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Grafting: A sustainable approach for nematode management in solanaceous vegetables

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Abstract

Solanaceous vegetables are nutritionally and pharmacologically important crops owing to their rich composition of bioactive compounds, including alkaloids, antioxidants, vitamins and phenolic compounds, which contribute to disease prevention, health promotion and various therapeutic applications. The productivity and quality of solanaceous vegetable crops are substantially constrained by plant-parasitic nematodes, particularly root-knot nematodes (*Meloidogyne* spp.), which pose a major threat to sustainable production. These nematodes can spread through infected seedlings, contaminated planting materials, irrigation water, farm machinery and other agricultural practices, facilitating their establishment and dissemination in production systems. Vegetable grafting using nematode-tolerant or resistant rootstocks has emerged as an effective and environment friendly method for nematode management. Grafting enhances plant resilience by combining desirable scion characteristics with the nematode resistance or tolerance of suitable rootstocks, thereby reducing nematode damage and supporting sustainable crop production.

Keywords: Grafting, Solanaceous Crops, Rootstock, Scion and Nematodes Tolerance

1. Introduction

Solanaceous vegetable crops play an important role in human nutrition and contribute to addressing malnutrition. They are commonly regarded as “protective foods” because they are rich sources of minerals, vitamins and various phytonutrients. These vegetables also contain potent antioxidants, including lycopene in tomato and peppers and nasunin in eggplant. Such antioxidant compounds may help reduce the risk of long-term diseases by preventing free-radical-induced damage, influencing the metabolic activation and detoxification of carcinogens and potentially affecting processes involved in the progression of tumour cells. In worldwide, several economically important nematode groups are associated with a wide range of vegetable crops. These include root-knot nematodes (*Meloidogyne* spp.), cyst nematodes (*Heterodera* spp.), lesion nematodes (*Pratylenchus* spp.), reniform nematodes (*Rotylenchulus* spp.), lance nematodes (*Hoplolaimus* spp.) and stem and bulb nematodes (*Ditylenchus* spp.) (Bahadur, 2022). Among these, root-knot nematodes (*Meloidogyne* spp.) are considered one of the

most destructive groups of plant-parasitic nematodes affecting solanaceous vegetable crops. These nematodes have a wide host range and can cause considerable reductions in plant growth and crop productivity (Kayani *et al.*, 2013). Nematodes can be disseminated through infected seedlings, planting materials, irrigation water and farm implements. Their attack on the root system weakens seedlings and may also increase their susceptibility to infection by secondary pathogens, including soil-borne fungi and bacteria (Patil and Yadav, 2021).

2. Why nematodes are difficult to manage?

Plant-parasitic nematodes are challenging to manage due to their microscopic nature, diverse life cycles, persistence in soil and ability to withstand unfavourable environmental conditions. Nematicides are commonly employed by farmers as a rapid means of nematode management; however, their repeated application can result in environmental contamination and raise concerns regarding pesticide residues in soil and vegetables. Moreover, nematodes can persist in soil, crop residues and alternative host plants,

allowing them to survive between cropping cycles. Therefore, reliance on a single management practice may not provide sufficient and sustainable long-term control, particularly under continuous cultivation of susceptible crops. Although conventional breeding and biotechnological approaches can be employed to overcome nematode losses, these approaches are often time-consuming and require substantial investments in research, experimentation and both on- and off-field trials. Among the available management strategies, vegetable grafting represents an effective approach for enhancing nematode tolerance by using resistant rootstock with a high-yielding scion (Louws *et al.*, 2010). The rootstock can contribute to disease resistance by restricting pathogen entry, enhancing systemic resistance, and improving water and nutrient uptake, thereby reducing disease severity (Guan *et al.*, 2012).

3. What is vegetable grafting?

Grafting is a technique where in two living plant parts (rootstock and scion) are united together to grow as a single plant (Mudge, 2009). The upper part of the combined plant is called the scion while the lower part is called the rootstock. Commercial vegetable grafting originated in Japan and Korea and was practiced for about 30 years. The first time of vegetable grafting was done along with rootstock of watermelon (*Citrullus lanatus*) and pumpkin (*Cucurbita moschata*) in Japan and Korea in the late 1920s to manage soil borne diseases (Leonardi, 2016). During early 1950s commercial grafting of solanaceae crops are concerned, eggplant (*Solanum melongena* L.) was grafted onto scarlet eggplant (*Solanum integrifolium* Poir.). Similarly, grafting in tomato was started in 1960s (Oda, 1999).

4. Grafting methods commonly used in solanaceous vegetable crops

Splice grafting: 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. After placing the scion on the rootstock grafting clips are used to fix the grafted position at the union site.

Cleft grafting: 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.

Tongue approach grafting: The grafting cut for

rootstock should be made in a downward direction and the scion cut in an upward direction at an angle, usually 30°-45° to the perpendicular axis and joined to the rootstock with the cut surfaces aligned.

5. How grafting can help against nematodes?

Grafting can contribute to nematode management through several interconnected mechanisms associated with the resistance characteristics of the rootstock. Resistant rootstocks may develop thickened cell walls and enhanced suberin deposition, which form physical barriers that restrict nematode penetration and movement within the root tissues (Cookson *et al.*, 2013). In addition, grafting can activate induced systemic resistance (ISR), whereby nematode attack stimulates plant defense pathways and promotes the production of defense-related phytohormones, including jasmonic acid and salicylic acid, thereby strengthening host defense and limiting nematode activity (Aloni *et al.*, 2010). Genetic resistance also contributes to nematode suppression, as some resistant rootstocks possess resistance (R) genes, such as the Mi-1.2 gene, which provides resistance against *Meloidogyne incognita* by inducing a hypersensitive response. This localized defense response results in cell death around the infection site, thereby restricting nematode development and reproduction. Furthermore, resistant rootstocks may produce root exudates containing phenolic compounds, alkaloids, and other secondary metabolites that can interfere with nematode behaviour and consequently reduce infection (Thieme *et al.*, 2015). Grafting may also be associated with epigenetic and molecular interactions that influence resistance in the scion. Mobile RNAs and small interfering RNAs (siRNAs) have been identified as potential mediators of stress responses and may contribute to enhanced resistance of the scion against nematode infection (Paultre *et al.*, 2016).

6. Important rootstocks against nematode tolerance in solanaceous vegetables

Crops	Wild Species	References
Brinjal	<i>Solanum torvum</i>	Black <i>et al.</i> (2003)
Brinjal	<i>Solanum khasianum</i>	Rahman <i>et al.</i> (2002)
Brinjal	<i>Physalis peruviana</i> , <i>Solanum torvum</i>	Dhivya <i>et al.</i> (2014)
Brinjal	<i>Solanum integrifolium</i>	Gisbert <i>et al.</i> (2011)
Tomato	<i>Solanum pimpinellifolium</i>	Rai <i>et al.</i> (2010)

Tomato	<i>Solanum sisymbriifolium</i>	Baidya <i>et al.</i> (2017)
Tomato	<i>Solanum macrocarpon</i> , <i>Solanum aethiopicum</i>	Benjamin <i>et al.</i> (2018)
Tomato	<i>Solanum peruvianum</i>	Rossi <i>et al.</i> (1998)
Sweet pepper	<i>Capsicum annuum</i>	Oka <i>et al.</i> (2004)

7. Performance of grafted and non-grafted solanaceous plants for nematode tolerance

Nematode infestation in a wide range of crops can be effectively managed through grafting seedlings onto resistant rootstocks (Holajjer *et al.*, 2024). At the University of Florida Plant Science Research and Education Unit, Citra, sixty-six accessions, comprising 11 *Solanum* species and eight accessions intermediate between *S. melongena* and *S. insanum*, were screened against root-knot nematodes. Among these, *S. insanum* accession IC316278 and the intermediate accession between *S. melongena* and *S. insanum* (IC253952) were identified as moderately resistant, with a root-knot index (RKI) of 3 and 11–30 galls per root system, during the initial screening. At ICAR-Indian Institute of Vegetable Research (IIVR), Varanasi, vegetable grafting was initiated from 2013 onwards to identify suitable rootstocks for resistance against root-knot nematodes (RKN) and soil-borne diseases. The grafted plants exhibited greater resistance to nematode infestation, as indicated by reduced root galling (GI = 1) and a lower multiplication factor (MF) ratio; notably, a 96% reduction in MF ratio was recorded in interspecific grafts compared with the self-grafted control (Phani *et al.*, 2024). Rahman *et al.* (2002) evaluated six wild *Solanum* species as rootstocks for resistance to *Meloidogyne incognita* in aubergine and reported that *Solanum torvum* and *Solanum sisymbriifolium* exhibited resistance to root-knot nematodes. Similarly, Polimera *et al.* (2022) observed that *S. torvum* resulted in the maximum reduction in the number of galls, egg masses per root system, final nematode population and rate of reproduction.

8. Conclusion

Vegetable grafting has become an integral practice in global vegetable production, serving as a critical component of integrated pest management (IPM) strategies for controlling soil borne diseases and nematode management. In India, there is considerable scope for vegetable breeders and private enterprises to develop rootstocks resistant to nematode infestations and other pathogens. Technological advancements, particularly in the design of efficient grafting robots capable of performing

large-scale operations, have substantially reduced the production costs of grafted seedlings. Ensuring the availability of healthy, cost-effective quality grafted seedlings is essential for promoting widespread adoption and enhancing the productivity and resilience of vegetable production systems.

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