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Grafting of Vegetable Crops in the Era of Nanotechnology

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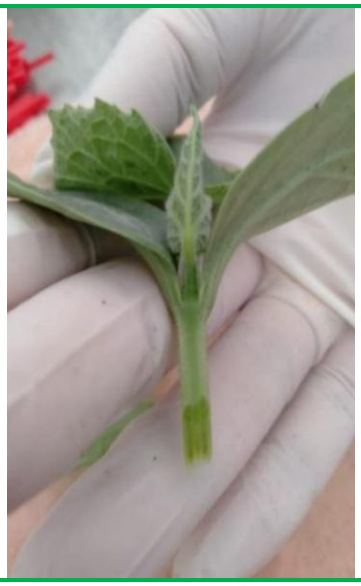
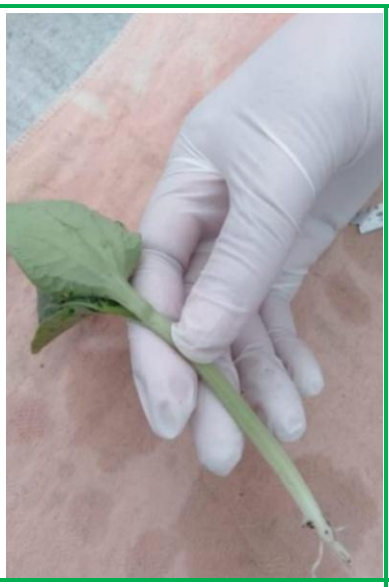
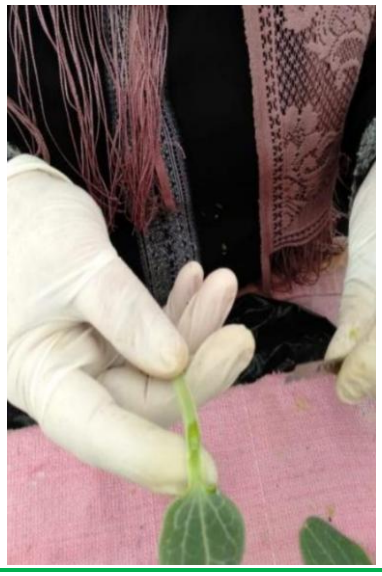
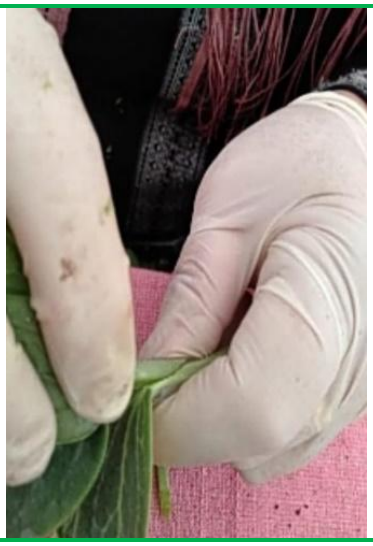
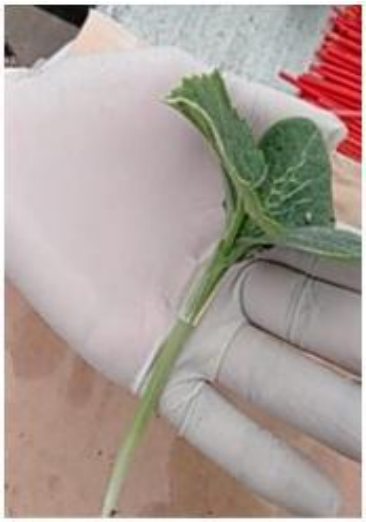
It is well known that grafting, as a special plant propagation technique, is forming new plant by joining the scion (an aerial part of a plant) to a rootstock (another root part of a plant). This new plant (grafted plant) is employed to improve plant production, by getting greater plant development, vigour, and defence against abiotic/biotic stresses, as well as improving the uptake of nutrients, and their use efficiency. The grafted vegetable crops are common to overcome many plant diseases like Fusarium wilt. The most well-known grafted vegetables include both solanaceous and cucurbitaceous seedlings mainly in Europe, Asia, and North America. How can improve the efficiency of grafting process? Can the applied nanoparticles improve the quality of fruits and their nutrient content in grafted vegetables?

The applications of nanotechnology in agricultural sector are unlimited and uncountable. These applications include the food, energy, wastewater treatment, and the crop production especially in horticultural crops. Nanofertilizers, especially nanobiofertilizers, nano-sensors, and nano-pesticides are the most important applications of nanotechnology along with nano-food processing.

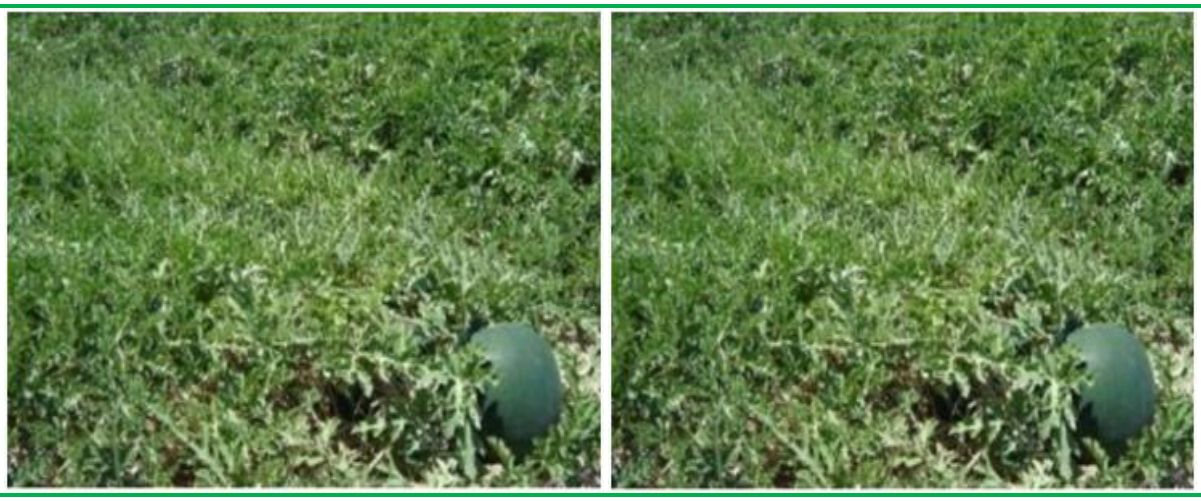
Nano-biofertilizers are defined as "the newest and technically advanced eco-friendly and cost effective way of sustained and slow delivery of nutrients to plants to promote their growth, yield, and quality parameters along with the benefits of increasing the nutrient use efficiency, minimizing volatilization and leaching, and reducing soil and water pollution". Among agricultural practices, grafting is a special plant propagation technique, by which we could produce and form a new plant by joining an aerial part of the plant (scion) and root part (rootstock). The success of grafting mainly depends on the compatibility between the rootstock and the scion, which can support the grafted plants against stresses by improving the nutrients uptake, transport, and their use efficiency. Several open questions are still needed to be answered in particular the nano-grafting by using grafting of vegetables under applied nano-pesticides. Nano-fertilizers could be applied to vegetable crops for enhancing the productivity because they can easily penetrate the stomata, then translocated by the vascular bundles of the xylem and phloem to other tissues.

Grafting of vegetables for abiotic/biotic stress

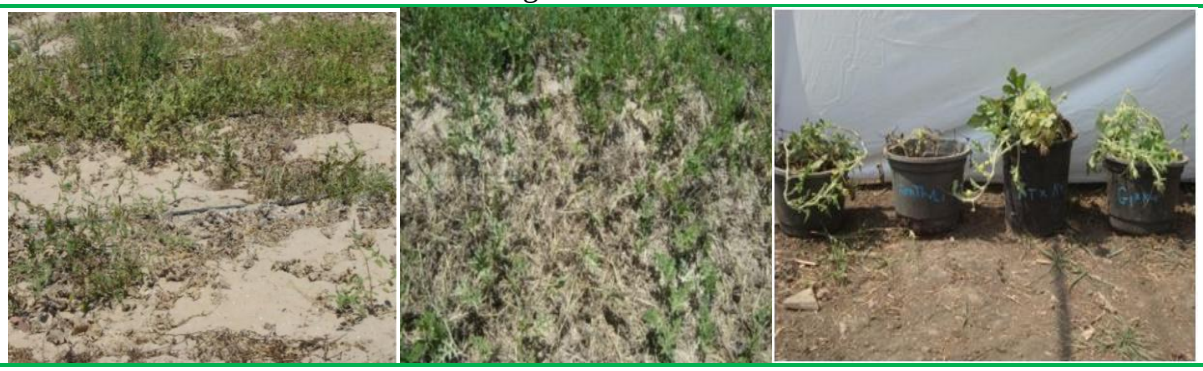
The sector of vegetable crop production is one of the main sectors in agriculture, which supply humans with essential food. As an old technique, grafting of vegetable seedlings is considered a unique horticultural technology, which already has been practiced all over the world since 2000 BC. Grafting is considered an effective and sustainable tool in producing the intensive vegetable growing system by securing the stability of yield and its quality in vegetable crops, to overcome soil-borne diseases and pests and to increase plant vigour under various environmental stress conditions such as salinity ,drought, flooding and low nutrient stress. In simple meaning, grafting is a successed approach to avoid the soil borne diseases or soil factors prevent growing and productivity of cultivated vegetables by using new grafted plant (scion and rootstock). The main grafting techniques may include splice grafting, hole insertion, single cotyledon, tongue approach, self-rooted control.

		
Selecting proper scion and rootstock	cutting the scion	removing one cotyledon and cut it down the rootstock
		
Matching the cut surfaces of both rootstock and scion	Hold the union by clip	Standing the seedling

Different grafting stages in cucumber plants in a nursery: Slant cut grafting method

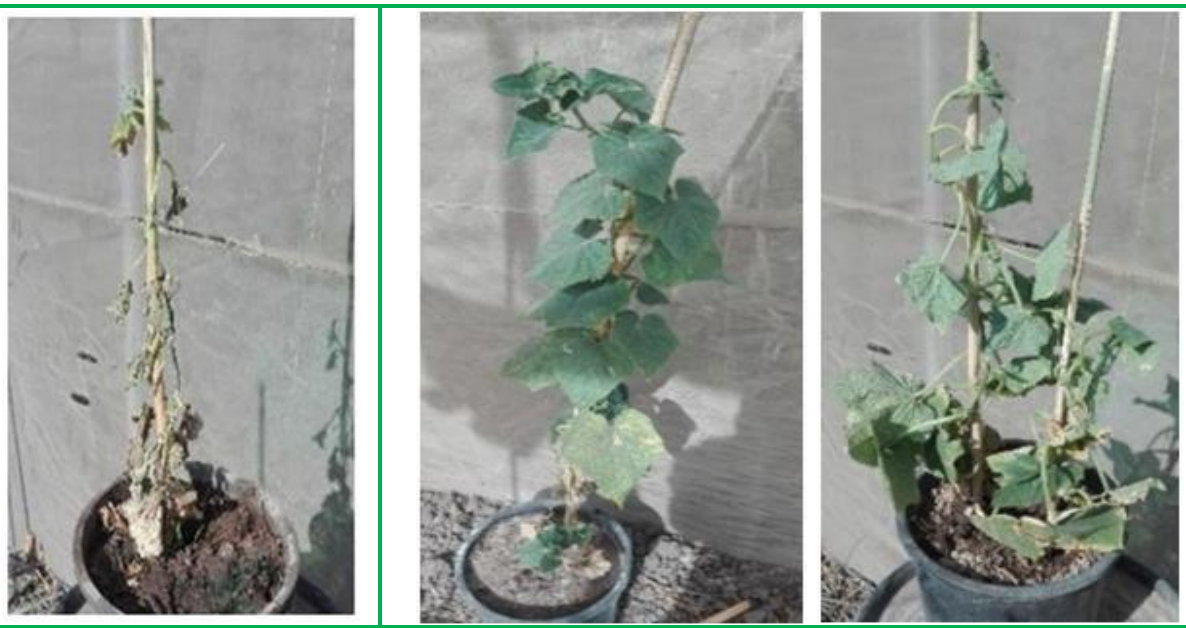


Watermelon grafted for Fusarium wilt



Fusarium wilt in ungrafted watermelon

Impacts of grafting in watermelon plants on resistance to Fusarium wilt



Ungrafted cucumber | After grafting in cucumber on different rootstock

Impact of grafting cucumber plants on different rootstocks on the resistance to Fusarium oxysporum f. sp. Cucumerinum

The good grafted vegetables require a perfect incubator, and healthy plants

Impact of grafting in tomato plants on different rootstocks in open field after grafting by 35 and 60 days from transplanting on the growth of plants and fruits as well

What is the nano-grafting

1. Suggested mechanism of nano-grafting in vegetable crops

- The general mechanism of grafting may include effects of rootstocks in modifying the nutrients uptake in grafted plants, which improve development, and growth of grafted plants. Rootstocks may also can improve the acquisition of essential nutrients and reduce uptake and transport of salts (e.g., Na and Cl) and heavy metals (e.g., Cr, Ni, Cd, Sr) by ion exclusion or retention (Nawaz et al. 2016).

- Prompting higher levels of mineral contents (N, P, K, Ca, Mg, Fe, and Zn), phytohormones (gibberellic acid and abscisic acid), peroxidase and proline in tomato shoots under grafting and nano-silicon application (Sayed et al. 2022)
- The newly-grafted plants are more resistance to pathogens and stress conditions (Kubota et al. 2022)

2. What does mean "nano-grafting of vegetable crops"?

It means application of nanoparticles/nanomaterials during cultivation and production of grafted vegetable crops to improve vegetable crop productivity and its quality especially under stress such as
- Applied nanofertilizer, e.g., ZnO-NPs or nano-Si (Uresti-Porras et al. 2021; Sayed et al. 2022),
- Applied nano-pesticides (still open question and need further investigations),
- Applied nano-encapsulation for grafted vegetables (still open question and need further investigations)

Conclusion

Day by day, a new approach or technology or tool could be found in the field of agriculture. This field is very fertile and easily to accept several innovations. The grafting is one of the old/new agricultural practice that had been used in vegetable production as well as fruit tree grafting. Simply, it could form a new plant by grafting through a physical combining between two plants with different genetic background, with one donating the roots (rootstock) and the other providing the shoots (scion). The grafting mainly is needed to overcome the environmental problems or stresses including abiotic/biotic stresses. Any supporting agent or material can enhance the grafting process is profitable such as application of nanomaterial/nanoparticles including abiotic/biotic stresses. Any supporting agent or material can enhance the grafting process is profitable such as application of nanomaterial/nanoparticles.