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Review of Grafting as a Potential Method for Reducing Biotic and Abiotic Stresses in Cucurbits

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ABSTRACT: India is the world's second-largest producer of veggies after China, yet the amount consumed is still much lower than the amount advised. Vegetable grafting is one of the effective methods that can be used to address the rising demand for vegetables. It is a useful approach to utilize in conjunction with more environmentally friendly crop production methods, such as in many nations, lower rates, and general usage of soil fumigants. It serves as a good option because there is little room to expand the area under cultivation because there are fewer arable lands available due to population growth. Due to the huge demand at the moment, it has also spread to other solanaceous crops including cucumber and watermelon. Apart from boosting resistance to abiotic stressors and increasing water usage efficiency, grafting in vegetables has primarily been documented for tolerance to soil-borne illnesses. However, if grafting is used more frequently in the future, the microbial habitat of the soil will probably change, which could encourage the emergence of new infections. Despite the fact that grafting has been shown to control a variety of common diseases, the ultimate effectiveness will probably depend on how effectively we keep an eye out for changes in pathogens as well as any other unintended outcomes. There are some big challenges in grafting like compatibility issues, disease transmission, labor intensive, limited genetic diversity, and cost. Grafting has several contributions to the reduction of biotic and abiotic stresses in cucurbits. Disease resistance, tolerance to abiotic stress, improved yield and quality, reduced chemical inputs, and an extended growing season are some of the benefits of grafting in cucurbits. However, it is important to consider the challenges associated with grafting before using this method.

Keywords: Grafting, biotic and abiotic stress management, cucurbits.

INTRODUCTION

Grafting is an asexual plant propagation technique that unites plant parts by tissue regeneration; as a result, the combined plant parts attain physical union and develop into separate plants. Grafting is a commercial practice in herbaceous plants principally *cucurbitaceous* (watermelon, muskmelon, cucumber, etc.) and the solanaceous crops (tomato, brinjal, and bell pepper) (Besri, 2008). It took 30 more years (the 1960s) for solanaceous vegetables to commercialize grafting in their production, and the first record of eggplant (*Solanum melongena* L.) grafted on scarlet eggplant (*Solanum integrifolium* Poir.) was reported in the 1950s. Another example is that muskmelons were grafted to interspecific hybrid squash (*Cucurbita maxima, Cucurbita moschata*), which has been around since 1920. The primary purpose of grafting vegetables worldwide has been to provide tolerance to biotic and abiotic stress (Maurya *et al.,* 2019).

Biotic stress primarily constitutes insect pests and diseases and is reported to cause damage to the tune of 68% (Mudge *et al.,* 2009). Most important are soil, root, foliar and other diseases, viruses, pests, nematodes, etc. Among abiotic stress, temperatures, water, heavy metals, organic pollutants, nutrients, etc. are major factors influencing cucurbits cultivation to a greater extent. Vegetable grafting has been successfully practiced to identify and develop rootstocks that are resilient and can withstand biotic and abiotic stressors. Traditional grafting techniques have some drawbacks and limitations. Incompatibility, disease transmission, lack of genetic diversity, high labor costs, time-consuming procedures, and limited application are some of the problems associated with old techniques in grafting. New and improved grafting techniques are needed to overcome these challenges and increase the potential benefits of grafting in cucurbits.

Biotic stress management in vegetables. It includes the management of the following important diseases:
1. Soil-borne diseases
2. Root rot diseases
3. Foliar diseases
4. Other diseases

5. Viruses
6. Pests
7. Nematodes
8. Parasitic weeds

1. Soil-borne diseases

The vegetables are very much susceptible to soil-borne diseases primarily during the nursery stage causing damping off and preventing the germination of seeds. Pathogens particularly Fusarium exhibit heavy damage to vegetables and can be managed through grafting. The vigorous rootstocks demonstrate excellent tolerance and the degree of the tolerance varies from rootstock to rootstock. The most common disease controlled by grafting appears to be fusarium wilt on cucurbit crops caused by various pathovars of *Fusarium oxysporum.* The most common rootstocks for cucurbit crops include *Lagenaria siceraria* and *Cucurbita moschata* and *Cucurbita maxima* hybrids, both of which are highly resistant to the common pathovars of *Fusarium oxysporum* affecting thesecrops. In melon, fusarium wilt has traditionally been controlled by host plant resistance, which proved very effective until the appearance of *Fusarium oxysporum f.* sp. *melonis.* Grafting is now advocated as an effective control for this new race of *Fusarium oxysporum*, at least until new cultivars become available (Trionfetti Nisini *et al.,* 2002). Unlike fusarium wilt in melon, *monosporascus vinedecline*, caused by the soilborne pathogen *Monosporascus cannonballus* has proven difficult to control using host plant resistance. Grafting has proven effective for controlling *monosporascus vinedecline*, although results are sometimes variable (Edelstein *et al.,* 1999). It was discovered that the rootstocks employed to stop the fall of the *monosporascus* vine were not fungus-resistant but were robust enough to support crop growth even in the presence of the disease. Additionally, it was discovered that the season had an impact on the degree of resistance, with spring plantings achieving a higher degree of resistance than autumn plantings (Cohen *et al.,* 2005). Since a buildup of the pathogen could negate the control provided by grafting, integrated control approaches are advised in addition to grafting to explain the varying results of grafting. In tomato and aubergine production systems, grafting has been employed frequently to combat verticillium wilt (VW), but less frequently in cucurbit production systems. *Cucurbita pepo* and *Lagenaria siceraria* were the most tolerable of the 33 cucurbit rootstocks, while all exhibited some symptoms and were all colonized by Verticillium dahlia. According to Paplomatas *et al*. (2002), watermelons and melons were both vulnerable and very susceptible, respectively. Verticillium wilt incidence was reduced by the interspecific hybrid (ISHc) *Cucurbita maxima*, *Cucurbita moschata* 'Mamouth' to 37% from 87% in non-grafted 'Crimson Sweet' watermelons (Paroussi *et al*., 2007). Three variations of *Lagenaria siceraria* in the same study reduced incidence to 20–30%, and a fourth variation had an incidence of 58%. The lack of immunity in cucurbit crop-compatible rootstocks emphasizes the need for different strategies to reduce VW issues (Davis *et al.,* 2008). Increased root biomass and vigor have been linked to mechanisms of grafting benefits in Verticillium-infested soils (Bletsos *et al.,* 2003), as well as increased water and nutrient intake (Lee, 1994). According to Paplomatas *et al.* (2002), the use of resistant rootstock is also thought to lower the rate of colonization in the vascular tissue, resulting in a lower rate of wilt.

2. Root rot diseases. In semi-arid and hot climates, and with a preference for saline and alkaline soils, *Monosporascus cannonballus* causes vine loss in melons (Cohen *et al.,* 2007). A "pepper spot" look is caused by the pathogen's propensity to develop perithecia in root cortical tissues. The asci that the perithecia produce normally contain one long-lasting pigmented spore with a strong wall. Due to the pathogen's longevity in soils, thermophilicity, and ability to recolonize uninfested soil, crop rotation, solarization, and fumigation have little efficacy. As the fruit ripens, the pathogen may induce a rapid wilt. Grafting has been seen as a method to reduce crop losses because all melon and watermelon cultivars are susceptible (Davis *et al.,* 2008). The best outcomes to date were from rootstocks of *Cucurbita maxima* and *Cucurbita moschata.* In contrast to other pathosystems like Fusarium Wilt, where the stability of control is mediated by specific host resistance, managing *Monosporascus cannonballus* seems to be dependent on environmental factors, the scion used, geographic location, and inoculum load because these factors affect the host: pathogen interaction. According to Fita *et al*. (2007), a more vigorous root system with greater branching and length that modify water and nutrient intake may be associated with resistance/tolerance to infection by *Monosporascus cannonballus* and lower symptom development. The grafted plants' enhanced water status; this may directly or indirectly impact the degree of vine decline (Jifon *et al.,* 2008). In contrast, it was proposed that 'Shintosa' roots do not increase spore germination but susceptible roots can (Beltran *et al.,* 2008), which is in line with findings of rhizosphere rootstock effects in other pathosystems.

3. Foliar pathogens. Grafting has been seen to affect foliar diseases as well. Although the levels remained excessive for production needs, downy mildew incidence in the scion tissue was dramatically reduced utilizing *Cucurbita ficifolia* rootstock when compared to non-grafted cucumber plants (Gu *et al*., 2008). Specific scion/rootstock combinations, however, might make foliar diseases more prevalent. According to Hasama *et al.* (1993), cucumber grafted on a bloomless rootstock increased the occurrence of the target spot (*Corynespora* sp.) on the scion and may have been related to a decreased uptake of silica. The effects of rootstock on the foliar incidence of powdery mildew (PM) have received increased attention. Depending on the rootstock chosen, the incidence of powdery mildew and target leaf spot (*Corynespora cassicola*) in cucumber scions increased or reduced. PM incidence was generally increased by rootstock selected for their bloomless trait, which was linked to a decreased SiO_2 content in the scion tissue and was mediated by the rootstock. The fact that rootstock selections with higher levels of resistance to powdery mildew provided improved resistance or tolerance in cucumber scions, even to mature plants, was an intriguing result made clear in this study (Sakata *et al.,* 2006).

4. Other diseases. In the majority of agriculture production systems, *Pythium species* are common. The best methods of management include cultural practices that restrict excessive water usage, avoidance of high salt concentrations or other harm, conductive temperatures, and the use of fungicides and fumigation, among other control measures. Finding rootstock resistant to particular *Pythium* issues has not become a top goal due to the intermittent nature of many *Pythium* illnesses and the effectiveness of other control strategies. Although squash rootstock offered protection, *Pythium debaryanum* caused watermelon grafted on bottle gourd to wilt (Tominaga *et al*., 1983). In contrast, *Phytophthora species*, especially *Phytophthora capsici*, significantly reduce crop yields in many regions of the world. Numerous solanaceous and cucurbit crops, which are frequently grown in rotation with one another, are included in the extensive host range of this disease. Oospores are produced by the pathogen and persist in the soil for a very long time. Before colonizing the stem, the primary inoculum first affects the root system of the host. Grafting might be able to stop this stage of the illness. But, particularly in squash plants, the virus can potentially splash spread into above ground foliage, developing fruit, or into the crown tissue. Any benefit of grafting with resistant rootstock might be negated by this infection process. According to Takahashi and Kawagoe (1971), cucumber plants grafted onto *Cucurbita moschata* provided *Phytophthora melonis* (Phytophthora blight) and Fusarium wilt tolerance. Phomopsis sclerotioides infects bottle gourd rootstock and produces black root rot and wilt in a number of cucurbit crops, usually at fruiting, endangering the production of grafted watermelons (Shishido *et al.,* 2005). ISHc, *Cucurbita ficifolia*, and *Benincasa hispida*, among other varieties, have been used to lessen or manage the disease of cucumbers (Yamaguchi and Iwadate 2009). A wide variety of fruiting vegetables are susceptible to the disastrous crop losses brought on by *Sclerotium rolfsii*. Rootstock hybrids of *Cucurbita maxima* and *Cucurbita moschata* offered resistance, but 'RS 481 was preferred for melon production because to its complementary qualities of improved fruit output and no reduction in fruit quality (Crino *et al.,* 2007). In order to handle GSB, certain *Cucumis species*, *Benincasa hispida*, and Cucurbita hybrid rootstocks were shown to be resistant (Trionfetti Nisini *et al.,* 2000). These rootstocks may be useful in melon grafting systems.

5. Viruses. Grafting is a popular method for researching how easily viruses spread. It is usually necessary to introduce genes for virus resistance into the rootstock to reduce transmission to the scion. The danger of virus infection rises if rootstocks are more prone than the scion. Grafting is a practical strategy to reduce virus infection from soil sources. Melon necrotic spot virus (MNSV) is vectored by *Olpidium* sp. Rootstocks that have been particularly bred to be resistant to MNSV have been created and put into use (Cohen *et al*., 2007). When compared to non-grafted plants, grafting on interspecific rootstock lessened yield losses brought on by PepMV (Schwarz *et al*., 2010). For virus complexes thought to contain Cucumber Mosaic Virus (CMV), Watermelon Mosaic Virus II (WMV-II), Zucchini Yellows Mosaic Virus (PRSV), or Zucchini Yellows Mosaic Virus (ZYMV), Wang *et al.* (2002) showed enhanced tolerance in seedless watermelons.

6. Pests. By transferring spider mite (*Tetranychus cinnabarinus*) control from a resistant *Lagenaria siceraria* to a spider mite-vulnerable *Cucurbita maxima*, Edelstein *et al.* (2009) were successful. They failed to provide a sensitive melon with spider mite resistance through grafting. Conversely, reciprocal grafts did not offer an advantage. Lagenaria rootstock offered resistance to the carmine spider mite in sensitive cucurbit scions, and the resistance it offered was comparable to that of ungrafted Lagenaria rootstock (Edelstein *et al.,* 2009).

7. Nematodes. Root knot nematodes (RKN) are obligatory endoparasites with a wide range of hosts, including weeds. They are particularly destructive in sandy soils where intensive vegetable farming is practiced. *Meloidogyne ingognita, M. arenaria, M. javanica,* and *M. hapla* (*Mi, Ma, Mj, Mh*) are the four primary species encountered. On contaminated soil, plant root debris, or sick plants, nematodes can be either native or brought to new fields or production locations. Although soil fumigation/disinfestation and crop rotation with non-hosts are successful strategies, resistance is preferable and a more long-term solution. Numerous tomato cultivars and rootstocks frequently introduce the effective resistance gene (Mi locus). It is well known that resistance degrades at high soil temperatures (over 28°C). Effective resistance or tolerance is provided by the ISHs rootstocks. However, resistance to various RKN species or populations within a species is variably expressed in distinct genetic backgrounds (Rivard *et al.,* 2010). Commercial cucurbits are not known to be resistant to RKN, so finding resistant rootstock has been a top objective (Cohen *et al.,* 2007). According to Lee and Oda (2003), the African horned cucumber and the bur cucumber have the best nematode tolerance and show promise for cucurbit grafting. Grafting has also shown to increase resistance to root-knot nematodes. Root-knot nematode resistance was discovered in grafted cucumbers grown in Greece by Giannakou and Karpouzas (2003), and in Spanish watermelons by Maroto-Borrego and Miguel (1996).

8. Parasitic weeds. Programs for weed management may be indirectly impacted by grafting. As the use of fumigants decreases, rootstocks may be chosen or produced that have improved resistance to particular herbicides, expanding the spectrum of effective herbicides for particular crop production systems (Cohen *et al*., 2008).

Table 1: Pathogens controlled by grafting (Miguel, 2004).

Pathogens	Melon	Cucumber	Watermelon
F. oxysporum f.sp. *melonis* (*Cucumis melo*) *F. oxysporum* f.sp. *niveum*	+	-	-
(*Citrillus lanatus*)	-	-	+
F. oxysporum f . sp. *cucumerinum* (*Cucumis sativus*) *Phomopsis*	-	+	-
scleriodes	-	+	-
Monosporascus cannonballus	+	-	+
Melon Necrotic Spot Virus (MNSV)	+	-	+

Table 2: A list of crops and diseases reported to be controlled by grafting (King *et al.*, 2008).

Crop	Disease	Organism	Reference
Cucumber	*Fusarium* wilt	*Fusarium oxysporum*	(Pavlou *et al.,* 2002)
	Phytopthora blight	*Phytopthora capsici*	(Wang *et al*., 2004)
	Root-knot nematodes	*Meloidogyne* spp.	(Giannakou & Karpouzas 2003)
	Verticillium wilt	*Verticillium dahliae*	(Paplomatas *et al*., 2002)
Melon	*Fusarium* wilt	*Fusarium oxysporum*	(Bletsos, 2005)
	Vine decline	*Monosporascus cannabarinus*	(Cohen *et al*, 2000)
	Root-knot nematodes	*Meloidogyne* spp.	(Siguenza *et al*., 2005)
	Gummy stem blight	*Didymela bryoniae*	(Crino *et al*., 2007)
Watermelon	*Verticillium* wilt	*Verticillium dahliae*	(Paplomatas *et al.,* 2002)
	Virus Complex	Cucumber Mosaic Virus	(Wang *et al.,* 2002)

Abiotic stress management. It includes management of the following environmental factors:
1. Temperature
2. Water
3. Organic pollutants
4. Heavy metals
5. Nutrient toxicity
6. Alkalinity

1. Temperature. By limiting plant growth and development, inducing wilt and necrosis, and delaying the rate of truss emergence and fruit ripening, temperature is one of the most significant environmental factors contributing to significant economic yield losses (Ahn *et al.,* 1999). Grafts were used to encourage resistance against low and high temperatures (Rivero *et al*., 2003; Venema *et al.,* 2005), to improve nutrient uptake (Colla *et al.,* 2010a), increase production of endogenous hormones (Dong *et al.,* 2008), improve water use efficiency (Rouphael *et al*., 2008a), minimise soil-borne sorption of persistent organic pollutants (Otani and Seike 2007), increase alkalinity tolerance (Colla *et al.,* 2010b), increase salt and flooding tolerance (Yetisir *et al.,* 2006), and mitigate the harmful effects of poisoning caused by boron, copper, cadmium, and manganese (Edelstein *et al*., 2005, 2007; Rouphael *et al*., 2008b).

a. Low temperature. Tolerance to extreme temperature is crucial for the production of fruiting vegetables under the winter greenhouse conditions (Rouphael *et al.,* 2008b). Fruit harvesting usually comes to an end in the spring or the first half of the summer, and seedling transplanting for protected cultivation usually happens in the early to middle of the winter. The farmers find it challenging to maintain ideal temperatures in winter greenhouses, particularly when it comes to soil temperatures, which are much below ideal and harm transplanted plants during the early phases of culture. This is especially true for crops like watermelon and oriental melon that need high temperatures to grow at their best. Grafting watermelon, melon, cucumber, even summer squash onto low temperature tolerant rootstocks such as interspecific hybrid between *Cucurbita maxima* × *Cucurbita moschata* or figleaf gourd can considerably reduce the risk of severe growth restriction induced by low soil temperatures in winter greenhouses. Due to the rootstock's superior ability to absorb water and nutrients more effectively at low temperatures, cucumber grafted onto figleaf gourd (*Cucurbita ficifolia* Bouché), a great rootstock even at low soil temperature, grows much faster than own-rooted cucumber or even summer squash (Tachibana, 1982). The rootstocks for cucumber are figleaf gourd and bur cucumber (*Sicos angulatus* L.). The best root temperature for figleaf gourds is at 15°C, which is 6°C lower than the temperature for cucumber roots (Lee, 1994). When the squash rootstock cutting was subjected to a bottom heat treatment, which involved soaking the cut end of the cutting in a warm nutrient solution of 30°C for one day, it was recently tested to see if grafting a cucumber scion onto a squash rootstock (*Cucurbita moschata*) could tolerate suboptimal temperatures compared with a self grafted cucumber. In order to move up the planting date for watermelons during cool weather, rootstocks of the Shin-tosa type (an interspecific squash hybrid, *Cucurbita maxima* × *Cucurbita moschata*) are employed (Davis *et al*., 2008). The vegetative growth rate of eggplants at suboptimal temperatures can also be increased by using the same rootstocks (Gao *et al.,* 2008). 'Torvum vigour' is a different rootstock that can be utilised for this purpose (Okimura *et al.,* 1986).

b. High temperature. High temperatures can also limit fruit and vegetable production in hot, semi-arid environments as well as during the hot-wet and hot-dry seasons in lowland tropical regions (Palada and Wu 2008). The root environment, such as soil, substrate, or nutrient solution, may be heated by high temperatures and/or radiation under protected settings, which is an issue for greenhouse production, particularly under soilless cultivation (Wang *et al.,* 2007). The cultivation of *Solanaceae* rather than *Cucurbitaceae* is restricted at temperatures above 35°C. Similar to other abiotic stresses, supra-optimal temperatures result in a number of complex morphological, physiological, biochemical, and molecular alterations that have a negative impact on plant development and output. The issue is whether rootstocks can strengthen these defense mechanisms and so help to increase the plant's overall tolerance to heat.

2. Water stress.

a. Drought. In many parts of the world, water is swiftly turning into an economically scarce resource. Commercial vegetable production requires ongoing development of irrigation practises because to the rising rivalry for water among agricultural, industrial, and urban customers. Grafting high-yielding genotypes onto rootstocks that can lessen the effects of water stress on the shoot is one strategy to decrease production losses and enhance water usage efficiency during drought circumstances (Satisha *et al*., 2007).When grown under conditions of deficit watering, mini-watermelons that were grafted onto a commercial rootstock (PS 1313 *Cucurbita maxima* × *Cucurbita moschata*) demonstrated a more than 60% higher marketable yield than ungrafted melons (Rouphael *et al.,* 2008). A higher N, K, and Mg concentration in the leaves, as well as increased CO_2 absorption, were indicators of improved water and nutrient uptake, which contributed to the higher marketable output observed with grafting.

b. Flooding. Flooding and submergence are significant abiotic stresses that have a negative impact on the growth and production of crops that are sensitive to flooding. Because gases diffuse slowly in water and because microbes and plant roots use oxygen, flooding results in oxygen shortage. Crops that can withstand floods can be grown, or intolerant plants can be grafted onto tolerant ones to tackle flooding-related issues. For instance, grafting on luffa *(Luffa cylindria* Roem) increased the flooding tolerance of bitter melon (*Momordia charanthia* L.) (Liao and Lin, 1996).This variation in flooding tolerance may be connected to lesser decrease of photosynthetic rate, stomatal conductance, transpiration, soluble proteins, and activity of RUBISCO. Contrarily, grafting onto squash rootstocks improved the loss in chlorophyll content in cucumber leaves brought on by waterlogging (Kato *et al.,* 2001). *Citrullus lanatus* (Thunb.) Matsum and Nakai cv. 'Crimson Tide' watermelon was grafted onto *Lagenaria siceraria* SKP (Landrace), and the drop in chlorophyll content was less pronounced than it was for non-grafted watermelons (Liao and Lin 1996). Additionally, under flooding, grafted watermelon showed adventitious roots and aerenchyma development, but not ungrafted watermelon.

3. Organic pollutants. According to Otani and Seike (2007), employing a low-uptake rootstock like "Yuyuikki-black" (*Cucurbita moschata*), pollution in cucumber can be decreased by almost 50%. A promising practical method to lower the quantity of dieldrin in cucumber fruits cultivated in contaminated fields is choosing low-uptake rootstock cultivars. To determine whether these rootstocks can also stop the uptake of other harmful substances, more research is required.

4. Heavy metal. Heavy metal contamination in agricultural soil poses an increasingly major risk to the environment, human health, intact plant growth, and output (Hong-Bo *et al*., 2010). While some heavy metals can be hazardous to plants even at very low concentrations, others can build up in plant tissues to a certain point without causing any obvious symptoms or a decrease in yield (Verkleij *et al.,* 2009). Industrial waste, reclaimed wastewater, and soil amendments from diverse sources are only a few of the factors that bring toxic non-nutrient heavy metals like cadmium, arsenic, lead, and mercury to agricultural ecosystems (Gupta *et al.,* 2010). Even though heavy metal contamination in fruit and vegetables is not yet a common issue, several recent instances raise concerns. In addition to having a negative effect on human health, Cd has been shown to have a significant impact on key plant functions, such as chlorophyll concentration, photosynthesis, nitrogen metabolism, oxidative phosphorylation in mitochondria, and water transport (Feng *et al.,* 2010). According to Zhang and Shu (2006), the effect of Cd on plant growth and development depends not only on the amount of the metal present in the surrounding medium but also on the genotype, location, and length of exposure.

Additionally, Edelstein and Ben-Hur (2007) used melon plants (cv. "Arava") that were both ungrafted and grafted onto the commercial *Cucurbita* rootstock "TZ-148" and irrigated with low-quality water to study the effects of grafting on heavy metal and trace mineral concentrations in the fruit under field conditions. Fruit from grafted plants had lower concentrations of B, Zn, Sr, Mn, Cu, Ti, Cr, Ni, and Cd than fruit from ungrafted plants. The lower quantities of heavy metals and trace elements in fruits were mostly attributed to variations in the root system features between the two plant species. However, more study is required to clarify the mechanisms that prevent heavy metals from moving from the root to the shoot in specific rootstock/scion combinations.

5. Nutrient Toxicity

High concentration. The concentrations of several nutrient ions have dramatically increased in soils used for open-field and protected cultivation due to the indiscriminate use of large amounts of chemicals, the use of reclaimed wastewater for irrigation, the application of sewage sludge or other contaminated soil amendments, and other anthropogenic activities. In these situations, soils may have excessive levels of NO_3, SO_4, H_2PO_4, K+, Ca^{2+}, Mg^{2+}, and metallic micronutrients (such as Cu), with effects that differ from those of excessive NaCl concentrations (Yu *et al.,* 2005). Cucumber grafted into 'Black Seeded' figleaf gourd may improve plant resistance to salt brought on by significant nutrients. By restricting the uptake and translocation of copper to the shoot, grafting the cucumber variety "Akito" onto the commercial rootstock "Shintoza" (*Cucurbita maxima*× *Cucurbita moschata*) was able to mitigate the negative effects of an excessive Cu supply on plant biomass and fruit yield. As an example, melon plants grafted onto the commercial rootstock "TZ-148" (*Cucurbita maxima*× *Cucurbita moschata*) have lower levels of boron toxicity than self-rooted plants (Edelstein *et al.,* 2007).

Low concentration. Increased food and water intake from the rootstock's more robust root system may improve the overall plant's growth rate and yield performance (Lee, 1994). In fact, numerous studies showed that, when compared to non-grafted plants, some graft combinations were significantly more effective at absorbing and transporting nutrients to the shoot, including phosphorus, nitrogen, potassium, magnesium, calcium, iron, and other micronutrients (Colla *et al*., 2010a, b). The nitrogen nutrition of these plants appears to be significantly enhanced by the grafting of *cucurbitaceae* to some rootstocks. Melon cultivars 'Yuma' and 'Gallicum' were grafted onto the rootstocks 'Shintoza', 'RS-841', and 'Kamel' by Ruiz *et al.* (1997). They found that the grafted plants were more effective in absorbing nitrogen. The fruit output and the foliar N concentrations showed a positive correlation. In addition to nitrogen uptake, grafting onto particular rootstocks appears to improve uptake of phosphorus as well. However, depending primarily on the genotype of the rootstock, grafting can lower phosphorus uptake (Kawaguchi *et al.,* 2008). This occurred when melon (*Cucurbita melo* L.) was grafted onto pumpkin (*Cucurbita moschata*) 'No.1 Shengzhen' (Qi *et al.,* 2006). Some authors have also reported that grafting can increase K uptake. These include Qi *et al.* (2006) for a melon grafted onto "No. 1 Shengzhen" (*Cucurbita moschata*), Rouphael *et al.* (2008b) for a mini watermelon grafted onto pumpkin ('PS 1313'), and Zhu *et al*. (2008) for cucumber seedlings grafted onto "Chaojiquanwang"

6. Alkalinity. Low bioavailability of plant nutrients, high quantities of insoluble $CaCO_3$ in the soil, and HCO_3 in the soil solution are the main characteristics of alkaline water and soils. It is frequently believed that the main cause of chlorosis in cultivated plants, which can result in significant yield losses, is the concentration of HCO_3, which interacts strongly with the availability of numerous micronutrient ions, mainly Fe^{2+}. The agronomical, physiological, and biochemical responses of grafting combinations of watermelon plants, cv. "Ingrid," were significantly different, according to Colla *et al.* (2010b).The watermelon plants were specifically exposed to two levels of nutrient solution pH, specifically 6.0 or 8.1 dSm-1, and either ungrafted or grafted onto two pumpkin [*Lagenaria siceraria*] rootstocks ('Macis' and 'Argentario') and two bottle gourd (*Cucurbita maxima*× *Cucurbita moschata*) rootstocks ('P360' and 'PS1313'). In general, the signs of leaf chlorosis were more evident in plants grafted onto bottle gourd rootstocks and in ungrafted plants than in plants grafted onto pumpkin rootstocks. Compared to plants grafted onto bottle gourd rootstocks and ungrafted plants, plants grafted onto pumpkin rootstocks were able to maintain higher net assimilation rates, displayed a stronger capacity to accumulate Fe in the aerial part, and had better plant nutritional status (higher P and Mg in the shoot tissue). The above responses of watermelon plants that had been grafted into pumpkins to high pH levels were linked to a stronger exudation of organic acids (citric and malic acids) by roots, which probably made it easier for the plants to absorb nutrients. In many parts of the world, crop plants may have problems due to excessive soil acidity. However, there are currently no studies in the international literature on how grafted plants respond to the pH of the rhizosphere, making this area of study urgently necessary.

Effect of grafting on biotic stresses. The bottle gourd and *Cucurbita moschata*/*C. maxima* hybrids are two rootstocks for cucurbits that are both extremely resistant to the *Fusarium oxysporum* that affects and causes severe crop losses (King *et al.,* 2008). In order to quickly control race 1 and 2 of Fusarium oxysporum f. melonis, grafting is used in the melon industry. Nisini and others The 'Crimson Sweet' plants were grafted onto the 'Shintoza' plants. The *Verticillium* colonisation may have been stopped by the grafting protection mechanism (King *et al.,* 2008). found. Using rootstocks resistant to *Verticillium* wilt allows for a three-week delay in the appearance of symptoms and the development of watermelon fruits, according to research by Paplomatas *et al*. (2002) Watermelon plants grafted onto wild watermelon rootstocks (*C. lunatus* var. *citroides*) were shown to be either resistant or moderately resistant to the nematode *M. incognita*, according to Thies and Levis. The 'Crimson Sweet' watermelon grafted onto the 'Emphasis' and 'Strong Tosa' two rootstocks grew more quickly and were more resistant to V. dahliae than ungrafted or self-grafted plants (Buller *et al.* 2013). According to Pavlou *et al.* (2002) root and stem rot can be effectively controlled (reduced by 75-100%) by grafting sensitive cucumber cv. Brunex F_1 and other Dutch-type cucumber hybrids onto *C. ficifolia*, *C. moschata*, and *C. maxima C. moschata.* Additionally, *C. moschata* rootstock, which is utilized for cucurbits, was found to have a high level of tolerance to the root-knot nematode, according to Siguenza *et al.* (2005).

Effect of grafting on abiotic stresses. Grafting is a technique used to lessen the impact of abiotic stressors. Watermelons that have been grafted may be able to withstand abiotic stress. In thick or loam soils, the watermelon grafted onto bottle gourd rootstock boosts flooding tolerance. In sandy soil, cucurbits can be grafted into pumpkin to provide some drought resistance (Anonymous, 2013). When produced in irrigation-scarce conditions, mini watermelon plants with grafting (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne) have demonstrated a yield improvement of over 60% over ungrafted melon plants (Rouphael *et al.,* 2008b). Grafting led to a greater marketable output, which was primarily the result of improved water and nutrient uptake (Schwarz *et al.,* 2010). According to Rouphael *et al.* (2008b) research, cucumber plants that are grafted onto rootstock of the Shintoza variety (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne) accumulate significantly less copper in their leaves and fruits. Increased concentrations of heavy metals in farming, including cadmium, mercury, lead, arsenic, and others, pose a growing risk to plant growth, development, and yield as well as to human health and the environment (Gupta *et al.,* 2010). These contaminants can come from a variety of sources, including industry, waste water, and soil amendments. Even at low quantities, some heavy metals are hazardous, whereas others can be found in plant tissues without causing yield loss or other obvious symptoms (Verkleij *et al.,* 2009).

According to a study on cv. Arava melon plants grafted on TZ-48 cucurbita rootstock, B, Zn, Sr, Mn, Cu, Ti, Cr, Ni, and Cd levels were lower in the fruits from the grafted plants. According to Feng *et al*. (2010) cadmium inhibits several processes including photosynthesis, nitrogen metabolism, water transport, phosphorylation in mitochondria, and chlorophyll concentration. The yields of watermelons grown in greenhouses with saline-tolerant rootstocks are increased by about 81% (Colla *et al.,* 2010a). According to Zhou *et al.* (2007), grafted cucumbers in NaCl stress conditions have increased flavor, taste, and nutritional content compared to non-grafted plants. According to Hong *et al.* (2010), grafting cucumber cultivar Jinchun no. 2 onto the bottle gourd rootstock Chaofeng 8848 can improve the plant's lowered shoot dry weight.

CONCLUSIONS

Vegetable grafting has been effectively used for many years in Asian nations, and it is gaining popularity globally. The development and distribution of rootstock seeds through commercial seed catalogs is a top priority for many international seed firms. A fundamental necessity for sustained success is the identification of appropriate multi-disease-resistant rootstocks with tolerance to abiotic stressors. The introduction of top-notch rootstocks with a variety of disease resistances and effective grafting tools, such as grafting robots, will considerably promote the continued use of grafted vegetables around the globe. Vegetable grafting and growing seedlings with grafts present a number of common issues. The price premium for rootstock seeds, the labor-intensive nature of grafting and growing grafted seedlings, inexperience with grafting and management of grafted plants, and the likelihood of grafting-related physiological diseases are a few of these drawbacks. However, adopting grafted seedlings has a lot of advantages. These include an increase in income from high yield and off-season growing, a reduction in fertilizer and irrigation water input due to the rootstocks' wide root systems, a significant reduction in agrochemical use due to the rootstocks' high resistance to disease and other physiological disorders, an extension of the harvest season, effective maintenance of well-known cultivars against diseases and other physiological disorders, a lack of requirement for lengthy crop rotations, the resolution of issues caused by saline soils and thermal stress.

FUTURE SCOPE

There is a vast scope for further research and development of grafting as a method for reducing biotic and abiotic stresses in cucurbits. Some of the areas of future research could include:

1. Identification of Rootstocks: There is a need to identify rootstocks that are resistant to a wide range of diseases and environmental stresses. Research could focus on identifying the genetic traits responsible for disease resistance and stress tolerance and developing rootstocks with these traits.

2. Development of New Grafting Techniques: New grafting techniques could be developed to reduce the time required for the procedure, increase the success rate, and reduce labor costs. Research could focus on developing automated grafting machines, alternative grafting methods, and improving the compatibility of different rootstock and scion combinations.

3. Study of the Molecular Mechanisms Involved in Grafting: Understanding the molecular mechanisms involved in grafting could help improve the success rate of the procedure and identify new targets for genetic engineering. Research could focus on identifying the genes involved in the grafting process, their regulation, and their role in disease resistance and stress tolerance.

4. Testing of New Combinations of Rootstocks and Scions: Testing new combinations of rootstocks and scions could help identify the best combinations for specific environmental conditions and diseases. Research could focus on identifying the best rootstock and scion combinations for specific crops and environments, including high salinity, drought, and extreme temperatures.

5. Development of Disease-Resistant Scions: There is a need to develop scion varieties that are resistant to a wide range of diseases. Research could focus on identifying the genetic traits responsible for disease resistance and developing scion varieties with these traits.

REFERENCES

Ahn, S. J., Im. Y. J., Chung, G. C., Cho, B. H. and Suh, S. R. (1999). Physiological responses of grafted-cucumber leaves and rootstock roots affected by low root temperature. *Scientia Horticulturae*, *81,* 397–408.

Beltran, R., Vicent, A., Garcia-Jimenez, J. and Armengol, J. (2008). Comparative epidemiology of Monosporascus root rot and vine decline in muskmelon, watermelon, and grafted watermelon crops. *Plant Disease, 92,* 158–163.

Besri, M., (2008). Grafting as alternative to Methyl Bromide for Cucurbits Production in Morocco. Fourteenth Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reduction, Orlando, Florida, November, 11-14.

Buller, S., Inglis, D. and Miles, C. (2013). Plant growth, fruit yield and quality, and tolerance to verticillium wilt of grafted watermelon and tomato in field production in the Pacific Northwest. *HortScience, 48,* 1003-1009.

Cohen, R., Burger, Y., Horev, C., Koren, A. and Edelstein, M. (2007). Introducing grafted cucurbits to modern agriculture: The Israeli experience. *Plant Disease*, *91* (8), 916–1060.

Cohen, R., Burger, Y., Horev, C., Porat, A., and Edelstein, M. (2005). Performance of Galia type melons grafted on to Cucurbita rootstock in *Monosporascus cannonballus* infested and non-infested soils. *Annals of Applied Biology, 146,* 381–387.

Cohen, R., Eizenberg, H., Edelstien, A., Horev, C., Lande, T., Porat, A., Achdari, G., and Hershenhorn, J. (2008). Evaluation of herbicides for selective weed control in grafted watermelons. *Phytoparasitica*, *36*, 66–73.

Cohen, R., Pivonia, S., Burger, Y., Edelstein, M., Gamliel, A., and Katan, J. (2000). Toward integrated management of Monosporascus wilt of melons in Israel. *Plant Disease, 84,* 496–505.

Colla, G., Suãrez, C. M. C., Cardarelli, M., and Rouphael, Y. (2010a). Improving nitrogen use efficiency in melon by grafting. *HortScience*, *45,* 559–565.

Colla, G., Rouphael, Y., Cardarelli, M., Salerno, A., and Rea, E. (2010b). The effectiveness of grafting to improve alkalinity tolerance in watermelon. *Environmental and Experimental Botany, 68,* 283–291.

Crinò, P., Lo B. C., Rouphael, Y., Colla, G., Saccardo, F. and Paratore, A. (2007). Evaluation of rootstock resistance to fusarium wilt and gummy stem blight and effect on yield and quality of a grafted 'Inodorus' melon. *HortScience*, *42,* 521–525.

Davis, A. R., Perkins, V. P., Dakata, Y., Lopez, G. S., Maroto, J. V., Lee, S. G., Hyh, Y. C., Sun, Z., Miguel, A., King, S. R., Cohen, R. and Lee, J. M. (2008). Cucurbit grafting. *Critical Reviews in Plant Science*, *27* (1), 50–74.

Edelstein, M., Cohen, R., Burger, Y., Shriber, S., Pivonia, S. and Shtienberg, D. (1999). Integrated management of sudden wilt in melons, caused by *Monosporascus cannonballus*, using grafting and reduced rates of methyl bromide. *Plant Disease*, *83,* 1142–1145.

Edelstein, M., Ben, H. M., Cohen, R., Burger, Y. and Ravina, I. (2005). Boron and salinity effects on grafted and non-grafted melon plants. *Plant Soil, 269,* 273– 284.

Edelstein, M. and Ben, H. M. (2007). Preventing contamination of supply chains by using grafted plants under irrigation with marginal water. In: Wilson, J. (Ed.), Proceedings of the International Symposium on Water Resources Management. Honolulu, Hawaii, USA, 150–154.

Edelstein, M., Ben, H. M. and Plaut, Z. (2007). Grafted melons irrigated with fresh or effluent water tolerate excess boron. *Journal of the American Society for Horticultural Science*, *132,* 484–491.

Edelstein, M., Tadmor, Y., Abo-Moch, F., Karchi, Z. and Mansour, F. (2009). The potential of Lagenaria rootstock to confer resistance to the carmine spider mite, *Tetranychus cinnabarinus* (Acari: Tetranychidae) in Cucurbitaceae. *Bulletin of Entomological Research, 90,* 113–117.

Feng, J., Shi, Q., Wang, X., Wei, M., Yang, F. and Xu, H. (2010). Silicon supplementation ameliorated the inhibition of photosynthesis and nitrate metabolism by cadmium (Cd) toxicity in *Cucumis sativus* L. *Scientia Horticulturae, 123,* 521–530.

Fita, A., Pico, B., Roig, C. and Nuez, F. (2007). Performance of *Cucumis melo ssp agrestis* as a rootstock for melon. *Journal of Horticultural Science and Biotechnology, 82,* 184–190.

Giannakou, I. O. and Karpouzas, D. G. (2003). Evaluation of chemical and integrated strategies as alternatives to methyl bromide for the control of root-knot nematodes in Greece. *Pest Management Science, 59,* 883–892.

Gu, J. T., Fan, S. X. and Zhang, X. C. (2008). Effects of rootstocks on the development, disease resistance and quality of *Cucumis sativus* L. *Acta Horticulturae*, *771,* 161–166.

Gupta, N., Khan, D. K. and Santra, S. C. (2010). Determination of public health hazard potential of wastewater reuse in crop production. World Review of Science, *Technology and Sustainable Development, 7,* 328–340.

Hasama, W., Morita, S. and Kato, T. (1993). Reduction of resistance to Corynespora target leaf spot in cucumber grafted on a bloomless rootstock. *Annals of the Phytopathological Society of Japan, 59,* 243–248.

Hong-Bo, S., Li-Ye, C., Cheng-Jiang, R., Hua, L., Dong-Gang, G. and Wei-Xiang, L. (2010). Understanding molecular mechanisms for improving phytoremediation of heavy metal-contaminated soils. *Critical Reviews in Biotechnology, 30,* 23–30.

Jifon, J. L., Crosby, K. M., Leskovar, D. I. and Miller, M. (2008). Possible physiological mechanisms for resistance to vine decline diseases in grafted watermelons. *Acta Horticulturae, 782,* 329–333.

Kato, C., Ohshima, N., Kamada, H., and Satoh, S. (2001). Enhancement of the inhibitory activity for greening in xylem sap of squash root with waterlogging. *Plant Physiology and Biochemistry, 39,* 513–519.

Kawaguchi, M., Taji, A., Backhouse, D. and Oda, M. (2008). Anatomy and physiology of graft incompatibility in solanaceous plants. *Journal of Horticultural Science and Biotechnology, 83,* 581–588.

King, S. R., Davis, A. R., Liu, W. and Levi, A. (2008). Grafting for Disease Resistance. *Horticulture Science*, *43* (6), 1673-1676.

Lee, J. M. (1994). Cultivation of Grafted Vegetables I. Current Status, Grafting Methods, and Benefits. *HortScience, 29*(4), 235-239.

Lee, J.M. and Oda, M. (2003). Grafting of herbaceous vegetable and ornamental crops. *Horticultural Reviews, 28,* 61–124.

Liao, C. and Lin, C. (1996). Photosynthetic responses of grafted bitter melon seedlings to flood stress. *Environmental and Experimental Botany*, *36*(2), 167-172.

Maurya, D., Pandey, A. K., Kumar, V., Dubey, S., and Prakash, V. (2019). Grafting techniques in vegetable crops: A review, *International Journal of Chemical Studies, 7*(2), 1664-1672.

Miguel, A. (2002). Grafting as a non-chemical alternative to methyl bromide for tomatoes in Spain. In: Proc. Int. Conf. *Alternatives to Methyl Bromide Spain*, 283–285.

Miguel, A., Maroto, J. V., Bautista, A. S., Baixauli, C., Cebolla, V., Pascual, B., Lopez, S. and Guardiola, J. L. (2004). The grafting of triploid watermelon is an advantageous alternative to soil fumigation by methyl bromide for control of fusarium wilt. *Scientia Horticulturae, 103,* 9–17.

Maroto-Borrego, J. V., & Miguel, A., (1996). El injerto herbáceo en la sandia (*Citrullus lanatus*) como alternativa a la desinfección química del suelo. Investigación Agraria. *Producción y Protección Vegetales, 11*, 239–253.

Mudge, K., Janick, J., Scofield, S. and Goldschmidt, E. E. (2009). A history of grafting. *Horticultural Reviews, 35,* 437-493.

Okimura, M., Matso, S., Arai, K. and Okitsu, S. (1986). Influence of soil temperature on the growth of fruit vegetable grafted on different stocks *Bulletin of the Vegetable and Ornamental Crops Research Station. Series C. Kurume (Japan), C9*, 43–58.

Otani, T. and Seike, N. (2007). Rootstock control of fruit dieldrin concentration in grafted cucumber (*Cucumis sativus*). *Journal of Pesticide Science, 32,* 235–242.

Palada, M. C., Wu, D. L. (2008). Evaluation of chili rootstocks for grafted sweet pepper production during the hot-wet and hot-dry seasons in Taiwan. *Acta Horticulturae*, *767*, 167-174

Paplomatas, E. J., Elena, K. and Tsagkarakou, A. (2000). Screening tomato and cucurbit rootstocks for resistance to Verticillium dahliae. *Bulletin of OEPP, 30,* 239–242.

Paplomatas E. J., Elena, K., Tsagkarakou, A. and Perdikaris, A. (2002). Control of verticillium wilt of tomato and cucurbits through grafting of commercial varieties on resistant rootstocks. *Acta Horticulturae, 579,* 445–449.

Paroussi, G., Bletsos, F., Bardas, G. A., Kouvelos, J. A. and Klonari, A. (2007). Control of fusarium and verticillium wilt of watermelon by grafting and its effect on fruit yield and quality. *Acta Horticulturae, 729*, 281–285.

Pavlou, G. C., Vakalounakis, D. J. and Ligoxigakis, E. K. (2002). Control of root and stem rot of cucumber, caused by *Fusarium oxysporum* f. sp *radicis-cucumerinum*, by grafting onto resistant rootstocks. *Plant Disease, 86,* 379–382.

Qi, H. Y., Liu, Y. F., Li, D. and Li, T.L. (2006). Effects of grafting on nutrient absorption, hormone content in xylem exudation and yield of melon (*Cucumis melo* L.). *Plant Physiology Communications, 42,* 199–202.

Rivard, C. L., O'Connell, S., Peet, M. M. and Louws, F. J. (2010). Grafting tomato with interspecific rootstock to manage diseases caused by *Sclerotium rolfsii* and southern root-knot nematode. *Plant Disease, 94,* 1015–1021.

Rivero, R. M., Ruiz, J. M., Sanchez, E. and Romero, L. (2003). Does grafting provide tomato plants an advantage against H_2O_2 production under conditions of thermal shock? *Physiologia Plantarum, 117,* 44–50.

Rouphael, Y., Cardarelli, M., Colla, G. and Rea, E. (2008b). Yield, mineral composition, water relations, and water use efficiency of grafted mini-watermelon plants under deficit irrigation. *HortScience, 43*, 730–736.

Rouphael, Y., Cardarelli, M., Rea, E. and Colla, G. (2008a). Grafting of cucumber as a means to minimize copper toxicity. *Environmental and Experimental Botany, 63,* 49–58.

Ruiz, J. M., Belakbir, A., López-Cantarero, I. and Romero, L. (1997). Leaf-macronutrient content and yield in grafted melon plants. A model to evaluate the influence of rootstock genotype. *Scientia Horticulturae, 71,* 227–234.

Sakata, Y., Sugiyama, M., Ohara, T. and Morishita, M. (2006). Influence of rootstocks on the resistance of grafted cucumber (*Cucumis sativus* L.) scions to powdery mildew (*Podosphaera xanthii* U. Braun & N. Shishkoff). *Journal of the Japanese Society for Horticultural Science, 75*, 135–140.

Satisha, J., Prakash, G. S., Bhatt, R. M., and Sampath, Kumar, P. (2007). Physiological mechanisms of water use efficiency in grape rootstocks under drought conditions. *International Journal of Agricultural Research*, *2,* 159–164.

Schwarz, D., Rouphael, Y., Colla, G. and Venema, J. H. (2010). Grafting as a tool to improve tolerance of vegetables to abiotic stresses: Thermal stress, water stress and organic pollutants. *Scientia Horticulturae*, *127*(2), 162-171.

Shishido, M., Yoshida, N., Usami, T., Shinozaki, T., Kobayashi, M. and Takeuchi T. (2005). Black root rot of cucurbits caused by *Phomopsis sclerotioides* in Japan and phylogenetic grouping of the pathogen. *Journal of General Plant Pathology, 72,* 220–227.

Siguenza, C., Schochow, M., Turini, T. and Ploeg, A. (2005). Use of *Cucumis metuliferus* as a rootstock for melon to manage *Meloidogyne incognita. Journal of Nematology, 37,* 276–280.

Takahashi, H. and Kawagoe, H. (1971). Escape from cucumber Phytophthora rot by using rootstock. *Agr. Hort, 46,* 1581–1584.

Tachibana, S. (1982). Comparison of effects of root temperature on the growth and mineral nutrition of cucumber and figleaf gourd. *Journal of the Japanese Society for Horticultural Science, 51*, 299–308.

Tominaga, T., Tamada, A., Shindo, S., Wada, H. and Kimijima, E. (1983). Pythium wilt of grafted watermelon/bottle gourd plants and some characters of its pathogen. *The Mycological Society of Japan, 24*, 319–328.

Trionfetti-Nisini, P., Colla, G., Granati, E., Temperini, O., Crino, P. and Saccardo, F. (2002). Rootstock resistance to Fusarium wilt and effect on fruit yield and quality of two muskmelon cultivars. *Scientia Horticulturae*, *93*, 281–288.

Venema, J. H., Linger, P., Van Heusden, A. W., Van Hasselt, P. R. and Brüggemann, W. (2005). The inheritance of chilling tolerance in tomato (*Lycopersicon spp*.). *Plant Biology, 7,* 118–130.

Verkleij, J. A. C., Golan-Goldhirsh, A., Antosiewisz, D. M., Schwitzguébel, J. P. and Schröder, P. (2009). Dualities in plant tolerance to pollutants and their uptake and translocation to the upper plant parts. *Environmental and Experimental Botany*, *67,* 10–22.

Wang, H. R., Ru, S. J., Wang, L. P. and Feng, Z. M. (2004). Study on the control of fusarium wilt and Phytophthora blight in cucumber by grafting. *Acta Agriculturae Zhejiangensis*, *16,* 336–339.

Yamaguchi, T. and Iwadate, Y. (2009). Adaptability of several cucurbit plants for use as rootstocks to prevent cucumber black root rot caused by *Phomopsis sclerotioides*. *The Society of Plant Protection of North Japan , 60,* 96–101.

Yu, H. Y., Li, T. X. and Zhou, J. M. (2005). Second salinization of greenhouse soil and its effects on soil properties. *Soils, 37,* 581–586.

Zhang, J. and Shu, W. S. (2006). Mechanisms of heavy metal cadmium tolerance in plants. *Journal of Plant Physiology and Molecular Biology, 32,* 1–8.

Zhou, Y. H., Huang, L. F., Zhang, Y., Shi, K., Yu, J. Q. and Nogues, S. (2007). Chill induced decrease in capacity of RuBP carboxylation and associated H_2O_2 accumulation in cucumber leaves and alleviated by grafting onto figleaf gourd. *Annals of Botany*, *100*, 839-848.

Zhu, J., Bie, Z., Huang, Y. and Han, X. (2008). Effect of grafting on the growth and ion concentrations of cucumber seedlings under NaCl stress. *Journal of Soil Science and Plant Nutrition, 54,* 895–902.

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