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SUSCEPTIBILITY OF SWEET CORN VARIETIES TO *USTILAGO MAYDIS* (DC)

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Abstract. Extensive possibilities of sweet corn kernel's use have resulted in the growth of its cultivation area in Poland. In 2007–2009 in Research Station of Poznan University of Life Sciences at Swadzim, field trials were carried out in which the vulnerability of a dozen or so varieties of sweet corn to *Ustilago maydis* (DC) was estimated. The tested varieties were ''Basin', 'Golda', 'GSS 5022', 'Harvest Gold', 'Helena', 'Passion', 'Rana', 'Sheba', 'Sweet Talk'. Some studied maize cultivars showed different susceptibility to infestation by pathogens. The number of infected plants was estimated in the BBCH 70–75 stage. The results were expressed as the percentage of infected plants. The research showed differences in the susceptibility of the varieties to this pathogen. The presence of *U. maydis* was more dependent on prevailing in a given year meteorological conditions. Only in the case of a variety Basin low infestation translated into a significant increase in grain yield.

Key words: common smut, sweet corn, susceptibility of varieties

INTRODUCTION

Sweet corn is favorable for fresh consumption because of its delicious taste, delicate crust, and soft-sugary texture compared to other corn types. The consumers generally prefer canned sweet corn or a mixture of sweet corn with other foods. It is used as an appetizer or in salads [Erdal et al. 2011, Oktem et al. 2003]. Ear length and single ear weight as a primary; ear diameter, kernel number of ear and leaf number as a secondary could be used as the main criteria for selecting the high yielding sweet corn for improvement [Oktem 2008].

Extensive possibilities of sweet corn kernel's use have resulted in the growth of its cultivation area in Poland. The intensified threat by agrophages certainly remains under the influence of the recently observed rise of the mean air temperature in the vegetation period contributing to the increasing numbers of thermopiles pathogens causing greater maize damages which already exist on the area of our country. The maize diseases most frequently occurring in Poland include fusarioris and common smut, while among pests, there dominate: fruit fly and European corn borer [Adamczewski et al. 1997, Lisowicz 2004]. To control corn smut disease, several methods have been recommended, including crop rotation, sanitation, seed treatments, modification of fertility, and biological controls. In spite of these frequently mentioned control tactics, host resistance is the only practical method of managing common smut in areas where *Ustilago maydis* is prevalent. Soilborne teliospores are the source of inoculum of *U. maydis*: they remain viable in the soil for several years [Faske and Kirkpatrick 2015]. At low storage temperatures (-5 to

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20°C), teliospores retained their germination capacity; this capacity was reduced at 37°C and was lost at 40°C and above.

Ustilago maydis (DC) Corda occurs in areas of maize production throughout the world. It can induce the formation of tumors on all aerial organs [Banuett 1995]. The sources of inoculum are teliospores, which can survive winters on plant debris and seeds. Pathogen infects all plant parts, causing specific symptoms including silvery nodes, filled with teliospores. Although found on field corn, it is more destructive to sweet corn. The average annual loss is 3 to 5 percent, but individual fields of corn may be totally destroyed. The fungus *U. maydis* was first described in Europe in 1754 but not found to occur here until 1822 [Horst 2008]. Some corn varieties are susceptible; other varieties are tolerant or resistant. Spores germinate on corn plant surfaces, particularly in wounds that could result from hail damage or corn stalks rubbing against each other in winds. Then the outer silvery-white membrane ruptures to release thousands of brown-black spores, much like a "puffball". Although *U. maydis* can infect all aerial parts of the plant, it has a high specificity for meristematic tissues which represent sink organs and are dependent on the import of assimilates from source organs [Wenzler and Meins 1987]. The tumors that develop in infected leaves often span the entire leaf blade. Such leaf infections first hamper the establishment of C_4 photosynthesis, which results in reduced CO_2 assimilation upon tumor initiation [Horst et al. 2008]. Several Latin and Oriental cultures consider the developing smut mass (before it ruptures to release spores) a delicacy stir-fried or cooked [Pataky 1991, Valverde et al. 1993]. The economic importance of common smut usually is greater in sweet corn than in dent corn. Smut galls on ears are particularly detrimental to sweet corn because even the smallest gall reduces sweet corn quality. Also, additional costs are incurred when sweet corn is harvested and processed from fields with smut. Sweet corn hybrids usually are classified resistant or susceptible based on their response to natural infection by *U. maydis*. Natural infection also is the primary selection criterion used to eliminate smut-susceptible lines in breeding programs [Pataky 1991]. No corn varieties or hybrids are completely resistant to smut. However, there is good field resistance to the disease in maize varieties. This resistance depends on the morphology and physiology of the variety. In general, sweet corn varieties are more susceptible to *U. maydis*. Sweet corn hybrids, whose pedigrees often include New England flint germplasm, tend to be more susceptible to common smut than field corn. This may be due to differences in the genetic backgrounds of field corn and sweet corn and/or differences in the diligence with which susceptible lines have been eliminated from field corn and sweet corn breeding programs.

The purpose of this study was to see the behavior of a large assortment of sweet corn varieties to infection with common smut (*Ustilago maydis*) under natural conditions from Poland.

MATERIALS AND METHODS

This experiment was conducted in Poznan University of Life Sciences, West part of Poland during 2007 to 2009. The experimental field is located in Swadzim (52°26′ N, 16°45′ E) where the climate may be cold and often dry from May to September, with temperatures reaching 20°C, and rainfall rare. The weather, and especially precipitation levels, of the growing seasons of 2007–2009 was shaped by variability. The 2007 season started under favorable humidity conditions. Warm and moist May boosted corn growth and water was not lacking even in the summer, when needed most. The next, 2008, was not so good, neither in terms of the amount, nor of the distribution of the rainfall. The season started following two dry months of April and May with June drier still and only July relatively moist. The year 2009 brought much precipitation in May and June, but temperatures barely exceeded 15°C. The daily mean broke the mark of 20°C only in July. However, due to uneven rainfall distribution, that month did not help the corn growth, either. Figure 1 charts the air temperatures over the growing seasons of 2007–2009, with arithmetic means and coefficients of variation v_e superimposed on the bars. The temperatures were fairly uniform with means between 17.2 and 17.5°C, and variation between 15.2 and 17.5%. Figure 2 illustrates the precipitation of the 2007–2009 vegetation peri-

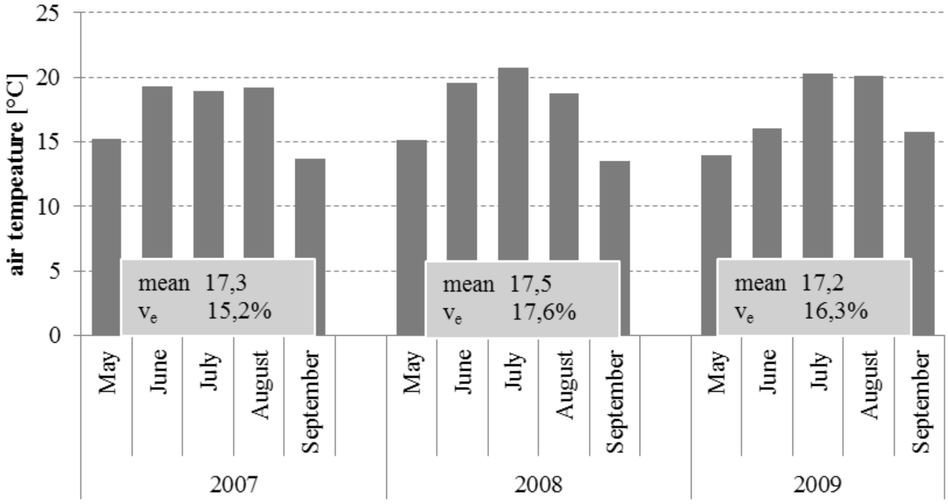

Fig. 1. Air temperatures during the vegetation period (°C)

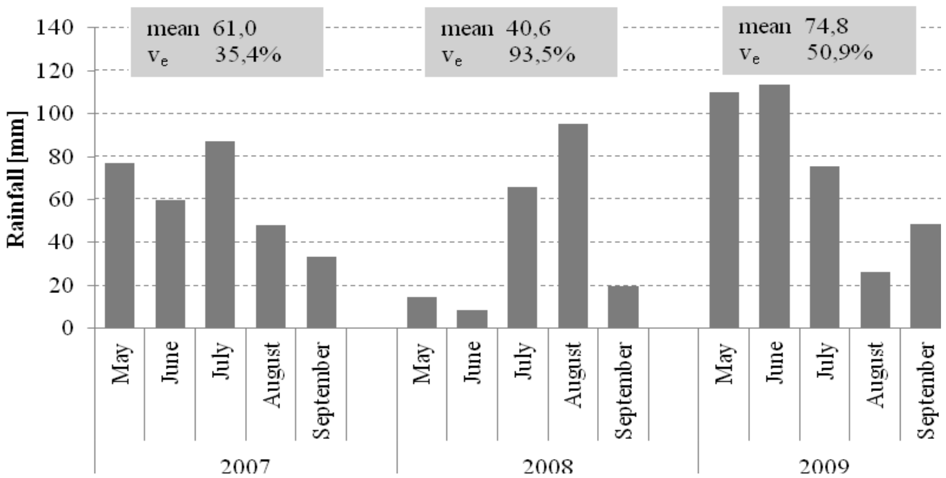

Fig. 2. Total rainfall during the vegetation period (mm)

ods, again with mean and variation measures. The average rainfall of 2009 was almost double that of 2008. This gap only widens when comparing corresponding months of May and June: the numbers were 7 and 13 times higher, respectively. The season of 2007 witnessed an elevated rainfall variation of v_e>30%, and in the following years the measure rose higher still. The year of worst weather for corn growing turned out to be the 2009, with the most severe levels of smut since the study began.

The soil of research field was mollisols loamy sands, slightly acidic. The macroelement and pH content was assessed according to research standards Regional Chemical and Agricultural Station in Poznań. Table 1 presents soil conditions in Swadzim.

Table 1. Content of nutrients and pH in the soil at Swadzim

Nutrient	2007	2008	2009
P ($mg \cdot kg^{-1}$)	80	85	96
K ($mg \cdot kg^{-1}$)	101	101	141
Mg ($mg \cdot kg^{-1}$)	70	75	66
pH ($1M_{KCl}$)	5.42	5.55	5.37

The field was ploughed and cultivated, and then prepared for planting with a single pass of a disk-harrow. The experiment was set up as a randomized complete block design with four replications. Each plot area was 25 m^{-2} (10 m × 2.5 m) and consisted of four rows. Distance between rows was 70 cm and intra row spaces were 20 cm. At sowing, 100 $kg \cdot ha^{-1}$ pure N, P, and K (15-15-15 composite) was applied to each plot and this was followed by 200 $kg \cdot ha^{-1}$ N as urea (46% N) at the 6 leaf stage. The fertilizer was placed 5 cm to the side of the seed row at a depth of 4 cm.

Biological material consist from the following varieties: 'Basin', 'Golda', 'GSS 5022', 'Harvest Gold', 'Helena', 'Passion', 'Rana', 'Sheba', 'Sweet Talk'. The study selected most often cultivated in Poland sweet corn varieties. The occurrence of the disease was observed both on the cob and the vegetative parts at the milk ripeness period (BBCH 70–75). The research material was made up of plants with symptoms of *Ustilago maydis*, arranged in 25 plants for precise estimation of the damage (25 plants from each plot × 4 replications = 100 plants of a combination). The number of diseased cobs was calculated in each sample. The procedure required opening of the ears and observing occurrence (or absence) of a black mass of spores; the results were expressed in percentage terms. The field work was followed by laboratory analysis to confirm that the fungus indeed belonged to the *Ustilago maydis* species. The specimens were identified based on their morphology and the size of spores [McGee 1998]. Incidence of ears with galls was calculated as a percentage: (number of ears with galls)/(total number of ears) × 100.

Descriptive statistics of location and dispersion were used in order to represent the percentage of plants infected with smut. The significance of differences between the incidence rates were measured with ANOVA Kruskal-Wallis test, followed by post-hoc comparisons of all pairs of mean ranks of the studied varieties. It was preferred as witness for results interpretation the experimental average because only on this way we can see the real tendency of sweet maize varieties behavior on fungus *Ustilago maydis* attack. The grain yield data were submitted to an analysis of variance (ANOVA) and the Tuckey test was used to verify the significant differences among treatment means at the 5% probability level.

RESULTS AND DISCUSSION

The field study results of the nine corn varieties indicate significant variability of incidence rates of *U. maydis* (Table 2). The percentage of affected plants was heavily influenced by weather conditions. In the good year of 2007 few cases of galls were observed, while in 2009, when scorching summer followed chilly spring, the ratios rose to 10% for some varieties – the highest numbers in all the years of the study. Figure 3 presents the percentages of infected plants, averaged over 4 repetitions, individually for each year and for each variety. The large variability of the examined percentages had overestimated some of the means calculated from the four repetitions. In some cases, one observation was much higher than the remaining three. In others, the observations were still spread too widely for the mean to give good representation of the level of infection. Therefore, more robust measures of location were calculated instead (Table 2) and presented on box-and-whisker plots (Fig. 4–6). The median percentage varied in 2007 from 0 to 3.6%, with 'Sheba' being the only variety unaffected; in 2008, from 0 to 4.7%, this time with three varieties, 'Basin', 'Rana', and 'Sweet Talk' having shown no symptoms; and in 2009, from 0 to 6.8%, the only variety without infection being 'Harvest Gold'. The maximum percentage in 2007 was 6% (Gold), in 2008 6.3% ('Harvest Gold'), and in 2009 – 11.7% ('Sheba'). Having observed medians calculated from the four repetitions each year one notes that over half of the observations exceeded the 3% mark for the following varieties: in 2007 – 'Golda' and 'Rana', in 2008 – 'Passion', and in 2009 – 'Basin', 'Rana', 'Sheba', and 'Sweet Talk'. For each year, statistically significant differences were found between the incidence rates of different varieties. Multiple comparisons of mean ranks between all pairs of varieties proved significance of the difference between the Rana and the 'Harvest Gold' varieties in 2009.

Table 2. Minimum, maximum, median values for the percentage of affected plants in the years of 2007–2009 for each variety, and the results of Kruskal-Wallis test

Variety		2007			2008			2009		
		Min	Median	Max	Min	Median	Max	Min	Median	Max
Basin		0	0.5	1.2	0	0	0	4.0	4.6	5.2
Golda		0	3.5	6.0	0	0	0.8	0	0	1.3
GSS 5022		0	1.1	3.0	2	2.1	2.6	0	0.6	1.2
Harvest Gold		0	0.7	1.6	0	0.5	6.3	0	0	0
Helena		1.2	2.4	3.6	0	0	1.4	0	0.8	2.8
Passion		0	1.3	3.7	4	4.7	5.3	2.0	2.4	4.4
Rana		1.9	3.6	5.3	0	0	0	5.0	6.0	10.0
Sheba		0	0	0	0	0	3.2	3.2	5.0	11.7
Sweet Talk		0	0	1.4	0	0	0	0	4.3	10.1
Kruskal-Wallis Test	H-statistics	17.0603			23.5703			25.7188		
	p-value	0.0295*			0.0027*			0.0012*		

The * star denotes statistically significant differences with $p<0.05$

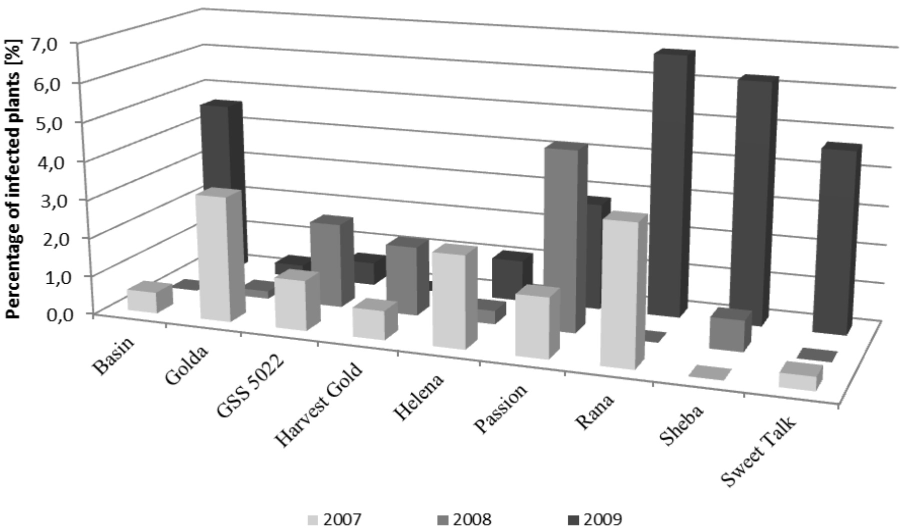

Fig. 3. The percentage of infection in four repetitions of the experiment

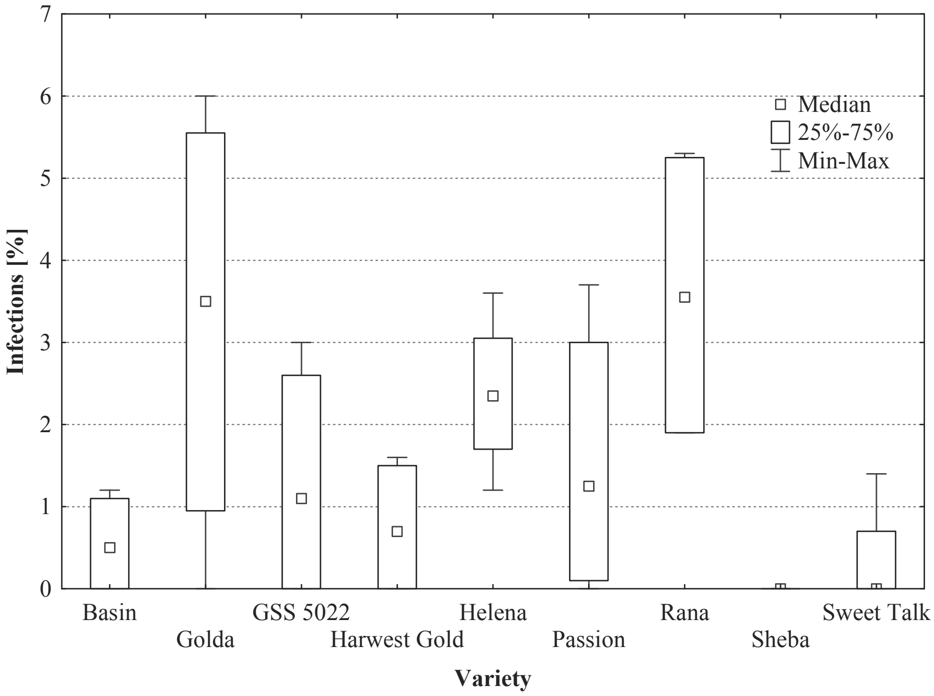

Fig. 4. Measures of location for the percentage of affected plants in 2007

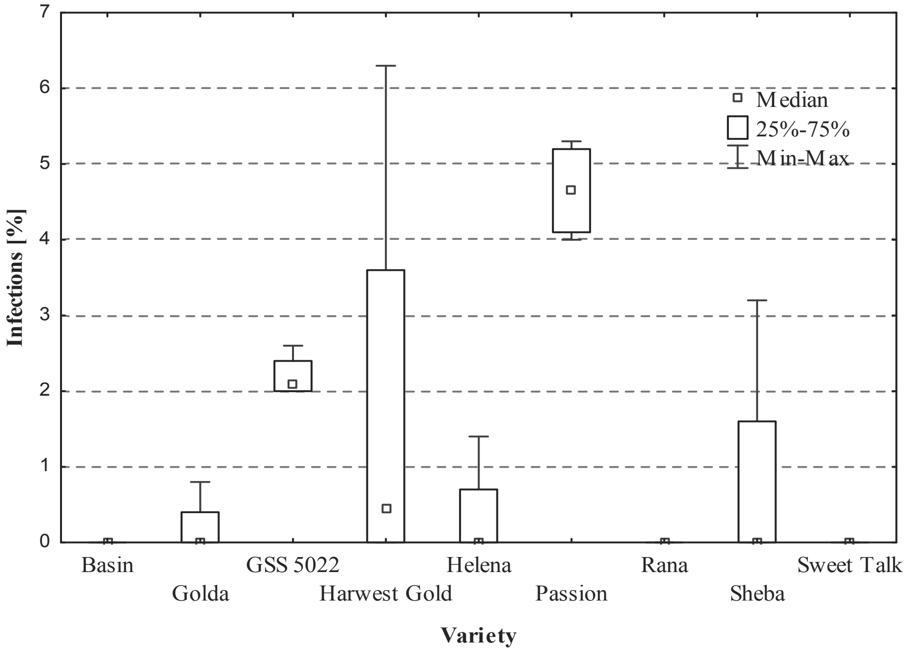

Fig. 5. Measures of location for the percentage of affected plants in 2008

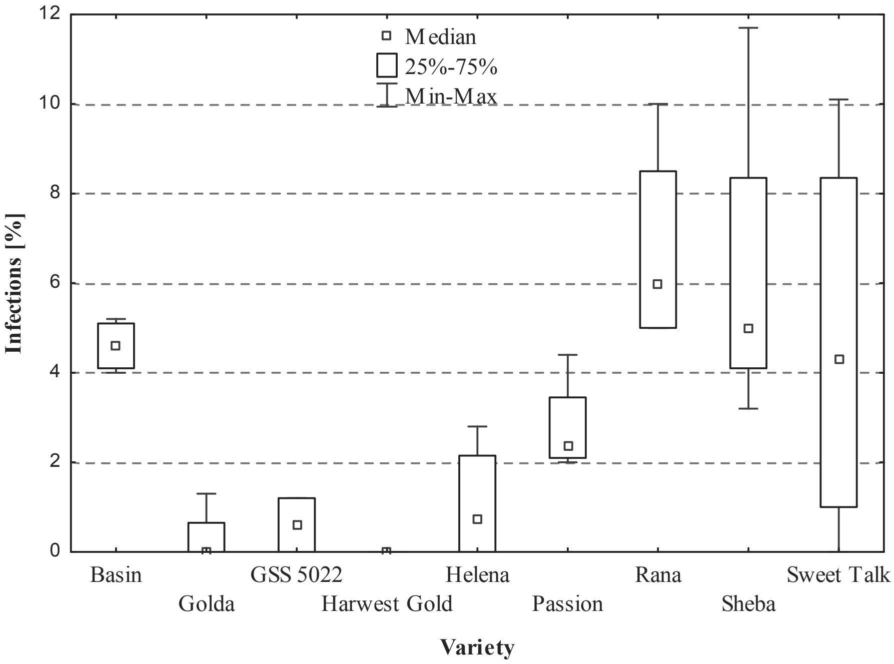

Fig. 6. Measures of location for the percentage of affected plants in 2009

Common smut is of greater economic consequence in sweet corn than in field corn. When sweet corn is grown for fresh market (e.g., farmers' markets, retail stores), ears with a single smut gall usually are not marketable because of "cosmetic injury" (i.e., lack of consumer acceptance). Percentage of affected plants varied in different environmental conditions. Hot and dry weather conditions favor *U. maydis* attack on maize during its early stage of development. In favorable for maize growing season 2007 and 2008, the percentage of infected plants was low. Similar results were obtained Ptaszyńska and Sulewska [2007] in their experiments in 2006, after cold spring followed by hot and dry summer, percentage of affected plants amounted to over 8% and was the highest among all tested seasons. In favorable for maize growing season 2004, common smut did not appear. According to Michalski et al. [2000] the most effective method to limit the corn infection by pathogens is cultivation of the resistant varieties. This applies equally to sweet, and to field corn. In both cases, every year new varieties are registered, less susceptible to particular pathogens. Studies conducted by Waligóra and Sulewska [1997] have shown that the percentage of affected plants of sweet corn is strictly related to the variety. Varieties 'Candle' and 'Sweet Trophy' researched in 1993–1995 and 2003–2006 turned out to be moderately susceptible to corn smut. These results inspired a search for a link between earliness of varieties and their susceptibility to the pathogen, just as had been the case of the European corn borer (*Ostrinia nubilalis*). Lisowicz [2004] reported that the earlier the variety, the more resistant to the corn borer. With the corn smut, this could be related to the early maturation and hardening of the plant's tissue, which would impede the progress of the disease. One might risk the claim that an analogous relationship exists in the case of sweet corn. The earliest of the examined varieties, 'Sheba', was characterized by high resistance to the smut, while the rather late 'Passion' was susceptible. On the other hand, many of the other studied early varieties were mildly, but still affected.

The literature also explores a connection between the incidence of *U. maydis* and the weather conditions. The optimum temperature for spore germination is 26 to 33°C. Corn smut thrives in warm weather. Also, the infection is likely to be more severe when scant rainfall occurs during the early stages of vegetation, followed by moderate rainfall as the corn approaches maturity. The important defense factor is the adequate water supply of the plants during the period of 10 days preceding and 5-7 days following the flowering. Severe early drought that weakens the plants and causes mechanical injuries, followed by heavy rainfall and high day-night temperature differentials constitute ideal conditions for germination of spores and growth of mycelium [Pataky and Richter 2007]. Kruczek [1997] also showed that seasonal droughts, or excess rainfall, or cold springs may influence the number of infected plants. Among analyzed varieties significant differences were found in the occurrence of *U. zeae*, and the percentage of affected plants varied between 2.1 and 6.2%. An early variety 'PR39T68', and semi-early 'Matilda' were barely affected (<2.2%). The most affected turned out to be the semi-early variety 'Black' and the semi-late 'Clarica'. The research conducted by Michalski and Bartos [2003] indicated that the late varieties were much more affected by *U. maydis* than the early ones. Commercially available sweet corn hybrids appear to have limited variation for resistance to common smut [Pataky et al. 1995]. It is recommended crop rotation (e.g. 4-year) has some effect in reducing soil-borne inoculum. The level of resistance varies among cultivars, and resistant cultivars should be used when possible [EPPO 1999].

Yield data were averaged across years because no year by corn varieties occurred for sweet corn grain yield. There were significant differences between the varieties in grain yield. Sweet corn grain yield was the highest for variety 'Basin', the lowest for 'Helena', 'Rana', 'Passion', and 'Sheba' (Fig. 7). Correlation coefficients of *Ustilago maydis* infection and grain yield showed that there was a highly significant correlation between *U. maydis* with varieties

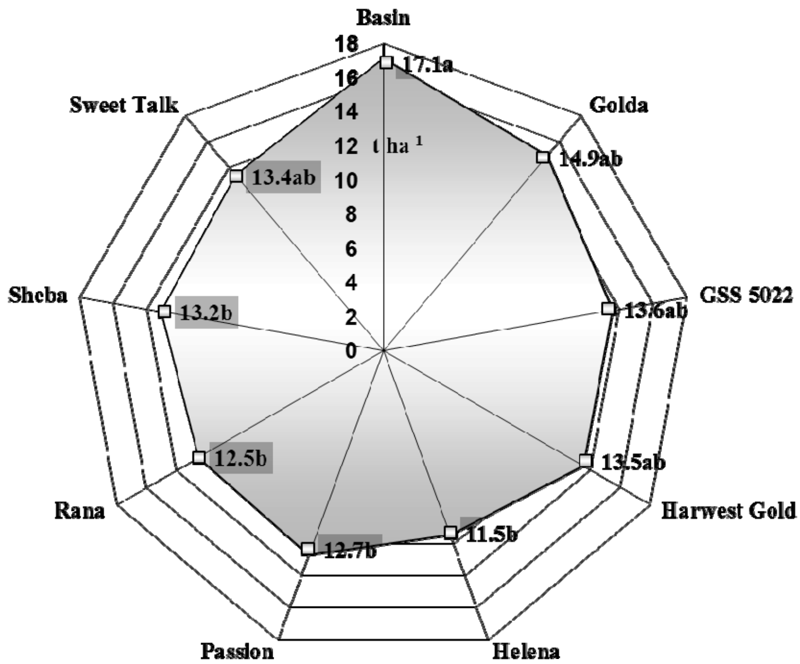

Fig. 7. Grain yield of sweet corn varieties (average 2007–2009)

‘Passion’, ‘Basin’, ‘GSS 5022’ and ‘Rana’ (Table 3). Hybrids have different reactions to disease, insect, and abiotic stresses [Simic et al. 2012]. Weather conditions, in particular air temperature during the growing season, have the greatest influence on sweet corn growth and yields [Stone et al. 1999]. Such that the results reported here offer an initial assessment of the effect meteorological factor and infected *U. maydis*.

Table 3. Correlation coefficients among *Ustilago maydis* infection (%) and sweet corn varieties grain yield

Trait	Sweet corn varieties								
	Basin	Golda	GSS 5022	Harwest Gold	Helena	Passion	Rana	Sheba	Sweet Talk
	Correlation coefficients								
Ustilago maydis infection	0.765**	0.067	-0.677*	-0.293	0.481	-0.606*	0.810**	0.365	0.208

** and *, significant at 1 and 5% level of probability, respectively

CONCLUSIONS

During the study, there was no explicit resistance of varieties on *U. maydis*. The presence of *U. maydi*s was more dependent on prevailing in a given year meteorological conditions. The year 2008 was characterized by higher temperatures favoring the occurrence of pathogens. Only in the case of a variety Basin low infestation translated into a significant increase in grain yield.

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PODATNOŚĆ ODMIAN KUKURYDZY CUKROWEJ NA PORAŻENIE PRZEZ *USTILAGO MAYDIS* (DC)

Synopsis. Zwiększone zapotrzebowanie na ziarno kukurydzy cukrowej przekłada się na wzrost powierzchni jej uprawy w Polsce. W latach 2007–2009 w Zakładzie Doświadczalno-Dydaktycznym Uniwersytetu Przyrodniczego w Poznaniu, zlokalizowanym w Swadzimiu, przeprowadzono doświadczenie w którym badano podatność odmian kukurydzy cukrowej na porażenie przez *Ustilago maydis* (DC) sprawcę głowni guzowatej kukurydzy. Badanymi odmianami były 'Basin', 'Golda', 'GSS 5022', 'Harvest Gold', 'Helena', 'Passion', 'Rana', 'Sheba' i 'Sweet Talk'. Porażenie oceniano w fazie rozwojowej kukurydzy BBCH 70–75. Występowanie choroby przedstawiono w procentach porażonych roślin. Odmiany różniły się wielkościa procentu porażonych roślin przez U. maydis. Wystąpienie choroby było zależne od przebiegu warunków pogodowych w danym roku. Jedynie w przypadku odmiany 'Basin' niskie porażenie patogenem przekładało się na istotny przyrost plonu ziarna kukurydzy.

Słowa kluczowe: głownia kukurydzy, kukurydza cukrowa, podatność odmian

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