Selection of Sweet Pepper (*Capsicum annuum* L.) Genotypes for Parthenocarpic Fruit Growth

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Abstract

Yield irregularity and blossom-end-rot are major problems in sweet pepper production, which can be reduced by parthenocarpy. However no commercial parthenocarpic cultivars are available. The purpose of this study was to find parthenocarpic genotype(s) of sweet pepper with the ability to produce good quality fruits without seeds. Eleven genotypes of sweet pepper were studied at normal (20/20°C D/N) and at low night temperature (20/10°C D/N), in two greenhouse compartments from January till May. Fruit length, diameter, fresh and dry weight and number of seeds per fruit were measured. A higher percentage of parthenocarpic fruits was observed for all genotypes at low night temperature compared to normal temperature. Within the genotypes which showed at least 60% parthencarpic fruit growth at low night temperature, two groups were distinguished, which showed a different expression of parthenocarpy in response to the environment. In one set of genotypes (Line 1 and Line 3) high expressivity for parthenocarpy was found irrespective of night temperature. In another set of genotypes (Gen A, Gen B, Gen C, Lamuyo A, Lamuyo B and Bruinsma Wonder), a high level of parthenocarpy was expressed at low night temperature only, which may be due to non-viable pollen at low night temperature. Further evaluation of the latter six genotypes resulted in one genotype (Bruinsma Wonder) for which the absence of seeds only marginally influenced shape and size of fruits. These selected genotypes may eventually lead to an exploitation of parthenocarpy in sweet pepper breeding.

INTRODUCTION

Fruit harvest in sweet pepper shows a cyclic behavior: weeks of high production are followed by weeks of low production, which leads to irregular labor requirements and marketing problems. Besides this, high commercial loss has been reported in sweet pepper due to its susceptibility to blossom-end-rot (BER), a physiological disorder caused by local deficiency of calcium during the early phase of fruit development (Bangerth, 1979). Parthenocarpy is a physiological phenomenon where an ovary grows into a fruit without fertilization (Varoquaux et al., 2000). It has been proposed as a possible solution to reduce yield flushing and to minimize BER in sweet pepper (Heuvelink and Körner, 2001). These authors reported that auxin application on unpollinated flowers of sweet pepper resulted in seedless fruits and a more regular production than in non-treated plants. Growth regulators inducing parthenocarpy have been reported for a large number of horticultural species (Schwabe and Mills, 1981). A high percentage of parthenocarpic fruit set was observed when sweet pepper plants were grown at low night temperature (8-10°C) (Cochran, 1936). Low temperature may impair pollen fertility (Polowick and Sawhney, 1985) causing hampered seed set (Rylski, 1973) and leading to the production of seedless fruits. The parthenocarpic fruits obtained either by hormone application or by preventing fertilization at low night temperature showed a deformed fruit shape (Bosland and Votava, 1999) and a reduced fruit size (Rylski, 1986). Genetically controlled parthenocarpy has been observed in tomato (Vardy et al., 1989), banana (Qrtiz and Vuylsteke, 1995) and cucumber (Rudich et al., 1977). A transgenic approach has been successfully applied for obtaining parthenocarpic fruits in eggplant and tobacco (Rotino et al., 1997). Parthenocarpy is a highly appreciated trait by consumers and process companies, not only because of easy processing (e.g. cut slices of sweet pepper) in a growing market (Gonzalez et al., 2004) but also because of an improved shelf life, higher sugar and higher soluble solid content in fruit (Varoquaux et al., 2000). Male sterility can be used for the commercial cultivation of a parthenocarpic genotype (Shifriss and Eidelman, 1986), but first a sweet pepper genotype expressing parthenocarpic gene(s) along with marketable fruit appearance should become available.

In this research, selected genotypes of sweet pepper were evaluated at normal and low night temperature to test their ability to produce parthenocarpic fruits. Seeded and seedless fruits of these genotypes were compared in order to find genotype(s) where the absence of seeds hardly influences the commercial quality of the fruits. This selected genotype(s) can be used as a candidate line in a breeding program for a parthenocarpic cultivar reducing yield flushing and minimizing the incidence of BER.

MATERIAL AND METHODS

Seeds of ten genotypes and 'Mazurka' (Table 1) as a standard cultivar of sweet pepper (*Capsicum annuum* L.) were obtained from commercial breeders and a Chinese colleague (Xue Linbao, Yangzhou University). These genotypes were expected to have the capacity to produce seedless fruits at low night temperatures. Seeds were sown on 23rd of November and seedlings of all genotypes were grown on Rockwool cubes with regular supply of nutrient solution. The crop was planted on Rockwool slabs (2.5 plants m^{-2}) on 23rd January 2006 in two compartments of a multispan Venlo-type glasshouse at Unifarm, Wageningen, The Netherlands and plants were pruned to two main stems. The genotypes were arranged in a randomized block design in both compartments, which consisted of three plots of 12 plants per genotype in each block (except Lamuyo B; 2 plots of 6 plants in each block) and 'Mazurka' was planted in two rows on the borders. From 13th of February onwards, two different temperature set points were given: 20/20°C D/N and 20/10°C D/N, however realized low night temperature was not always strict at 10°C. Average realized temperatures were 21°C and 13°C, for day and night, respectively. Normal night temperature setpoint of 20°C was realized. All flowers were left to develop until fruit ripening or natural abortion. Ripe fruits were harvested and their length, diameter (maximum distance across the shoulders) and fresh weight were measured. Also, an evaluation was performed for presence of knots: fruits with at least 50% reduction in fresh weight compared to seeded fruits (average of fresh weight of seeded fruit at 20°C) (Fig. 1). Then fruits were cut transversely and observations were made for carpelloid structure and number of seeds was counted. Finally, fruits were dried in a ventilated oven for two hours at 70°C followed by ten hours at 105°C and again two hours at 70°C to obtain the dry weight of individual fruits. The experiment ended on 31st May 2006.

RESULTS

A higher percentage of parthenocarpic fruits was observed for all genotypes at low night temperature as compared to normal temperature (Table 1). For Line 1 and Line 3, percentage of parthenocarpic fruit was high at both low and normal night temperature, while substantial parthenocarpic fruit growth was observed for Lamuyo A, Lamuyo B, Gen A, Gen B, Gen C and Bruinsma Wonder only at low night temperature. Reduction in percentage of carpelloid growth was observed at low night temperature for all the genotypes except for Serena, Line 1 and Line 3. For Serena, observed percentage of carpelloid growth was low at both temperature regimes, while 80-90% fruits of Line 1 and Line 3 were with carpelloid growth (Table 2; Fig. 2). Percentage of knots was high for all the genotypes at low night temperature, however the highest percentage was observed for Serena (56%) and the lowest for Bruinsma Wonder (9%). For the other genotypes, it was between 20 and 40%. Five genotypes (Lamuyo A, Gen A, Gen C, Bruinsma Wonder and Mazurka) showed only a small difference in length/diameter ratio between seedless and seeded fruit at low night temperature (Table 3). Fresh weight of seedless and seeded fruit was the same for Bruinsma Wonder and almost the same for Gen

C and dry weight was the same for seedless and seeded fruit of Lamuyo B and Gen C and almost the same for Lamuyo A, Gen A and Bruinsma Wonder at low night temperature (Table 4).

DISCUSSION

Expression of parthenocarpic fruit growth clearly showed genotypic variation. It was high for Line 1 and Line 3, suggesting the presence of parthenocarpic gene(s) expressed irrespective of night temperature. Most of the parthenocarpic fruit of Line 1 and Line 3 showed carpelloid growth inside the fruit: an internal growth abnormality also reported in *Arabidopsis thaliana* by Vivian-Smith et al. (1999). These authors presumed that vascular strands, which are a good marker of auxin-induced fruit development, automatically joins and forms in such cases where the ovule is homeotically converted into a carpel-like structure. However, it is not yet clear whether carpelloid growth is a linked trait or a pleiotropic effect of parthenocarpic gene(s) or that some other physiological or molecular change leads to this malformation. A high percentage of knots was found for all genotypes, except for Bruisma Wonder, at low night temperature (Table 2), where most likely the non-viability of pollen increased the percentage of unfertilized fruit. It has been reported that unfertilized fruit has poor sink strength (Nielsen et al., 1991) and deformed fruit shape (Rylski, 1973; Bosland and Votava, 1999) as compared to fertilized ones. This agrees with the high percentage of knots at low night temperature. Also Rylski (1986) reported that seedless fruits produced at low night temperature reached only half to one fourth of the weight of the corresponding fertilized ones.

Parthenocarpic fruit growth was observed in particular for Gen A, Gen B, Gen C, Lamuyo A, Lamuyo B and Bruinsma Wonder at low night temperature (Table 1), which may be due to non viable pollen as reported by Rylski (1986). These genotypes were further evaluated for selection of genotype(s) where absence of seeds has minimal effect on marketability (size and weight) of fruits. Lamuyo A, Gen A, Gen C and Bruinsma Wonder showed only a small difference and 'Mazurka' showed no difference in size between seeded and seedless fruit (Table 3) and only a marginal difference for fresh weight between seeded and seedless fruit was observed for Bruinsma Wonder and Gen C at low night temperature (Table 4). These results confirm the findings of Picken (1984) that seeds are one of the factors for determining the shape and size of fruit but not the only one.

High expressivity of parthenocarpy was observed for Line 1 and Line 3; however, carpelloid growth appeared in these lines as a linked trait or pleiotropic effect of parthenocarpic gene(s) or as a result of some physiological or molecular changes. Bruinsma Wonder showed low percentage of knots and also minor differences in fruit weight and shape between seedless and seeded fruits at low night temperature. Therefore Bruinsma Wonder is candidate genotype for further research and is proposed to be used in a breeding program for introgression and modulation of parthenocarpy in existing commercial pepper cultivars.

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Literature Cited

Bangerth, F. 1979. Calcium-related physiological disorders of plants. Ann. Rev. Phytopathol. 17:97-122.

Bosland, P.W. and Votava, E.J. 1999. Peppers: vegetable and spice capsicums. Crop Production Science in Horticulture vol. 12, Wallingford, Oxon: CABI Publishing.

Cochran, H.L. 1936. Some factors influencing growth and fruit setting in the pepper (*Capsicum annuum* L.). Mem. Cornell Agr. Expt. Sta. 190:1-39.

Gonzalez, A.G.A., Ayala, Z.J.F., Ruiz, C.S., Acedo, F.E. and Diaz, C.M.E. 2004. Effect of

temperature and modified atmosphere packing on overall quality of fresh-cut bell peppers. Food Sci. and Tech. 37:817-826.
Heuvelink, E. and Körner, O. 2001. Parthenocarpic fruit growth reduces yield fluctuation and blossom end rot in sweet pepper. Ann. Bot. 88:69-74.
Nielsen, T.M., Skjaerbaek, H.C. and Karlsen, P. 1991. Carbohydrate metabolism during fruit development in sweet pepper (*Capsicum annuum*). Physiol. Plant. 82:311-319.
Picken, A.J.F. 1984. Review of pollination and fruit set in the tomato (*Lycopersicon esculentum* Mill.). J. Hort. Sci. 59:1-13.
Polowick, P.L. and Sawhney, V.K. 1985. Temperature effects on male fertility and flower and fruit development in *Capsicum annuum* L. Scientia Hort. 25:117-27.
Qrtiz, R. and Vuylsteke, D. 1995. Effect of parthenocarpy gene P1 and ploidy in bunch and fruit traits of plantain and banana hybrid. Heredity 75:460-465.
Rotino, G.L., Perri, E., Zottini, M., Sommer, H. and Spena, A. 1997. Genetic engineering of parthenocarpic plants. Nature Biotech. 15:1398-1401.
Rudich, J., Baker, L.R. and Sell, H.M. 1977. Parthenocarpy in *Cucumis sativus* L. as affected by genetic parthenocarpy, thermo-photoperiod, and femaleness. J. Amer. Soc. Hort. Sci. 102:225-228.
Rylski, I. 1973. Effect of night temperature on shape and size of sweet pepper (*Capsicum annuum* L.). J. Amer. Soc. Hort. Sci. 98:149-152.
Rylski, I. 1986. Pepper (*Capsicum*). p.341-53. In: S.P. Monselise (ed.), CRC handbook of fruit set and development, CRC Press, Boca Raton, Fl, USA.
Schwabe, W.W. and Mills, J.J. 1981. Hormones and parthenocarpic fruit set: A literature survey. Hort. Abstr. 51:661-699.
Shifriss, C. and Eidelman, E. 1986. An approach to parthenocarpy in peppers. Hort. Sci. 21:1458-1459.
Vardy, E., Lapushner, D., Genizi, A. and Hewitt, J. 1989. Genetics of parthenocarpy in tomato under a low temperature regime: I. Line RP75/59.Euphytica 41:1-8.
Varoquaux, F., Blanvillain, R., Delseny, M. and Gallois, P. 2000. Less is better: new approaches for seedless fruit production. Trends Biotec. 18:233-242.
Vivian-Smith, A. and Koltunow, A.M. 1999. Genetic analysis of growth regulators induced parthenocarpy in *Arabidopsis*. Plant Physiol. 121:437-451.

Tables

Table 1. Genotypes and their origin, percentage of seedless fruit and fruit with less than five seeds/fruit observed at low (10°C) and normal (20°C) night temperature. Total number of fruit used for the measurements ranged between 94-415, except for Lamuyo B (34-79 fruits).

Genotype	Origin	zero seeds/fruit (%)		<5 seeds/fruit (%)	
		10°C	20°C	10°C	20°C
Line 3	China	100	73	100	82
Line 1	China	96	49	97	91
Lamuyo A	De Ruiter Seeds	78	10	84	16
Lamuyo B	De Ruiter Seeds	70	0	89	3
Gen A	Vilmorin	64	2	83	6
Gen B	Vilmorin	70	10	88	15
Gen C	Vilmorin	63	7	83	31
Serena	Rijk Zwaan	51	9	74	12
Bruinsma Wonder	PRI (2004001)	66	13	89	24
Orlando	De Ruiter Seeds	9	2	22	2
Mazurka	Rijk Zwaan	20	5	33	7

Table 2. Percentage of fruits with carpelloid internal growth and average percentage of knots observed at low (10°C) and normal (20°C) night temperature for 11 genotypes of sweet pepper.

Genotype	% Carpelloid		% Knots	
	10°C	20°C	10°C	20°C
Line 1	82	82	42	15
Line 3	83	92	19	4
Lamuyo A	42	80	34	4
Lamuyo B	46	56	26	0
Gen A	35	69	25	1
Gen B	46	49	26	5
Gen C	44	66	41	8
Serena	32	26	56	9
Bruinsma Wonder	76	91	9	5
Orlando	3	41	23	2
Marzurka	21	27	20	4

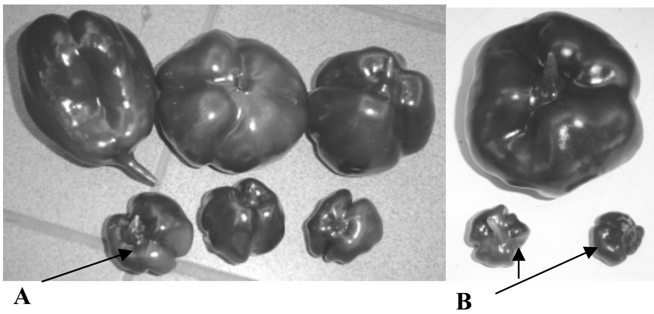
Table 3. Genotypes which expressed substantial parthenocarpy at low night temperature were evaluated along with control cultivar for length (L) and length/diameter ratio (L/D) of seedless and seeded fruit at low night temperature (10°C).

Genotypes	Seedless		Seeded	
	L (mm)	L/D	L (mm)	L/D
Lamuyo A	82	1.12	100	1.32
Lamuyo B	84	1.11	112	1.63
Gen A	81	1.17	98	1.32
Gen B	97	1.16	126	1.61
Gen C	55	0.70	67	0.86
Bruinsma Wonder	75	0.91	87	1.14
Marzurka	64	0.91	71	0.94

Table 4. Average fresh weight (g) and dry weight (g) of seeded fruit (S) and ratio of fresh weight and dry weight between seedless and seeded fruit (SL/S) at low night temperature (10°C), for genotypes which showed substantial parthenocarpy at low night temperature and control cultivar 'Mazurka'.

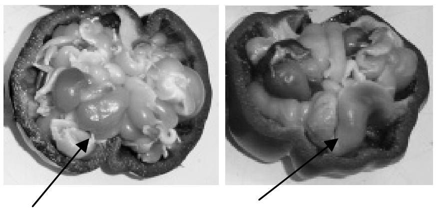
Genotypes	Fresh weight (g/fruit)		Dry weight (g/fruit)	
	S	SL/S	S	SL/S
Lamuyo A	158	0.80	12	0.92
Lamuyo B	159	0.86	11	1.00
Gen A	153	0.74	12	0.92
Gen B	214	0.86	16	0.75
Gen C	133	0.92	11	1.00
Bruinsma Wonder	136	1.00	12	0.92
Mazurka	141	0.76	11	0.82

Figures



A B

Fig. 1. Shape and size of knot fruits compared to the normal fruit for Line 1 (A) and Line 3 (B). Average length and diameter for knots were 18 x 32 and 13x 24 mm for Line 1 and Line 3 respectively and average length and diameter for normal fruits were 42 x 67 and 45 x 75 mm for Line 1 and Line 3 respectively.



A B

Fig. 2. Carpelloid growth observed in most of the parthenocarpic fruits of genotype Line 1 (A) and Line 3 (B).