ROLE OF GRAFTING IN CUCURBITACEOUS CROPS - A REVIEW

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Received: 31-10-2012 Accepted: 25-03-2013

ABSTRACT

Due to limited availability of arable land and high market demand for off-season vegetables, cucurbits (plants in the family Cucurbitaceae) are continuously cultivated under unfavorable conditions in some countries. These conditions include environments that are too cold, wet, or dry, or are cool low-light winter greenhouses. Successive cropping can increase salinity, the incidence of cucurbit pests, and soil-borne diseases like fusarium wilt caused by *Fusarium* spp. These conditions cause various physiological and pathological disorders leading to severe crop loss. Chemical pest control is expensive, not always effective, and can harm the environment. Grafting can overcome many of these problems. Some seed companies now offer watermelon transplants grafted on squash or bottle gourd rootstocks, and some transplant facilities offer grafting services.

Key words: Cucurbitaceous, Economic feasibility, Grafting.

Vegetable grafting is most common in European and Asian countries where crop rotation is no longer an option and available land is under intense use. Grafting is an alternative approach to reduce crop damage resulting from soil-borne pathogens and increase plant abiotic stress tolerance, which increases crop production. Four grafting methods are available for vegetable production in cucurbits. The utilization of resistant rootstocks to adverse conditions is an alternative on disease control and the grafting has been detached on the soil pathogen inhabitant control of many fruits and vegetables. Additionally, grafting can affect vegetative growth, flowering, fruit ripening date and quality, and provide higher yields, especially under low-temperature conditions. Rootstock-scion combinations reportedly affect pH, flavor, sugar, color, carotenoid content, and texture of fruit. As early as in 1949, Imazu (1949) recommended *Cucurbita moschata* as a rootstock, since it confers resistance to fusarium wilt and improves plant vigour. This study demonstrated that quality traits can be improved by selecting rootstock-scion combinations that complement each other. Grafting is used to achieve resistance to soil-borne diseases and nematodes, to increase yield and quality and to improve the physiology of plants making them more adaptable to harsh environment.

Concerns associated with grafting: The main problems associated with grafting are the time and labour required, cost, rootstocks rendered ineffective by occurrence of newly migrated soil-borne diseases or pests, and changes in fruit quality. Grafted seedlings are more expensive than non-grafted seedlings. It is difficult for farmers to provide the intensive care required to raise newly grafted plants, often requiring the added cost of a transplant facility that has healing chambers and trained personnel. Changes in resistance to diseases or pests must be taken into account as well as changes in fruit quality, which occur with some rootstocks. These problems should be regarded as important research topics, given that grafting cultivation is an indispensable production technique for sustainable agriculture.

Economic Feasibility: It is difficult for farmers to perform the grafting to maintain adequate humidity and low light levels while grafted plants heal. However, since some organizations provide transplant facilities, grafting services with improved grafting techniques and mechanization making, purchase of grafted seedlings more affordable. Grafted seedlings are more expensive than non-grafted seedlings, reflecting the cost of the rootstock seeds, which are often F₁ hybrids or triploids.
There are added costs involved in the grafting operation:
Raising the grafted seedlings, and Transporting them to growers’ fields (Taylor et al., 2006)

Additionally, grafting decreased the transplant survival rate by up to 60% in high-wind conditions. The resultant loss of transplants and the need for replanting greatly increases the cost of grafting in high-wind areas (Davis and King, 2005).

Why graft cucurbits: The primary motive for grafting cucurbits is to avoid damage caused by soil borne pests and pathogens. The vigorous roots of the rootstock exhibit excellent tolerance to serious soil borne diseases. Grafting a susceptible scion on to a resistant rootstock can provide a resistant cultivar without the prolonged screening and selection required to breed resistance into a cultivar. Furthermore, grafting allows rapid response to new pathogen races, and, in the short-term, provides a less expensive and more flexible solution for controlling soil borne diseases than breeding new resistant cultivars. In addition, grafting may enhance tolerance against low and high temperatures, tolerant to salt stress, higher plant vigor, improved yield and quality, resistance to soil pathogens, tolerant to root knot nematodes, suitable for organic growers and greenhouse cultivators.

Disease control: One of the major advantages of using grafted plants is the control of many pathogens:

**TABLE 1:** Common and scientific names of crops used in this review and names of commonly used cultivars and their scientific names

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
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<tbody>
<tr>
<td>Snake melon</td>
<td>Cucumis melo var. flexuosus</td>
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<tr>
<td>Bitter melon</td>
<td>Momordica charantia</td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>Lagenaria siceraria</td>
</tr>
<tr>
<td>Cantaloupe</td>
<td>Cucumis melo L. var. cantaloupensis</td>
</tr>
<tr>
<td>Chinese snake gourd</td>
<td>Trichosanthes anguina</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Cucumis sativus</td>
</tr>
<tr>
<td>Figleaf gourd</td>
<td>Cucurbita ficifolia</td>
</tr>
<tr>
<td>Luffa</td>
<td>Luffa cylindrica</td>
</tr>
<tr>
<td>Melon</td>
<td>Cucumis melo L.</td>
</tr>
<tr>
<td>Muskmelon, netted melon</td>
<td>Cucumis melo var. reticulatus</td>
</tr>
<tr>
<td>Oriental pickling melon</td>
<td>Cucumis melo var. conomon</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>Cucurbita moschata</td>
</tr>
<tr>
<td>Summer squash</td>
<td>Cucurbita pepo</td>
</tr>
<tr>
<td>Squash</td>
<td>Cucurbita spp.</td>
</tr>
<tr>
<td>Squash interspecific hybrid</td>
<td>Cucurbita maxima x Cucurbita moschata</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Citrullus lanatus</td>
</tr>
<tr>
<td>Wax gourd</td>
<td>Benincasa hispida</td>
</tr>
<tr>
<td>Winter melon, honeydew</td>
<td>Cucumis melo var. inodorus</td>
</tr>
<tr>
<td>‘Shin-tosa’</td>
<td>Cucurbita maxima x Cucurbita moschata</td>
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</table>
the rootstocks: Watermelon Charleston Gray and Round Melon Yellow showed susceptible to the pathogen. For the production effects, was grafted under resistance genotypes, ‘Bonus nº 2’. The Benicia hispid rootstock is the most indicated to melon.

**Grafting for Black root rot control:** Phomopsis sclerotiodes Kesteren commonly causes black root rot in greenhouse-grown cucumbers (Cappelli et al., 2004), and has also been shown to cause disease in melon, pumpkin, bottle gourd and watermelon (Shishido et al., 2006). The pathogen can survive in soil and soil-less media and even on plastic containers, making control difficult. Grafting was shown to be an effective control measure for greenhouse grown cucumbers.

**Low temperature tolerance:** Low temperatures have an effect on flowering, bees pollination, fruit size, fruit quality and total yield. Grafting cucurbits on to low temperature tolerant rootstocks reduces the risk of severe growth inhibition. Early reports on cold tolerance mechanisms, state that grafted cucumber plants with increased total lipids per gram fresh weight, high unsaturated fatty acids, an increase in fatty acid to total lipid ratio, and a reduced ratio of esterol to total lipids, had higher low temperature tolerance (Horvath et al., 1983). More recently it was reported that chilling tolerance is related to higher antioxidative ability and membrane stability. Grafted watermelon seedlings under low temperature stress have higher antioxidants and antioxidative enzyme activities in leaves than self-rooted watermelon seedlings (Liu et al., 2003a).

**Yield increase:** In many countries, yield increase with grafting has been reported. In Spain, more than 90% of watermelon plants are grafted, using different Cucurbita hybrids (C. maxima x C. moschata) as rootstocks. In Morocco, experiments have been conducted in the main cucurbits producing areas to compare yields of grafted and non-grafted melon and water melon. The average yields of grafted plants 60-3 were much higher than the yields of the non-grafted plants Table The yield increase is 44 % and 84 %, respectively for melon and watermelon. Cucumber plants grafted onto pumpkin rootstocks had 27% more marketable fruit per plant than self-rooted cucumber (Seong et al., 2003). Salam et al. (2002) demonstrated a 3.5 times higher yield due to larger fruit size, more fruit per plant, and improved plant survival rates.

**Wet/Flood/Drought/Salinity tolerance:** Yang et al. (2006) demonstrated that grafted cucumber plants have higher net photosynthesis, stomata conductance, and intercellular CO₂ concentrations under NaCl stress than self-rooted plants. Grafting bitter melon onto luffa rootstock improved scion flood tolerance (Liao and Lin., 1996). Non grafted watermelon and watermelon grafted onto wax gourd showed greater resistance to drought stress than watermelon grafted onto bottle gourd (Sakata et al., 2007) A Cucurbita moschata cultivar, ‘Higata 2’, performed well even in waterlogged fields. Under salt stress, watermelon grafted onto salt-tolerant rootstock demonstrated improved vigor and yield, and maintained good fruit quality compared to watermelon-watermelon-grafted controls. It was suggested that increased salt tolerance of grafted watermelon is linked to increased peroxidase activity and decreased superoxide dismutase activity.

**Effect of grafting on flowering and harvest:** Sex expression and flowering order are controlled by plant hormones. The root-scion combination may alter amounts of hormones produced and their influence on grafted plants organs (Satoh, 1996). Watermelon grafted onto bottle gourd caused early formation of female flowers when compared to other rootstocks (Kurata, 1976). Blooming is caused mainly by emission of SiO₂ from trichomes, which appear on the fruit epidermis and cover the pericarp. Cucumber varieties grafted onto a squash interspecific hybrid rootstock inhibited flowering (Satoh, 1996). It was suggested that the root may control floral transition by the production of inhibitory factors in some day-neutral Cucurbitaceae plants. Blooming of cucumber fruit is almost completely suppressed when seedlings are grafted onto the cultivar ‘Kitora’ (Cucurbita moschata).

**Nutrient uptake:** Grafting influences absorption and translocation of phosphorus, nitrogen, magnesium, and calcium (Pulgar et al., 2000). One advantage of grafting is the utilization of the rootstock’s vigorous root system. Hu et al. (2006) suggested that improved nutrient uptake in grafted seedlings increases photosynthesis, which is particularly noticeable under less than optimal growing conditions such as weak sunlight and low
CO2 content in solar greenhouses during winter months. It has been suggested that these conditions allow grafted plants to produce higher yields, sometimes with improved fruit quality (Xu et al., 2005, 2006; Zhu et al., 2006).

**Grafting methods:** Grafting methods mainly depend on choice of rootstock which in turn depends on following factors

**Choice of rootstock:**
- Scion to be grafted
- Pathogen resistance
- Vigour under specific conditions
- Salt, cold and drought tolerance
- Earliness
- Adaptation to field or to soil less culture
- Yield quality

**Scion to be grafted:** The most widely used rootstocks are interspecific hybrid between Cucurbita maxima and Cucurbita moschata. These hybrids exert strong resistance to the three f.sp of Fusarium (niveum, cucumerinum, melonis) and good graft compatibility with watermelon, melon and cucumber. Bottle gourd (Lagenaria siceraria) is exclusively used for water melons and does not have good compatibility with melons. Cucurbita ficifolia possessing excellent tolerance to low soil temperature is the preferred rootstock for greenhouse cucumbers and is used as a rootstock for off season production. Grafting could have many disadvantages on the fruit quality e.g. shape, appearance, taste, coloration, internal decay. New diseases e.g. Fusarium solani f. sp. cucbitae have also been observed on grafted plants.

**Plant physiology:** Tiedemann and Carstens-Behrens (1994) studied the phloem proteins that differed in cucumber (C. sativus) grafted on fig leaf gourd (C. ficifolia) or on pumpkin (C. maxima). They found four proteins on sodium dodecylsulfate polyacrylamide gel electrophoresis gels in grafted scions that do not appear in control plants but matched the rootstock phloem protein pattern. Two of the proteins match the phloem protein 1 and phloem protein 2 molecular weight of the rootstock. This migration is a novel mechanism likely used to integrate developmental and physiological processes on a whole-plant basis. The phloem proteins role may be in long-distance transport of RNA within plants (Golecki et al., 1998). Plants with vigorous root systems release more cytokinins into the ascending xylem sap, resulting in increased yield (Kato and Lou, 1989). For example, cucumber plants grafted on pumpkin rootstocks demonstrated a 2.2 times higher trans-zeatin root content, and were higher in dry matter than self-rooted cucumber (Seong et al., 2003).

**Quality:** Clearly, the scion variety affects final size, yield, and quality of fruit in grafted plants, but rootstock effects can drastically alter these characteristics. There are many conflicting reports on changes in fruit quality resulting from grafting. The differences in reported results may be attributable in part to different production environments; type of rootstock/scion combination used, and harvest date. Because grafting affects flowering and harvest date, it is often difficult to harvest ripe fruit from grafted and nongrafted plants.

**TABLE 2:** Available root stocks for cucurbits grafting

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rootstock(s)</th>
<th>Purpose*</th>
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</thead>
<tbody>
<tr>
<td>Water (Citrullus lanatus)</td>
<td>Watermelon</td>
<td>Bottle gourd (Lagenaria siceraria)</td>
</tr>
<tr>
<td>Melon</td>
<td>Bottle gourd (Lagenaria siceraria)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interspecific hybrids F1 (C. maxima x C. Moschata), Wax gourd (Benincasa hispida), Pumpkin (Cucurbita moschata), Squash (Cucurbita pepo), Sicyos angulatus</td>
<td>1,2,3,1,2,3,1,2</td>
</tr>
<tr>
<td>Cucumber (Cucumis melo)</td>
<td>Cucumber</td>
<td>Fig leaf (Cucurbita ficifolia), Interspecific hybrids F1 (C. maxima x C. Moschata), Cucumber (Cucumis sativus), Sicyos angulatus,</td>
</tr>
<tr>
<td>Melon (Cucumis melo)</td>
<td>Melon</td>
<td>Cucumis melo</td>
</tr>
<tr>
<td>Melon</td>
<td>Squash (Cucurbita pepo), Interspecific hybrids (C. moschata x C. maxima), Wax gourd (Benincasa hispida)</td>
<td>1,2,3,1,2</td>
</tr>
</tbody>
</table>

*1: Fusarium wilts, 2: growth promotion, 3: low temperature, 4: growth period extension, 5: nematodes resistance
controls concurrently, further confusing results. An early report stated that crops that are harvested immature such as cucumber have fewer reported negative quality effects resulting from grafting, although increased firmness and shortening of fruits have been noted (Muramatsu, 1981). However, later reports suggest that different rootstocks affect grafted cucumber quality characteristics such as fruit shape, skin and flesh colour and texture, skin smoothness, firmness, rind thickness, and soluble solids content (Robinson and Decker-Walters, 1997). Zhu et al. (2006) reported an increase in ascorbic acid content with grafting.

Grafting Techniques
Grafting calendar and grafting steps
The grafting calendar generally adopted for watermelon is:

- Day 0: Variety sowing (January)
- Day 7: Rootstock sowing
- Day 14: Grafting
- Day 24: Plant transplanting
- Day 45: Field planting (February)

Sowing of the rootstock: The sowing date depends on the chosen rootstock, the variety to be grafted and on the sowing and greenhouse conditions. In general, the sowing date for the rootstock varies between 2 days and 7 days before the sowing date of the variety.

Seeds are sown in peat plugs at 240 cells per tray. After sowing, seed are covered with small medium gauge vermiculite. Trays are placed in warm, light area immediately after sowing. Trays are covered with clear plastic to avoid dehydration of the seed. Plastic is removed as soon as the very first green spot is visible. Humidity must be kept high as the seedling will otherwise dry out.

Grafting Methods: The survival rate of grafted plants depends on compatibility between scion and rootstock, quality and age of seedlings, quality of the joined section, and post-grafting management. Different grafting techniques are employed for different scions and rootstocks depending on grafting objectives, farmers’ experience, and post-grafting management conditions. When scion and rootstock have hollow hypocotyls, the hole insertion and one cotyledon grafting methods are preferred (Hang et al., 2005). In contrast, tongue approach and cleft techniques, which have high survival rates, are often chosen by the farmers who have plenty of space and adequate labour.

**Tongue Approach/Grafting (TAG):** It is easy to use and has a high success rate and the grafted seedlings have uniform growth rate. The scions and rootstocks should be approximately the same diameter in the TAG method. This is usually the case after the rootstock has fully developed cotyledons and the scion has cotyledons and the first true leaf. The rootstock is cut through the hypocotyl at a 35° to 45° angle. The growing point may remain by only cutting downward halfway through the hypocotyls or it may be removed with a grafting knife or razor blade. The scion is also cut at an angle (upward if the growing tip of the rootstock remains attached) and joined to the rootstock with the cut surfaces aligned. Lead strips, aluminum foil, or grafting clips are used to hold the grafts together. When metal strips are used they can remain on the plant once the plant has healed. However, the grafting clips need to be removed once the union is healed. There is an additional cost for clips, and for labour to remove those 15–20 days after grafting. If the top of the rootstock is left on, it should be removed five days after grafting. The scion hypocotyls are cut off seven to ten days after grafting at just below the graft union. Grafted plants are maintained in the greenhouse until ready for transplanting. This is at least two days after removing the scion roots. A humidity chamber

![Tongue Grafting Diagram]

**Step 1:** Preparing the rootstock;
**Step 2:** Preparing the scion;
**Step 3:** Joining the scion to the rootstock;
**Step 4:** Securing the joining with a metal strip; and
is not required. The advantage of the tongue approach, is that it is easy and requires a low relative humidity microclimate after grafting. Because of this, it is often adapted by the farmers. Although this method requires more space and labour compared to other methods, high seedling survival rate can be attained even by beginners. However, the grafting position is close to the ground making it easy for adventitious roots from the scion to reach the soil. Moreover, this method is not suitable for rootstocks with hollow hypocotyls, since scions may form adventitious roots inside the hypocotyls. Therefore, the TAG method is good for rootstocks with high solid hypocotyls.

**Cucumber: Tongue Approach Grafting:** The survival ratio is higher if tongue approach grafting is used. This is because the root of the scion remains until the formation of the graft union. Seeds of cucumber are sown 10-13 days before grafting, and pumpkin seeds 7-10 days before grafting. The shoot apex of the rootstock is removed. The hypocotyls of the scion and rootstock are cut in such a way that they tongue into each other. Graft is secured with a plastic clip.

**Time schedule of Tongue Approach Grafting in cucumber plants**

**Hole Insertion/Terminal/Top Insertion Grafting (HIG):** The Hole insertion graft (HIG) is the most popular cucurbit grafting method in China. This method is easy, has high survival rate, and the grafted plants have fewer incidence of soil borne disease because of the high graft union. One person can produce 1,500 or more grafts/day and post-grafting acclimatization is simple. This method was described in 1970 by Fujii and has recently been adopted by nurseries. A modified HIG method, where the root system is removed from the rootstock, was originally developed for watermelon grafting. Plants should not be older than 33 days before transplanting. The main problem with HIG is that the size of the rootstock hole is limited by rootstock size. Therefore, the scion size has to be controlled, narrowing the grafting period.

**One Cotyledon/Slant/Splice/Tube Grafting (OCG):** The one cotyledon graft (OCG) is commonly used, and has recently been adopted by commercial plug seedling nurseries (Fujii, 1970). This approach is preferred when rootstocks have thin stems, i.e. watermelon, cucumbers, and oriental melons. This method is suitable when rootstock and scion are of a similar size. The rootstock should be grafted when cotyledons and the first true leaf start to develop (about 7 to 10 days after sowing). One cotyledon and the growing tip are removed. The seedling is cut at a slant from the base of one cotyledon to 0.8-1.0 cm below the other cotyledon, removing one cotyledon and the growing tip. The length of cut on the scion hypocotyl should match that of the rootstock and should be at a 35° to 45° angle. The scion is attached to the rootstock and fixed tightly by a grafting tube or clip (Oda, 1999). Grafted plants should be maintained in the dark at 25°C and 100% humidity for three days or until the junction has healed, before moving them into a greenhouse maintained at 21°C to 30°C. Plants should not be
more than 33 days old before transplanting. This approach requires good post-grafting management since scions easily fall off at an early stage. OCG is called tube grafting when the joined plants are held together with a length of tube instead of a grafting clip.

**Cleft / Side Insertion Grafting (CG):** This method is simple and easy to learn, and is suitable for preventing soil borne diseases since the grafting junction is high on the hypocotyl. When cotyledons and the first true leaf start to develop (about 7 to 10 days after sowing) the rootstock is ready to graft. The growing tip of the rootstock can be removed during grafting or around five days after the grafted plants are removed from their high humidity chamber. A slit is cut on the rootstock hypocotyl with a razor blade and held open with a toothpick. The width of the cut varies depending on the diameter of the scion's hypocotyl. The scion hypocotyl is cut from both sides at a 35° to 45° angle and then inserted into the slit in the rootstock. The toothpick is removed. Then the two cut surfaces are matched and held together with a grafting clip or silicone sleeve. Grafted plants should be transferred to a humidity chamber or healing room. Plants should be maintained in the greenhouse until the junction is healed, and should not be more than 33 days old before transplanting.

**Pin Grafting (PG):** This method is similar to OCG, except that specially designed pins are used instead of grafting clips to secure the graft union. The cotyledons of the rootstock and scion are cut horizontally, and a ceramic pin is inserted into the cut surface this helps align and secure the joined sections. This method's limiting factor is that the scion and rootstock should be approximately the same diameter so the cambial regions are in close contact. This method is easy, reducing labor cost, but ceramic pins add expense, and a special environmentally-controlled chamber is needed to acclimatize the grafted plants (Lee et al., 1998).

**Double Grafting (DG):** Double grafting is used when a perfect rootstock for a specific scion is unavailable. For example, if the rootstock is too large and an intermediate sized stem is needed to bridge the rootstock and scion. The scion is first grafted onto a middle rootstock. The middle rootstock is then grafted onto another rootstock, which has good resistance to soil borne diseases. Unfortunately this method increases labour and cost while decreasing survival rate.

**Root Pruning:** Root pruning hole insertion grafting, and root pruning one cotyledon grafting employ the same procedures as the HIG and OCG methods except the rootstock hypocotyl is cut to remove the roots. This induces adventitious root growth,
increases the production of primary roots, and enhances the plant's tolerance to cold and heat thus ensuring vigorous growth (Lee and Oda, 2003). At present, more than 40% of watermelon grafting in Japan is performed with this method. However, this added procedure necessitates an exclusive grafting facility and is more dependent on soil conditions.

**Acclimatization:** Proper environmental conditions are important to facilitate rootstock and scion union for some grafting methods. Some nurseries have chambers that maintain temperature above 20°C, or for the tongue approach method, at around 25°C, and low light intensity for the first five to seven days. Relative humidity should be maintained between 85% to 100%. Most nurseries acclimatize grafted plants in small plastic tunnels inside greenhouses (HEALING TUNNELS) where it is possible to maintain a high relative humidity. Three to eight days after grafting, plants are acclimated to the natural conditions of the greenhouse by slowly dropping humidity.

**Potting and Spacing:** After 7 days, normal plant raising procedures are followed. Transplanting is recommended from day 9 to 10 days after grafting, once the rootstock and the variety are firmly joined.

**Compatibility:** The most obvious is rootstock/scion incompatibility, which induces undergrowth or overgrowth of the scion, leading to decreased water and nutrient flow through the grafted union, causing wilting. Incompatibility can be affected by tissue and structure difference, physiological and biochemical characteristics, growing stage of rootstock and scion, phytohormones, and the environment. Generally, grafting compatibility is related to taxonomic affinity, but there are significant exceptions. Graft incompatibility as reviewed by Andrews and Marquez (1993) is differentiated from graft failure, which often results from environmental factors or lack of skill of the grafter. When grafting conditions have been successfully ensured, graft incompatibility could be attributed to other factors such as failure of rootstock and scion to affect a strong union, failure of the grafted plant to grow, or premature death of either rootstock or scion after grafting. Physiological incompatibility may also occur as a result of lack of cellular recognition, wounding responses, presence of growth regulators, or incompatibility toxins (Andrews and Marquez, 1993).

**CONCLUSION**

Grafting can affect various quality aspects of vegetables. Rootstock and scion combinations should be carefully selected for specific climatic and geographic conditions. Appropriate selection can help control soil borne diseases and also increase yield and improve fruit quality. For decades, grafting has been successfully practiced in many Asian countries, and is becoming increasingly popular in Europe. Grafting is routinely employed for cucumbers, melons, oriental melons, squash, and
Breeding multipurpose rootstock and developing efficient grafting machines and techniques will undoubtedly encourage increased use of grafted seedlings not only in India, but also in many other countries. Identification of compatible multi-disease-resistant rootstocks with tolerance to abiotic stresses is a basic requirement for continued success. They may also increase grafted cucurbit crop production, and in turn, increase yield, and decrease chemical usage. Grafting of vegetables may be useful in the low-input, sustainable horticulture of the future. The low rate of grafting success results in high costs, reducing the appeal of grafting in developed countries. Unfortunately, the range of commercial rootstocks is limited, and the effect of unexplored rootstocks on fruit quality is still not clear. Further research needs to focus on rootstock development.

**REFERENCES**


