Effect of host plant on cornucopia of mango fruit flies (Diptera: Tephritidae) and their triumphant management in context of climate change

Haider Karara,⇑, Muhammad Amjad Bashirb, Abdul Bisis,1, Sagheer Attab, Ahmad Ali Anjumd, Ali Bakhse, Arif Hussainf, Abid Hameeda, Yong Wangc,⇑, Reem Atalla Alajmig, Dina M. Metwallyg,h, Muhammad Imam

aMango Research Institute, Multan, Pakistan
bDepartment of Plant Protection, Faculty of Agricultural Sciences, Ghazi University, DG Khan 32200, Pakistan
cDepartment of Plant Pathology, Agriculture College, Guizhou University, Guiyang 550025, PR China
dDepartment of Plant Protection Faculty of Agriculture, Nanjing Agriculture University, Nanjing, China
eDepartment of Plant Breeding & Genetics, Faculty of Agricultural Sciences, Ghazi University, DG Khan 32200, Pakistan
fDepartment of Soil & Environmental Sciences, Faculty of Agricultural Sciences, Ghazi University, DG Khan 32200, Pakistan
gZoology Department College of Science, King Saud University, Riyadh 11451, Saudi Arabia
hDepartment of Parasitology, Faculty of Veterinary Medicine, Zagazig University, Zagazig 44519, Egypt
iDepartment Soil & Environmental Sciences, Muhammad Nawaz Sharif University of Agriculture Multan, Pakistan

A study was performed to assess the preference of fourteen mango cultivars for fruit flies and their management by bagging. So the choice of Tephritid flies to mango cultivars during fruiting phase is crucial. Fourteen different cultivars of mango viz., 'Dusehri', 'Malda', 'Langra' early cultivars, 'Chaunsa', 'Fajri Klan', 'Sensation' medium whereas 'Sanglakhi', 'Retaul-12', 'Mehmood Khan', 'Tukhmi', 'Kala Chaunsa', 'Chitta Chaunsa', 'Dai Wala' and 'Sobey De Ting' late cultivars were assessed for their suitability for fruit flies. The results indicate that the population density of fruit flies was higher on late cultivars like 'Sanglakhi' (20.61 percent), 'Mehmood Khan' (20.22 percent) and 'Reutal-12' (19.92 percent) were proved to be highly susceptible to fruit flies. Among these the cultivar 'Reutal-12' was selected being commercial and future cultivar for the management of fruit flies through bagging. The results reported that the attack of tephritid fruit flies and other insect pests were zero in bagged fruits as compared with control. It was further recorded that the bagged fruits has maximum average fruit weight i.e. 203.50 and 197.83 g per fruit was noted in those treatments where butter paper bag and brown paper bag was wrapped with better coloration as compared with un-bagged fruit with 159.5 g per fruit. Similarly, on an average fruit length were more i.e. 90.17, 91.33 mm in bagged fruit and 85.33 in un-bagged fruits. Furthermore, bagged fruits have zero incidence of disease with reduced fruit crack, fruit sunburn, mechanical damage, bird damage, fruit blemished and agrochemical residues on the fruit. So, it is concluded that the special attention should be given on 'Reutal-12' for the management of fruit flies when devising an IPM program for the control of fruit flies. Further, bagging has proved to be the good agricultural practices for the production of quality mango.

1. Introduction

Mango is enriched with many nutrients which enhances its quality. Pakistan is one of the 4th largest mango producing country and amongst top ten mango fruit exporting countries. Pakistan faced some difficulties for exporting mango fruits to other countries. In this way the growers can generate maximum profit by production of fruit (Abdullah and Shamsulaman, 2008). In spite of fruit...
flies there are some other fruit damaging pests like fruit borer, leaf miner and scales which deteriorate the quantities and quality of fruit (Rajkumar et al., 2013). These insect pests reduced the quality and production (Pena et al., 1998) which can lessen yield of mango up to 50% or more (Patel et al., 2004). Among insect pests fruit flies and scales are known as quarantine pests, if their presence could be recorded in the exportable products, the consignment can be rejected and exporter bear huge losses. For example, a shipment of 1300 kg of mango was rejected by the UK quarantine department during 2018 over the presence of fruit flies larvae in the mango fruits (Ali, 2018). Moreover, fruit flies are considered a caustic crowd of insects that cause huge financial losses in fruits, vegetables and flowers. Some scientists worked on crop losses by fruit flies and reported that 12–60, 40–90 and 12–60 percent crop losses were estimated in mango, guava and papaya (Allwood and Leblanc, 1997). To produce fruit flies free fruits the uses of bags are considered the more important practice to overcome losses. To protect the fruits, bags are commonly used in Australia, China and Japan on grape, peach, apple, pear, loquat to improve the fruit coloration for better market price and by reducing pathological and physiological disorders (Joyce et al., 1997) leading to better look (Amarante et al., 2002b). A number of countries like Argentina, Mexico and Chile, don’t import ‘apples’ unless they are bagged (Sharma et al., 2014). To overcome the losses of these pests growers use diverse practices like chemicals, sanitation, pheromones traps and use of protein hydrolysat but no one approach has proved so much effective. Furthermore the use of insecticides causes residual limits so there is need of some improved type of IPM tools which not only manage these pests but also produce good qualities fruit. Further the bags protect the fruits from insect pests, mechanical, physical injuries, diseases and improve the quality of the fruit for export purposes. These improvements in quality of fruit playing role in development of mango fruit (Sharma et al., 2014). Due to beneficial effects, fruit bagging has become an essential part of quality fruit production for export. The development of varieties resistant to insect pests is chief part of an integrated pest management. The development and then cultivation of pest resistant mango cultivars has been limited, because of the lack of adequate information on the genetic variability and sources of resistance in the available mango genotypes and influence of these sources on the pest multiplication. Though the crop is economically important, the information on the fruit flies and screening of cultivars for the source of resistance to these pests of mango are very much lacking (see Table 1).

Therefore, the present investigations were undertaken to evaluate tolerance in prominent mango cultivars against fruit flies, for timely management. Further it is urgent to find some efficient and environmental friendly control strategies in present climate scenario that guarantee a sustainable production of fruits to full fill the need of world market.

2. Material methods

2.1. Screening of cultivars against fruit flies

A study was carried out at Mango Research Institute, Multan (30.1575°N, 71.5249°E) Punjab, Pakistan on stone fruit stage during, 2016–18. Fourteen most popular commercial cultivars i.e. ‘Dusehr’, ‘Malda’, ‘Langra’ (early cultivars), ‘Chaunsa’, ‘Fajri Khan’, ‘Sensation’ (medium) whereas ‘Sanglakhi’, ‘Retaul-12’, ‘Mehmood Khan’, ‘Tukhmi’, ‘Kala Chaunsa’, ‘Chitta Chaunsa’, ‘Dai Wala’ and ‘Sobey De Ting’ known late cultivars (different time of harvesting) were selected and tagged for recording the data of fruit flies. Fifty fruits per tree were observed randomly from height of 5–6 feet above ground level weekly from three directions i.e. east, south and west. The data was recorded from three trees of the cultivars under three replications. The fruit showing the symptoms like oozing of water from the fruit were considered as infested by fruit flies. Similarly dropped mango fruits on the ground under the tree were collected and cut for recording the data of fruit flies larvae. Further the most susceptible cultivar was undertaken for the management of fruit flies. The data was compiled and analyzed statistically.

2.2. Laboratory studies

The preferences of fruit flies to different cultivars were tested at MRI laboratory. The fruits of all the mango cultivars were collected from the MRI orchard as well as from grower orchard. The collected fruits were ensured free from the infestation of fruit flies and were arranged cultivar wise in two cages of size 1.5 × 1.5 feet on one inch sand layer for the period of three days. After three days the fruits were re-examined for the presence of fruit flies. Two pairs of newly emerged fruit flies adult were released in each cage. The walls of the cages were impregnated with honey solution at five different places as food for female. After ten days the fruits were cut and larvae were counted from each cultivar separately.

2.3. Wrapping of bags

A highly susceptible mango variety to fruit fly ‘Retaul-12’ was selected for bagging with the collaboration of Mango Research Institute, Kinzo agro chemicals and Muhammad Nawaz Sharif, University of Agriculture, Multan. The fruits were wrapped on 1st June 2018 when the fruit was at stone stage before the attack of pest and harvested on 20th of August 2018. There were three treatments i.e. T1: Brown paper bag with black layer inside, T2: Butter paper bag and T3: Control (with no bag). The trees of 15–20 feet height were selected for the bagging. Three hundred bags were wrapped uniform hanged fruits either single or in bunches and left were remained un-bagged as control treatment on the same tree. The bags were closed properly as per instructions from the stalk of each fruit of all the treatments. There were no spaces left behind for invasion of any foreign substances. At the time of harvesting fifty fruits of each treatment were taken as sample randomly to study weight, physical and chemical parameters. From fifty fruits percent damage fruits were calculated.

2.4. Statistical analysis

After compiling the raw we used the ANOVA with help of Stat version 9 and then means were separated with the help of HSD.

3. Results

3.1. Infestation of fruit flies on the trees

The data regarding abundance of fruit flies on mango cultivars remained zero on dated 17.06.16 and 24.06.16. The infestation was started on 1st July 2016 on ‘Retaul-12’ with 0.30 percent infestation and go on increasing with the passage of time. The data regarding the fitness of host plant on fruit flies populations revealed a highly significant differences (F = 146.40; df = 11, 22; P < 0.01) (Table 1) among treatments. The results revealed that average maximum fruit flies infestation i.e. 0.90 percent were recorded on cultivars ‘Mehmood Khan’ and ‘Retaul-12’ which differed significantly from those of recorded on all other cultivars of mango followed by ‘Sanglakhi’ and ‘Sobhay Wali Ting’ i.e. 0.50 and 0.44 percent infestation. All other cultivars showed zero infestation till 08.07.16. The data recorded on 15.07.2016 regarding the
The ‘Tukhmi’ has 12.92 percent infestation (Table 5). by ‘Mehmood Khan’ and Sohbay Di Ting (16.90 and 14.97 percent). from those of recorded on all other varieties of mango followed variety ‘Sanglakhi’ and Retaul-12 which differed significantly mum fruit flies infestation (23.13 and 21.22 percent were recorded other varieties of mango followed by ‘Retaul-12’, ‘Sobey Di Ting’ differed significantly from those of recorded on all cultivars ranging from 12.34 to 9.13 percent infestation recorded on 12.8.16.

### Table 1
Mango cultivars characteristics along with their breeding centers.

| S/No | Cultivars     | Breeding center | Parentage       | Leaf Colour | Leaf Shape | Inflorescence Length | Inflorescence Colour |
|------|---------------|-----------------|-----------------|-------------|------------|----------------------|----------------------|
| 1    | Dushehri      | MRS-Shujabad     | Chance seedling | Medium Green| Elliptical | Medium long          | Light green          |
| 2    | Malda         | Data not available| –               | –           | –          | –                    | –                    |
| 3    | Langra        | MRS-Shujabad     | Chance seedling | Light Green | Elliptical | Medium long          | Light yellow         |
| 4    | Chaunsa       | MRS-Shujabad     | Chance seedling | Dark Green  | Elliptical | Long and medium branched | Yellowish pink       |
| 5    | Fajri Klan     | MRS-Shujabad     | Chance seedling | Medium Green| Elliptical | Medium long and medium branched | Yellowish pink       |
| 6    | Sensation     | MRS-Shujabad     | Chance seedling | Dark Green  | Elliptical | Long and well branched | Yellowish pink       |
| 7    | Sanglakhi      | Data not available| –               | –           | –          | –                    | –                    |
| 8    | Retaul-12     | MRS-Shujabad     | Chance seedling | Dark Green  | Elliptical | Medium long and medium branched | Light green          |
| 9    | Mehmood Khan   | Data not available| –               | –           | –          | –                    | –                    |
| 10   | Tukhmi        | Data not available| –               | –           | –          | –                    | –                    |
| 11   | Kala Chaunsa   | MRS-Shujabad     | Chance seedling | Medium Green| Elliptical | Medium long and branched | Yellowish pink       |
| 12   | Chitta Chaunsa | MRS-Shujabad     | Chance seedling | Dark Green  | Elliptical | Long                 | Pinkish Yellow       |
| 13   | Dai wala       | Data not available| –               | –           | –          | –                    | –                    |
| 14   | Sobey De Ting  | MRS-Shujabad     | Chance seedling | Medium Green| Elliptical | Long and medium branched | Yellowish green      |

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Khan (2012).

fitness of host plant revealed a highly significant differences (F = 128.76; df = 10, 20; P < 0.01) (Table 2) among treatments. The data revealed that average maximum fruit flies infestation i.e. 14.23, 13.76, and 13.24 percent were recorded on cultivars ‘Retaul-12’, ‘Sanglakhi’ and ‘Mehmood Khan which differed significantly from those of recorded on all other mango followed by ‘Tukhmi’ and ‘Sohbay Di Ting’ with 8.76 and 6.40 percent infestation. The cultivars ‘Chaunsa’, ‘Fajri’, ‘Chita Chaunsa’, ‘Kala Chaunsa’ and ‘Sensation’ showed 0.00–0.89 percent infestation. The data on fruit flies populations revealed a highly significant differences (F = 156.41; df = 10, 20; P < 0.01) (Table 3) regarding the fitness of host plant among treatments. The data showed that average maximum fruit flies infestation i.e. 19.13 and 17.39 percent were recorded on cultivars, ‘Sanglakhi’ and ‘Mehmood Khan’ followed by ‘Retaul-12’ i.e. 15.32 percent infestation which differed significantly from those of recorded on all other cultivars of mango. The cultivars ‘Tukhmi’ and ‘Sohbay Di Ting’ showed similar fruit flies infestations with 10.39 and 9.43 percent infestation followed by, Fajri, ‘Chaunsa’, ‘Dai wala’, ‘Sensation’, ‘Chita Chaunsa’ and ‘Kala Chaunsa’ showed 0.00–2.12 percent infestation on 22.07.2016. Further the suitability of host plant on fruit flies infestation revealed significant differences (F = 255.20; df = 10, 20; P < 0.01) among treatments (Table 2) regarding the fitness of host plant among treatments. The average maximum fruit flies infestation (23.13 and 22.22 percent were recorded on variety ‘Sanglakhi’ and Retaul-12 which differed significantly from those of recorded on all other varieties of mango followed by ‘Sanglakhi’ and Sohbay Di Ting (16.90 and 14.97 percent). The ‘Tukhmi’ has 12.92 percent infestation (see Table 5).

The average minimum infestation of fruit flies was recorded on all other cultivars ranging from 2.27 to 0.78 percent infestation on 29.07.16. The data recorded on 05.08.2016 on the suitability of host plant to fruit flies infestation recorded that three cultivars i.e. 32.47, 31.25 and 29.33 percent were recorded on variety ‘Retaul-12’, ‘Mehmood Khan’ and ‘Sanglakhi’ which differed significantly from those of recorded on all other varieties of mango followed by ‘Sobey Di Ting’ and ‘Tukhmi’ (44.77, 39.14 and 32.75 percent). The average minimum infestation of fruit flies was recorded on all other cultivars ranging from 12.34 to 9.13 percent infestation recorded on 12.8.16.

#### 3.2. Cumulative damage on trees

The cumulative data of all dates reported that three cultivars i.e. ‘Sanglakhi’, ‘Mehmood Khan’ and ‘Retaul-12’ were reported to have the highly susceptible to fruit flies i.e. 20.61, 20.22 and 19.92 percent infestation as compared with other cultivars. The ‘Retaul-12’ being commercial cultivars was selected for the management of fruit flies (Fig. 1).

#### 3.3. Infestation of fruit flies on dropped fruits

The early cultivars were escaped from the infestation of fruit flies so the late cultivars were considered for further studies. The data regarding the suitability of host plant to fruit flies infestation recorded from fallen fruits found under the tree populations revealed a highly significant differences (F = 43.38; df = 7, 14; P < 0.01) (Fig. 2) among treatments. The average maximum infested fruits i.e. 45.30 were recorded from the cultivar ‘Sanglakhi’ followed by ‘Retaul-12’, ‘Tukhmi’, ‘Mehmood Khan’ and ‘Dai wala’ i.e. 34.82, 34.00, 27.16 and 27.00 percent on 15.07.2016. The cultivar ‘Sobay Walli Ting’ has less infested fruits i.e. 19.87 percent statistically similar to ‘Kala Chaunsa’ with 13.00 percent infested fruits. Cultivar ‘Chitta Chaunsa’ has low infested fruits i.e. 5.10 percent found under tree. Similarly the data regarding the suitability of host plant to fruit flies infestation recorded on dated 22.7.2016 from fallen fruits found under the tree populations revealed a highly significant differences (F = 46.62; df = 7, 14; P < 0.01) (Fig. 3) among treatments. The average maximum infested fruits i.e. 53.24 percent were recorded from the cultivar ‘Sanglakhi’ statistically similar to ‘Mehmood Khan’ and ‘Retaul-12’ with 49.67 and 44.44, followed by ‘Dai wala’ having 38.29 percent on 22.07.2016 statistically similar to ‘Tukhmi’ having 36.11 percent infested fallen fruits. The cultivar ‘Chitta Chaunsa’ has low infested fruits i.e. 5.23 percent found under the tree. The data recorded on dated 29.7.2016 from fallen fruits found under the tree populations revealed a highly significant differences (F = 125.46; df = 7, 14; P < 0.01) (Fig. 2) among treatments. The average maximum infested fruits i.e. 53.24 percent were recorded from the cultivar ‘Sanglakhi’ statistically similar to ‘Mehmood Khan’ and ‘Retaul-12’ with 49.67 and 44.44, followed by ‘Dai wala’ having 38.29 percent on 22.07.2016 statistically similar to ‘Tukhmi’ having 36.11 percent infested fallen fruits. The cultivar ‘Chitta Chaunsa’ has low infested fruits i.e. 5.23 percent found under the tree. The data recorded on dated 29.7.2016 from fallen fruits found under the tree populations revealed a highly significant differences (F = 125.46; df = 7, 14; P < 0.01) (Table 2) among treatments.

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39.60 percent followed by ‘Kala Chaunsa’ have 31.42 percent infested fruits. The cultivar ‘Chitta Chaunsa’ has low infested fruits i.e. 16.25 percent found under the tree. The data recorded on dated 05.08.2016 from fallen fruits found under the tree populations revealed a highly significant differences ($F = 148.59; df = 7, 14; P < 0.01$) (Table 2) among treatments. The average maximum infested fruits i.e. 81.00 percent were recorded from the cultivar ‘Retaul-12’ statistically similar to ‘Sanglakhi’ with 73.56 percent

### Table 2
Data regarding fruit flies infestation recorded hanging fruits on trees.

| Cultivars       | Average percent damage of fruit flies recorded on the mango trees |
|-----------------|---------------------------------------------------------------|
|                 | 17.6.16 | 24.6.16 | 1.7.16 | 8.7.16 | 15.7.16 | 22.7.16 | 29.7.16 | 5.8.16 | 12.8.16 |
| Dusehri         | 0.00     | 0.00     | 0.00    |        |         |         |         |        |        |
| Malda           | 0.00     | 0.00     | 0.00    |        |         |         |         |        |        |
| Langra          | 0.00     | 0.00     | 0.00    | 0.00   | 0.89    | 2.15d    | 2.27d    | 3.18d  | 9.19c   |
| S.B. Chaunsa    | 0.00     | 0.00     | 0.00    | 0.00   | 0.39    | 2.12 d    | 1.57 d    | 2.47d  | 9.16c   |
| Fajri           | 0.00     | 0.00     | 0.00    | 0.00   | 1.04 d    | 1.19 d    | 1.98c   | 29.33 a  | 39.14 ab |
| Sensation       | 0.00     | 0.00     | 0.00    | 0.00   | 13.43   | 23.14 a  | 29.33 a    | 39.14 ab |
| Sanglakhi       | 0.00     | 0.00     | 0.00    | 0.50   | 14.23   | 17.39 ab    | 16.90b  | 31.25 a    | 44.77 a  |
| Retaul-12       | 0.00     | 0.00     | 0.30    | 0.90   | 21.39   | 19.60  | 31.25 a    | 44.77 a  |
| Mehmood Khan    | 0.00     | 0.00     | 0.00    | 0.90   | 34.87   | 22.13    | 32.47  | 32.75b    |
| Tukhmi          | 0.00     | 0.00     | 0.00    | 0.00   | 21.39   | 21.39  | 31.25 a    | 44.77 a  |
| Kala Chaunsa    | 0.00     | 0.00     | 0.00    | 0.00   | 0.00    | 0.00 d    | 0.00  | 1.50 d    | 2.76c    |
| Chita Chaunsa   | 0.00     | 0.00     | 0.00    | 0.00   | 0.00    | 0.00  | 1.50 d    | 2.76c    |
| Dai wala        | 0.00     | 0.00     | 0.00    | 0.00   | 4.34    | 1.12 d    | 0.78 d    | 4.35c  | 12.34c   |
| Sohbay Wali Ting | 0.00  | 0.00     | 0.00    | 0.44   | 6.40    | 9.43c  | 14.97 bc  | 19.65b  | 33.98b   |
| **F-Value**       |          |          |          |          |          | 156.41 | 255.20 | 113.47 | 79.98 |
| **Tukey’s HSD @ 5%** |          |          |          |          |          | 3.08  | 2.88  | 6.17  | 8.08 |

### Table 3
Data regarding average fruit flies infestation recorded on dropped fruits of mango.

| S/No. | Cultivars | Date of observation of fallen fruits of late varieties to fruit flies |
|-------|-----------|---------------------------------------------------------------|
|       |           | 15.7.16 22.7.16 29.7.16 5.8.16  |
| 1-    | Sanglakhi | 45.00 a 53.24 a 72.34 a    73.28 ab |
| 2-    | Retaul-12 | 35.00b 44.44 abc 78.89 a    81.00 a  |
| 3-    | Mehmood Khan | 27.16 bc 49.67 ab 51.29b    71.99b |
| 4-    | Tukhmi    | 34.00b 36.11 cd 46.67 bc    55.49c  |
| 5-    | Kala Chaunsa | 13.00 de 26.67 d 31.42 d    35.29 e  |
| 6-    | Chita Chaunsa | 5.10 e 5.23 e 16.25 e    29.21 e  |
| 7-    | Dai wala  | 27.00 bc 38.29 bc 41.23c    44.87 d  |
| 8-    | Sohbay Wali Ting | 19.87 cd 24.85 d 39.60 cd    45.02 d  |
|       | **F-Value** | 43.38 46.62 125.46 148.59 |
|       | **Tukey's HSD @ 5%** | 9.75 11.41 9.15 7.83 |

### Table 4
Data regarding of different pest on covered vs uncovered fruits of Retaul-12.

| Types of bags                  | Average percent insect attack per fruit | Average number of pests per fruit | Diseases | Colour of fruits | Attraction of Exporter/purchaser |
|--------------------------------|----------------------------------------|----------------------------------|----------|-----------------|---------------------------------|
|                                | Fruit flies | Fruit borer | Thrips | Scales | Mites |                       |                              |
| Brown paper bags with inner black paper bag | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Yellowish with red bluish | Very attractive |
| Butter paper bags              | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Greenish | Normal |
| No bags                        | 17.23 | 4.57 | 7.29 | 3.21 | 2.97 | Greenish | Normal |

### Table 5
Cost benefit ratio of mango variety Retaul-12 bagging and without bagging.

| S/No | Cost benefit ratio |
|------|--------------------|
|      | Fruits covered with bags | No bags/ Control |
|      | Brown paper | Butter paper |
| 1-   | Average rate of fruit per kg | 77.50 | 55.00 | 47.50 |
| 2-   | Rate per mound | 3100 | 2200 | 1900 |
| 3-   | Difference with control | 1200 | 300 | 0.00 |
| 4-   | Cost per bag (Rs.) | 2.00 | 1.50 | 0.00 |
| 5-   | Labor rupees charges per fruit (Rs.) | 0.80 | 0.80 | 0.00 |
| 6-   | Average cost of 2 sprays per fruit (Rs.) | 0.00 | 0.00 | 3.00 |
| 7-   | Average price per fruit (Rs.) | 15.33 | 11.19 | 7.58 |
| 8-   | Benefit per fruit = Price per fruit-labor charges per fruit-cost of spray per fruit (Rs.) | 12.53 | 8.89 | 4.58 |
| 9-   | Benefit over control (Rs.) | 7.95 | 4.31 | 0.00 |
| 10-  | Cost benefit ratio | 2.73 (2.73:1.00) | 1.94 (1.94:1.00) | 1.00 |
followed by ‘Mehmood Khan’ with 71.99 percent infested fruits. The cultivar ‘Tukhmi’ has 55.49 percent infested fallen fruits followed by ‘Sobay Wali ting’ and ‘Dai wala’ having 45.02 and 44.87 percent infested fruits. The cultivar ‘Kala chaunsa’ and ‘Chitta Chaunsa’ has low infested fruits i.e. 35.29 and 29.21 percent found under the tree (see Fig. 8).
3.4. Cumulative fruit flies damaged fruits under the tree

The damaged fallen fruits by fruit flies reveal that average maximum 60.97, 59.83, 50.03 and 43.07 percent damaged fruits were recorded under the tree of cultivar ‘Sanglaki’ ‘Retaul-12’, ‘Mehmood Khan’ and ‘Tukhmi’. Whereas less damaged 13.95 percent were recorded under the ‘Chitta Chaunsa’ tree. The cultivars ‘Kala Chaunsa’, ‘Dai wala’ and ‘Sobey Wali Ting’ has damaged fruit flies fruits were 26.60, 37.85 and 32.34 percent were found under the trees as shown in Fig. 1.

3.5. Preference of fruit in laboratory

The graph shows that in laboratory the fruit flies preferred the late cultivars ‘Sanglaki’, ‘Mehmood Khan’ and ‘Retaul-12’ for egg laying. It was recorded with average 17.29, 14.23 and 11.87 numbers of larvae per fruit was observed as compared with early cultivars. More number of fruit flies larvae was detected in late cultivars.

3.6. Effects of bagging on fruit quality

**Pest control:** The data in the Table 4 reported that covered fruits either with brown paper or butter paper were remained free from all types of insect pest and diseases. The colour of the fruits was attractive with red blush was recorded in those bags where brown paper bags wrapped. These fruits were gorgeous to purchaser and exporter. Whereas the fruits wrapped in butter paper bags also free from pests but their colour remain green as was in control. It was further observed that there were no physical, mechanical injuries, bird damage and blemishes were recorded on bagged fruits. In case of those fruit which was uncovered having 17.23 and 4.57% fruit flies and fruit borer attack and other insect like thrips, scales and mites 7.29, 3.21 and 2.97 mites per fruit were recorded on the fruits at the time of harvesting.

**Graphically shown fruit damage by bird:** There was no bird damage on wrapped fruits but 2.00% damage was recorded on control fruits as shown in Fig. 4.

**Graphically shown average fruit weight (gram) and length (mm):** Bagging of fruits had a significant role in growth and development of fruit. Those Fruits which were wrapped with brown paper bags and butter paper shows weight i.e. 197.83 and 203.5 g on an average per fruit where as 159.5 g weight was recorded in un-bagged fruits as shown in Fig. 5.

**Graphically shown pulp, stone and peel ratio:** The pulp, stone and peal ratio was recorded from covered and uncovered fruits. It was found that ration of pulp, was 84.89: 113.44: 76.52 g of brown, butter and uncovered fruits. Similar peal ration was 57.81:62.86:46.81 g. The stone ratio was 35.84:40.37:28.65 g was recorded in covered and uncovered fruits as shown in the Fig. 6.

**Graphically shown TSS of fruit:** The total soluble solids content (TSSC) of the fruit wrapped in brown paper was 26.06 and 24.47% of those fruits which were wrapped in butter paper bag whereas the fruits with no bag have 19.30% as shown in (Fig. 7).

**Acidity of fruit:** Similarly in case of acidity 0.18, 0.18 and 0.19 percent was recorded in brown paper, butter paper bag and control.

**Determination of cost benefit ratio:** The fruits produced by such technique are very much attractive for purchasers, because of beautiful colour development and fine quality of the produce. The cost benefit ratio of the fruits covered with brown paper bags were (2.73:1) compared with fruits with butter paper bags (1.94:1) and control treatment (1.00) respectively. So one can earn money by spending Rs. 1.00 per fruit and gaining Rs. 2.73/fruit, so net profit is Rs.1.73 per fruit in brown paper bags and Rs.0.94 /fruit in butter paper when compared with control.

4. Discussion

This pest cause huge losses for growers internationally in changing weather and are known as quarantine pests. The peach fruit fly, B. zonata infestation is more i.e. 92 percent whereas oriental fruit fly, B. dorsalis is less that is only 8 percent. The results of our study similar to Qureshi et al., 1991. To overcome fruit flies losses so many practices are adopted like sanitation, use of traps, protein hydrolysate and chemicals, contagion of soil and water, health problems for the growers, insecticide resistance and decrease in parasites and predators populations. Further it was noted that the residues of chemicals can alter the market value of the product (Daff, 2010). The practice of growing resistant varieties of agricultural crop is considered one of the superior management practices which is environmentally, naturally and economically beneficial. In this way the crop is saved from insect pest and yield can be protected without or minimum use of insecticides. By the use of such type of practice one can decrease the use of broad spectrum insecticides resulting in decreased soil, water contamination and reduced negative effects on non-target organisms including beneficial insect fauna and labor (Krattiger, 1997). Plants that are less susceptible to injury caused by insect pests are important for more production and better quality of the produce. Further commercial, high value susceptible varieties can also be protected with some other kind of practices like use of bags on fruits. In our project, fourteen most popular commercial cultivars of mango i.e. ‘Dusehri’, ‘Malda’, ‘Langra’ (early cultivars), ‘Chausna’, ‘Fajri Khan’, ‘Sensation’ (medium) whereas ‘Sanglakhi’, ‘Retaul-12’, ‘Mehmood Khan’, ‘Tukhmi’, ‘Kala Chaunsa’, ‘Chitta Chaunsa’, ‘Dai Wala’ and ‘Sobey De Ting’ were known as late cultivars (different time of harvesting) were evaluated for their screening against fruit flies. The results suggested that that there were significant differences among different varieties of mango regarding infestation of fruit flies. Some varieties were vulnerable to fruit flies infestations while others were tolerant. Our results suggested that the early maturing mango cultivars escaped from the infestation of fruit flies whereas medium varieties suffered less and late varieties had more infestation of fruit flies. Among late varieties ‘Retaul-12’ was proved to be the most susceptible to fruit flies. The present findings can be compared with those of Karar et al., 2016 who reported that Retaul-12, a late variety of mango has more infestation of fruit flies and having more number of larvae per fruit as compared with other varieties of mango. Our results suggest that some varieties are susceptible while others are tolerant, so there is significant difference among different varieties of mango. The current findings add significantly to those of (Karar et al. 2012), concluded that pecan varieties responded different to pecan black aphids, onion varieties against thrips (Karar et al. 2013) mango varieties against mango mealy bug and mango hoppers (Karar et al. 2015; Karar and Bakhsh, 2018). For sustainable management practices our results suggests bagging of fruits proved to be the best practice for insect pest of mango. In our experiment two types of bags are used for the protection of fruits from insect pest complex i.e. brown paper bag with inner layer black and butter paper bags. These bags managed the infestation successfully and show high degree of protection not only from fruit flies but also other pests of mango fruit like fruit borer, mealy bugs, thrips, mites, leaf miner and birds. Our results are in line with that of Johnson et al. (2006) who concluded that bagging discourage the birds and avoidance of toxic while Sarker et al. (2009) reported 100 percent protection from fruit flies. Further it was found that brown paper bags improve the quality of fruits and results can be compared Sarker et al. (2009), who found
Fig. 4. Average percent fruit damage due to birds.

Fig. 5. Average fruit weight (g) and length (mm).

Fig. 6. Average pulp, peel and stone in gram of mango fruits.

Fig. 7. Average TSS percentage of mango fruits.
that by the use of bags the better physical quality of mango can be achieved. Our results recommend that the bags not only control the insect pests but also increase in weight and size of the fruits. So keeping in mind the production cost of the produce, bagging is much more reasonable. In this technique, no insecticide application is required whereas in control treatment the average numbers of 3–4 sprays are required to overcome insect pest complex. On the other hand, the average rate of fruits per kg is higher of bagged of 3–4 sprays are required to overcome insect pest complex. On the other hand, the average rate of fruits per kg is higher of bagged fruits as compared with control treatments. The reason could be due to micro environment created by the bagging material that plays a significant role in growth and development of fruits (Sharma et al., 2014) as well as fruit coloration.

5. Conclusion

It is confirmed that only exportable fruits for getting more income. This is only possible in case of late varieties. In this experiment our results suggested that late varieties infested by fruit flies severely. So if we protect the late varieties from the attack of fruit fly, the more income can be generated. Consumers also like to buy high quality fruits free from pests, blemishes, sunburn, spray and of good outlook. These qualitative characteristics fruits can be produced by the use of bags. In this way more income can be generated by exporting high quality fruits with increased volume and consignment can be saved from destruction.

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References

Abdullah, F., Shamsulaman, K., 2008. Insect pests of Mangifera indica plantation in Chuping, Perlis, Malaysia. J. Entomol. 5, 239–251.
Ali, M., 2018. UK rejects mango consignment upon detecting fruit fly. July 19th DAWN newspaper; Available online at https://fp.brecorder.com/2018/07/2018071939205/.
Allwood, A.J., Blanc, L.L., 1997. Losses caused by fruit flies in seven Pacific island countries. In: A.J. Allwood, Drew, R.A.I. (Eds.), Management of Fruit Flies in the Pacific. Canberra, ACFAR Proceedings No. 76, pp. 208–211.
Amarante, C., Banks, N.H., Max, S., 2002b. Pre-harvest bagging improves pack out and fruit quality of pears (Pyrus communis). New Zealand J. Crop Hort. Sci. 30, 93–98.
Daff, 2010. Fruit Fly Code of Practice. Document prepared for Working Group workshop 22 October 2010 (Sydney), Department of Agriculture, Fisheries and Forestry, Canberra.
Johnson, M.W., Zalom, F.G., Steenwyk, R.V., Vossen, P., Devarenne, A.K., Daane, K.M., Krueger, W.H., Connell, J.H., Yokoyama, V., Bisabri, B., Capriole, J., Nelson, J., 2006. Olive fruit fly management guidelines. UC Plant Port. Quart. 16, 1–7.
Joyce, D.C., Beasley, D.R., Shorter, A.J., 1997. Effect of pre-harvest bagging on fruit calcium levels, and storage and ripening characteristics of ‘Sensation’ mangoes. Austr. J. Experi. Agri. 37, 383–389.
Karar, H., Abbas, G., Dutcher, J.D., 2012. Pecan cultivars differences in aphid reproduction and abundance. J. Entomol. Sci. 47, 86–91.
Karar, H., Abbas, G., Hameed, A., Shahzad, M.F., Ahmad, G., Ali, A., Saleem, M., 2013. Relative susceptibility of onion, Allium cepa genotypes of Pakistan to onion Thrips, Thrips tabaci, (Thysanoptera: Thripidae). Pak. J. Agri. Sci. 50, 351–357.
Karar, H., Arif, M.J., Arshad, M., Ali, A., Abbas, Q., 2015. Resistance/ susceptibility of different mango cultivars against mango mealy bug, Drosichia mangiferae (G.). Pak. J. Agric. Sci. 52, 367–377.
Karar, H., Saeed, S., Ullah, U.N., Rehman, S., Abbas, M.A., Ayyaz, A., Sadiq, H., Qayyum, M., Ahmad, M., 2016. Production of quality and cosmetic valued Mangoes and management of fruit fly (Tephritidae: Diptera). Pak. Entomol. 38, 1–5.
Karar, H., Bakhsh, M.A., 2018. Effect of host plant on abundance of mango hoppers, Idioscopus clupealis (Lethierry) (Hemiptera: Cicadellidae). Pak. Entomol. 40, 57–61.
Khan, M.I., 2012. Catalogue of mango germplasm. Mango Research Station, Shujabad. pp. 1–90.
Krattinger, A.F., 1997. Insect Resistance in Crops: A Case Study of Bacillus thuringiensis (Bt) and its Transfer to Developing Countries. ISAAA Briefs No. 2. ISAAA, Ithaca, NY. pp. 42.
Patel, J.R., Shekh, A.M., Ratnapara, H.C., 2004. Seasonal incidence and effect of minimum temperature and vapour pressure on the population of mango hoppers in middle Gujarat. Gujarat Agric. Univ. Res. J.20, 5–8.
Pena, J.E., Mohyuddin, A.I., Wysoki, M., 1998. A review of the pest management situation in mango agro-ecosystems. Phytoparasitica 26, 129–148.
Qureshi, Z.A., Hussain, T., Siddiqui, Q.H., 1991. Relative preference of mango varieties by Dacus zonatus and D. dorsalis. Pak. J. Zool. 23, 85–87.
Rajkumar, B.G., Khan, R.M., Kumar, H.K., 2013. Integrated pest management for enhancing quality production of subtropical fruits under high density planting with canopy modification. In: Singh, V.K., Ravishankar, H. (Eds.), Canopy Management and High Density Planting in Subtropical Fruit Crops. CSIR, as Central Inst. of Subtropical Hort., Lucknow, India, p. 269.
Sarker, D., Rahman, M.M., Barman, J.C., 2009. Efficacy of different bagging materials for the control of mango fruit fly. Bangladesh J. Agric. Res. 34, 165–168.
Sharma, R.R., Reddy, S.V.R., Jhalegar, M.J., 2014. Pre-harvest fruit bagging a review. J. Hort. Sci. Biotech. 89, 101–113.

Fig. 8. Average acidity percentage of mango fruits.