Research Report

Potential Yield Increase by Grafting for Watermelon Production in Arizona

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Summary

Grafting cucurbits onto rootstocks resistant to diseases and abiotic stresses can be a method to overcome limited availability of effective pre-plant fumigants or land to rotate and to allow earlier planting. Commonly used rootstocks for cucurbits have resistance to Fusarium (race 1&2) as well as cold tolerance, among other favorable traits like increased vigor of the scion. Grafting of cucurbits was developed in Asia primarily to allow production without rotation, because arable land is so limited. In the US, crop rotation schedules for seedless watermelon can be 3 years or longer reducing the amount of watermelon a grower can produce in a season. We have been growing grafted and non-grafted seedless watermelon on the same field/plot for 4 years, with no fumigation or off-season rotation of other crops. During the last 2 years, we planted early (March 1) to determine if grafting could overcome low night temperatures in addition to disease pressures. Treatments included grafted and non-grafted plants, covering with frost protection and non-covered. The results of the last 2 years indicate that grafted plants yielded nearly twice as much as non-grafted plants, suggesting that grafting can be a promising technology for Arizona watermelon producers.

Introduction

Watermelon is a minor crop in Arizona vegetable production. However, in 2012, a total of 4,876 acres were harvested, being ranked as 8th in the U.S. (USDA, 2014). Arizona watermelon production is mainly concentrated in Maricopa, La Paz and Yuma counties. Typical production of melons in Arizona involves two crops a year with appropriate land rotation programs. Watermelon is known to be sensitive to possible yield decline due to intensive cultivation and rotation is essential to avoid soil-borne disease such as fusarium. Traditionally watermelon was cultivated with a relatively long rotation program such as 9 or 10 years; however, rotation becomes more challenging due to the land availability. For example, currently 2 to 3 years of rotation (with garbanzo beans or wheat) is typical in Maricopa and little or no rotation is practiced in Yuma. Anecdotally watermelon yield in Arizona is relatively small (20-25 ton/acre), presumably due to various factors including limited rotation programs.

In Asian and European countries, where arable land is limited and therefore more intensive land use is performed, grafting has been used effectively to sustain watermelon production without relying on rotation programs as well as to increase the yield (Davis et al., 2008; Lee et al., 2010). Vegetable grafting was introduced to Arizona initially in the European based greenhouse industry in the late 1990s but also to field production in the early 2000s. While it became a standard technology of increasing yield in greenhouse tomato (Kubota et al., 2008) in Arizona, evaluations for watermelon have not been performed yet. Because of the rather high costs of seedlings (50-70 cents per plant), large increases in yield or reduction of costs associated with reduced application of pesticides, reduced management...
practices or reduced frequency of land rotation need to be considered together as benefits of grafted watermelon production.

In spring production of watermelon in Arizona, seedlings with 2–3 leaves are transplanted between January and March. During this time, some growers apply floating row covers over newly transplanted watermelon seedlings to protect them from the cold nights. While this practice allows growers to start the seedlings early and thereby targeting the early premium market, the additional cost as well as the need of temperature management are considered problematic. While watermelon is sensitive to chilling, rootstocks (squash or bottle gourd) widely used for grafting watermelon are known to be cold tolerant (Spalholtz and Kubota, 2016). Therefore, we hypothesized that grafting may eliminate the need of row cover during early spring planting season and conducted a small scale trial in an experimental field at the Campus Agriculture Center, the University of Arizona (Tucson, AZ). In this report we summarize the comparison of grafted and non-grafted watermelon plants grown with and without cover, repeated over two years in 2015 and 2016.

**Procedure**

Grafted and non-grafted plants were produced for the trials. The scion was ‘Tri-X 313’ seedless watermelon (Syngenta Seeds, Boise, Idaho) and rootstock was ‘Strongtosa’ interspecific hybrid squash (Syngenta Seeds). Seeds of scion and rootstock were planted into 98 cell plug trays on multiple dates during first week of February and grafted on February 16 using the single cotyledon method. Plants were healed for 7 days in healing chambers, then acclimated and grown in greenhouse until March 1.

Non-grafted ‘Tri-X 313’ was seeded on February 10 and grown in the same greenhouse. Plants were planted in a field at The University of Arizona Campus Agriculture Center in soil characterized as Gila fine sandy loam on raised beds with bed/rows on 80 inch centers and plants in row on 43 inch spacing using a Latin square design. The planting density is 1,823 plants per acre. Treatments were 1) grafted - non-covered, 2) grafted - covered, 3) non-grafted - non-covered, 4) non-grafted - covered. There were 4 replications of 7 plants per treatment. Pollinizer plants (SP-6, Syngenta Seeds) were planted between every third plant in the row. Covered treatments were covered on the day of planting with a 0.9 oz yd² spunbonded polypropylene fabric (AG-30; J & M Industries, Ponchatoula, LA) following the practice of Yuma growers (K. Nolte, personal communication) and vented as necessary to moderate temperature and completely removed when risk of frost was low (3/21/15 and 3/16/16).

Plants were irrigated by buried drip tape (Chapin model 11704420; Jain Irrigation Systems LTD, Maharashtra, India.) based on plant demand. Starting 3 weeks after planting fertilizer was applied weekly through the drip. Nitrogen was applied for 14 weeks using UAN-32 to achieve a cumulative total actual N rate of 160 lb/acre (180 kg ha⁻¹) (2015) and 110 lb/acre (120 kg ha⁻¹) (2016). Phosphorus was applied during the first 7 weeks using mono-potassium phosphate (0-52-34) to achieve a cumulative total actual P rate of 30 lb/acre (75 kg ha⁻¹), and potassium was applied during the last 7 weeks using potassium sulfate (0-0-50) to achieve a cumulative total actual K rate of 125 lb/acre (140 kg ha⁻¹). Too high nitrogen might make grafted plants too vegetative so limiting N is a standard practice in managing grafted watermelon plants. Therefore, in 2016, plant’s tissue nitrogen level was monitored periodically to not exceed the upper limit of 1200 ppm during early development stages and 800 ppm during late development stage according to the recommendation by Brust (2013).

Plants were measured for vine growth, initial flowering, transplant mortality and yield as number and weights of fruit. Fruit quality was measured by brix. Fruit was considered harvestable when the 3 tendrils adjacent to the fruit had dried, but by recommendation, the grafted fruit was harvested 5
days after this (R. Hassell, personal communication). Fruit was harvested from 5/25/15 to 7/3/15 and from 6/14/16 to 7/12/16. There was no significant interaction by year and so the data were combined to analyze the main factors of the four treatments.

**Results/discussion**

Covering after transplanting significantly increased the early vegetative and reproductive development of watermelon plants regardless of plant type (grafted vs. non-grafted). It also largely reduced the loss of primarily non-grafted plants due to transplant failure (Table 1). However, these differences in early production stage did not affect the fruit yield enough to have a statistically significant difference (Table 2). In these trials, we replaced the transplants lost during the first two weeks of field establishment. Without replacing seedlings, covering might have significantly affected the yield.

It is suggested that seedless watermelon seed be planted when the soil temperatures reaches 70F (Shrefler et al., 2015). The soil temperature in the upper 4” did not reach 70F until 5/25/15 and 5/11/16 (data not shown), suggesting suboptimal soil temperatures after planting for more than 9 weeks. The cold tolerance of the Strongtosa rootstock would have provided an advantage over the non-grafted plants during this time, allowing for more vegetative plant development.

Grafted plants are sensitive to N, and too much N can result in flower abortion. In 2016 the application of N was reduced early in the growing season with the intended effect to reduce the amount of early flower abortion in grafted plants, which it did as there were more female flowers per plant early in the crop in 2016 than 2015 (4.1 ± 0.21 in 2016 vs 2.3 ± 0.38 in 2015, p=0.001) as measured on 54-58 days after planting. There was no effect reduced N on non-grafted plants for female flowers (1.35 ± 0.24 in 2016 vs 1.32 ± 0.28 in 2015, p=0.9469).

Non-grafted plants produced an average of 25.8 ± 3.4 lbs. per plant, which is equated to 23.5 tons per acre, a similar level of yield observed in Arizona watermelon production (S. Martori, personal communication). Grafted plants produced 55.5 ± 6.9 lbs. per plant or 50.6 tons per acre, twice as much yield as non-grafted plants. This is due to more fruit and larger fruit in grafted plants than in non-grafted plants. Similar results of increased watermelon fruit size by grafting onto interspecific hybrid rootstock (Cucurbita maxima x Cucurbita moschata) have been reported (Sakata et al., 2007).

Fruit quality is sometimes reported as affected by rootstock. A typical difference between grafted and non-grafted plants was the speed of maturation of fruit. For this reason, we picked the fruit of grafted plants 5 days past the first indication of conventional maturation. Soluble solid content of the fully ripe fruit was 10.6 ± 0.11 for grafted plants and 10.7 ± 0.07 for non-grafted plants with no significant difference the two treatments.

**Conclusion**

Seedless watermelon grafted on to a hybrid squash resulted in twice the yield of non-grafted plants, without causing any negative influence in fruit quality. This yield increase was a result of more and larger fruit, presumably due to the more vigorous, cold tolerant and disease resistant root system of the rootstock. Even at a wholesale price of $0.10 per lbs. this average yield increase of more than 25 lbs. per plant more than pays for the cost of the grafted plant ($0.50 – 0.70). Considering the possible elimination of covering, fumigation and repeated cropping this value of grafting is increased.
Acknowledgements
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References cited
Figure 1. Acclimated grafted plants (a) and non-grafted plants (b) on day of planting.
Figure 2. Watermelon at harvest time (a) and nearing harvest (b).
Table 1. Plant characteristics measured for 2015 and 2016 combined. Number of vines measured on 55 days after planting (DAP). Number of female flowers measured on 54 – 58 DAP. Percent of plants that were replaced due to mortality within 14 DAP. Values are mean ± SE.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of vines</th>
<th>Number of female flowers</th>
<th>% of replaced transplants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grafted</td>
<td>11.1 ± 0.9***</td>
<td>3.2 ± 0.3***</td>
<td>1.8 ± 1.2***</td>
</tr>
<tr>
<td>Non-grafted</td>
<td>4.7 ± 0.3</td>
<td>1.3 ± 0.2</td>
<td>24.1 ± 4.7</td>
</tr>
<tr>
<td>Covered</td>
<td>9.5 ± 1.1***</td>
<td>2.7 ± 0.3'</td>
<td>8.0 ± 3.4'</td>
</tr>
<tr>
<td>Non-covered</td>
<td>6.4 ± 0.7</td>
<td>1.8 ± 0.4</td>
<td>17.9 ± 5.0</td>
</tr>
</tbody>
</table>

* 0.05, ** 0.01, *** 0.001
ns Not significant

Table 2. Yield responses for 2015 and 2016 combined for treatment main effects of grafted and non-grafted plants, covered and non-covered plants. Fruit was harvested from 5/25/15 to 7/3/15 and from 6/14/16 to 7/12/16. Planting density was 1823 plants per acre. Values are mean ± SE.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>tons/acre</th>
<th>lbs/plant</th>
<th>Fruit size (lbs)</th>
<th># fruit/plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grafted</td>
<td>50.6 ± 6.3***</td>
<td>55.5 ± 6.9***</td>
<td>15.6 ± 0.7*</td>
<td>3.4 ± 0.3***</td>
</tr>
<tr>
<td>Non-grafted</td>
<td>23.5 ± 3.1</td>
<td>25.8 ± 3.4</td>
<td>12.3 ± 0.9</td>
<td>1.9 ± 0.2</td>
</tr>
<tr>
<td>Covered</td>
<td>38.1 ± 6.7ns</td>
<td>41.8 ± 7.3ns</td>
<td>14.1±0.88ns</td>
<td>2.7 ± 0.3ns</td>
</tr>
<tr>
<td>Non-covered</td>
<td>36.0 ± 5.3ns</td>
<td>39.5 ± 5.8ns</td>
<td>13.9±1.10ns</td>
<td>2.6 ± 0.3ns</td>
</tr>
</tbody>
</table>

* 0.05, ** 0.01, *** 0.001
ns Not significant

Data were transformed using SQRT