Introducing Grafted Cucurbits to Modern Agriculture

The Israeli Experience

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Grafted vegetables have been cultivated in eastern Asia for decades (32), but their adoption in the western world has only begun since the banning of the fumigant methyl bromide in 2005 by the Montreal Protocol (46). The primary motive for using grafted plants is to avoid damage caused by soilborne pests and pathogens in situations in which genetic or chemical approaches for disease management are not available (39). Grafting a susceptible scion onto a resistant rootstock provides a resistant plant without the need for a prolonged breeding program. Furthermore, grafting plants allows for a more rapid response to the appearance of new races of a pathogen, and provides a less expensive and more flexible solution for controlling soilborne diseases than breeding new resistant cultivars. In addition, grafted plants may contribute to enhanced tolerance to abiotic stresses, more efficient water and nutrient use, and improved fruit yield and quality (32,38,39,47,48,50).

Methyl bromide is still in use in certain areas and countries under special permits. The feasibility of grafting compared with soil disinfection with methyl bromide is thus different for each country, affected by conditions such as the price of the chemical, the price of seeds and grafted transplants, and the growers' income. For example, in Israel, grafted cantaloupe is more expensive than soil disinfection by \$3,000 per hectare, whereas grafted watermelons are economically feasible. In Ja-

pan, farmers generally have very small land areas, and they often encounter increasing populations of pathogens that threaten their crops due to continuous cropping. With the establishment of large-scale greenhouse cultivation, grafting became an essential technique for production of vegetable crops.

The ban on the use of methyl bromide for soil fumigation stimulated the introduction of grafting technology to the Mediterranean area and to European countries (12,33,37,39). Currently, researchers in the United States are also becoming more interested in this technology. Studies with grafted melons for the suppression of *Monosporascus* sudden wilt are in progress in Texas as part of a joint project with Israel. Grafting is also being investigated in Oklahoma, where researchers are using grafted watermelons for controlling soilborne disease and improving fruit quality (52). In addition, they are trying to improve the strength of grafted watermelons in order to reduce damage due to windy weather (29). In the United States, however, plant cultivation is generally carried out on large acreages and crop rotation prevents catastrophic crop losses. There is also very little greenhouse cultivation. Thus, to the best of our knowledge, vegetable grafting is not yet commercialized. Nevertheless, in fields with high disease risk, some growers in Texas use grafting for the early watermelon season (Kevin Crosby, *personal communication*). Melons grafted onto various *Cucurbita* rootstocks have been tested in Honduras and Guatemala, an activity being promoted by UNIDO (United Nations Industrial Development Organization) as part of the worldwide effort to phase out methyl bromide. Subsequently, almost 20% of the commercial melon fields of Honduras are now grafted (Reuben Ausher, *personal communication*).

Grafting cucurbits was first introduced to Israeli agriculture in 1995. Until that time, methyl bromide was extensively used for managing soilborne diseases of annual crops (30). With the phasing out of methyl bromide (46) and the lack of available farmland for appropriate crop rotation, growers began to look for alternative pest management tools. When we first began studying the grafting issue, we assumed that the performance of grafted plants, including suppression of soilborne diseases, depended only on the contribution of the rootstock. We were sure that finding a resistant and vigorous rootstock would be all that was required and that everything else needed for use in Israel could be adapted from practices used in the Far East. Reality, however, turned out to be different: as with the introduction of new cultivars, adaptation of the grafted plants to the specific combination of crop and environment is necessary. Not only does the response of the grafted plants depend on the rootstock, but the total performance also depends, to a great extent, on the rootstock-scion physiological interaction, and on the response of the scion to biotic and abiotic factors prevailing in the field.

The use of grafted vegetables in Israel is increasing rapidly and is estimated at five million transplants per year. Grafted watermelons now account for 60 to 70% of the total cultivated area of this crop (31). All early watermelons grown in the Arava Valley of southern Israel (transplanted in mid-winter and harvested in April) are grafted. Grafting muskmelons and cucumbers is less common due to the high price of the grafted transplants. With watermelons, growers commonly reduce the stand of grafted transplants in the field as compared with nongrafted transplants. This reduction is often accompanied by a compensatory increase in plant productivity such that total yields are maintained and

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the crop is profitable despite the higher cost of grafted transplants. Moreover, grafted plants are protected from the Melon Necrotic Spotted Virus (MNSV), which is not controlled by methyl bromide fumigation. In muskmelons and cucumbers, however, yield compensation is less pronounced or nonexistent (12) and the higher price for grafted transplants threatens the profitability of the crop; nevertheless, the acreage of grafted melons increased in the last two years, especially for early melons, which bring high prices in the local and export markets.

Comprehensive descriptions of various aspects (grafting methods, diseases targeted, acreage, etc.) related to grafted vegetables, especially in the Far East, has been reviewed by Lee and Oda (32). In this article, we will concentrate on sharing the experience we acquired in Israel with grafted cucurbits, which is the main plant family grafted around the world.

Intra- and Interspecific Grafting

Suppression of soilborne pathogens can be achieved by grafting susceptible scions onto resistant rootstocks of the same species (intraspecific grafting) or on a close member of the same botanical family (interspecific grafting). In tomatoes, for example, a large collection of tomato rootstocks is available. These stocks contain different genes for resistance to fungal pathogens, viruses, and nematodes; thus intraspecific grafting is very common (2,20,41). In melons, however, resistant muskmelons or *Cucurbita* rootstocks are used for different purposes. Intraspecific grafting is mainly used to avoid damage caused by wilt pathogens such as *Fusarium oxysporum* f. sp. *melonis* for which resistance genes exist in certain melon varieties. This approach provides complete protection from the disease, with no reduction in fruit quality and quantity (7). The possibility of using melon rootstocks for reducing *Monosporascus* wilt damage was studied in order to avoid undesirable effects of the *Cucurbita* rootstock on fruit quality. Although there are muskmelon accessions with differing levels of quantitative resistance to the disease (23) that may serve as rootstocks, it has not been possible to obtain grafted plants with reliable resistance under a variety of environmental conditions (R. Cohen and M. Edelstein, unpublished data). In fact, for suppression of root and stem rot diseases for which dependable resistance is not available in melons, only *Cucurbita* rootstocks provide the required nonspecific resistance.

Intra- and interspecific grafting have their own beneficial and detrimental characteristics as to phytopathological and horticultural behavior (7,13,15). *Cucurbita* rootstocks provide nonspecific but efficient protection against a wide range of soilborne pathogens and against some abiotic

stresses, but such rootstocks may in certain cases affect fruit size and quality (38,53). On the other hand, susceptible muskmelons grafted onto resistant muskmelons have fewer horticultural problems related to scion–rootstock compatibility, but their resistance is often limited to one or a few pathogens, or even to a specific race of one pathogen.

Muskmelon Diseases

Fusarium wilt. *Fusarium* wilt of muskmelons is an important disease worldwide (34). In Israel, the disease is a limiting factor for growing Ananas-type muskmelons in the summer under dry-land farming conditions. *Fusarium*-resistant Ananas types do exist, but their fruit quality is lower than that of the susceptible ‘Ofir’, the most desirable commercial cultivar grown in Israel. Grafting a susceptible cultivar onto a resistant rootstock is one of the approaches that enable the cultivation of such varieties in *Fusarium*-infested soils in the Mediterranean area (53), including Israel (7).

We evaluated the effects of grafting on the horticultural and pathological performance of grafted *Fusarium*-susceptible muskmelons in *Fusarium*-infested and -noninfested soils (7). Muskmelon/muskmelon combinations performed better than the muskmelon/*Cucurbita* combinations with respect to yield. In infested soil, *Fusarium* wilt symptoms were observed only in the nongrafted susceptible muskmelons, and there was no wilting with any of the grafted combinations. However, some yellowing of old vines of the muskmelons grafted onto *Cucurbita* was observed, and these plants were also less vigorous than those grafted onto muskmelon rootstocks, suggesting that the pathogen may have

caused some damage to the grafted plants (7; Fig. 1).

Interestingly, a difference in rootstock–scion compatibility, as expressed in yield, was evident in muskmelons grafted on two different muskmelon rootstocks (Fig. 2). The Ananas-type muskmelon Ofir had a significantly higher yield when grafted onto the Ananas-type muskmelon ‘Adir’ than when grafted onto the Charentais-type muskmelon ‘Orca’, indicating differences in rootstock–scion compatibility even among melon rootstocks. The vigor of the muskmelon/*Cucurbita* combinations was lower than that of the muskmelon/muskmelon combinations (Fig. 1). We also found that the contribution of grafting to disease reduction was influenced by the susceptibility of the scion. Disease incidence in nongrafted ‘Ananas En Dor’ muskmelons (highly susceptible) and in those grafted onto ‘Brava’ (*Cucurbita* rootstock), was 82 and 20%, respectively, compared with only 36 and 0% in nongrafted and grafted Ofir muskmelons (moderately susceptible), respectively. Susceptible muskmelon scions grafted onto resistant muskmelon rootstocks were colonized less by *F. oxysporum* f. sp. *melonis* than the same muskmelons grafted onto *Cucurbita* rootstocks (7). In *Fusarium*-free soil, the grafting process itself did not affect yield. The yield was similar in all grafted plant combinations and in the nongrafted control (7).

Monosporascus sudden wilt. *Pathological aspects.* Sudden wilt of muskmelons caused by *Monosporascus cannonballus* is a worldwide problem mainly in arid and semiarid regions (35), including southern Israel (6,8). Soil disinfestation with methyl bromide is a common and effective tactic for disease control (15), but reinfes-

Fig. 1. Suppressed growth and some wilting of old vines in melons (cv. Ofir) grafted onto the *Cucurbita* rootstock TZ 148 (right foreground) compared with normal growth of melons grafted onto Adir, a resistant melon rootstock (left foreground)

tation by the pathogen is relatively rapid due to sandstorms carrying the pathogens' ascospores. Indeed, *Monosporascus* sudden wilt can damage muskmelon crops even after methyl bromide treatment. The objectives of the first series of field trials conducted 10 years ago were to identify appropriate *Cucurbita* rootstocks and to evaluate the performance of the grafted plants alone or as part of an integrated management strategy (15). Of the rootstocks tested, the *Cucurbita maxima* × *Cucurbita moschata* hybrid Brava provided the best level of wilt reduction (15). Grafting, when used alone, significantly reduced wilt incidence by 84 to 87% compared with nongrafted plants. Integration with low concentrations of methyl bromide fumigation provided 75 to 100% reduction in the treated compared with the non-treated plots. Because disease control by either process alone varied, the integrated application was preferable (15).

Although all the cucurbits are susceptible to *M. cannonballus*, differential associations between the pathogen and various hosts were reported by Mertely et al. (36). The pathogen was readily isolated from the diseased roots of watermelon and muskmelon. The fungus was also recovered in low percentages from *Cucurbita* spp., but the host did not show wilt symptoms. However, perithecia containing ascospores were produced on dead roots of *Cucurbita* spp. (36).

The low susceptibility of the *Cucurbita* rootstocks may explain the ability of the grafted plant to eliminate or reduce *Monosporascus* wilt damage (15). Nevertheless, in some field trials, we have noticed that the rootstock was not damaged by soil-

borne pathogens whereas lesions were observed on the scion. Most of the plants exhibiting this phenomenon survived (Fig. 3).

Environmental aspects. Most of the Israeli muskmelon production is concentrated in the Arava region of southern Israel (6,25). The muskmelons grown in the Arava are destined mainly for export to Europe. Therefore, growing seasons are planned for spring and autumn harvest, in order to capture the window during which European muskmelons are not available on the market. Numerous attempts made about 10 years ago to grow 'Galia' muskmelons grafted onto *Cucurbita* rootstocks yielded inconsistent results (25). These ranged from satisfactory disease suppression accompanied by profitable yields in the northern Arava (15) to minor and non-significant effects of grafting in the late summer (6). As a result of the different findings, it was assumed that the Galia-type muskmelon (that was never grafted elsewhere) could not be grafted as effectively as other varieties. To clarify this issue, we evaluated the vegetative development of grafted Galia and other muskmelons in a pot experiment and found that grafted and nongrafted plants of any given cultivar grew at a similar rate, indicating that there is no genetic barrier to the use of Galia-type muskmelons as scions (6,14). When the response of four grafted Galia-type muskmelons to *M. cannonballus* was compared with that of nongrafted muskmelons in the field in the spring and fall cropping seasons, significant differences in disease incidence were found among cultivars between grafted and nongrafted plants and between growing seasons. Disease

reduction was evident in both seasons, but the beneficial effect of grafting on yield was more pronounced in the spring crop. These results are consistent with our knowledge about melon cultivation in different seasons, including the response to soilborne disease. Late summer is characterized by high nocturnal temperatures that result in a short growing season and high disease incidence. In contrast, spring temperatures are moderate and provide a longer growing season and lower disease incidence (44). The results indicate that grafted Galia-type muskmelons need to be adapted to the growing area and to the season (6).

In exploring why grafted plants did not perform as well in the summer as in the spring, we observed an interesting phenomenon, probably related to the combined effects of rootstock-scion compatibility and environmental stress. Muskmelons that were transplanted into disease-free soil in the central Arava Valley in mid-July showed markedly suppressed growth compared with the normal development of nongrafted muskmelons (Fig. 4). Similar plants that were transplanted on the same day into *M. cannonballus*-infested soil in the Negev Heights did not show disease symptoms and developed normally. The aerial distance between the two locations is approximately 100 km. Temperatures in the central Arava (day/night) average 39/25°C and in the Negev Heights 35/19°C. We hypothesized that the high nocturnal temperature interfered with the normal development of grafted plants, but attempts to reproduce this phenomenon in a growth chamber were unsuccessful. Grafted muskmelons transplanted in the same field in early spring developed properly. The reason for the suppressed growth

Fig. 2. Accumulation yield of grafted and nongrafted melons (cv. Ofir) in *Fusarium*-infested soil. NG = nongrafted, TZ 148 = *Cucurbita* rootstock, Adir and Orca = melon rootstocks. Values followed by different letters are significantly different ($P \geq 0.05$). (adapted from 7)

Fig. 3. Lesion on melon (scion) versus undamaged *Cucurbita* rootstock. Grafted plant grown in soil infested mainly with *Monosporascus cannonballus*. The grafted plant survived the infestation.

of grafted plants in mid-summer is still unknown, and this phenomenon demonstrates the need to adapt the grafting methodology to each specific area and growing season. On the other hand, rootstock–scion incompatibilities were also observed in the winter. Some grafted plants that were transplants in mid-winter and exposed to low soil temperatures collapsed due to

inhibition of assimilates transfer from the foliage to the root system (Fig. 5).

Watermelon and Cucumber Diseases

Watermelons are grafted worldwide on different rootstocks (32) to prevent the damage caused by diverse pests in the various growing areas and different sea-

sons. Fusarium wilt, caused by *F. oxysporum* f. sp. *niveum*, is probably the most commonly reported disease worldwide that can be successfully managed with grafted transplants (33,37,39). In Israel, Fusarium wilt of watermelon occurs mostly in the northern valleys and is not currently a major problem that limits watermelon production; grafting is aimed at reducing damage caused by other soilborne diseases.

In the early season in southern Israel, grafting is aimed at preventing *Monosporascus* wilt and wilting caused by the soil-borne virus *Melon necrotic spot virus* (MNSV). Use of grafted muskmelons and watermelons against MNSV was also reported in Crete (3) and Almeria, Spain (21). The control of MNSV is a significant advantage of grafting compared with methyl bromide, as the fumigant does not control the virus.

In central and northern Israel, watermelons are transplanted in middle and late summer. In these growing seasons, watermelons are grafted mainly to overcome the vine decline phenomenon (Fig. 6), which commonly occurs in watermelons grown in fields with a history of watermelon cropping. Decline is characterized by reduction in plant vigor, much smaller fruit size, and overall reduction in total yield. The causal agents of vine decline are not clear, but the fungus *Macrophomina phaseolina*, which causes vine decline and yield losses in muskmelons (5), is commonly isolated alone or with *Fusarium solani*. Reduction of plant fresh weight, but not wilting, was found in experiments in which watermelons were grown in pots containing soil infested with *M. phaseolina*, alone or combined with *F. solani* (9). We therefore believe that *M. phaseolina* is probably one of the fungi contributing to vine decline and yield losses in watermelons in Israel.

Fig. 4. Suppressed growth of melons grafted onto *Cucurbita* rootstocks (foreground) compared with normal development of nongrafted melons in the background and the left side of the field. Plants were transplanted in mid-July to methyl bromide treated soil in 'En Hazeva, central Arava Valley.

Fig. 5. Scion overgrowth caused probably by blockage of assimilates transfer from the scion to the rootstock. The plant died as a result of poor support of the root system.

Fig. 6. The vine decline phenomenon and its suppression in watermelons. Poor vegetation and small fruits exposed to sunlight in nongrafted watermelons (left). Vigorous plant canopy and shaded fruits in grafted watermelons (right).

Cucumber Diseases

Crown rot of cucumber, caused by *Fusarium oxysporum* f. sp. *radicis-cucumerinum*, is a new disease of greenhouse-grown cucumbers. The disease was recorded between 1989 and 2000 in Greece, Canada, France, Spain, and Israel (42,45). Disease incidence can be partially reduced by application of fungicides throughout the growing season (45). Greater reduction in disease incidence can be achieved by means of methyl bromide fumigation of the soil and disinfestation of the internal space of greenhouses with formaldehyde solution. However, grafting may also provide adequate suppression of this pathogen. In Crete, Greece, the disease incidence of grafted cucumbers ranged from 0 to 25% compared with 96% in nongrafted controls (42). Similar disease reduction was achieved by grafting in experiments conducted for the last two years in Israel (J. Katan, *personal communication*). As with muskmelons, the price of the grafted transplants is the main factor that limits large-scale adoption of this technology.

Response of Grafted Cucurbits to Nematodes

Genetic resistance to root-knot nematodes, *Meloidogyne* spp., is not present in commercial cucurbits. However, cucurbit accessions that are less susceptible to these nematodes are being used as rootstocks in Korea (32,27). In a study conducted in southern California (51), susceptible melons grafted on *Cucumis* and *Cucurbita* stocks had lower gall ratings and higher shoot weights compared with nongrafted melons, but the final galls observed were similar in both grafted and nongrafted plants. Grafting prevented growth reduction and lowered the buildup of nematode populations, and it was concluded that grafting made the plants tolerant but not resistant to nematodes (51).

The lack of rootstocks possessing dependable resistance to root-knot nematodes can endanger the use of grafted plants in heavily infested soils. The current status is not satisfactory, and progress should be made to improve the resistance of *Cucurbita* and other cucurbit rootstocks to nematodes; however, detailed knowledge is currently lacking on issues such as host range of different nematode species, levels of susceptibility among various cucurbits, relationship between root infection and damage in grafted plants, and mode of resistance. In greenhouse experiments, we evaluated the response of *Cucurbita* accessions to *Meloidogyne javanica*. Differences in susceptibility were found, and two *Cucurbita* breeding lines out of the 23 tested did not produce any galls (R. Cohen and Y. Oka, *unpublished*). Interestingly, galls on the roots of the susceptible *Cucurbita* lines were much smaller than those on susceptible muskmelons, watermelons, and cucumbers that were tested as additional control plants. These results indicate that it might be possible to breed *Cucurbita* rootstocks that will be resistant or at least less susceptible to root-knot nematodes.

Physiological and Abiotic Stresses

Tolerance to salinity and boron. Agricultural production in arid and semiarid regions such as Israel relies heavily on irrigation. The water resources in these regions are scarce; thus the use of marginal water sources (saline water and treated sewage effluent) for irrigation is increasing. These marginal waters contain relatively high salt levels and, in some cases, high boron concentrations (18). Moreover, weathering of minerals could increase the salt and boron concentration in the soil solution (4,26).

Fernandez-Garcia et al. (19) showed that under saline conditions, the Cl^- and Na^+ uptakes of grafted tomato were signifi-

cantly lower than those of nongrafted plants, indicating that the former plants had higher salinity tolerance than the latter. Likewise, Romero et al. (48) compared the effects of salinity on two varieties of grafted muskmelon. They found that the grafted muskmelons were more tolerant to salinity than the nongrafted ones; they suggested that grafted plants developed various mechanisms to prevent the physiological damage caused by excessive accumulation of Cl^- and Na^+ in the leaves, including exclusion of Cl^- and/or reduction of Cl^- absorption by the roots. Similar results were found in experiments conducted in the Negev Heights of southern Israel: grafted watermelons were more tolerant to irrigation with saline water than nongrafted plants (Fig. 7). Grafted plants might also be more tolerant to excessive boron concentrations than nongrafted ones. Boron is a trace element that is essential to plant growth, but it can be toxic to plants when its concentration in the soil solution exceeds a certain value (11).

The combined effects of boron and salinity on the growth and yield of grafted and nongrafted muskmelon plants were reported recently (13). The grafted plants accumulated less boron than the nongrafted ones and were less damaged when exposed to similar boron concentrations (Fig. 8). It was suggested that the *Cucurbita* rootstock excluded some boron, consequently decreasing the boron concentration in the scion of the grafted plants. Both plant types absorbed less boron when irrigated with water containing higher salt concentrations. The fruit yield of grafted plants was less affected by boron accumulation in the leaves than that of nongrafted plants. The low boron uptake under high-salinity irrigation was considered to be mainly a result of reduced transpiration of the plants. Increasing water salinity decreased the sensitivity of both plant types to increases in leaf boron concentration, which indicates that the effects of boron and salinity on muskmelon plants were not additive. The increased use of marginal water in agriculture in Israel and in other regions that suffer from water shortage may lead to the use of grafted plants for this purpose as well.

Rootstock-scion interaction. As grafting is a composite of two different plants, the interaction may confer other beneficial or negative effects besides those relative to soilborne pathogens. In the Arava Valley of southern Israel, growers prefer growing trellised melon plants because this procedure saves labor, increases yields, and makes pesticide applications easier and more effective. Trellised muskmelon plants are pruned to one main branch that bears three or four fruits, compared with one to two fruits per prostrate plant. In experiments conducted in disease-free soil pretreated with methyl bromide, trellised grafted muskmelons collapsed when they

Fig. 7. Effect of irrigation with saline water ($\text{Ec} = 4.5$) on nongrafted watermelon (foreground) and grafted watermelon (background).

were loaded with fruit, in contrast to those grown prostrate which matured properly (R. Cohen, *unpublished*). Fruit load subjects the plants to a progressive increase of water stress (43), and it seems that when grown trellised the grafted plants cannot cope with this demand. Plant collapse was evident only in a hot climate, whereas in cooler weather, in which the water demand was lower, trellised grafted plants survived. In addition to their greater fruit load, trellised plants are exposed to solar radiation from all directions, whereas in prostrate plants radiation is intercepted only in their upper canopy, while the lower leaves and fruits are shaded. Preliminary results of our research indicate that besides water, the auxin balance between the scion and the rootstock is involved in this physiological collapse.

Similar alterations in growth regulators were seen with cucumber plants grafted onto squash roots. The grafted cucumber plants bore no female flowers, whereas the control plants developed female flowers above the second node (49). Another but different effect of the rootstock on the scion was resistance to the carmine spider mite *Tetranychus cinnabarinus* that was found in a *Lagenaria* accession and transferred to some of the scions grafted onto it (16). Grafting the susceptible *Cucurbita* cv. Brava onto the *Lagenaria* rootstock increased the resistance of the scion to the same level as that of the nongrafted *Lagenaria* rootstock, but grafting the susceptible *Cucumis melo* cv. Noy Yizre'el onto the resistant *Lagenaria* did not affect its susceptibility to mites.

Directions for Future Research

Grafting is a fascinating tool for studying basic and applied questions regarding plant physiology, including mechanisms of resistance. The occurrence of signal transduction from rootstock to scion that affects gene expression in the scion is well documented (40). For example, grafting tomatoes with a leaf mutation enabled demonstration of the movement of mRNA from the mutant rootstock into the wild-type scions: the translocated mRNA caused changes in the leaf morphology of the wild-type scions (28). Another possible phenomenon that may play a role in the grafting system is RNA silencing, the reduction of specific gene transcript levels in the presence of a related RNA. From studies of RNA silencing in several systems, much is now known about the mechanisms involved, but its systemic spread in plants remains unclear (24).

DNA macro/microarray technologies provide large-scale information on patterns of gene expression (17). A major advantage of this approach is its capacity to generate comprehensive knowledge of the genes expressed in a given biological process. A further and unique advantage is its potential to detect unknown genes that are

involved in these processes. Suppression Subtractive Hybridization (SSH) is a useful tool for selecting genes that are exclusively expressed in one tissue or process but not in the other (10). The combination of SSH and macroarrays (54) is currently being applied in Newe Ya'ar, Israel (Nurit Katzir, *personal communication*) in an attempt to identify genes that are differentially expressed in different combinations of grafted plants. Comparison between the gene expressions in compatible and incompatible scions may enable the identification of genes associated with the compatibility of scions and rootstocks.

Conclusions

Grafting is an old technology that has been, and still is being investigated in fruit trees (1,22). The use of grafted vegetables will likely become more common as a replacement for soil fumigation as a means for managing soilborne diseases. Integrating this technology with other environment-friendly technologies could ease the transition into the post-methyl bromide

era. There is, however, much to learn about how to optimize this technology. It seems that combating soilborne pests is the easier part of the whole grafting issue, while rootstock–scion compatibility is one of the major obstacles to increased usage of the grafting technology. Advanced molecular technologies are offering new tools for understanding rootstock–scion compatibility. Time will tell if nurseries will find ways to lower the grafted plants' prices and if research will lead to enhancement of grafted plant performance. If not, we will have to learn to live with the limitations of this technology and adapt it to our needs wherever possible.

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Fig. 8. Damage caused by boron at 10 mg/liter in grafted (A) and nongrafted (B) melon plants.

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Dr. Burger is a melon breeder and plant physiologist. He joined the Agricultural Research Organization (ARO) in 1980 and received his Ph.D. in 2000 from the Hebrew University of Jerusalem, Israel. Dr. Burger is developing Galia-type melons for Israeli and European seed companies. His breeding programs concentrate on improving horticultural traits and introducing a broad spectrum of soilborne and foliage disease resistance to the new cultivars. Dr. Burger is involved in the genetics and breeding aspects of our research and breeding program for developing resistant rootstocks.

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Mr. Koren is the chief agronomist at 'Hishtil' nurseries in Israel. He received his B.Sc. in crop protection in 1977 and his M.Sc. in plant pathology in 1978 from the Hebrew University of Jerusalem, Israel. His M.Sc. research focused on the biology and management of powdery mildew in tomatoes caused by *Leveillula taurica*. Mr. Koren was a pioneer in introducing grafting technology into Israeli agriculture. He is in charge of research and development for the 'Hishtil' group in Israel and serves as a consultant on 'Hishtil' international activities.

Dr. Edelstein is head of the division of cucurbit research and breeding in the ARO, Neve Ya'ar Research Center, Israel. He joined the ARO in 1976 and received his Ph.D. in 1992 from the Hebrew University of Jerusalem, Israel. As a crop physiologist, he is concentrating on research on the horticultural aspects of grafting melons and watermelons onto *Cucurbita* rootstocks.

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