The Study Of Traditional And Mechanized Efficiency On Orange Harvest Within Use Of Abscission Material

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ABSTRACT

The orange fruit harvesting in Iran is carried out manually due to unavailability of the mechanization systems which increases the production costs. Systematic investigation of the factors which could lead to higher productivity in the agro-inputs and sustainability of the production system becomes paramount. Therefore, the targets of this research were carried out on sweet orange to comparison mechanized harvest method to traditional hand picked up method. A factorial Completely Randomized Design in three replication was used, treatment on mechanized method was: two types of sprayer Mist Blower and one hundred litters sprayer with lance types and abscission material at three levels of 400 ppm, 800ppm and 1000 ppm and the independents variables were: fruit harvest efficiency, fruit harvest percentage, fruit detachment force in two stage (three and six days after spraying). Variance analysis and means comparison showed, there is significant difference among harvest treatments at the level of 1% and the type of sprayer is not significant, but the effect of abscission material density was significant at 1% and the most harvest treatment 90.38 % within 1000 ppm of abscission material treatment and the least was 76.8 % within 400 ppm and harvest treatment efficiency at 1% was significant, means, mechanized harvesting within abscission material increased harvest efficiency up to 71 %,but the effect of sprayer type and abscission material density and their interaction was not significant. The fruit detachment force at two stages (three and six days after Ethephone sprayed) at the level of 1% was significant, and reduced it 84 and 97% at the first and second stages in order. The effect of type sprayer on fruit detachment force at two stages at the level 1% was significant, and the one hundred litters sprayer with lance due to better spraying and penetrated abscission on fruits, reduced fruit detachment force 59 and 66 percent in order in comparison to Mist Blower sprayer. The effect of abscission material density and their interaction at the level of 1% was significant, and 1000 ppm and 400 ppm at the first stage of spraying reduced fruit detachment force 57% and at the second stage 72% in order, and the one hundred litters sprayer with lance within 1000 ppm bearded the least and Mist Blower spryer within 400 ppm bearded maximum fruit detachment fruit reduced and were 78 % and 90% in order. The total soluble solid in all treatments were also measured in juice quality, no significant different was seen. Regarding to conclusion best treatment in this research is applying shaker machine and Ethephon within 1000 ppm and one hundred litters sprayer with lance witch is recommend able to orchards owners.

Key words: abscission material, fruit detachment force, harvest percentage, harvest efficiency

Introduction

Fruit harvesting method in orchards of Iran is carried out through non-mechanized and traditional methods and by using sticks and similar tools which may damage the branches and leaves of trees. Furthermore striking the fruits and their fall on the ground will cause an increase in the wastes and a decrease in storage quality of the product [7]. On the other hand, applying traditional methods is time-consuming and this will impose limitations on time management of harvest and decrease the ability of orchard owners to prevent possible damages resulted from an early frost which is due to long period of harvest. In order to escape from the current conditions of harvest, the proper solution is to use more effective methods and in other words to use mechanized harvest which in addition to maintain the quality and
quantity of the product makes the costs of harvest competitive. Abscission material is a chemical composition which causes physiological changes and decreases the required force to detach fruit from tree, when sprayed on the tree [20]. In a study aiming at investigation of the effect of spraying type on efficiency of abscission materials in mechanized harvest of citrus, it was indicated that, when using Mist Blower sprayer, fruit harvesting was changed, especially in long and thick vegetation [11]. A five years study indicated that using abscission materials, in comparison with not using them, increases detachment of fruits by trunk shakers up to 17 to 26 percent, without having any effects on crops or growth of trees [10]. Abscission materials accelerate mechanized harvest of fruits, because fruits are detached by the use of trunk shaker in a short time and as a result less energy is consumed and erosion of trunk shaker machine decreases. For instance in conducted studies, effective chemicals on abscission, increased the speed of crop harvest by trunk shaker machine and the harvest efficiency of product [5]. The capacity of trunk shaker was increased up to 400% and the harvest efficiency of fruit up to 60% [23].

This study was conducted for the first time in Iran, in order to compare the harvest efficiency of orange in two ways of traditional and trunk shaker method and to determine the appropriate amount of the abscission material, Ethephone, on the trees by selecting the suitable kind of sprayer.

Methods and Materials

The study was conducted in orchards of ShahidBeheshti agro-industry in Dezful in agricultural season of 2010-2011. The method to conduct the study was to record characteristics of the site including name of the orchard, type, age and distances between trees before doing the experimental plan. The characteristics of the site have been indicated in table 1.

![Fig. 1: Specifications Place of testing](image)

**Table 1: Specifications Place of testing**

<table>
<thead>
<tr>
<th>Name Location</th>
<th>Name the Garden</th>
<th>variety</th>
<th>Age of trees (Year)</th>
<th>Trees away from each other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agro-industry</td>
<td>Local Orange</td>
<td>Siavarz</td>
<td>8</td>
<td>6×6</td>
</tr>
<tr>
<td>Shahid Beheshti of Dezful</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Independent variables used in the study were harvesting method (traditional and by applying trunk shaker), type of sprayer (one hundred liters sprayer with lance and Mist Blower sprayer). Also the abscission material used in this study was under the commercial name of Ethrel, the common name of Ethephone and the chemical name of Di-Choloro Ethyl Phosphoric Acid with density of 400, 800 and 1000 portion per million. Dependent variables include harvest efficiency, harvest percentage and the force needed to detach fruits from trees. Characteristics of experimental plot have been reported in figure 1 and those of treatments in table 2. It should be noted that the number of trees in each experimental plot is 9 and sampling has been made from three trees of the middle row and the two side rows have been considered as margins.
The study was conducted as a factorial experiment with a completely randomized base design in three repetitions. Variance analysis and comparison of the mean of data (using Danken’s Test) were made two times; one time through a random method in order to compare and assess all treatments with the control treatment and the other time by the factorial method to assess sprayers and to determine the appropriate amounts of abscission material.

The trunk shaker machine used in this experiment was a type of Pneumatic trunk shaker manufactured by Campagnola Company of Italy, kinetic force of which was consisted of a mono-cylinder four stroke engine equipped with a coolant system of 8-9 horse power. The procedure of the shaker system was as a two inches swinging range, having the ability to shake trunks with frequency of 7-8 Hertz. The weight of machine was 25 kilograms and it was able to generate 80 horse powers in 2500 rpm during the harvest, which from among the similar machines is considered to be a relatively cheap and available machine with an appropriate performance. A picture of this machine has been indicated in figure 2.

**Fig. 2: Trunk shaker machine**

A) Measurements of the field:

1. Harvest percentage:

   At harvest time, fruits of each plot in mechanized and traditional harvest methods were picked up and weighed. In mechanized method, after finishing the harvest, the remained fruits on trees were detached manually and weighed. Fruits detached from trees were poured on canvas spread under the tree and collected. The harvest percentage for each plot was calculated and determined [22].

   Equation 1:

   \[
   \text{Harvest percentage} = \frac{B}{A+B} \times 100
   \]

   A: weight of the fruits remained on trees in mechanized harvest
   B: weight of fruits harvested through mechanized method

<table>
<thead>
<tr>
<th>Treatments</th>
<th>type of sprayer</th>
<th>Concentration abscission material (ppm)</th>
<th>Harvesting methods</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>0</td>
<td>traditional (A₁)</td>
<td>A₁</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>0</td>
<td>trunk shaker (A₂)</td>
<td>A₂</td>
</tr>
<tr>
<td>3</td>
<td>one hundred liters sprayer with lance (B₁)</td>
<td>400 C₁</td>
<td>trunk shaker (A₂B₁)</td>
<td>A₂B₁C₁</td>
</tr>
<tr>
<td>4</td>
<td>one hundred liters sprayer with lance (B₁)</td>
<td>800 C₂</td>
<td>trunk shaker (A₂)</td>
<td>A₂B₁C₂</td>
</tr>
<tr>
<td>5</td>
<td>one hundred liters sprayer with lance (B₁)</td>
<td>1000 C₃</td>
<td>trunk shaker (A₂)</td>
<td>A₂B₁C₃</td>
</tr>
<tr>
<td>6</td>
<td>Mist Blower sprayer (B₂)</td>
<td>400 C₁</td>
<td>trunk shaker (A₂)</td>
<td>A₂B₂C₁</td>
</tr>
<tr>
<td>7</td>
<td>Mist Blower sprayer (B₂)</td>
<td>800 C₂</td>
<td>trunk shaker (A₂)</td>
<td>A₂B₂C₂</td>
</tr>
<tr>
<td>8</td>
<td>Mist Blower sprayer (B₂)</td>
<td>1000 C₃</td>
<td>trunk shaker (A₂)</td>
<td>A₂B₂C₃</td>
</tr>
</tbody>
</table>
2. Harvest efficiency:

The time required harvesting the fruits for all treatments and also amount of harvested fruits was recorded and weighed. Harvest efficiency for each plot was obtained through equation 2 and 3 [1].

Equation 2:

\[
\text{traditional harvest efficiency} = \frac{\text{weight of fruits harvested by a worker (in kilogram)}}{\text{the time needed to harvest the fruits by a worker (hour)}}
\]

Equation 3:

\[
\text{mechanized harvest efficiency} = \frac{\text{weight of fruits harvested by machine (in kilogram)}}{\text{the time needed to harvest the fruits by machine (hour)}}
\]

3. The force needed to detach fruits:

In order to measure the detachment force, following the use of abscission material, 9 fruits were selected randomly from each plot and the detachment force was measured by a digital dynamometer according to Newton.

The measurement was made in two phases (three and six days after spray) in order to compare abating procedure of detachment force in the unit of time. To measure the detachment force, Loteron’s digital dynamometer, model FG-5020 was used. In figure 3, a picture of this has been indicated.

![Digital dynamometer](image)

**Fig. 3**: Digital dynamometer

* B) Experimental measurements:

The amount of soluble solids in orange juice (TSS):

The procedure to measure the amount of soluble solids in orange juice was so that following the fruit harvest from the field, 9 fruits were selected randomly from each plot and were put in nylon bags and after washing and drying in the lab, they were cut into two halves by a knife and the juice was extracted manually from each fruit by applying a little pressure about 5 to 10 CC and the juice was poured in a 50 CC container in order to do experiment. Then one milliliter of 50 CC sample container was taken by a dropper and read and recorded on a refract meter, made in England, in order to determine the chemical materials percentage in fruit essence.

Data analysis method:

MSTATC statistical software was used to analyze the obtained data and data management and drawing the graphs were carried out by Excel software.

Results and Discussion

Table 3 indicates variance analysis of different properties using completely randomized experiment method.

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>d.f</th>
<th>Fruits harvester % Efficiency harvested</th>
<th>Force detachment fruit</th>
<th>Force detachment fruit</th>
<th>T.S.S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>First phase FDF₁</td>
<td>Second phase FDF₂</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>7</td>
<td>365.135** 19758.673**</td>
<td>6.447** 5.732**</td>
<td>0.236 n.s</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>16</td>
<td>24.295 3149.849</td>
<td>0.166 0.175</td>
<td>0.355</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>5.97 20.55</td>
<td>17.49 23.87</td>
<td>4.47</td>
<td></td>
</tr>
</tbody>
</table>

* =Difference between treatments at level 5%
** =Difference between treatments at level 1%
n.s= Non significance
1) **Fruit harvest percentage:**

Considering table 3, fruit harvest percentage between treatments of the experiment is significant in level of 1%. According to this, manual harvest (A₁) with one hundred percentage fruit harvest and harvest using a shaker and a Mist Blower sprayer with density of 1000 PPM of abscission materials (A₂ B₂ C₃) and also harvest by shaker and by using one hundred liters sprayer with lance with density of 1000 PPM of abscission materials (A₂ B₁ C₃) with the percentage of 89.77% and 91% respectively in one level, have the highest percentage of fruit harvest. Also, harvest by a shaker, without using any abscission material (A₂) with a percentage of 63.83% has the lowest fruit harvest percentage (diagram 1).

**Diagram 1:** Comparison means harvesting percentage the experimental treatments

In manual harvest, because the harvest is carried out by the workers, all fruits are harvested from trees and then the harvest percentage is 100%. However in the method of harvest using shaker, all fruits are not harvested from trees and some fruits remain on the trees. In treatments with abscission material, in comparison with not using this material, the harvest percentage increased. To confirm the above mentioned matters, in a study it was concluded that the citrus harvest machines can harvest between 80-97 percent of the crop in different conditions of orchards [2]. In another study, researchers reported that in mechanized harvest of orange using abscission material, the fruit harvest percentage increased and the number of fruits remained on trees decreased [12]. Also studies indicated that in order to increase the percentage of fruit harvest, abscission materials plus trunk shakers should be used [3].

Variance analysis table through factorial method was used to examine the effects of sprayer type and the amount of density of abscission material on fruit harvest percentage. It has been reported in table 4.

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>d.f</th>
<th>Fruit harvest percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of sprayer</td>
<td>1</td>
<td>6.722 n.s</td>
</tr>
<tr>
<td>Concentration abscission material</td>
<td>2</td>
<td>284.895 **</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>6.804 n.s</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>23.243</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>%Cv</td>
<td></td>
<td>5.82</td>
</tr>
</tbody>
</table>

*=Difference between treatments at level 5%  
**=Difference between treatments at level 1%  
n.s= Non significance

Considering table 4 of variance analysis there isn’t any significant difference between the types of sprayer regarding fruit harvest percentage, but among treatments related to density of abscission materials, there is a significant difference in level of 1%. Also the results of variance analysis indicated that there is not any significant difference between the interactions of the type of sprayer with density of abscission material.

Lack of any significant difference between sprayers in fruit harvest percentage indicates that two types of sprayers are effective regarding the percentage of orange harvest.

Researchers compared the common Mist Blower sprayer with a Mist Blower sprayer with a multi-channels outlet and concluded that trees which are sprayed with Mist Blower sprayer with a multi-
channels outlet, have a higher harvest percentage [11].

1.1) Fruit harvest percentage with regard to density of abscission material:

Considering diagram 2, the use of an abscission material with density of 1000 PPM (C3) and a fruit harvest percentage of 90.38% in comparison with the density of 800 PPM (C2) and 400 PPM (C1) and fruit harvest percentages of 81.23% and 76.88%, respectively has the highest level. It was indicated that 10% increase is in fruit harvest percentage compared with using an abscission material with density of 800 PPM (C2) and a 15% increase is in that compared with using an abscission material with density of 400 PPM (C1).

**Diagram 2:** Comparison means harvesting percentage with concentration of abscission material

The results indicated that using abscission material in orange harvest caused an increase in harvest percentage. The more this density increases the more absorption will add up and this causes more increase in fruit harvesting from the tree.

In similar results, using abscission material will increase orange harvest percentage through trunk shaker [10,24,6,17]. Also in a similar study, it was reported that, without using fruit abscission material, mechanized harvest systems cannot be successful in maximum fruit harvest from trees [25].

2) Harvest efficiency:

According to table 3, harvest efficiency between the studied treatments is significant at the level of 1%. Harvest efficiency in trunk shaker harvest method, without using abscission material (A2) can be increased up to 54% compared with manual method (A1). However in trunk shaker harvest method in the presence of abscission material compared with the above case, harvest efficiency was increased up to 37%. Also in trunk shaker harvest method using abscission material compared with manual harvest method, harvest efficiency increases up to 71% (diagram 3). This increase in harvest efficiency results from the increase in the amount of harvested crop at the unit of time, and this time reduction results from high efficiency of trunk shaker compared with traditional method and in treatments using shaker plus abscission material, the reduction of detachment force followed by reduction of harvest time, has caused an increase in shaker machine efficiency.

**Diagram 3:** Comparison means harvest efficiency the experimental treatments
Researchers considered it necessary to use abscission materials for mechanized harvest of citrus [21]. On the other hand, these materials cause a decrease in fruit detachment force and an increase in efficiency of shaker [10,24,6]. In comparison of both mechanized and manual methods, it was found that the efficiency of mechanized harvest is 3.5 to 4 times higher than the manual method [1]. Also researchers found that using the abscission materials accelerates the mechanized fruit harvest, because shaker causes the fruit to be detached from tree in a short time and as a result less energy is consumed and erosion of the shaker machine will decrease. For example by the use of effective chemicals in abscission, the speed of crop harvest by shaker and as a result crop harvest efficiency in conducted studies was increased. Also it was reported that the capacity of shaker using abscission material increased up to 400% and fruit harvest efficiency up to 60% [5,23].

In order to examine the effect of sprayer type and the amount of density of abscission material on harvest efficiency, variance analysis table with factorial experiment method was used, which has been reported in table 5.

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>d.f</th>
<th>Harvest efficiency kg/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of sprayer</td>
<td>1</td>
<td>11714.70 n.s</td>
</tr>
<tr>
<td>Concentration abscission material</td>
<td>2</td>
<td>891.860 n.s</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>10285.068 n.s</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>3643.840</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

\% CV = 19.71

Considering this table, there isn’t any significant difference regarding the type of sprayer, the amount of abscission material and also their interaction, because all treatments containing shaker plus abscission material are at the same level, according to graph 3 of mean comparison. So it causes that the effect of sprayer type and abscission material density on harvest and also their interactions is not significant and it can be accounted for by relatively the same harvest time in these treatments.

3) Fruit detachment force:

According to table 3, fruit detachment force among the studied treatments is significant at the level of 1% in the first phase (FDF1) and the second phase (FDF2) and as seen in diagrams 4 and 5, the highest fruit detachment force relates to harvest methods without using abscission material and the method in which harvest has been carried out by shaker using an abscission material with density of 1000 PPM and one hundred liters sprayer with lance (A2B1C3) has the lowest fruit detachment force.

In treatments not using abscission material compared with treatments containing this material, at the first phase, fruit detachment force is 26 to 84 percent more and that of the second phase is 28 to 93 percent more.

Abscission material is a chemical composite that when it is sprayed on a tree before harvest, causes some physiological and biochemistry changes in the sprayed area and this leads into production of Ethylene and some changes in the amount of proteins and also causes separation of the cell wall and a result weakness and reduction of fruit detachment force [20].

Diagram 4: Comparison means fruit detachment force in the first phase the experimental treatments
Diagram 5: Comparison means fruit detachment force in the second phase the experimental treatments

Considering diagram 6, in treatments using abscission material, this material has caused a decrease about 3.5 to 58 percent in fruit detachment force in the second phase compared with the first phase and this indicates that following the use of abscission material when time passes it causes more fruit detachment force.

Diagram 6: comparison fruit detachment force in the first phase (FDF1) and the second phase (FDF2) the experimental treatments

In a similar experiment it was reported that abscission material application in different used volumes causes a significant decrease in the required fruit detachment force. In another research, Farooq et al., [6] indicated that using ethephone in orange harvest can weaken the ripe fruit effectively [13]. In a study it was reported that the amount of fruit detachment force for all orange trees subject to CMNP decreased up to 50%, compared with trees which were not subject to CMNP [20]. Also in another research, ethephone was used to harvest olive and it was reported that the fruit detachment force using abscission material decreased less than 50 percent compared with not using this material.

Variance analysis table with factorial method, the experiment was used to examine the effect of sprayer type and abscission material density on fruit detachment force in the first and second phases (3 and 6 days after spray). The results are shown in the table 6.

Table 6: variance analysis fruit detachment force using factorial experiment method

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>d.f</th>
<th>FDF1</th>
<th>FDF2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of sprayer</td>
<td>1</td>
<td>9.188**</td>
<td>6.456**</td>
</tr>
<tr>
<td>Concentration abscission material</td>
<td>2</td>
<td>2.657**</td>
<td>3.638**</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>0.824***</td>
<td>1.003*</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>0.085</td>
<td>0.141</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

%CV

n.s= Non significance
** =Difference between treatments at level 1%
* =Difference between treatments at level 5%
3.1) The effect of the sprayer type on fruit detachment force:

Considering table 6 of variance analysis in detachment force of the first and second phases, there is a significant difference at the level of 1% between the type of sprayer, density of abscission material and also the interaction of sprayer type and the density of abscission material. Considering diagrams 7 and 8, fruit detachment force in the first and second phases by the use of Mist Blower sprayer (B2) in comparison with a hundred liters sprayer with lance (B1) has a higher detachment force with the amount of 59 and 66 percent, respectively. So it can be concluded that a hundred liters sprayer with lance could better spray the abscission material on trees and decreases fruit detachment force and the Mist Blower sprayer couldn’t do so effectively because it didn’t cover the upper parts of tree’s head and as a result this sprayer had a higher fruit detachment force, compared with a hundred liters sprayer with lance.

Diagram 7: comparison means the effect of the sprayer type on fruit detachment force in the first phase (FDF1)

Diagram 8: comparison means the effect of the sprayer type on fruit detachment force in the second phase (FDF2)

Considering diagram 9, fruit detachment force in Mist Blower sprayer and a hundred liters sprayer with lance, decreased up to 25 and 37.5 percent respectively, in phase FDF2 compared with phase FDF1. Examination of detachment force of treatments indicated that in both measuring phases, a hundred liters sprayer with lance was more effective in comparison with the Mist Blower sprayer and that was because of better penetration and more uniform coverage.

Diagram 9: comparison the effect of the sprayer type on fruit detachment force in the first phase (FDF1) and the second phase (FDF2) the experimental treatments
The effect of different methods of sprayer on fruit detachment force and mechanized harvest by shaker were studied and it was found that the type of sprayer is effective on uniform spread of material on the tree [14].

3.2) the effect of abscission material density on fruit detachment force:

Considering diagram 10, in the first phase, fruit detachment force using an abscission material with the density of 400 PPM (C1) and force of 22.5 N is the highest, compared with densities of 800 PPM (C2) and 1000 PPM (C3) and forces of 17.5 and 9.6 N, respectively. In other words, fruit detachment force in the first phase using an abscission material with density of 400 PPM (C1), compared with densities of 800 PPM (C2) and 1000 PPM (C3) was 22 and 57 percent more, respectively. Although fruit detachment force with densities of 800 PPM and 1000 PPM is in the same level, fruit detachment force with the density of 800 PPM is about 45 percent more than that in density of 1000 PPM.

Diagram 10: comparison means the effect of abscission material density on fruit detachment force in the first phase (FDF1)

Considering diagram 11, in the second phase of fruit detachment force using an abscission material with density of 400 PPM (C1) and force of 19.6 N is the highest compared with densities of 800 PPM (C2) and 1000 PPM (C3) and forces of 9.7 and 5.39 N, respectively. In other words, fruit detachment force in the second phase using an abscission material with density of 400 PPM (C1), compared with densities of 800 PPM (C2) and 1000 PPM (C3) was 50 and 72 percent more, respectively. Although fruit detachment force in densities of 800 PPM (C2) and 1000 PPM (C3) is at the same level, fruit detachment force in density of 800 PPM is about 44 percent more than that in density of 1000 PPM.

Diagram 11: comparison means the effect of abscission material density on fruit detachment force in the second phase (FDF2)

In a study, CMNP abscission material with densities of 0, 300 and 500 PPM was used for Hamlin and Valencia varieties of orange crop. Four days after spraying, the fruits were taken by shaker. The results indicated that the more increase in density, the more fruit detachment force will decrease and falling of fruits after spray increases [11].

By taking diagram 12 into consideration and with the comparison of decrease in detachment force in the second phase with the first phase and by taking the density of abscission material into consideration as well, it can be said that in densities of 400, 800 and 1000 PPM, detachment force decreased up to 45, 13 and 44 percent, respectively.
The effects of CMNP abscission material in densities on 0, 200, 500, 1000 and 2000 PPM and ethephone with densities of 400 and 800 PPM on fruit detachment force of orange was examined and it was found that high densities decrease fruit detachment force rapidly [16].

Diagram 12: comparison the effect of abscission material density on fruit detachment force in the first phase (FDF1) and the second phase (FDF2) the experimental treatments

By comparison of the slope of curve in diagram 12, it can be seen that the slope of the curve in detachment force of the first phase with density increase from 800 to 1000 PPM is higher compared with that of second phase, so it can be concluded that the more density of abscission material increases, the more the time adequate to harvest after spraying decreases and vice versa.

3.3) Interaction of sprayer type and density of abscission material on fruit detachment force:

Considering diagrams 13 and 14, in examination of interaction between sprayer type and density of abscission material, it was found that treatments using Mist Blower sprayer plus abscission material with density of 400 PPM (B2C1) and the same sprayer with 800 PPM (B2C2) of abscission material, had highest fruit detachment force in the first and second phase and the rest of treatments were in the other level. Using a hundred liters sprayer with lance with different densities of abscission material are all at the same level and it indicates that the effect of abscission material in a hundred liters sprayer with lance is not significant, but only in the second phase of Mist Blower sprayer, more density of abscission materials creates lower detachment force. Fruit detachment force in the first and second phases, using abscission material with density of 400 PPM in Mist B lower sprayer compared with 100 liters sprayer with lance are 58 and 65 percent more, respectively. Also using abscission material with density of 800 PPM in Mist Blower sprayer compared with a hundred liters sprayer with lance is 68 percent more in the first phase and 65 percent more in the second phase, and finally using this material with density of 1000 PPM in Mist Blower sprayer compared with a hundred liters sprayer with lance in both phases is about 45 percent more.

Diagram 13: comparison Interaction of sprayer type and density of abscission material on fruit detachment force in the first phase (FDF1)
Diagram 14: comparison Interaction of sprayer type and density of abscission material on fruit detachment force in the second phase (FDF$_2$)

2) The amount of solids soluble in orange juice (T.S.S.):

Considering table 1, there isn’t any significant difference between the studied treatments regarding the amount of solids soluble in orange juice and it means that ethephone didn’t have any effect on quality of orange juice and there isn’t any significant difference between experimental and control treatments.

In a five years study, different abscission materials with different amounts were used on Hamlin variety of orange trees during December, January and February, and it was concluded that fruit quality was not affected by measurement of solids soluble in orange juice [19].

Suggestions:

1) Considering the obtained results, the best treatment is to apply a trunk shaker machine and by using 1000 PPM of abscission material (ethephone) plus applying a hundred liters sprayer with lance that can be recommended to the orchard owners.

2) Since using abscission material has a positive effect on the reduction of fruit detachment force, it is recommended that the amount of frequency and amplitude of trunk shaker be assessed as a variable in an experiment and the best frequency and amplitude are determined regarding the amount of abscission material.

3) Considering the presence of other abscission materials and the possibility of mixing some of these materials with each other, conduction of an experiment for selection of the best abscission material in mechanized harvest of citrus is needed.

4) Regarding the fact that the type of sprayer has a significant effect on uniform penetration and spray of abscission material, so it is recommended that by making changes in current sprayers (for example by applying multi-ways outlets in Mist Blower sprayer) the amount of spray and their efficiency be assessed.

References