ROOTSTOCK-SCION INTERACTIONS IN THE CUCUMBER: IMPLICATIONS FOR CULTIVATION AND BREEDING

A.P.M. den Nijs
Institute for Horticultural Plant Breeding (IVT)
P.O.B. 16
6700 AA Wageningen
The Netherlands

Abstract

Grafting cucumbers onto low temperature tolerant rootstocks *Cucurbita ficifolia* and *Sicyos angulatus* promoted vegetative growth and early fruit production at suboptimal temperatures in winter. The positive effect of grafting onto *C. ficifolia* on length growth and leaf initiation depended on the genotype of the scion. Lines which benefit much from the grafting may possess a relatively inefficient root system to sustain growth of the shoot.
At normal growing temperature in winter, *S. angulatus* as a rootstock drastically reduced leaf necrosis of powdery mildew resistant cucumbers, especially when the plants were grown on rockwool. The reduction of necrosis of the leaves was accompanied by a higher fruit yield. In rockwool grown plants, the concentrations of Mg, Mn and Cu in the xylem sap were much higher in grafted plants, while no clear systematic differences were found in plants grown in soil.
Further studies may possibly demonstrate a relation between these differences in the xylem sap and the intensity of necrosis. Detailed studies of rootstock-scion interactions could result in lower costs for the glasshouse cucumber cultivation.

Rootstock *Cucurbita ficifolia* promotes growth and production at low temperature

During the last three winter seasons grafting experiments at the IVT have demonstrated, that the rootstock *Cucurbita ficifolia* promotes vegetative growth and increases early fruit yield of cucumber lines and cvs grown at low temperature. Preliminary results of such trials were reported (den Nijs, 1980, 1982).
In the present contribution some results of a grafting experiment carried out in 1982/1983 are presented. The trial involved nine low temperature adapted breeding lines and cv Farbio. Air temperature was 20°C/15°C D/N, and soil temperature was 20°C throughout the experiment.
Seeds were sown 5-11-1982. Half of the plants were grafted on 10-11-'82 according to the approach grafting method (den Nijs, 1980). The grafts were allowed to take during 10 days at 20°C constant, after which the cucumber stem was cut away under the graft union. On 9-12-1982 seven replications of paired grafted and non-grafted control plants per line were planted in the glasshouse. First measurements were taken on 13-12-1982. The leaf area per plant was estimated by multiplying width and length of each individual leaf (Liebig, 1978). Plant growth and fruit production were recorded per plant, and results were analysed by analyses of variance.

Table 1. Effect of grafting on initial plant size, vegetative growth and fruit production of 10 cucumber lines grown at low temperature, and the significance of the effects of grafting, lines and their interaction.

Character	Grafted plants	Non-grafted plants	Significance[1] of effects: Grafting	Lines	G x L
At planting time (13/12/1982)					
1. Plant length (cm)	22.4	20.9	n.s.	++	++
2. Number of leaves	4.0	3.7	++	++	n.s.
3. Leaf area (cm^2)	239	228	n.s.	++	n.s.
From planting until 1/2/1983					
4. Mean length growth ($cm.day^{-1}$)	2.2	1.7	++	++	+
5. Leaf initiation rate (day^{-1} * 10)	2.2	1.8	++	++	+
6. Leaf area growth ($cm^2.day^{-1}$ * 10)	19.8	17.2	++	++	n.s.
At last harvest (31/3/1983)					
7. Number of fruits per plant	6.4	5.0	+	++	n.s.
8. Total fruit yield (kg)	1.53	1.09	++	++	n.s.

1)+: significant at p = 0.05 ++: significant at p = 0.01

The average effect of grafting on several aspects of vegetative growth and fruit production of the 10 lines is presented in Table 1. In the same table the significance of the statistical effects of grafting, of the lines, and of their interaction is indicated as deduced from the analyses of variance. Four days after planting (13-12-1982) the grafted plants and the non grafted controls did not differ with respect to plant length and total leaf area. The number of leaves of non-grafted plants was lower than that of grafted plants. The lines differed very significantly for all traits as could be expected from the choice of the materials.

Grafting promoted plant length growth, leaf initiation rate and leaf area growth during the period from planting until 31-1-1983 very significantly. The positive effect of the grafting depended on the line with respect to length growth and leaf initiation, some lines benefitting much more from the rootstock than others. Grafting also promoted fruit production of the lines at low night temperature, the increase in total fruit weight being the most significant. The lines differed greatly for fruit yield, and no significant interaction effect for either production trait was obtained.

The reaction of the individual lines to grafting is illustrated in Table 2, which contains the average plant length of grafted and control plants at 31-1-1983, and the total fruit weight per plant two months later. Although no statistically significant interaction between the grafting effect and the lines effect was found for fruit weight, the differences between control and grafted plants ranged from zero (line 5) to 0.8 kg (lines 2 and 3).

Breeding lines 2, 3 and 7 reacted especially favourably to grafting with respect to plant length. By contrast, lines 9 and 10 attained an almost equal plant length irrespective of their root system. Some high yielding lines (2, 3, 4 and 6) appeared to benefit much from the grafting. As the root system of C. ficifolia apparently stimulated the shoot growth of these lines, their own roots seemed insufficiently strong to meet the demands made by the shoots. It will be worthwhile to search for genotypes of cucumber, which grow and produce well at low temperature, and also possess a strong root system to support such growth of the shoot. Line 9 with its similarly strong growth on its own root and on C. ficifolia may possess such a good root system. Reciprocal grafting experiments involving such diverse genotypes of cucumber might help to distinghuish between root and shoot potential, as was demonstrated in the tomato (Zijlstra et al. 1984). However grafting cucumber onto cucumber proved to result in weak transplants which could not withstand the harsh environment of low temperature cultivation (den Nijs, unpublished results).

Genetic recombination between genotypes with outstanding shoots and roots may offer possiblities for selection of genotypes which grow and produce well at low temperature without the necessity of laborious grafting. Until such cvs are available, it appears to be profitable to use grafted plants for better yields at low temperatures in winter cultivation. This is especially true in cultures without soil heating, because the stimulative effect of the rootstock appeared to be larger at lower soil temperatures (den Nijs, 1980, 1982). The insensitivity of the vegetative growth of C. ficifolia to root temperature was documented in solution culture experiments (Tachibana, 1982). The sap stream from the roots through the stem of this species was also

Table 2. Effect of grafting onto *C. ficifolia* on plant len[gth] and fruit production of ten cucumber lines grown at 20°C da[y] and 15°C night.

Line	Plant length (m) at 1/2/83 (m) grafted	Plant length (m) at 1/2/83 (m) control	Total fruit weight until 31/3/83 (kg) grafted	Total fruit weight until 31/3/83 (kg) control
Farbio	1.2	1.0	1.2	0.9
2	1.5	1.1	2.2	1.4
3	1.5	1.1	2.0	1.2
4	1.6	1.3	1.8	1.3
5	1.3	1.1	0.9	0.9
6	1.5	1.2	2.1	1.4
7	1.3	0.8	1.5	0.5
8	1.4	1.2	0.9	0.7
9	1.4	1.3	1.2	1.0
10	1.2	1.1	1.6	1.3
Average	1.4	1.1	1.5	1.1

Table 3. Number of fruits (yield in kg) per plant at 12 weeks from planting of grafted and non-grafted cucumbers grown at low and normal temperature.

Cv/line	Corona	IVT-79345	IVT-79349
		20°C/12°C D/N	
Root system			
own root, non-grafted	3.3 (1.3)	7.0 (1.9)	8.1 (2.1)
C. ficifolia	4.7 (1.8	7.4 (2.0)	10.7 (2.4)
S. angulatus	5.0 (2.0)	8.8 (2.4)	10.8 (2.7)
		23°C/20°C D/N	
own root, non-grafted	9.3 (3.7)	12.5 (3.3)	11.0 (3.2)
C. ficifolia	7.7 (3.0)	11.0 (3.1)	8.7 (2.5)
S. angulatus	8.2 (3.2)	11.4 (3.2)	10.8 (3.2)

less affected by temperature than that of the cucumber (den Nijs et al, 1984).

Potential of *Sicyos angulatus* as a rootstock

In a separate grafting trial seven different cucurbit rootstocks were tested for their capacity to stimulate the growth of the cucumber at low temperature. Three cucumber genotypes grafted onto each of the rootstocks were grown with 10 replications in heated soil (20°C) at 20°C/12°C D/N temperature and another 10 replications at 23°C/20°C D/N. Planting was on 21-12-1981, and grafting, growing and note taking proceeded as described above.

Fruit yields of grafted and non-grafted plants of cv Corona and two IVT-breeding lines are listed in Table 3. Only two rootstocks are presented, viz. the best accession of *C. ficifolia* and a new rootstock, *Sicyos angulatus* L. All other rootstocks were less successful. At low temperature, both rootstocks stimulated production and *S. angulatus* (S. a.) did so more than *C. ficifolia* (C. f.). The breeding lines yielded better than cv Corona, and the benefit from grafting appeared to depend on the line, as in the former trial. The plants of cv Corona on S. a. produced approximately the same average fruit weight as the breeding lines on their own root. At normal temperature the plants of cv Corona on their own root outyielded all other entries. C. f. clearly had a negative effect, while that of S. a. was on average slightly negative.

It becomes clear from these and other more recent results, that S. a. stimulates growth and production at low temperature at least as well as C. f.. This cucurbit with its very distinct morphology is known as the "bur cucumber" and originates from Central America. It has been used for some time in Japan as a rootstock in glasshouse cucumber cultivation on cold soils. The growth stimulation of this rootstock is remarkable, because it grows as a very slender, trailing vine, which is much less robust than e.g. C. f. Grafting is rather tedious, even more so because germination of the hard seeds is often erratic. Despite the disadvantages of the species in grafting, it has stirred some interest in practical cucumber growing. Recent trials at the Glasshouse Crops Research and Experiment Station at Naaldwijk (Netherlands) with grafted cucumbers in late spring cultures showed a higher early and total fruit yield of plants grafted onto S. a. than those on C. f. or on their own roots (v. Uffelen, 1984). In a similar late spring planting at Bamberg (FRG) the extra yield of S. a. grafted plants could be attributed to the resistance of this species to root knot nematodes (Hönick, 1984). In seedling tests carried out at our institute S. a. also proved to be resistent to nematodes as well as to black root rot (Boukema, unpublished results). The use of S. a. as a rootstock is therefore especially worthwhile in cultures on cold soils where soil desinfection is not feasible and air temperatures may reach suboptimal levels.

Necrosis of powdery mildew resistant (pmr) cucumber cvs

The introduction of glasshouse cucumber cvs. with resistance to powdery mildew (*Sphaerotheca fuliginea*) is severely hampered by the occurrence of leaf necrosis of these cvs. in the early heated cultures. Although the severity of the necrosis differs amongst

cvs, none of 14 pmr cvs tested recently at the IVT remained completely free of this adverse physiological disorder (den Nijs, 1983). The ever increasing use of rockwool instead of soil in cucumber cultivation aggravates the problem since necrosis occurs earlier and more severely under these conditions (den Nijs, 1983).
In recent grafting trials of pmr cvs grown on rockwool and in soil during the winter season at low light intensity and at normal temperature, S. a n g u l a t u s drastically lowered the intensity of necrosis of all five pmr cvs tested (den Nijs, 1984). Some results of these cvs and cv Farbio on rockwool are summarized in Table 4.

Although these results will be more fully treated elsewhere, the conclusion can be drawn that S. a. reduced the intensity of necrosis in pmr cvs at least by two thirds, and in plants grown on rockwool even more. Rootstock C. f. did not show this effect. There was a close negative correlation of the intensity of necrosis with fruit yield, with plants on S. a. having the highest yields. The use of this rootstock thus offers also interesting prospects for early cultures of pmr cucumbers at low light intensity.

Chemical analyses of plant sap

In an attempt to find clues to the nature of the observed rootstock effects, the xylem sap of a number of plants was analysed at the conclusion of the above experiment. Early in the morning the plants of cv Farbio and line 81 were carefully cut from the roots at about 15 cm with a razor blade. After the bleeding had started a wick of chromatography paper was placed on the stem surface, so that the sap could be collected in a 25 ml plastic cup. After two hours of bleeding the weight of the sap was measured, and the concentration of solutes was determined by the lowering of the freezing point in an Osmomat apparatus. The osmolarity could then be calculated. Sap of all 10 plants per treatment was thereafter combined, and sent to the Glasshouse Crops Research and Experiment Station for further analyses. Some results are summarized in Table 5, for plants grown on rockwool and in full soil.

The osmolarity of the sap of soil grown plants was slightly higher than of those on rockwool. The osmolarity of S. a.-plants on rockwool was always higher than the others, and in the same range as that of soil grown plants. The three elements Mg, Mn and Cu were the only to show variation between treatments, so NO_3, K, Ca, Fe, Zn and B are not discussed here.

The Mg-concentration was more than twice as high in soil grown plants than in rockwool. For the Mn-concentration the reverse was found. The concentration of Mg in the nutrient solution in the rockwool mat at the same time was 2.2. mmol/l., and that of Mn only 4.0 mol/l., so Mn appears to be preferentially taken up by the rockwool plants. The plants on their own root on rockwool contained always less Mg and Mn than those grown on either rootstock. S.a.promoted Mg in line 81, which coincides with a large decrease in necrosis. In the soil grown plants the rootstocks also increased the Mn concentration, but the Mg concentration was always higher in the plants on their own roots. These differences seem to have no relationship to the differences in necrosis of these plants. The concentration of Cu was evidently low in the control plants on rockwool. Grafting them onto either rootstock increased

Table 4. Effect of rootstock S. a n g u l a t u s (S.a.) on leaf necrosis and fruit yield at 10 weeks from planting of five pmr cvs and cv Farbio grown on rockwool.

Cv	Necrosis*		Fruit number		Yield (kg)	
	Own root	S.a.	Own root	S.a.	Own root	S.a.
79	2.40	0.91	3.5	3.8	1.1	1.4
80	2.65	0.40	3.8	4.6	1.1	1.4
81	3.33	1.08	2.6	4.5	0.8	1.3
82	1.64	0.70	2.6	5.0	0.7	1.3
84	2.80	1.28	1.8	2.9	0.6	1.0
Farbio	1.15	0.15	3.7	4.6	1.2	1.4

* Necrosis expressed on a scale from 0 (no symptoms) to 5 (extreme necrosis and dying of leaves).

Table 5. Chemical properties of bleeding sap of cucumbers grown on different rootstocks

Cv/root system		Necrosis	Osmolarity $\times 10^{-2}$	Mg mmol l^{-1}	Mn $\mu mol\ l^{-1}$	Cu $\mu mol\ l^{-1}$
	Rockwool					
Line 81	own root	3.33	3.3	0.70	10.9	0.03
	C.f.	2.95	4.2	1.16	25.1	0.12
	S.a.	1.08	5.4	1.65	20.7	0.19
Farbio	own root	1.15	4.3	1.19	15.3	0.10
	C.f.	0.18	4.6	1.37	24.1	0.25
	S.a.	0.15	5.6	--	--	--
Average		1.47	4.6	1.21	19.2	0.14
	Soil					
Line 81	own root	1.55	5.7	4.00	4.0	0.13
	C.f.	2.23	5.7	2.18	8.4	0.15
	S.a.	0.65	5.7	2.34	8.5	0.13
Farbio	own root	0.20	5.0	3.45	3.4	0.08
	C.f.	0.33	5.2	2.07	17.2	0.23
	S.a.	0.13	5.4	--	--	--
Average		0.85	5.5	2.81	8.3	0.14

the Cu concentration to the level of soil grown plants. On the whole, there appears to be no clearcut relationship between any of the chemical properties of the bleeding sap and the intensity of necrosis in the leaves. Nevertheless, the differences in Mg, Mn and Cu warrant further study of these elements in a larger population of genotypes with different necrosis levels, Such studies might shed some light on the physiology of necrosis in pmr cucumbers, and possibly indicate ways to circumvent this serious disorder which hampers the introduction of the valuable powdery mildew resistance into early season glasshouse cucumber cultivation.

Acknowledgement

I am indebted to Drs. H. Nilwik, Ing. C. Sonneveld and Ing. D.L. Visser for statistical analyses, chemical analyses and general technical assistance, respectively.

References

HONICK, A., 1984. Neue Veredlungsunterlage für Gurken unter Glas. Gemüse 2: 45 - 46.

LIEBIG, H.P., 1978. Einflüsse endogener und exogener Faktoren auf die Ertragsbildung von Salatgurken, usw. Dissertation Univ. Hannover pp 155.

NIJS, A.P.M. den, 1980. The effect of grafting on growth and early production of cucumbers at low temperature. Acta Hortic. 118. 57 - 63.

NIJS, A.P.M. den, 1982. Grafting cucumbers for better growth at low temperatures in winter (abstr.) XXI ISHS Congress, Hamburg, BRD: p 2147.

NIJS, A.P.M. den, 1983. Nekrose bij meeldauwresistente komkommers in de vroege stookteelt. Zaadbelangen 37(5): 93 - 95.

NIJS, A.P.M. den, 1984. Ervaringen met een nieuwe onderstam voor komkommer: Sicyos angulatus. Groente en Fruit 39(40): 38 - 41.

NIJS, A.P.M. den, H. v. AS and J.E.A. REINDERS, 1983. Watertransport in cucumberplants measured by nuclear magnetic resonance (abstr.) Proceedings 10th Eucarpia Congress.

TACHIBANA, S., 1982. Comparison of effects of root temperature on the growth and mineral nutritition of cucumber cultivars and figleaf gourd. J. Japan. Soc. Hort. Sci. 51: 299 - 308.

UFFELEN, J. van, 1984. Nieuwe onderstam biedt voordelen. Tuinderij 38: 16 - 17.

ZIJLSTRA, S, A.P.M. den NIJS and N.G. HOGENBOOM, 1984. Contribution of the root system of tomato to the growth and early production at low temperature, studied in grafting experiments. Synopses IX Meeting Eucarpia tomato working group. pp 61 - 65. IVT, Wageningen, the Netherlands.