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Indexing melon physiological decline to fruit quality and vine morphometric parameters

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ABSTRACT

While grafting cucurbits has become essential in the management of soil borne diseases and for improving performance under conditions of abiotic stress, commercial melon grafting has been curbed by the incidence of non-pathological decline, usually expressed right before harvest and attributed to physiological scion-rootstock incompatibility. The current study investigated the potential indexing of physiological incompatibility to plant performance, vine morphometric parameters and fruit physicochemical characteristics. Graft combinations sensitive to physiological incompatibility (scions: melon cvs. Elario, Polynica and Raymond; rootstocks: interspecific hybrids 'TZ148', 'N101', 'Carnivore' and '30900') were grown between February and May in a disease-free soil environment. Results indicate that plant collapse shortly before harvest is a onetime event that does not necessarily reflect on the performance of the asymptomatic, surviving plants. However, a negative rootstock effect on scion dry weight was indicative of rootstock-scion combinations subject to incompatibility and prone to decline. The attenuation of the 1st internode's diameter relative to the hypocotyl's ('Elario' 29.1%; 'Raymond' 41.5%; 'Polynica' 44.0%) and the loss of mesocarp firmness reflected the categorical sensitivity of the scions to physiological decline. No systematic pattern was identified connecting fruit soluble carbohydrate (fructose, glucose and sucrose) content to physiological incompatibility and plant decline. However, earliness of harvest maturity, pronounced in sensitive climacteric scions 'Polynica' and 'Raymond', may relate to ethylene-mediated comprehensive acceleration of ripening stressing rootstock-scion synergy to collapse.

1. Introduction

Owing to the environmental restrictions imposed on the use of chlorofluorocarbon-based soil fumigants, grafting cucurbits has become an essential tool in the management of soil borne disease, employing most notably the resistance of inter-specific *Cucurbita maxima* × *C. moschata* rootstocks. Further to conferring phytoprotective resistance, a resilient rootstock system may augment crop yield by enhancing nutrient uptake (Colla et al., 2010a) and water use efficiency (Rouphael et al., 2008). Increase in yield has also been attributed to stimulation of scion growth (San Bautista et al., 2011) mediated by increased synthesis and translocation of endogenous hormones from the acquired root (Dong et al., 2008). Under conditions of edaphoclimatic stress the exploitation of resilient rootstocks may sustain high yields by exploiting traits such as increased tolerance to salinity (Colla et al., 2006; He et al., 2009; Romero et al., 1997), to temperature extremes (Rivero et al., 2003; Schwartz et al., 2010) and soil alkalinity (Colla et al., 2010b), and heavy metal contaminations (Kumar et al., 2015a,b).

The use however of grafted plants in commercial melon production is not the one anticipated. This can be attributed partly to the higher cost incurred but also to frequent problems of incompatibility involving inter-specific *Cucurbita* rootstocks, which may eventually lead to plant decline (Aloni et al., 2010). The rather inconsistent information available on the performance of melon scions grafted onto *Cucurbita* rootstocks constitutes an additional disincentive for grafting. In fact, the ultimate conclusion of several reports is that incompatibility in melon is foremost subject to the dynamics of rootstock/scion interaction (Aloni et al., 2010; Cohen et al., 2002; Davis et al., 2008; Rouphael et al., 2010), in contrast to watermelon where compatibility of squash inter-specific hybrid rootstocks is usually unequivocal across commercial scions (Kyriacou and Soteriou, 2015; Soteriou and Kyriacou, 2015).

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Incompatibility expressed as graft failure and premature seedling death may be caused by unfavorable conditions (e.g. temperature) prevailing during the connection of vascular bundles between scion and rootstock at the nursery (Davis et al., 2008). Andrews and Marquez (1993) referred discretely to physiological incompatibility which results in plant decline either at the early stages after transplanting a healthy grafted seedling, or as late as the beginning of harvest. Such incompatibility has been related to oxidative stress triggered by hormonal signaling from the scion to the rootstock (Aloni et al., 2008a).Moreover, the effect of factors (e.g. high air temperature) suspected of triggering physiological incompatibility is random, causing decline only to a variable fraction of the presumably incompatible scion-rootstock population. Limited evidence exists linking the effect of grafting on plant morphological characteristics to the incidence of plant decline (Edelstein et al., 2004; Traka-Mavrona et al., 2000). Hence, extensive field trials are still essential before recommending specific scion × rootstock combinations.

Conflicting reports regarding the effect of grafting on melon fruit quality characteristics (Colla et al., 2006, 2010a; Crinò et al., 2007; Trionfetti-Nisini et al., 2002), can be explained partially on the basis of variation in the prevailing production practices (Rouphael et al., 2010). It is possible however that latent, non-pathological incompatibility elicited by rootstock-scion interaction under triggering stress conditions may impair certain fruit quality traits or plant morphometric characteristics in the surviving population. This hypothesis is underpinned by the association of incompatibility with changes in water and nutrient flow through the graft union potentially causing plant wilting (Davis et al., 2008; Rouphael et al., 2010). An etiology for melon physiological incompatibility and plant decline proposed by Aloni et al. (2008a) is the occurrence of hormonal imbalance in the rootstock after the establishment of vascular connections. Any potential stress imposed by self-grafting has never been found deleterious on melon plants, provided a healthy transplant stock; neither any positive or negative effects of self-grafting on yield and quality traits have been reported (Guan et al., 2014; Guan et al., 2015; Schultheis et al., 2015; Zhao et al., 2011).

Indexing physiological incompatibility to fruit quality and vegetative morphometric parameters in the surviving plant population, may provide useful tools for diagnosing latent incompatibility and identifying rootstock-scion combinations prone to decline. It may also enhance our understanding of the physiological mechanisms behind grafted melon plant decline. Accordingly, the objective of the current work has been to investigate the possible expression of physiological incompatibility in plant performance and morphometric parameters, and in fruit physicochemical characteristics. For the purposes of this study scion-rootstock combinations sensitive to physiological incompatibility were selected on the basis of preliminary experimental results and extension service reports on grafted melon decline incidence. Scion selection in particular was based on the relative frequency of physiological incompatibility incidence prior to harvest as follows: (a) infrequent plant mortality – cv. Elario; (b) frequent plant mortality – cv. Raymond; (c) ubiquitous symptomatic incompatibility and persistent plant mortality – cv. Polynica on inter-specific rootstock 'N101'.

2. Materials and methods

2.1. Plant material

Transplants of melon (*Cucumis melo* L.) Galia type cv. Elario and Ananas type cv. Raymond were grafted onto four inter-specific (*Cucurbita maxima* Duchesne × *C. moschata* Duchesne) hybrid rootstocks: 'TZ148', 'N101', 'Carnivore' and '30900'. Moreover, Galia type cv. Polynica was grafted solely onto 'N101′ since preliminary work and commercial experience showed that, under stressful temperature conditions, simulated in the controlled environment of the current study, cv. Polynica grafted on common commercial *C. maxima* × *C. moschata* rootstocks, such as TZ148, N101, Carnivore and 30900, demonstrates a persistent morphological incompatibility that results in significant plant decline. Grafts were made after the appearance of the first true leaf on seedlings using the approach method (Lee et al., 2010). The root system of the scion was removed about 15 days after grafting. Non-grafted (self-rooted) plants were used as the control. All plants were produced by Solomou Nurseries (Nicosia, Cyprus). Potted plants were spaced 0.5 m apart within rows and 1.0 m apart between rows amounting to a plant density of 20,000 plants ha^{-1}.

Table 1
Incidence of plant decline in grafted and non-grafted melon plants of cultivars Elario, Polynica and Raymond (N = 30).

Cultivar	Rootstock	Plant Decline (%)	Pearson Prob > ChiSq
Elario	TZ148	3.3	
	N101	0.0	
	Carnivore	3.3	0.3839
	30900	3.3	
	Non-grafted	0.0	
		n.s.	
Raymond	TZ148	23.3 a	
	N101	36.7 a	
	Carnivore	16.7 a	0.0069*
	30900	30.0 a	
	Non-grafted	0.0 b	
Polynica	N101	20.0 b	0.0112*
	Non-grafted	0.0 a	

* Signicant rootstock effect according to Pearson ChiSquare test ($P \leq 0.05$). Scion-specific values within columns followed by the same letter are not significantly different according to Pearson ChiSquare test ($P \leq 0.05$).

2.2. Experimental conditions

The study was conducted at the Zygi Experimental Station (34° 44′ 00″ N; 33° 20′ 15″ E) of the Agricultural Research Institute of Cyprus between February and May 2014 in a 400 m^2 greenhouse covered with double-layer polyethylene sheet and insect proof windows. A climate controller system (Galileo, Galcon, Kfar Blum, Israel) regulated maximum air temperature set at 28 °C during the day and night air temperature was kept above 15 °C, until the oldest fruits (first to harvest) reached a diameter of about 8 cm. Subsequently, maximum day and minimum night greenhouse temperatures were raised to 32 and 19 °C, respectively, for better simulation of summer field conditions.

A mixture of perlite and peat moss (in 1:2 vol ratio) was used as the growing medium in 30.0 l black plastic pots (height = 0.30 m; diameter = 0.40 m). Soil moisture sensors (Mas-1, Decagon Devices, Pullman, USA), calibrated for the specific medium and connected to the climate control system, were established for monitoring pot volumetric water content. Daily irrigation was regulated to allow 20–30% leaching of the total irrigation volume per plant per day. Pressure-compensated drip irrigation at a rate of 4 l h^{-1} per plant was used in combination with constant nutrient feeding. The nutrient solution formula, based on variable N levels at different stages of plant growth, was adopted from Rodriguez et al. (2006). All treatments were irrigated and fertilized uniformly.

Plants were trellised in a single-truss system and allowed to reach the next plant within row on the horizontal trellis cable before they had their tops pruned. All lateral shoots below the 6th node were removed. Lateral shoots from the 7th node and above were allowed to set fruit on the 1st or 2nd node and pruned past two nodes. When fruits reached approximately the size of a lemon,