Europ.J.Hort.Sci., **71** (3). S. 97–101, 2006, ISSN 1611-4426. © Verlag Eugen Ulmer KG, Stuttgart

Variation of Plant Growth and Macronutrient Uptake in Grafted Tomatoes and Eggplants on Three Different Rootstocks

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Summary

Grafting, even for tomatoes and eggplants, can be considered a useful tool for tackling the problems of soil borne diseases. However, marked variations in plant vigour in relation to scion rootstock combinations are observed in field conditions. Among the mechanisms causing such variations, are those connected to plant nutrition; however, information on this is incomplete and limited mainly to the cucurbits species. Bearing this in mind, the purpose of this study was to verify in which ways grafting combinations in tomato and eggplant determine variations in plant assimilation and macronutrient uptake. The study was carried out on tomato ('Rita' F_1) and eggplant ('Mission Bell' F_1) grafted with three rootstocks (Energy, PG3 and Beaufort) and self-grafted (Control).

Self-grafted tomato plants and those grafted on intraspecific rootstocks (PG3 and Energy) were less vigorous and produced less dry epigeous biomass than plants grafted on interspecific rootstock (Beaufort). However, the converse was found in eggplant when Beaufort was used, proving the interaction between scion and rootstock. Nutrient uptake per hectare differed greatly in relation to grafting combinations, particularly with regard to phosphorous, calcium and sulphur for which the variations ranged between 100 and 300 %. This variability seems related to a differing degree of nutrient absorption, expressed by varying concentrations of these in the plant tissues, as well as to the different plant vigour expressed by the biomass production.

The results have allowed highlighting how, scion/rootstock combinations in tomato and eggplant can considerably affect plant growth and the content of different macronutrients; therefore, fertilization should take account of the different uptakes in relation to grafting combinations when grafted plants are used.

Key words. absorption – eggplant – rootstock – scion – tomato – vigour.

Introduction

Among the alternatives to methyl bromide, grafting represents one of the more widely considered possibilities to exploit the resistance to diverse soil borne pathogens and allow the cultivation of non-resistant cultivars (Leonardi and Romano 2004).

The response of grafted plants depends not only on the resistance to one or more pathogens, but also on variations in plant vigour (Temperini et al. 1999). These seem to derive directly from the joint action of the absence of disease symptoms and the changing functional relationships between scion and rootstock (Don et al. 1997; Gyu et al. 1997; Ping and Ikuo 1997).

For tomato and eggplant, too, grafting represents a useful tool to cope with problems of soil borne diseases. However, there is little in-depth knowledge on the functional relationships between the scion and the rootstock (Ginoux and Laterrot 1991). Indeed, the grafting combination may determine different plant vigour expressed through variations in growth, yield and product quality (Teruo and Hiromichi 1994; Canizares and Goto 1998; Leonardi and Paratore 1998; Romano and Paratore 2001).

The mechanisms that may determine such effects can be manifold and can be traced back to the synthesis and translocation of plant growth regulators, to the sizes of the root system, to water and nutrients absorption, as well as the assimilation of the latter (Lee 1994). Regarding aspects linked to plant nutrition, available information is not exhaustive and in any case mainly limited to cucurbit species (Atsushi et al. 1994; Teruo and Hiromichi 1994; Ruiz et al. 1997).

In view of these considerations, it was believed worthwhile to explore the effects of using rootstocks with different vigour on the response of tomato and eggplant. A deeper knowledge of the effects of the scion-rootstock combination on absorption of macronutrient might, besides, be useful to provide directions concerning the nutrient requirements of grafted vegetable crops. The aim of the work was therefore to verify to what extent the rootstock in tomato and eggplant may determine variations in growth and development, as well as on absorption of macronutrients and, thus, in their uptake by the crops.

Materials and Methods

The trials were carried out from 1998–1999 in a commercial cold greenhouse in the coastal belt of the Ragusa province. The scions used were 'Rita' F_1 (tomato) and 'Mission Bell' F_1 (eggplant). As rootstocks for both species, the tomato hybrids F_1 PG3 (De Ruiter) and Energy (Vilmorin) and the interspecific hybrid Beaufort (De Ruiter) were used. The choice of rootstocks was made on the basis of indications by the seed companies, according to which the rootstocks are characterized by a similar spectrum of resistance/tolerance to biotic adversities, but different vigour towards the scion.

The control comprised self-grafted plants of tomato and eggplant. The slanting cut was adopted as graft technique. To exclude interference from soil pathogens, the plants were cultivated in sandy soil previously sterilized with methyl bromide.

Transplanting was done mid-November and the crop management, until the end of the growing cycle, was typical of the two crops in the area. The amount of fertilizers applied with fertigation was 350 N, 130 P_2O_5, 500 K_2O kg ha^{-1} for tomato and 500 N, 180 P_2O_5, 400 K_2O kg ha^{-1} for eggplant.

The plants were arranged in the field following an experimental random block design with four replicas. The density per square meter was three plants for the tomato (100 x 33 cm) and two for the eggplant (100 x 50 cm). The eggplant was grown with two stems and tomato with one stem. For the latter, the topping was carried out at the setting of the eighth truss. Harvest began on 19/3 and 23/3 for the tomato and eggplant, respectively, and ended on 31/5 for both.

The effects of different rootstocks were studied by evaluating the main parameters of plant growth and development. Following the aims of the experiment, the macronutrient concentration in plant tissues was also determined. In this regard, for each treatment and for each replica, a dry matter sample was obtained from the different plant organs during pruning, harvesting and the end of cultivation cycle and gathered in proportion to their contribution to the produced epigeous biomass.

The macronutrients were determined using Kjeldhal's method (reduced nitrogen) and ion chromatography (NO_3^-, $H_2PO_4^-$, SO_4^{2-}, K^+, Ca^{2+}, Mg^{2+}). The ions extraction was performed adopting the method described by Elia and Santamaria (1995), but using ultra pure water for the anions. The determinations were done with a Dionex IC 25 Ion Chromatograph using an IonPac AG11-HC guard column and an IonPac AG11-HC separation column for the anions, and an IonPac CG15 guard column and an IonPac AS15 separation column for the cations. As regards the anions, the obtained amounts were transformed and expressed as N, P, S.

Analysis of variance (ANOVA) was performed to test the significance of the observed differences. Different letters in the tables and the figures represent significant variations according to LSD ($P \leq 0.05$).

Results

Plant growth

At the end of the cultivation cycle (i.e.: 194 DAT), the plants showed growth differences that were clearly ascribable to the grafting combination. In fact, tomato grafted on Beaufort was more vigorous, as shown by the greater stem height and diameter (Table 1), as well as by the epigeous dry biomass (Fig. 1). For the latter, variations between roughly 180 and 310 g plant^{-1} were observed, for the plants grafted on PG3 and Beaufort, respectively. The reproductive potential, expressed by the number of fruits per plant and the corresponding unit dry weight, showed significant variations only with regard to the number of fruit which was about 30 % higher when the Beaufort rootstock was adopted (Table 1).

From an agronomical point of view, the best production results in tomato were observed in the plants grafted on Beaufort (Table 1); the yield (marketable product) reached 82.6 t ha^{-1}, about 30 % higher than that obtained in the other treatments.

In the eggplant, the variations in vigour were more moderate, though differing depending on rootstock, with respect

Table 1. Stem characteristics and fruit production at the end of the growing cycle (194 days after transplanting). [Yield data considers marketable product].

/ rootstock	Stem		Total fruit		Yield
	Height (cm)	Diameter (cm)	Number plant^{-1}	Unit dry weight (g)	(t ha^{-1})
Tomato					
Self-grafted	221 b[1]	1.67 a	46.5 b	3.2	60.9 b
/ PG3	213 b	1.53 b	43.7 b	2.7	56.2 b
/ Energy	221 b	1.48 b	44.6 b	3.1	59.9 b
/ Beaufort	256 a	1.71 a	61.7 a	3.0	82.6 a
Eggplant					
Self-grafted	145 a	1.90 a	13.3	28.1	86.8 a
/ PG3	141 ab	1.69 bc	12.1	23.3	64.1 b
/ Energy	130 b	1.66 bc	11.7	27.3	59.9 b
/ Beaufort	150 a	1.82 ab	12.8	23.7	66.9 b

[1]Different letters represent significant differences according to least significant difference ($P \leq 0.05$).

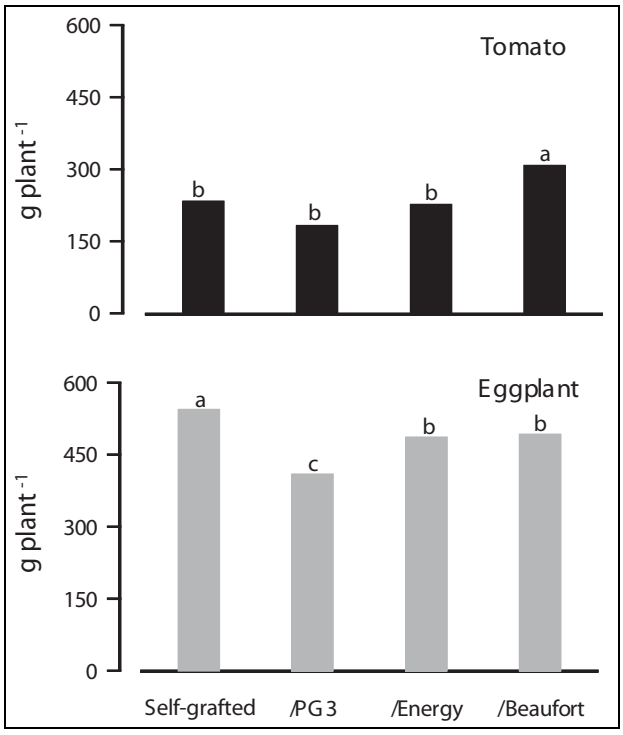


Fig. 1. Dry epigeous biomass produced at the end of the growing cycle (g plant^{-1}) [data concern the sum of biomass of fruits, stems, leaves and lateral shoots]. Different letters represent significant differences according to least significant difference (P≤0.05).

to those observed in tomato. In fact, only the plants grafted on Energy showed a significant reduction in plant height; as regards the dry biomass, the lowest value was recorded on plants grafted on PG3 (410 g plant^{-1}), while the highest on self-grafted plants (544 g plant^{-1}). From a biological point of view, no differences were observed in the number and amount of dry biomass of fruit. On the contrary, the agronomic results showed a significant reduction in yield (marketable product) (Table 1) in all the treatments compared to the control in relation to the lower percentage of marketable fruit (data not shown).

Nutrient content

The macroelement content found in the plant tissue of tomato and eggplant showed appreciable differences in relation to the rootstock, albeit to a variable extent for the different nutrients considered.

In tomato plants, the variations of the macronutrient content in comparison to self-grafted plants (control) (Table 2) were positive except for nitrogen, phosphorous and calcium in the plants grafted on Energy and for phosphorus when PG3 was adopted as rootstock (Fig. 2). The lowest values of the three elements were recorded in the plants grafted on Energy (19.4 mg g^{-1} for N, 2.5 mg g^{-1} for P and 13.1 mg g^{-1} for Ca) and the highest on plants grafted on Beaufort (22.8 mg g^{-1} for N, 3.1 mg g^{-1} for P and 19.3 mg g^{-1} for Ca).

The changes in the macroelement content ascribable to the grafting combination were more evident in eggplant than those recorded in tomato. With respect to the control, the macronutrient content was higher, whatever the adopted rootstock. However, these variations reached a significant level only with regard to nitrogen, phosphorous and sulphur. For these three elements the lowest values were found for the plants grafted on Beaufort (27.8 mg g^{-1} for N, 2.9 mg g^{-1} for P and 2.7 mg g^{-1} for S), while the highest were recorded on plants grafted on Energy, namely nitrogen (30.4 mg g^{-1}) and sulphur (4.0 mg g^{-1}) and on PG3 regarding phosphorous (3.1 mg g^{-1}).

Nutrient uptake

The nutrient uptake also led to record important differences in relation to the grafting combination. For tomato, the amount of macroelement uptake per hectare showed converse variations in relation to the adopted rootstock, compared to the control (Table 3). On the plants grafted on PG3, with the exception for sulphur, there was a reduction in the uptake between 6 and 26 %, while there was an increase between 31 and 112 % with plants grafted on Beaufort. Overall, considering the four grafting combinations, the most important variations were recorded for phosphorous, calcium and sulphur, whose uptake doubled on passing from plants grafted on PG3 to those grafted on Beaufort.

The uptake per ton of marketable tomato fruit showed, excepting sulphur, variations comprised between −19 and +33 %. Such variations, though appreciable, were not statistically significant.

In eggplant, the effects on the uptake were even more manifest than those recorded on tomato (Table 3). The nitrogen, potassium and magnesium uptake were higher or lower than the control in relation to the adopted rootstock. For the other elements instead, there was an increase in uptake regardless of the rootstock; such variations were more moderate in plants grafted on PG3 and more evident in those grafted on Energy. The most important effects on the amount of removed nutrients were recorded for phosphorous, calcium and sulphur, for which the absorption of plants grafted on Energy increased by 140, 190 and 290 % compared to the control. The uptake per marketable product showed significant variations only for nitrogen, phosphorous, calcium and sulphur. For

Table 2. Macronutrient content in self-grafted plants (mg g^{-1} of dry matter) [mean ± SE; n=4].

	N	P	K	Ca	Mg	S
Tomato	20.5 ± 0.3	2.7 ± 0.10	31.7 ± 0.8	14.1 ± 1.1	2.2 ± 0.1	3.7 ± 1.40
Eggplant	24.4 ± 0.7	1.1 ± 0.01	26.5 ± 7.0	5.2 ± 1.4	1.5 ± 0.6	0.9 ± 0.01

(1)Different letters represent significant differences according to least significant difference (P≤0.05).

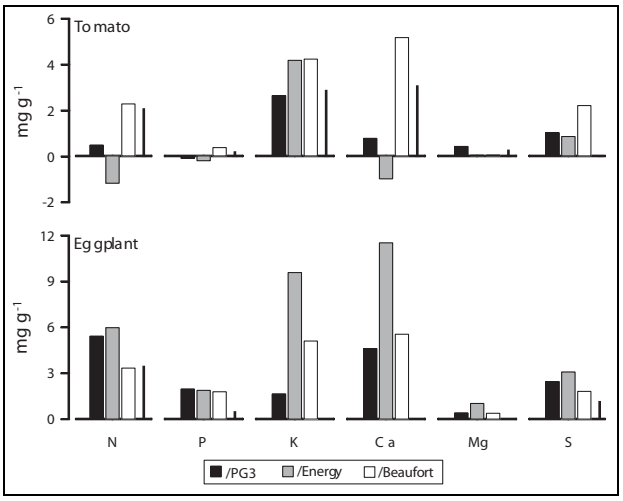


Fig. 2. Variations (mg g^{-1} of dry matter) of the nutrient content in comparison to self-grafted plants [vertical bars when present indicate least significant difference for P≤0.05].

the plants grafted on Energy, in particular, the amount of the four elements per ton of marketable production increased from 50 to 300 %.

Discussion and Conclusion

Numerous papers in literature demonstrate the important effects on the productive response of tomato and eggplant that may be determined by the resistance of rootstocks to soil borne diseases (Dufour and Taillens 1994; Reist et al. 1996; Ioannou 2001) and to enhanced scion vigour (Zhao et al. 1997; Zhou et al. 2001). In our research, the effects of rootstocks on fruit production were not so evident; this probably because of the absence of adverse biotic agents due to soil sterilization. With reference to plant vigour and epigeous dry biomass, self-grafted tomato plants and those grafted on intraspecific rootstocks (PG3 and Energy) were less vigorous and produced less dry epigeous biomass than tomato grafted on interspecific rootstock (Beaufort). However, converse results are found in tomato and eggplant when Beaufort was used, proving the interaction between scion and rootstock. In this regard, working with tomato grafted on two species (tomato and scarlet eggplant) Oda et al. (1996) found a depressive effect on growth and yield when scarlet eggplant was used; this was related to potential water deficiency caused by poor vascular connections and/or small root systems. A lower hydraulic conductivity was observed in tomato by Weng (2000) using *Solanum mammosum* as rootstock in comparison to tomato species. In our research, all adopted rootstocks did not manifest problems related to nutrient uptake as revealed by the generally positive variation of the nutrient content on grafted plant tissues in comparison to the self-grafted one. The influence of the grafting combination on the macroelement content of the plant tissues concurs with that observed by other authors on melon, water melon and tomato (Atsushi et al. 1994; Teruo and Hiromichi 1994; Ruiz et al. 1997; Santa-Cruz et al. 2001).

According to some authors, the diverse capacity of nutrient uptake and assimilation seems to play an important role among the mechanisms determining different vigour in grafted plants (Chaplin and Westwood 1980; Kato and Lou 1989). However, in this research a positive relationship between biomass production and macronutrient concentration of the epigeous biomass was only observed for tomato grafted on Beaufort.

Nutrient uptake per hectare showed notable changes between the different grafting combinations; this was especially observed for phosphorous, calcium and sulphur for which the variations ranged between 100 and 300 %. The variability in the uptakes, observed in relation to the rootstocks, the scion and the macronutrient, seems at times ascribable to a differentiated absorption capacity of nutrients, expressed by varying concentrations of these in

Table 3. Uptake of macronutrients kg ha^{-1} and kg $^{-1}$ of marketable product in tomato and eggplants in relation to the scion/rootstock combination.

/ rootstock	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
	Uptake in kg ha^{-1}						Uptake in kg t^{-1} of marketable product					
Tomato												
Self-grafted	145 b	19 b	224 bc	99 b	16 b	26 b	2.4	0.31	3.7	1.6	0.3	0.4
/ PG3	116 b	14 c	189 c	82 b	15 b	26 b	2.1	0.25	3.4	1.5	0.3	0.5
/ Energy	132 b	17 b	245 b	90 b	16 b	31 b	2.2	0.28	4.1	1.5	0.3	0.5
/ Beaufort	212 a	28 a	334 a	179 a	21 a	55 a	2.6	0.34	4.0	2.2	0.3	0.7
Eggplant												
Self-grafted	265	12 b	288 ab	56 b	17	10 c	3.1 b	0.14 b	3.4	0.7 b	0.2	0.1 c
/ PG3	245	25 a	231 b	80 ab	16	27 b	3.8 ab	0.39 a	3.6	1.3 b	0.3	0.4 b
/ Energy	296	29 a	352 a	163 a	25	39 a	5.0 a	0.48 a	5.9	2.7 a	0.4	0.7 a
/ Beaufort	274	29 a	312 ab	106 ab	19	27 b	4.1 ab	0.43 a	4.7	1.6 ab	0.3	0.4 b

(1)Different letters represent significant differences according to least significant difference (P≤0.05).

the plant tissues, at others to different plant vigour expressed by the variable biomass production. The observed uptake variations agree with the results of CHAPLIN and WESTWOOD (1980), who have traced the different macronutrient content of the leaves on tree crops, to a different absorption capacity of nutrients by the rootstock, as well as the genetic characteristics of the scion. This is in accordance with numerous researches that indicate a different macronutrient uptake in relation to the cultivars (HO et al. 1995; MORENO et al. 1999; THAKUR et al. 2000).

If related to the marketable product, the macronutrient uptake in tomato was not different between the treatments and similar to those found by HEDGE (1997). In eggplant, different amounts of nitrogen, phosphorus and calcium are necessary to obtain the same quantity of commercial products, since the uptakes of these macroelements in the grafted plants are higher than in the control, as also observed by HEDGE (1997).

In conclusion, the results of the research lead to affirm that the rootstock may influence plant vigour and nutrient content. Therefore, when grafted plants are used, the fertilization should be adapted to the different uptakes in relation to grafting combinations, not only to improve the productive results of the crop, but also to reduce the amount of elements that are not absorbed by the crop and which may become a cause of environmental pollution.

Acknowledgements

Paper partially supported by the ECOPONICS project and financed by the European Union, [INCO-MED 2 (1998-2002), Project N° ICA3-CT-2002-10020 (2003-2006)]. This work is to be attributed in equal parts to the authors.

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Received June 24, 2004 / Accepted September 12, 2005

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