A PLANT BREEDING APPROACH TO ELIMINATE THE DEVELOPMENT OF CALCIUM DEFICIENCY SYMPTOMS IN SWEET PEPPER GROWING

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ABSTRACT

Plants show significant differences regarding the dynamics of the uptake and transport of the nutrients. The results of our experiments gave an explanation of the fact that the Ca^{2+} uptake and transport ability of pepper is different in each genotype. The Ca^{2+} requirement of the fruits of certain varieties is significantly higher than the amount the plant itself can take up. The determined selection and the further breeding work aimed to solve this anomaly and enable the safe growing of sweet pepper irrespectively of the $CaCO_3$ level of the soil. The basic goal of our breeding work was to improve the calcium utilization efficiency of the tomato-shaped sweet pepper variety 'PAZ' which is sensitive to calcium deficiency. Crossing with a suitable partner (Torkál F_1) resulted in a hybrid (Tokyo) the Ca^{2+} uptake, translocation and ecological adaptability of which proved to be far better compared to the free-pollinating variety. Regarding fruit quality, the hybrid did not leg behind the biological and consumers' values of the parental genotypes.

Keywords: Ca^{2+} deficiency, sweet pepper breeding, visual plant diagnosis

INTRODUCTION

In our days, sweet pepper is grown mainly in intensive vegetable production systems, in forcing facilities equipped with modern technology. Among vegetable crops, with its ca. 2000 hectares, intensive production of sweet pepper (*Capsicum annuum* L.) gives 50% of the domestic area of protected cultivation of vegetables. From this area, 150-175 thousand tons of yields are harvested each year. In Hungary, 10-12 kilograms of sweet pepper are consumed per person per year. The success of production, however, is influenced by several factors. Perturbations in nutrient supply of plants are not caused only by processes generated by nutrient deficiency of soil each case. In the formation of deficiency symptoms, inherited, endogenous characteristics of plants can also play an important role. According to MENGEL AND KIRKBY (2001), in the case of plants the nutrient uptake and utilization of which is under genetic control, the conscious selection and breeding can offer possibilities for the improvement of adaptability and yield. This idea is supported by RADEMACHER's (1937) thesis saying that such kind of varieties should be bred which successfully resist the nutrient supply disturbances occurring in the course of cultivation on the growing medium.

The deficiency symptom occurring the most frequently in the domestic pepper forcing is the so–called blossom-end rot caused by calcium deficiency. It can fully deteriorate marketing quality of the yield. Calcium occurs in plants as the salt of organic and inorganic acids, furthermore as an ion adsorbed to plasma colloids. Interacting with ß-indole acetic acid, Ca^{2+} ions have significant roles in cell elongation, furthermore in cell differentiation. Calcium is the main component of the middle lamella of the primary cell wall where it has a stabilizing role (BERGMANN, 1960; SZALAI, 1974). Abiotic stresses such as drought, heat-stress, especially in the root zone, have a significant effect in the development of calcium deficiency (TUBA ET AL., 2003). In tomato and pepper, the development of calcium deficiency is related to the transpiration rate. Low transpiration increases the number of calcium deficient fruits. Transpiration rate is also indicated by the temperature of the foliage surface (HELYES, 1990; HELYES AND VARGA, 1994). In the case of calcium deficiency, we have to make a distinction

between the real Ca^{2+} deficiency of the plants and the calcium viz. lime deficiency of the soil. According to SHEAR AND FAUST (1971), calcium deficiency can be detected in the yield even in cases when soil could cover the calcium demand of the plants. Blossom-end rot is an irreversible damage that does not recover even if calcium is immediately supplied. This is the consequence of the insufficient Ca^{2+} ion supply of the fruits (BUSSLER, 1963; WOJCIECHOWSKI ET AL., 1969; SOMOS, 1981). In domestic pepper production, the lime content of the soil must be in the range of 1-5% as determined by TERBE ET AL. (2005). LANTOS ET AL. (2010) observed that in protected cultivation, a significant difference can be found in the rate of calcium deficient fruits between growing in soil or in rockwool.
The basic goal of our selection work was to improve the calcium utilization efficiency of the tomato-shaped sweet pepper variety from Szentes, 'PAZ' which is sensitive to calcium deficiency. We have chosen a crossing partner which helped to achieve a reasonable yield even on so-called border soils which have a soil lime content diverging from the optimum of pepper cultivation.

MATERIALS AND METHODS

In our work, the 'Tokyo' hybrid was produced by the crossing of two varieties of different types. The mother was the tomato-shaped sweet pepper 'PAZ' from Szentes, which is a free-pollinating variety, while the pollinator parent was the California-type hybrid 'Torkál' F_1 (*Figure 1*).

Figure 1. The formation of blossom and fruits on the parents and on the hybrid

In the course of the cultivation tests, the extent of blossom-end rot symptoms occurring on the fruits due to Ca^{2+} deficiency was determined post-harvest via visual diagnosis. Productive characteristics studied in the 'Tokyo' hybrid and in the parental lines were as follows: fruit weight (g), 1000 grain weight (g), fruit-wall thickness (mm), length of the vegetation period (day) and susceptibility to fruit rot/gray mold *(Botrytis cinerea)*. To determine the traits, 4-4 fruits of biological maturity were collected from 12-12 plants each (*Tables 3-4*). Hybrid crossings were followed by cultivation tests performed on 6 sites of different soil lime content (*Tables 1-2*). Intensive ridge planting, foil-covered technology and the so-called Bulgarian method characteristic for the Szentes region were applied alike.

Table 1. Basic parameters of cultivation of the parents 'PAZ' and 'Torkál' F_1 in Nagymegyer and Szentes

Action	Site of selection	
	Nagymegyer	Szentes
sowing	28 March 2006	23. March 2006
pricking out	15 April 2006	22. April 2006.
planting out	10 May 2006	17. May 2006
spacing	85 + 40 x 40 cm	
population density	4 individuals/m^2	
pruning	bush form without pruning	

Table 2. Soil quality parameters of the test cultivation sites

Site	pH	Salt (m/m%)	Soil plasticity K_A	$CaCO_3$ (m/m%)	Humus (m/m%)	P_2O_5 (mg/kg)	K_2O (mg/kg)	NO_3-NO_2-N (mg/kg)
Nagymegyer	7.23	<0.02	36	5.0	0.58	1324	648	33.3
Szentes	7.60	<0.02	48	1.0	2.90	300	550	10.0
Ópusztaszer	6.98	<0,.02	60	2.32	2.34	287.6	313	65.4
Bánhegyes	7.60	<0.02	48	1.0	2.90	300	550	10.0
Mórahalom	7.40	<0.02	26	8.57	-	170	260	1.6
Japan	4.98	<0.02	60	0.5	5.70	514	763	31.4
Kyrgyzstan	7.93	<0.02	35	12.9	2.56	301	392	36.7

RESULTS

The summarized results show that during the whole growing period, symptoms of blossom-end rot never occurred on the fruits of the 'Tokyo' hybrid irrespectively of the site of production. Visual diagnosis of the fruits of the mother genotype 'PAZ' collected from six production sites showed that the occurrence of blossom-end rot was not typical in the period of the first and second harvests. In the later stages of growing, however, especially in the months June and August, symptoms of blossom-end rot could be detected on the fruits of 'PAZ' to various extents but on each growing sites (data not shown).
The frequency of blossom-end rot symptoms on 'PAZ' fruits showed significant difference (p = 0,1%) between the production sites of different soil lime content (*Tables 3-5*). As expected, the highest level of difference could be detected between the results of Japan showing the lowest and Kyrgyzstan showing the highest soil lime content (*Tables 2 and 5*).

Table 3. Averaged results of the crossing parents in Nagymegyer, at 5% soil lime content

	PAZ	Torkál F_1
blossom-end rot	above 10%	no
fruit weight	130 g	183 g
fruit-wall thickness	6.8 mm	10.8 mm
seed production	medium	excellent
susceptibility to fruit rot	susceptible	no
length of vegetation period	105 days	105 days

Table 4. Average results of the crossing parents in Szentes, at 1% soil lime content

	PAZ	Torkál F_1
blossom-end rot	above 10%	no
fruit weight	150 g	187 g
fruit-wall thickness	7.8 mm	11 mm
seed production	medium	excellent
susceptibility to fruit rot	susceptible	no
length of vegetation period	105 days	105 days

Table 5. Percentage values of the occurrence of blossom-end rot symptoms on 'PAZ' fruits depending on the $CaCO_3$ level of the production sites

Site	Blossom-end rot (%)		Significance levels		
	Mean	Standard deviation	Site	t- value	Significance level (p%)
Japan	68.75	12.9	Szentes	1.96	ns
			Bánhegyes	3.01	1
			Ópusztaszer	5.05	0.1
			Mórahalom	5.61	0.1
			Kyrgyzstan	7.30	0.1
Szentes	54.17	17.9	Bánhegyes	1.04	ns
			Ópusztaszer	2.53	5
			Mórahalom	3.65	0.1
			Kyrgyzstan	5.33	0.1
Bánhegyes	46.43	17.3	Ópusztaszer	2.04	5
			Mórahalom	2.61	5
			Kyrgyzstan	4.29	0.1
Ópusztaszer	31.25	11.3	Mórahalom	0.56	ns
			Kyrgyzstan	2.25	5
Mórahalom	27.80	12.9	Kyrgyzstan	1.68	ns
Kyrgyzstan	14.58	16.7			

Regarding fruit quality, the new hybrid did not leg behind the biological and consumers' values of the parental genotypes. Its vitamin C and carotene content was between those of the parents. Fructose content was close to equal in all of the three genotypes. Only the glucose content of the 'Tokyo' hybrid was slightly below the levels of the parents (*Table 6*). In the shaping of these features, besides breeding, the suitable ecological, light and nutrition supply conditions also had an important role, of course.

Table 6. Main quality values of the 'Tokyo' hybrid and those of the parental genotypes at the production site of Szentes

		Vitamin C (mg/100 g)	Carotene (g/100 g d.m.)	Carotene (g/100 g f.m.)	Fructose (mg/100 g d.m.)	Fructose (mg/100 g f.m.)	Glucose (mg/100 g d.m.)	Glucose (mg/100 g f.m.)
PAZ	mean	157.60	135.8	15.4	24.5	2.8	23.0	2.6
	st. deviation	8.65	56.08	5.43	0.55	0.41	1.68	0.06
Torkál F_1	mean	174.0	31.5	4.5	24.1	3.4	24.4	3.4
	st. deviation	26.58	12.38	2.35	1.16	0.64	0.82	0.57
Tokyo	mean	172.70	74.7	7.9	24.5	2.6	21.8	2.3
	st. deviation	20.81	22.18	2.33	1.21	0.17	1.68	0.22

d.m.: dry matter; f.m.: fresh matter

CONCLUSIONS

On the basis of our work performed in the summer forcing period on border-soils of different $CaCO_3$ content it can be concluded that the Ca^{2+} uptake and translocation ability of pepper is a complex trait depending also on the genotype. It can be transmitted through crossing thus in the next generation plants of good calcium uptake and healthy fruit building ability can be selected. The Ca^{2+} uptake, translocation and ecological adaptability of the hybrid proved to be by far better in contrast to the free-pollinating variety. The free-pollinating variety responded more sensitively to the changes in the ecological, nutrient, water and meteorological conditions of the area. Thus its reaction regarding calcium uptake and transfer is also more expressed.

The selection and breeding work described here can help to put an end to the formation of blossom-end rot generated by calcium deficiency in pepper.

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