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Shielding The Veggies Crops: Managing the Soil-Borne Diseases with The Power of Vegetable Grafting

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Introduction

The term "vegetable" typically denotes the edible components of specific herbaceous plants. These plant parts are consumed fresh or subjected to various culinary preparations. Most vegetables are cultivated by sowing seeds directly in the fields where they will grow. However, at times, they are initiated in a nursery or greenhouse and subsequently transplanted as seedlings to the field. Throughout the growing season, both synthetic and organic herbicides, pesticides, and fungicides are frequently employed to mitigate damage caused by weeds, insects, and diseases, respectively.

In the year 2020, more than three-quarters of the world's vegetable production originated from Asia. In 2021, China emerged as the foremost global producer of fresh vegetables, with a production volume exceeding 594 million metric tons. In fiscal year 2023, India's total vegetable production was estimated at approximately 212 million metric tons, encompassing various vegetables such as potatoes, tomatoes, onions, eggplants, and cabbages. India, known for its abundant production of cost-effective fruits and vegetables, also boasted a thriving export market. The All-India coordinated research project on vegetable crops, initiated during the fourth five-year plan in 1970-71, aimed to establish a nationwide network for the multi-location testing of vegetable technologies developed by various research institutes and state agricultural universities. A significant challenge in vegetable cultivation is the presence of diseases, pests, nematodes, and other issues. To combat these problems, research institutes employ diverse strategies, including the introduction of resistant plant varieties and the application of chemicals in the field.

In recent times, vegetable grafting has gained popularity as a unique technique. It involves the fusion of two different plants to create a single plant possessing the desired traits of both. The upper part of the plant, known as the scion, contributes shoots, while the lower part, referred to as the rootstock, provides a root system that is resistant to soil-borne diseases and environmental stresses. Common soil-borne diseases include damping-off, root rot, and vascular wilt, which manifest as symptoms like tissue discoloration, wilting of foliage, root decay, and sudden plant death. If not managed effectively, these diseases can substantially diminish crop yields and devastate large segments of the agricultural sector.

History

Vegetable grafting is a unique technology practiced for many years in East Asia to address challenges associated with intensive cultivation using limited arable land for vegetable production (Kubota et al., 2008). Grafting of herbaceous seedlings is a unique horticultural technology practiced for many years in East Asia to mitigate issues related to intensive cultivation using limited arable land for vegetable production. The earliest documented instance of herbaceous grafting was with watermelon. The use of grafted seedlings in commercial vegetable production occurred as early as the 1930s in Japan. Research on grafting cucumber (*Cucumis sativus*) also started in the late 1920s but broader commercial applications did not happen until 1960 (Sugiyama et al., 2006). The grafted tomato (*Lycospercum esculentum*) was introduced commercially in the 1960s. In India, vegetable grafting work was first started by IIHR, Bengaluru in 2013. Their work involved identifying rootstock for various vegetable crops such as tomato, cucumber, and pepper, that can withstand biotic and abiotic stresses.

Current status of vegetable grafting

Presently, China occupies the forefront as the principal global producer of cucurbitaceous and solanaceous vegetables. Approximately 40% of watermelon, 20% of melon, 30% of cucumber, 15% of eggplant, 1% of tomato, and 1% of pepper crops are subject to grafting techniques. Furthermore, grafting methods are also applied to cultivate bitter gourd and wax gourd (Lee et al., 2010).

Although quantifying the exact proliferation of grafted plants in use across North America presents a challenge, surveys conducted by faculty at the University of Arizona in 2002 and 2006 provide valuable insights. These surveys revealed that the total number of grafted seedlings employed in North America exceeded 40 million, with the predominant majority being deployed within hydroponic tomato greenhouses. In most propagation operations throughout North America, tomato grafting is accomplished through the utilization of an elastic-plastic tube that secures the graft union, cut at an angle (Lee et al., 2010).

Fortunately, seed companies have been able to selectively breed scion cultivars that are well-suited for intensive cultivation. Despite the widespread recognition of the advantages associated with using grafted seedlings, successful implementation of this innovative technology hinges on meticulous consideration of several other critical factors. For instance, the excessive use of chemical fertilizers and synthetic pesticides should be minimized to ensure the production of environmentally friendly agricultural products—a sphere of significant interest that has experienced exponential growth in recent years.

Fig 1. ***Cucumis sativus*** **scion grafted on** ***Lagenaria siceraria*** **rootstock**

Techniques for vegetable grafting

Common Techniques

1. **Side Grafting (Approach Grafting):** entails the creation of a 45-degree downward angle incision slightly exceeding the midpoint of the rootstock stem, positioned below the cotyledons. A corresponding incision is made on the scion stem, situated above the cotyledons. Subsequently, these two stems are meticulously aligned and firmly pressed together.
2. **Cleft Grafting (Wedge Grafting):** involves the removal of the upper portion of the rootstock stem, situated below the cotyledons, and the formation of a vertical slit at the center of the resulting cut surface. The scion is skillfully shaped into a wedge and then inserted into the slit on the rootstock.
3. **Splice Grafting (Top Grafting**): both the rootstock and scion stems are severed at angles equal to or exceeding 45 degrees. These cut stems are precisely aligned and joined together. To ensure stability, a silicon tube is employed to secure the graft.

Additional grafting techniques encompass Tongue Grafting, Tube Grafting, Hole Insertion Grafting, and One-Cotyledon Grafting, each offering distinct methodologies for successful graft union formation.

Soil-borne diseases in vegetable crops

Soil-borne fungi

In the context of protected cultivation, cucurbitaceous and solanaceous vegetables are highly susceptible to detrimental effects caused by soil-borne fungi, which inflict damage upon root and crown tissues. Soil-borne pathogenic fungi and oomycetes, including Phytophthora spp. and Pythium spp., exhibit similar symptoms within root, crown, or stem tissues. These symptoms typically manifest as browning, scarring, stem constriction, stunting, diminished root density, wilting, decay, damping-off, and root and crown rot. It's noteworthy that each pathogen exhibits distinct structural and symptomatic characteristics that facilitate their identification.

Wilt Disease:

Wilt disease in solanaceous crops, induced by the bacterial pathogen Gastonia solanacearum, represents a globally significant soil-borne ailment that severely restricts solanaceous vegetable crop production, impacting over 450 plant species.

Plant-Parasitic Nematodes:

Belonolaimus spp. are documented to attack vegetables from diverse botanical families, encompassing Apiaceae, Asteraceae, Brassicaceae, Cucurbitaceae, Convolvulaceae, Fabaceae, Malvaceae, Poaceae, and Solanaceae worldwide.

Root-Knot Nematode (Meloidogyne spp.):

Root-knot nematode infestation, especially on monocotyledonous crops like onions and leeks, is characterized by the presence of protruding egg masses on the root surface.

Root-Lesion Nematode (Pratylenchus spp.):

This migrating endoparasitic nematode has been identified in the rhizosphere or roots of various vegetable crops, with p. Indicus being the predominant species in Indian settings. Tomato and brinjal are among the vegetables attacked by this nematode.In the context of protected cultivation, root-knot nematode proliferation is accelerated by favorable environmental conditions. Nematode populations increase rapidly within polyhouses, often surpassing threshold levels by five to six times within 18-24 months, rendering protected cultivation economically impractical.

Management of Soil-Borne Diseases by vegetable grafting:

Robust rootstocks exhibit exceptional resistance to severe soil-borne diseases caused by pathogens such as Fusarium, Verticillium, Phytophthora, Pseudomonas, *Didymella bryoniae*, *Monosporascus cannonballs*, and nematodes.

Rootstock Selection:

Rootstock screening from existing cultivars has traditionally been employed for each crop. Nevertheless, seed companies and breeders have increasingly focused on developing superior rootstocks tailored to specific environmental conditions.

Grafting Technology:

Grafting plays a pivotal role in controlling soil-borne pathogens, particularly Fusarium wilt in cucumber, melon, and watermelon. Continuous improvements in grafting techniques are ongoing. Rootstocks confer heightened vigor and yield, even in the absence of pathogens, while also providing tolerance to abiotic stresses like low temperature and salinity.

Grafting in Cucumber:

Cucumber benefits significantly from grafting, as it is highly susceptible to Fusarium wilt and root-knot nematodes, which cause substantial global yield losses. Grafting cucumber onto *C. maxima* has demonstrated effective control against *P. aphanidermatum* in greenhouses. Damping-off infections were not observed in cucumber grafted onto squash hybrids 'Titan' and 'Hercules.'

Grafted Melon:

Melon grafted onto squash hybrids exhibited resistance to wilting, contrasting with 80% and 70% wilting observed in un-grafted melon when exposed to *M. phaseolina* in field conditions. Although necrosis could occur in the scion tissue above the grafting union, melon yields remained unaffected.

Grafting Watermelon:

Squash hybrids offer effective resistance to Fusarium wilt due to their non-host resistance to *Fusarium* f. sp. *nivem* (FON). In Spain, routine grafting of watermelon onto squash hybrids like 'Brava,' 'Shinto,' and 'RS-841' for Fusarium wilt control may also indirectly manage Acremonium collapses. *Lagenaria siceraria* is also employed as a watermelon rootstock due to its moderate resistance to FON and high compatibility.

Impact of Grafting on Root-Knot Nematode-Infested Soils:

The efficacy of grafting in enhancing crop yield in soils infested with root-knot nematodes (RKN) hinges on pre-planting nematode densities in the soil and crop susceptibility. Grafting outcomes in nematode suppression and yield enhancement can vary significantly. Squash hybrids 'Strong Tosa' and 'RS841,' as well as *L. siceraria*, exhibited susceptibility comparable to or higher than un-grafted cucumber, melon, and watermelon plants concerning RKN infestation (Ayala-Doñas et al., 2020).

Benefits of Vegetable Grafting:

1. Enhanced Pathogen Resistance: Grafted plants often display greater resistance to soil-borne diseases like wilt, nematodes, and Fusarium.
2. Improved Environmental Stress Tolerance: Grafted plants are better equipped to withstand adverse environmental conditions, including salinity, extreme temperatures, and nutrient deficiencies.
3. Vigorous Growth and Increased Yield: Grafted plants typically exhibit enhanced growth and productivity compared to their non-grafted counterparts.

Limitations of Vegetable Grafting:

Despite its advantages, vegetable grafting is not without limitations:

1. Compatibility Issues: Grafting necessitates the careful selection of compatible plant species or varieties. Failure to achieve successful graft unions can result in wasted efforts.
2. Disease Transmission: Grafting can potentially transmit diseases from the rootstock to the scion, jeopardizing the overall health of the grafted plant.
3. Increased Costs: The adoption of grafting increases production costs due to the use of double seeds, additional greenhouse space, certified seeds, specialized equipment, and the cultivation of indeterminate varieties. Grafted seedlings can cost 10 to 20 times more than non-grafted counterparts.

Future Prospects for Vegetable Grafting:

Recent literature suggests several avenues for future research in vegetable grafting that can advance our understanding and application of this technique. Key areas of interest include elucidating the molecular mechanisms governing graft union formation and compatibility between different genotypes, exploring epigenetic changes induced by grafting and their impact on plant traits, and investigating genetic exchange between rootstock and scion, which could lead to the development of chimeric plants with novel characteristics.

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