties. These findings are consistent with previous research indicating that fruit fly infestation can vary significantly by region and host variety due to local environmental conditions and pest populations (Dhillon *et al.*, 2005; Vargas *et al.*, 2008).

In contrast, locations like Hazara and Kanju report lower infestation rates. Hazara, for example, has an infestation rate as low as 5% for Khurmani and Sharbati varieties (Table 2 and Figure 4). Kanju's rates are also relatively low, with 15% for Khurmani and as low as 10% for Sharbati, highlighting a potentially less favorable environment for fruit fly proliferation. This suggests that these areas might have more effective natural control

agents or less conducive environmental conditions for fruit fly survival and reproduction (Papadopoulos *et al*., 2009).

The analysis of Sharbati peaches indicates that Tree T2 yields heavier fruits compared to T1 and T3, with weights of 296.5g for F2 and 323.8g for F1 (Table 3). Length measurements show that T3 consistently produces longer fruits, with F2 being longer overall, as indicated by measurements in Table 3. Additionally, T1 and T2 typically produce larger diameters compared to T3. The Total Soluble Solids (TSS) levels are highest in T3 for both F1 and F2, with values of 13.7 and 14.1 Brix, respectively. Stone weight remains relatively consistent, with T2 producing shorter but wider stones compared to T1 and T3 (Table 3). These results align with findings that fruit characteristics such as size and TSS can influence fruit fly infestation, with larger fruits and higher sugar content potentially attracting more pests (White and Elson-Harris, 1992; Norrbom *et al*., 1999). Red Sun peaches from Tree T1 are the heaviest, with weights of 206.5g (F1) and 202.3g (F2) (Table 4). Length measurements show T3 produces longer fruits for both F1 and F2, while T1 generally has a larger diameter compared to T3. TSS levels are highest in T1, with 15.0 Brix for F1, and lowest in T2 (Table 4). Stone weights and dimensions are relatively consistent across trees, with T2 producing longer but narrower stones compared to T1 and T3. This suggests that fruit size and sugar content may play a role in susceptibility, as fruit flies are known to prefer larger, sweeter fruits (Koyama *et al*., 2013; Lopez *et al*., 2018). In Shan e Punjab peaches, Tree T1 produces the heaviest fruits, with weights of 235.7g (F1) and 210.1g (F2), while T3 has the lowest fruit weight (Table 5). Length measurements indicate T2 yields longer fruits for both F1 and F2, with T3 having higher TSS levels (13.8 Brix for F2). Stone weights and dimensions show T1 and T3 produce longer but narrower stones compared to T2 (Table 5). This is consistent with the literature suggesting that fruit size and TSS can influence pest attraction and infestation rates (Fitt, 1989; De Meyer *et al*., 2002). For Khurmani peaches, Tree T1 consistently shows heavier fruits compared to T2 and T3, with weights of 183.9g (F1) and 162.4g (F2) (Table 6). Length and diameter measurements show T3 producing longer fruits but with a smaller diameter. TSS levels are highest in T3, with 14.0 Brix for F1, and stone weights and dimensions are relatively consistent across trees (Table 6). These observations support findings that fruit characteristics such as TSS can affect fruit fly behaviour and infestation rates (Iida *et al*., 2006; Mangan and Ekesi, 2021).

The results underscore the importance of considering both the physical characteristics of peach varieties and local infestation rates when developing pest management strategies. The variation in infestation rates across locations highlights the need for localized pest control measures. Areas with high infestation rates, such as Ningolai and Kuza Bandai, may require more intensive management strategies compared to locations with lower rates, such as Hazara and Kanju. This localized approach is supported by studies emphasizing the need for region-specific pest management practices (Bateman *et al*., 2005; Vreysen *et al*., 2007).

The physical and chemical attributes of peaches, including weight, length, diameter, and TSS levels, influence fruit fly behaviour and infestation rates. Understanding these relationships can help tailor pest management strategies to specific peach varieties and local conditions. The findings also stress the importance of on-going research and education for farmers to improve pest

management practices and reduce reliance on agrochemicals. Proper handling, storage, and transportation practices are crucial to minimizing post-harvest losses and enhancing overall peach production in District Swat (Kader, 2009; FAO, 2016).

5. Conclusion

Current study sheds light on the differential impact of fruit fly infestations on various peach varieties across District Swat. Significant variations in infestation rates were observed by location, with Ningolai and Kuza Bandai showing higher rates compared to Hazara and Kanju. The analysis of peach physical and chemical characteristics also indicates that fruit attributes, such as weight and Total Soluble Solids (TSS), influence susceptibility to fruit fly attacks. These findings underscore the importance of location-specific and variety-targeted pest management strategies.

6. Author's Contribution

All authors Fawad Khan, Prof. Dr. Farman Ali, Samina Yasmin, Dr. Gul Zamin Khan and Inam Ullah have contributed equally towards the project design, data collection and manuscript writing.

7. Conflict of Interest

The authors declare no conflict of interests.

8. Novelty Statement

The findings of present study underscore the importance of developing targeted pest management strategies that consider both infestation data and the specific attributes of each peach variety to enhance pest control and improve production practices.

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