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Grafting in Vegetable Crops: A new tool to boost productivity

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Abstract:

India is the world's second largest producer of vegetable crops after China, accounting for about 14 percent of the world production. In 2013-14, India acreage of vegetable cultivation is around 9.396 million ha area with the annual production of 162.89 million mt, and productivity is 17.3 mt/ha. With increasing population, there is need to boost the production of vegetable crops. The grafting is one of the tools for sustainable vegetable production by using resistant rootstock. It reduces dependence on agrochemicals for the organic production. Grafting has been utilized in horticulture ever since the first millennium. The process involves union of two parts (a rootstock and scion) together from two different plant parts to form a single, living plant. The first attempt in vegetable grafting was done by grafting watermelon (*Citrullus lanatus*) onto pumpkin (*Cucurbita moschata*) rootstock in Japan and Korea in the late 1920s. Production and demand for grafted vegetable plants continues to increase across Asia and Europe, and has begun to expand to North America. Watermelon is one of the vegetables in which grafting is performed intensively in the world.

Now a day's, grafting of vegetable crops is used to induce vigour, precocity, better yield and quality, survival rate, reduce infection by soil-borne pathogens and to enhance the tolerance against abiotic stresses by using desired rootstocks. In global, this method of propagation has gained much fame in grafting of cucurbits, tomato, eggplant and pepper onto vigorous and disease-resistant rootstocks to ensure adequate yields where salinity, biotic stresses, and environmental stresses/or unfavorable growing temperatures limit productivity Further inventions are mechanized and robotic grafting has given a fillip to this novel eco-friendly approach. (Kumar and Kumar 2017)

Basic pre-requisites for vegetable grafting:

1. Selecting the right rootstock/scion: Select the desirable rootstock and scion having the same stem size (diameter). Grafting should be done at 2-3 true leaf stage.

2. Graft compatibility: Compatible rootstock and scion minimizes the Mortality rate even in later stage of growth. Rapid Callus formation takes place between scion and rootstock and leads the formation of vascular bundles.

3. Grafting aids: Commonly used aids to perform grafting i.e., Grafting clips, Tubes, Pins, and Grafting Blade**.**

4. Screening house: Used for growing seedlings prior to grafting. It should be constructed with 60-mesh nylon net. Arrange double door, the upper half of the structure should be covered with a separate UV resistant polyethylene to prevent UV light penetration.

5. Healing of grafts: Healing is most critical to provide favorable conditions to promote callus formation of grafted seedlings. In healing chamber, temperature should be 28-29 0C with 95% relative humidity for 5-7days in partially shaded place (darkness for 1-2 days) to promotes callus formation at union. It helps in formation of better graft union by reducing transpiration, maintains high humidity, maintains optimum temperature and reduces light intensity. The main aim is to initiate environment by controlling temperature and humidity.

6. Acclimatization of the grafted plants: After the callus has formed and the wounded surfaces are healed, plants may be put under a mist system, greenhouse or placed under a clear plastic cover for acclimatization to prevent leaf burning and wilting.

Methods of grafting

The familiar methods used for vegetable grafting were listed in and a few methods were explained as per the commercial use.

1. Cleft grafting: This is widely used method of grafting in solanaceous crops. Here scion plants are pruned to have 1-3 true leaves and the lower stem is cut to slant angle to make a tapered wedge and clip is placed to make contact between scion and rootstock after placing scion into the split made.

2. Tongue approach/Approach grafting: This method most widely used by farmers and small nurseries. This method requires more space and labor compared to other methods but high seedling survival rate can be attained even by beginners. Grafted seedlings have a uniform growth rate but it is not suitable for rootstocks with hollow hypocotyls.

3. Hole insertion/Top insertion grafting: This is most popular method in cucurbits scion and rootstock should have hollow hypocotyls are preferred in this method. To achieve a high rate of success, relative humidity should be maintained at 95%. The optimum temperature should maintain at 21-36◦C up to transplanting. One person can produce 1,500 or more grafts/day.

4. One cotyledon/Slant/Splice grafting

It has recently been adopted by commercial seedling nurseries and applicable to most vegetables. The grafted plants should be maintained in the dark at 25 ◦C and 100% humidity for three days for graft union formation. This method has been developed for robotic grafting of cucurbits.

5. Tube grafting: It is similar to slant grafting except that in this method root stock & scion joined are held with an elastic tube instead of clips. It is more popular in tomato, brinjal.

6. Pin grafting: Pin grafting is basically the same as the splice grafting. Instead of placing grafting clips, especially designed pins are used to hold the grafted position. The pins are made of natural ceramic so it can be left on the plant without any problem.(Kumar and Kumar 2017)

Different method of grafting in water melon:

Splice Graft:

Rootstock seedlings should have at least one true leaf, and scion seedlings should have one or two true leaves. With a single angled cut, remove one cotyledon with the growing point attached. It is important to remove the growing point and the cotyledon together so that the rootstock seedling is not able to grow a new shoot of its own after being grafted. This is one of the advantages of using this type of graft. It's also important, when removing the cotyledon and growing point together, not to remove too much tissue because the remaining cotyledon must be well attached to the stem of the seedling.

Cut the scion and match the two cut surfaces, rootstock and scion. Hold in place with a grafting clip. Place the grafted seedling in a chamber with high humidity at about 77°F and discard the unused parts.

Advantages:

1) Simple technique, almost anyone can do this type of graft.

2) The only task after grafting is to remove the clip. There is no trimming of unwanted plant parts after healing of the graft union.

Disadvantages:

1) Requires careful control of humidity, light, and temperature after grafting. Can experience high losses due to poor environmental control and possible disease under high humidity conditions.

Side Graft:

Rootstock seedlings should have at least one true leaf, and scion seedlings should have one or two true leaves. With a sharp knife or razor blade, cut a slit all the way through the stem of the rootstock. The cut doesn't need to be too long, just long enough to insert the scion.

Cut the scion at an angle and insert into the slit of the rootstock. Hold in place with a grafting clip. Place the grafted seedling in a chamber with high humidity at about 77°F and discard the unused parts.

Advantages:

1) Simple technique.

Disadvantages:

1) Requires careful control of humidity, light, and temperature after grafting. Can experience high losses due to poor environmental control and possible disease under high humidity conditions.

2) After healing of graft union, requires removal of top portion of rootstock. This requires additional time and labor but allows scion alone to establish plant canopy.

Approach Graft:

Rootstock and scion seedlings should have one or two true leaves. With a sharp knife or razor blade, cut an angled slit halfway through the stem of the rootstock and an oppositely angled slit halfway through the stem of the scion. Match the slits so that they overlap and then seal with aluminum foil or specialty materials available for this purpose.
Place the grafted seedlings in a seedling tray with larger cell size than what they were grown in. Place root balls of both rootstock and scion together in the same cell and add potting media if needed to fill the larger cell. Return to greenhouse or other growing area. High humidity and low light is not necessary to ensure success with this type of graft.

Advantages:

1) Relatively simple technique.
2) High humidity and low light environment not required for successful healing of the graft union. A normal greenhouse environment is sufficient.

Disadvantages:

1) After healing of graft union, requires removal of top portion of rootstock about nine days after making graft. Also requires severing of scion roots after an additional two or three days. Can then be planted to field in about three more days.

Hole Insertion Graft:

Rootstock seedlings should have one small true leaf and scion seedlings should have one or two true leaves. With a pointed probe, remove from the rootstock the true leaf along with the growingpoint. It is important to remove all of the growing point to prevent future shoot growth of the rootstock. This is one of the advantages of this type of graft.
Use the probe to open a slit along one side on the upper portion of the rootstock's stem, where the stem connects to the cotyledons. Cut the scion and insert into the rootstock. Hold in place with a grafting clip. Place the grafted seedling in a chamber with high humidity at about 77°F and discard the unused parts.

Advantages:

1) The only task after grafting is to remove the clip. There is no trimming of unwanted plant parts after healing of the graft union.

Disadvantages:

1) Requires slightly more skill than most other grafting techniques.
2) Requires careful control of humidity, light, and temperature after grafting. Can experience high losses due to poor environmental control and possible disease under high humidity conditions. (http://edis.ifas.ufl.edu.)

Effect of grafting on different factors in watermelon:

Grafting can be used with a variety of cucurbits to provide control of Fusarium wilt, drought tolerance, and flooding tolerance. Currently, watermelon is one of the vegetables in which grafting is performed intensively in the world . The success of grafting includes survival rate, compatibility, and effect on quantity and quality traits tolerance / resistance to biotic and abiotic stresses.

Graft compatibility and survival rate:

Graft compatibility is defined as an adequately close genetic relationship between stock and scion to form successful graft union, assuming that all other factors (technique, timing, temperature, etc.) are satisfactory. The Inter-generic grafting of highly nematode-susceptible watermelon (*Citrullus lanatus*) cultivars 'Congo' and 'Charleston Gray' onto highly nematode-resistant wild watermelon (*Cucumisa fricanus*) and wild cucumber (*C. myriocarpus*) seedling rootstocks resulted in 36 % survival of the intergrafts reported by Pofu and Mashela . Various rootstocks of cucurbits that are using for different quality, quantity, biotic and abiotic stresses elaborated under subheadings.

Effect of grafting on quantitative characters:

Grafting increases the yield of watermelons due to an increase in mean fruit size. As shown by Yetisir, et al., Huitron-Ramirez, et al., watermelon grafted onto interspecific squash rootstock (*C. maxima × C. moschata* Duchesne) found to increase fruit size by 52% and yield were significantly higher with firm flesh than fruit from non-grafted plants. The Khankahdani, et al. observed maximum fruit yield in grafted watermelons on 'Bottle gourd' rootstock by splice grafting technique (13.60 kg/plant) and the least recorded in seedy watermelons (4.37 kg/plant. Grafting mini-watermelons onto a commercial root-stock (PS 1313 *Cucurbita maxima* × *Cucurbita moschata*) revealed more than 60% higher marketable yield when grown under conditions of deficit irrigation compared with un-grafted melons. A study on growth and yield of grafted cucumber on different soilless substrates showed that, grafted plants formed a significantly larger stems and longer root systems which led to 24% increased yield by Marsic and Jakse. Reid and Klotz Bach also proved that grafting in cucumber increases yield.

Effect of grafting on qualitative characters:

According to Ali made observations on fruit quality and showed that fruit quality varies with both cultivar and rootstock and more vigorous plants tended to have better quality fruit. With regard to watermelon fruit, grafting on to different rootstocks has been known to increase fruit firmness and thus increase shelf life. Bruton, et al. evaluated fruit quality of grafted plants and found that when watermelon plants grafted onto *C. maxima* × *C. moschata* and *C. ficifolia* rootstocks, fruits had higher firmness. Fruit soluble solid content (SSC) and lycopene also varied with the cultivar and rootstock. Irregular fruit quality issues reported for watermelon comprise of reduced soluble solids, improved number of yellowish bands in the flesh, dull taste, poor texture and decreased firmness . However, others report have optimistic effects on grafting watermelon, including an increase in fruit firmness, soluble solids and lycopene content by Salam, et al. . Yetisir, et al. reported that quality (Brix, firmness, rind thickness, and fruit shape) of watermelon was greatly affected by grafting, but the results were dependent on the rootstock used. Zhu, et al. found an enhanced content of ascorbic acid with grafting. Proietti, et al. Reported vitamin-C content increased by 7% grafted mini watermelon plants and 40% increased lycopene content if mini watermelon grafted onto hybrid rootstock 'PS1313' *C. maxima × C. Moschata*. A report of grafted watermelon, mentioned a 20% increased percentage of lycopene and total carotenoids by Davis, et al. Huang, et al. Evaluated an increased vitamin-C in case of cucumber. A watermelon var. F-90 was grafted onto the rootstock of *Cucubirta maxima* var. Dulce Maravilla, found an improved iron uptake as well as the consequent translocation of this micronutrient towards the shoot than un-grafted watermelon plants.

Effect of grafting on biotic stresses:

Grafting plays an important role in controlling disease by using various rootstocks. Grafting of watermelon onto other cucurbitaceous rootstocks to provide soil-borne disease resistance has been highly successful. Grafting is a speedy technique in melon for controlling race 1 and 2 of *Fusarium oxysporum f. melons.* The plants of 'Crimson Sweet' grafted onto 'Shintoza' *Verticillium* colonization was checked, possibly due to the grafting defence mechanism identified by King, *et al.* It has been shown that by using Verticillium wilt tolerant rootstocks; commencement of symptoms can be postponed for three weeks, consequently the watermelon fruits can reach to maturity. Thies and Levi reported that watermelon plants grafted onto wild watermelon rootstocks (*C. Lanatus* var. *citroides*), were screening resistant or moderately resistant to the nematode, *M. incognita***.** 'Crimson Sweet' watermelon grafted onto 'Emphasis' and 'Strong Tosa' two rootstocks had a elevated rate of growth and improved tolerance to V. dahliae than non grafted/ self-grafted plants.

Effect of grafting on abiotic stresses:

Grafting used as a tool for reducing the effect of abiotic stresses. Grafted watermelon has potential to survive under abiotic stress. The watermelon grafted onto bottle gourd rootstock in heavy or loam soils, it enhances flooding tolerance. Cucurbits may be grafted onto pumpkin will provide some drought tolerance in sandy soil. Mini watermelons grafted on to a commercial rootstock PS1313 (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne) shown that an increase of over 60 % higher yield when grown under scarcity of irrigation conditions in contrast to ungrafted melon plants . The higher marketable yield recorded with grafting was mainly due to an improvement in water and nutrient uptake. In watermelons, the quantity of chemical fertilizers can also be reduced to about one-half to two-third in grafted plants as compared to the standard recommendation for the non-grafted ones. An increased levels of heavy metals such as cadmium, mercury, lead, arsenic etc., in farming constitute an rising hazard to plant growth, development, and yield, even also for human health and environment that are integrated from various sources either industry, waste water or by soil amendments . Some heavy metals are poisonous even in low concentrations while others present in plant tissues devoid of losing yield and observable symptoms. A report on melon plants, cv. Arava grafted on the cucurbita rootstock i.e. TZ-48 found that B, Zn, Sr, Mn, Cu, Ti, Cr, Ni and Cd were lesser in fruits from grafted plants . Cadmium restricts the photosynthesis, nitrogen metabolism, water transport, phosphorylation in mitochondria and chlorophyll content. The watermelons grafted onto saline-tolerant rootstocks increases around 81% yields under greenhouse production. Goreta, et al. reported watermelon cv. Fantasy was grafted onto Strongtosa rootstock (C. maxima Duch × C. moschata Duch) increases the shoot weight and leaf area even under saline conditions.

Period of flowering and harvest:

The rootstock and scion join together may adjust amounts of hormones produced and their influence on grafted plants parts. Flowering is delayed in grafted pumpkin, bottle gourd, wax gourd, and watermelon, especially in plants with 'Shintosa'-type rootstocks. Sakata*et al*., stated that compared with other rootstocks, watermelon grafted onto bottle gourd causes early formation of female flowers. Flowering date affects fruit harvest time, which can have a direct impact on quality. No much report found that could provide more information about grafting effects on flowering and earliness. (Kumar and Kumar 2017)

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