



EFFECTIVENESS OF PRE-HARVEST FRUIT BAGGING IN CITRUS CROP: PROTECTION OF CITRUS AGAINST FRUIT FLIES, BLEMISHES AND DISEASES AND IMPACT ON PHYSIOCHEMICAL PARAMETERS OF CITRUS

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ABSTRACT

Current study was conducted at Citrus Research Institute, Sargodha, Pakistan during 2020 to determine the effectiveness of different fruit bagging materials to reduce the fruit fly infestation and also to check their impact on skin color of developing fruits and also upon the fruit quality in citrus variety "kinnow mandarin". The fruits were covered with four types of bagging materials such as perforated polyethylene, butter paper, muslin cloth bag and brown paper. No fruit fly infestation was observed in fruits covered with different types of bags as compared with un-wrapped fruits. However, 12.43% fruit fly infestation was recorded in non wrapped bags. Fruits covered with brown paper bags and butter paper bags did not show any blemish problem and were also free from citrus canker. Bagging with perforated polyethylene, brown paper and butter paper materials also resulted in improving the fruit colour. None of the bagging material resulted in increase in fruit size (length × width) and fruit weight in citrus fruits. Statistically, the highest amount of juice weight (54.22 g) was detected in fruits enveloped in brown papers followed by butter paper bag (53.31 g), perforated polyethylene bags (50.89 g), muslin cloth bag (48.43 g) and non-bagged (47.43 g) fruits. The highest amount of TSS was found in fruits wrapped in brown paper bags (11.67%) followed by muslin cloth bag (11.41%) and were statistically at par with each other but significantly different with perforated polyethylene bags (11.11%), butter paper bags (10.35%) and un-wrapped fruits (10.60%). Lowest (0.87%) and highest (1.02%) acidity was observed in fruits wrapped with brown paper and muslin cloth bags, respectively was observed. In short bagging material could be used to protect citrus from fruitfly attack.

KEYWORDS: *Citrus reticulata*; bagging; fruit fly; TSS; blemishes; Pakistan

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INTRODUCTION

Citrus (*Citrus reticulata* L.) is a valuable fruit and its greater productivity is necessary for growers and national economy. Citrus production in Pakistan is successful on account of favourable climatic conditions (Syed, 2007). Main hub of citrus production is Punjab which yields superior quality citrus that is exported to different countries. Major regions in Punjab which produce huge amount of citrus are Sargodha, Mianwali, Sahiwal, Jhang, Rahim Yar Khan, Toba Tek Singh and Multan. However, among these cities the share of Sargodha is maximum in citrus production and export. As Pakistan's largest fruit crop, citrus holds vital importance concerning export and about 533 thousand tonnes is exported by Pakistan (GoP, 2019). Pakistan has taken a prominent position in the citrus industry among leading kinnow exporting countries

with an average 2.132 million tonnes production with the cultivated area of 199.9 thousand hectares (Ahmed *et al.*, 2006; Ahmed *et al.*, 2007). Currently, the average citrus production in Pakistan is 9.5 tons/ha although the potential is 18-20 tons/ha (FAO, 2019). A large productivity gap which exists between potential and actual citrus yield is correlated to many factors such as insect pests and diseases. Poor control of many citrus pests for example leafminer, mealybug, mites, termites, red scales, aphids and fruit fly deteriorate the citrus fruit quality and reduce its yield. Insect pests role is counted as significant in lowering the production (Ashraf *et al.*, 2014).

Fruit flies (Diptera: Tephritidae) are a serious threat to fruit worldwide. However, studies indicate that fruit flies are not fully adapted to this host (Dias *et al.*, 2017). Fruit flies attack on healthy and damaged fruits as

well as vegetables. Eggs are laid beneath the skin and hatched larvae feed in the pulpy portion of fruits and vegetables leading to fruit decay (Sarwar, 2015). Apart from direct losses, many countries enforce strict quarantine checks to prevent the trade of fruit fly infested citrus fruits as new fruit fly species could be introduced and established among trading countries in the absence of such measures (Allwood *et al.*, 2001). Farmers' sole reliance on haphazard insecticide applications in controlling the fruit flies in vegetables and fruit orchards did not result in sustainable pest management and also raised many unwanted problems such as insecticide resistance development, soil and water contamination, accumulation of insecticide residues in crops, destruction of beneficial insect fauna and health issues for farmers (Ganie *et al.*, 2013). Reliance upon other control methods such as physical barriers, use of entomopathogenic fungi and biological control using predators are the important methods to minimize pest attack (Javed *et al.*, 2019; Javed and Qiu, 2020; Javed *et al.*, 2020).

Several monitoring and control measures have been employed in recent years to limit the damage from fruit fly including fruit baggings. Fruit bagging is one of the mechanical production procedures in which fruits are wrapped with bags made of different materials. This practice results in pest exclusion, improvement in fruit quality and appearance and also in reduction of chemical residues (Sharma *et al.*, 2014). Previously, Kim *et al.* (2008) used the large brown craft paper bag and a small transparent paraffin paper bag for wrapping of 'Housui' pears and obtained fruits shiny and smooth skin with better appearance and uniform in size. Similarly, Lin *et al.* (2012) in their study observed that pears wrapped in paper bags were more attractive, brighter and, with fewer blemish dots as compared to non-bagged pears.

In citrus, there is no evidence about the effect of covering the fruits with different bagging materials. Therefore, this study was planned to evaluate the effectiveness of pre-harvest fruit bagging in citrus to check which type of bagging materials provide protection against fruit flies and also to observe whether bagging has an effect on enhancing the citrus fruit quality. The results could be helpful in reducing the risk of fruit flies in citrus orchards if implemented on a wider scale.

MATERIALS AND METHODS

The research work was done in the research area of Citrus Research Institute, Sargodha, Pakistan in a randomized complete block design (RCBD) with five replicates during 2020. The kinnow fruits were covered with four types of bagging materials such as perforated polyethylene, butter paper, muslin cloth bag and brown

paper. The bagging of fruits was done in September to November, depending upon fruit maturity. A total of 300 fruits (60 per replicate) was covered for each treatment. The fruits of control treatment were kept un-wrapped. The damaged bags by winds or rainfall were replaced at regular intervals. Data regarding fruit fly infestation were recorded throughout the season by observing fruit fly infestation and fruit drop. The fruits were harvested at maturity according to standardized maturity indices of the variety. The physicochemical parameters i.e. fruit weight, fruit colour, blemishes, peel thickness, fruit size, weight of juice, peel, rag and no. of seeds/fruit were recorded. Chemical analysis was done to determine TSS, acidity and TSS/acid ratio. In each replication, ten fruits were weighed by digital electric balance to measure the average fruit weight. The juice of 10 harvested fruits was extracted with the help of electric juice squeezer and weighed.

$$\text{Juice content (\%)} = \frac{\text{Juice weight}}{\text{Fruit weight}} \times 100$$

After extraction of juice, the leftover residue was considered as rag content. The percent rag content was estimated with the help of the following formula:

$$\text{Rag content (\%)} = \frac{[\text{Fruit weight} - (\text{peel weight} + \text{Juice weight})]}{\text{Fruit weight (g)}} \times 100$$

Selected fruits were peeled manually. Peel was weighed with an electronic balance, and the percent peel content was calculated by using the formula:

$$\text{Peel content (\%)} = \frac{\text{Peel weight (g)}}{\text{Fruit weight (g)}} \times 100$$

To measure the total soluble solids (TSS) about 1-2 drops of citrus juice were put on the prism of an automatic digital refractometer (ATAGO, Tokyo, Japan, RX 5000). To determine the juice acidity, 10 ml of juice from each sample was diluted with distilled water using a beaker of 100 ml. Evaluation of the endpoint was done by adding 2-3 drops of phenolphthalein. Titration of samples was performed using 0.1 N NaOH solution. The results were expressed as percent citric acid (Ahmed *et al.*, 2006) and overall, ten fruits were used for TSS, and acidity measurement and then means were calculated:

$$\text{Acidity (\%)} = \frac{N/10 \text{ NaOH} \times 0.0064}{\text{Volume of weight of sample used}} \times 100$$

The numbers of fruits dropped and infested with fruit fly were counted and their averages were calculated.

The impact of different bags and non bag treatments was also determined on physical appearance of fruit and also on disease development. A total of 300 bagged fruits were inspected for fruit fly infestation and other physiochemical parameters. The data regarding different physical and chemical parameters were analyzed by RCBD using statistix version 8.1 software and means were compared by LSD (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Fruit drop and fruit infestation rates

Significant differences in the fruit fly infestation (%) between bagged and un-bagged citrus fruits were observed (Table 1). No fruit fly infestation was observed on citrus fruits covered with different bags as compared to un-wrapped fruits where 12.43% infestation was recorded. The minimum fruit drop was observed in citrus fruits wrapped with brown paper ($n = 12$) and butter paper ($n = 22$) bags while among the bagging treatments, the fruit drop was maximum with muslin cloth bag. However, large number of fruit drop ($n = 75$) was observed in non-bagged fruits that is maximum among all treatments (Table 1).

Physical appearance and disease

Bagging of citrus fruits brought significant colour changes and also effected the appearance of blemishes and diseases mainly citrus canker. The fruits covered with perforated polyethylene bags, brown paper bags and butter paper bags developed favourable colour i.e., orange, yellowish, and fresh orange, respectively. But the citrus fruits covered with muslin cloth bag remained greenish. The non-bagged citrus fruits remained greenish yellow in colour. The citrus fruits covered with brown paper bags and butter paper bags remained blemish free while fruits wrapped in perforated polyethylene and muslin cloth bags were found to carry blemish problem. Effect of bagging on blemish causing diseases such as canker was also evident, non-bagged citrus fruits and fruits covered with perforated polyethylene bags and muslin cloth bag were not free from canker. However, there was no incidence of citrus canker in fruits enveloped in brown paper and butter paper bags (Table 1).

Fruit weight, fruit size and peel thickness

The average citrus fruit size (fruit length \times width in mm) of 51.04×66.64 , 54.41×69.74 , 50.72×65.38 , 53.35×65.99 and 53.67×68.67 (mm) wrapped in bagging materials of different composition and non-bagged, respectively were statistically at par with one another (Table 2). The results for average fruit weight showed that fruit weight (g) was significantly higher in those citrus fruits which were wrapped in brown paper bags (145.30 g) as compared to muslin cloth bag (115.08 g). However, fruit weights of wrapped and un-wrapped were statistically at par (Table 2). The peel thickness (mm) was statistically at par in both bagged and non-bagged citrus fruits (Table 2).

Juice weight, peel weight, rag weight and seediness

Juice weight was significantly higher in citrus fruits which were wrapped in brown paper bags (54.22 g) and butter paper bags (53.31 g) as compared to other bagging and non-bagging treatments; however for both brown paper and butter paper bagged fruits there was no significant difference in juice weight. Fruits in non-bagged and muslin cloth bag treatments resulted in significantly lower juice weight as compared to all other treatments but they were statistically at par with each other (Table 3). The citrus fruits wrapped in brown paper bags exhibited significantly higher peel weight (40.75 g) as compared to all bagging treatments but it was statistically at par with non-bagged treatment. Moreover, among the bagging treatments, significantly lower peel weight was observed for citrus fruits covered with muslin cloth bags (28.96 g) (Table 3). The rag weight of citrus fruits in all bagged and non-bagged treatments remained statistically at par (Table 3). Seediness in citrus fruits was not affected to greater extent in both bagged and non-bagged treatments, significantly higher number of seeds/fruit (16.20) were found in citrus fruits covered with muslin cloth and it was statistically at par with brown paper wrapped citrus fruits. The number of seeds/fruit were significantly lower in non-bagged treatment (12.60/fruit) as compared to muslin cloth, and brown paper bagged citrus fruits but it was significantly similar to butter paper and perforated polyethylene bagged citrus fruits (Table 3).

Table 1. Fruit drop, infestation and physical appearance in bagged and non-bagged citrus fruits

Treatments	Av. fruit drop	% Fruit fly infestation	Physical appearance and disease		
			Fruit colour	Fruit blemishes	Diseases
Perforated polyethylene bags	30	0	Orange	Yes	Canker
Brown paper bags	12	0	Yellowish	Nil	Nil
Muslin cloth bag	67	0	Greenish	Yes	Canker
Butter paper bag	22	0	Orange	Nil	Nil
Non-bagged	75	12.43%	Greenish yellow	Yes	Canker

Table 2. Comparison of fruit weight (g), fruit size (mm) and peel thickness (mm) in bagged and non-bagged citrus fruits

Bag type	Avg. fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Peel thickness (mm)
Perforated polyethylene	122.26ab	51.04a	66.64a	3.15a
Brown paper	145.30a	54.41a	69.74a	3.05a
Muslin cloth	115.08b	50.72a	65.38a	3.06a
Butter paper	130.80ab	53.35a	65.99a	3.63a
Non-bagged	139.60ab	53.67a	68.67a	3.31a
LSD	26.62	3.73	5.95	0.62
F value	1.93	1.77	0.88	1.45
P value	0.1551	0.1845	0.4955	0.2629

*Means not sharing a letter in common significantly differ from each other

Table 3. Comparison of bagging and non-bagging treatments on citrus juice, peel and rag weight (g) and seediness.

Bag type	Juice weight (g)	Peel weight (g)	Rag weight (g)	No. of seeds/ fruit
Perforated polyethylene	50.89b	32.82c	38.56a	13.20bc
Brown paper	54.22a	40.75a	50.33a	15.00ab
Muslin cloth	48.43c	28.96d	37.72a	16.20a
Butter paper	53.31a	36.35b	41.43a	13.00bc
Non-bagged	47.43c	42.26a	49.95a	12.60c
LSD	1.41	1.66	26.47	2.17
F value	38.53	98.31	0.48	4.50
P value	<0.00001	<0.00001	0.7485	0.0126

*Means not sharing a letter in common significantly differ from each other

TSS, acidity and TSS/acid ratio

The highest amount of TSS was found in fruits wrapped in brown paper and muslin cloth bags which was 11.67 and 11.41%, respectively as compared to other bagged and non-bagged treatments but both brown paper and muslin cloth treatments were statistically at par with one another (Table 4). However, TSS was significantly lower in citrus fruits wrapped in butter paper bags (10.35%) as compared to all the bagging treatments but it was significantly similar to TSS of non-bagged treatment (10.60%) (Table 4). Acidity was another important citrus quality parameter. Significantly lowest acidity was found in fruits bagged in brown paper bags (0.87%), butter paper bags (0.89%) and perforated polyethylene bags (0.91%) but they were at par with each other while significantly higher acidity percentage was observed in fruits wrapped in muslin cloth bags (1.02%) as compared to all bagged and non-bagged treatments (Table 4). TSS/acid ratio known as brix was significantly higher in brown paper wrapped fruits (13.56) as compared to muslin cloth, butter paper bag, and non-bagged treatments but it was statistically at par with TSS/acid ratio of citrus fruits wrapped in perforated polyethylene bags (12.23) (Table 4).

Bagging materials of different composition exert their influence on the physical appearance and quality of the fruit. In this study we have found that fruit bagging has significant impact in reducing the risks of fruit flies, fruit drop, blemishes and development of one of the major disease known as citrus canker. The results of this study suggested that fruit bagging in standing citrus fruits before harvesting could also help in improving the physical and chemical parameters of citrus which could further help in boosting the citrus exports. Although,

many other methods such as physical, biological and host plant resistance are also potential control methods (Javed *et al.*, 2019; Javed and Qiu, 2020; Javed *et al.*, 2020) but bagging method may also have impact upon pest pressure.

Table 4. Comparison of chemical characteristics of citrus fruits in bagged and non-bagged treatments.

Bag type	TSS	Acidity	TSS/acid ratio
Perforated polyethylene	11.11bc	0.91bc	12.23ab
Brown paper	11.67a	0.87c	13.56a
Muslin cloth	11.41ab	1.02a	11.23b
Butter paper	10.35d	0.89bc	11.58b
Non-bagged	10.60cd	0.97ab	10.94b
LSD	0.53	0.094	1.43
F value	9.54	3.77	4.73
P value	0.0004	0.0242	0.0103

*Means not sharing a letter in common significantly differ from each other

As a mechanical tool, fruit bagging acts as physical obstacle for female fruit flies from gaining access to fruits, thus help in preventing the fruit fly infestation and subsequent fruit drop due to fruit flies. In many Asian countries, newspaper bags are used to minimize the infestation of fruit flies (Huangm, 2015). In this study, we also tested four type of bagging materials in citrus fruits to see their impact on reduction of fruit fly infestation. We found the citrus fruits wrapped with all type of bagging materials such as muslin cloth bags, perforated polyethylene bags, butter paper bags and brown paper bags, were 100% free from fruit fly damage. The findings of our studies that have no infestation of fruit fly in bagged fruits are in accordance with that of Xia *et al.* (2020), Graaf (2010) and Estradea (2004). Our work is also compatible with that of Chen (2015) and Huang *et al.* (2007), who adopted bagging in pomelo production in China and found that fruit bagging provided control against fruit pests. Pccard

and Parrfi (1994) also produced 100% fruit flies free mangoes (Manila mango variety) in Veracruz, Mexico using the polythene bags. Sarker *et al.* (2009) also evaluated the brown paper bag, black polybag and transparent polybag in protection against fruit fly in mango and found that all bagging materials provided 100% protection against fruit flies similar to our study. Blemishes due to physical factors and diseases like citrus canker often deteriorate the quality of citrus and make them unmarketable and unconsumable. Moreover, these problems also have significant negative impacts in citrus exports. Therefore, in this study effect of bagging apart from reduction in infestation of fruit flies was also studied in playing their role in reducing the risk of blemishes and citrus diseases such as citrus canker, scab and melanose. Citrus canker is devastating disease of citrus plantations in the citrus growing regions of the world which result in huge losses to citrus growers, exporters and citrus processing industries. We found that blemish free citrus fruit was produced in treatments in which we used brown paper bags and butter paper bags; moreover there was no incidence of citrus canker in fruits wrapped with both these type of bags. Similar to our study, Huangm (2015) also reported that bagging of mango fruits with white fruit-bagging paper 86-92 days before harvest significantly reduced the severity and incidence of mango anthracnose and stem-end rot.

Peel colour of fruit plays a significant role in attracting the consumer to market thus an optimum fruit colour fetches reasonable prices for fruit in national and international market. It is believed that different types of bagging materials either help in improving the physical appearance of fruit by developing attractive fruit colour or it may also have reverse effect (Sharma *et al.*, 2014). In this study we have found that optimum colour of citrus peel at maturity i.e., orange and yellow were obtained in fruits which were wrapped in perforated polyethylene, brown paper and butter paper bags. Muslin cloth bags did not result in development of attractive colour at maturity and fruits remained greenish, similarly in non-bagged fruits the peel colour of citrus fruits at the time of harvesting was still greenish yellow which is not preferred in market. Similar to our study, peel colour in mango was improved using brown and/or black paper bags previously (Ding and Syakirah, 2010). Previously, it was also reported that in sweet orange cultivar 'Tarocco' bagging improved the peel colour as compared to un-bagged fruits (Xie *et al.*, 2013). The attractive colour development in peel of bagged fruits is considered to be due to production of more anthocyanin (Ju, 1998; Xie *et al.*, 2013).

Bagging effect on fruit weight, fruit size and peel thickness in citrus was also explored in this study

but results showed that these parameters were not effected by any type of bagging material. Different studies have reported the contradictory results about impact of fruit bagging on weight and size of fruit which could be due to variation in fruit age at bagging, type of bags used, and prevailing climatic conditions (Zhen *et al.*, 2000; Chen *et al.*, 2012; Tyas *et al.*, 1998; Wang *et al.*, 2002; Huang *et al.*, 2007; Zhou *et al.*, 2012; He *et al.*, 2003). Chen (2015) reported that in banana bunch covered with polyethylene bags, total fruit weight was not improved significantly. Similarly, no improvement in size or weight of pear fruits was observed when bagged with micro-perforated polyethylene bags prior to harvest (Dias *et al.*, 2017).

Often, fruit bagging increases fruit quality, which mainly depends upon chemical characteristics of fruits such as acidity, sugar contents and brix. In this study, our results have indicated that fruit bagging also influences the eating quality of fruit (total soluble solids and acidity). Findings of our results are also comparable to the study of Bentley and Viveros (1992), who reported that sweetness in 'Granny Smith' apple fruit was improved by bagging in brown paper bags. Likewise, enhancement in TSS have been reported in 'Red Globe' grape (Zhou and Guo, 2005), peach (Kim *et al.*, 2008), guava (Singh *et al.*, 2007), litchi (Debnath and Mitra, 2008), pear (Liu *et al.*, 2004), mango (Watanawan *et al.*, 2008), apple (Sharma *et al.*, 2013) and loquat (Liu *et al.*, 2004; Ni *et al.*, 2010; Xu *et al.*, 2010). Some bagging products use again from year to year, have relatively low cost, and easy to use when compared to chemical spraying.

CONCLUSION







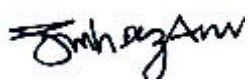

It can be concluded from this study that any type of bagging material can be used in citrus orchards to protect the fruits from infestation of fruit fly. However, optimum fruit colour can be obtained using perforated polyethylene bags, brown paper bags and butter paper bags. Moreover, in order to obtain blemish and canker free citrus fruit, brown paper bags and butter paper bags are recommended to citrus growers. Citrus fruits wrapped in brown paper bags also resulted in higher TSS, low acidity and increased TSS/acidity ratio, therefore these bags are recommended to use by citrus growers to get high quality fruits. Fruit bagging complements other management options as components in designing more appropriate fruit fly management strategies for their relevant communities. Fruit bagging is an easy, grower-friendly technology that is safe to apply and has several valuable effects on the physical appearance and quality of fruit. However, It is a painful process, and necessitates the development of biodegradable bags that rot after application.

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