Influence of weed infestation on morphological parameters of maize (*Zea mays* L.)

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ABSTRACT

The influence of various ways of regulation in weed infestation of silage maize stands was studied in 1999–2001. Four variants of stands were compared: 1. without weed eradication (check), 2. mechanically weeded throughout the whole vegetation period, 3. mechanically weeded from the beginning of vegetation till the phase of 5th leaf and later on without protection, 4. chemical weeding. The yield of dry mass and morphological characters (height of plants, stem diameter, number of ears per plant etc.) show the substantial negative effect of weed infestation upon the studied parameters. The yield from the check variant reached 8.09 t/ha, from the 2nd variant 13.24 t/ha, from the 3rd variant 11.46 t/ha and from the 4th variant 12.34 t/ha. The decrease of mass in individual parts of plants were observed but their percentage portions were not affected by the level of weed infestation. A high dependence ($\alpha = 0.01$) between the mass of the whole plant and the ear mass ($r = 0.98$) was proved. The total number of leaves was not affected by the level of treatment. The results show that the mechanical cultivation of stands at the beginning of vegetation cannot prevent the yield depression cost by weed infestation and the studied parameters cannot reach the level of fully weeded variants.

Keywords: maize; weed infestation; chemical treatment; mechanical treatment; yield; morphological parameters

The silage maize is the most important annual fodder crop grown on arable land. The crucial yield components are: the number of plants per area unit and their mass. Revilla et al. (1999) and Vrzal et al. (1999) found the parameters such as plant mass, height, number of leaves per plant, number of leaves under the ear, length of flowering, grain mass, portion of grain on total yield and earliness as very important. The maize yield formation is negatively affected by unfavourable weather conditions, pests and diseases and mainly by weeds (Tollenaar et al. 1994, Martinková and Honěk 1998). The high level of weed infestation is caused by lack of water in the soil. Unfavourable conditions gradually affect the height of plants, stalk diameter at the base of the plant, number of leaves and vitality of maize, number of grains in the ear and the thousand seed mass (Gonzales-Ponce and Salas 1995, Ali et al. 1999).

Amador-Ramirez (1995) and Martinková and Honěk (2001) concluded that the yield was increasing by the lengthening of time in the stand without weed infestation. The weed infestation in this experiments caused the grain yield reduction by 86–90% throughout the whole vegetation period. Chemically treated maize stands give significantly higher plants, bigger, heavier and healthy cobs, bigger grains and higher yield (Magbool et al. 1998). By the weed infestation regulation the exploitation of radiation can be affected as well as the dry mass yield and the quantity of nutrients gained from the unit area (Yelverton and Coble 1991, Tollenaar 1992, Stanojevia 2000).

The aim of the experiment was to clear up and quantify the effect of weed infestation on the productive ability and morphological parameters of silage maize at various ways stand treatment throughout the vegetation period. The gained results enable to propose the optimum way of treatment of maize stands against weeds.

MATERIAL AND METHODS

The plot experiments with silage maize were established in 1999–2001 on the field of the Faculty of Agronomy Czech University of Agriculture in Prague-Suchdol. The experimental plots were established in the sugar beet production area, of sugar beet-cereal type, wheat subtype (latitude: 50°08′ N, longitude: 14°24′ E, altitude: 286 m).

The soil in the experimental area is deep loamy degraded chernozem with permeable underlayer. The kind of soil is medium. The soil reaction is neutral or slightly alkalic. The content of available phosphorus and potassium in the layer 100–200 mm

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Table 1. Average temperatures (T) and precipitation (P) by month in growing seasons 1998/1999–2000/2001 and long-term average in Prague-Ruzyně

Month	10.	11.	12.	1.	2.	3.	4.	5.	6.	7.	8.	9.	Year	Warm half year
T 1998/1999 (°C)	8.5	0.6	–0.7	0.5	–1.3	4.9	9.0	14.2	15.3	18.8	17.3	16.8	8.7	15.2
T 1999/2000 (°C)	8.4	2.1	0.7	–1.1	3.1	4.1	11.0	15.6	17.9	15.6	19.0	13.5	9.2	15.4
T 2000/2001 (°C)	10.6	5.2	0.8	–1.6	0.9	3.8	7.2	14.4	14.3	18.3	18.6	11.7	8.7	14.1
T long-term average (°C)	8.3	2.9	–0.6	–2.4	–0.9	3.0	7.7	12.7	15.9	17.5	17.0	13.3	7.9	14.0
P 1998/1999 (mm)	73.6	30.6	8.7	29.3	19.6	20.2	19.6	43.0	49.2	99.2	20.9	53.8	467.7	285.7
P 1999/2000 (mm)	21.3	25.9	24.7	21.2	19.5	89.9	10.0	55.0	41.9	65.9	39.6	20.7	435.6	233.1
P 2000/2001 (mm)	55.2	28.0	9.2	31.3	16.8	51.1	57.4	40.0	72.4	98.8	86.0	67.6	613.8	422.2
P long-term average (mm)	30.5	31.9	25.3	23.5	22.6	28.1	38.2	77.2	72.7	66.2	69.6	40.0	525.8	363.9

is very high, the available magnesium content is high. According to the agrometeorological characteristics the places belongs from moderate to warm and mostly dry climatic area. The hydrotermic coefficient according to Seljaninov is 1.0–1.3. The vegetation period is 172 days. The mean annual temperature 7.9°C throughout 30 year normal and during the warm half-year 14.0°C, the mean length of sun light in 30 year normal 1921 hours and during the warm half-year 1408 hours. The long-term annual sum of precipitations 526 mm and during the warm half-year 364 mm (Table 1).

The early Tc (three lines) hybrid Agio (FAO 240) was used in all the experimental years. Lovofert NPK-1, the industrial universal combined fertilizer, was applied in to the soil (120 kg N/ha, 52.8 kg P/ha and 99.6 kg K/ha). The experiment was situated in the same place in the same field in all the experimental years, in randomized blocks, in four variants with four replicates in each variant. The plot area was 15 m^2. The sowing rate was 92 000 plants per hectare with the interrow distance 0.75 m. The studied variants: 1. without weed eradication (check), 2. mechanically weeded throughout the whole vegetation period, 3. mechanically weeded from the beginning of vegetation till the phase of 5^{th} maize leaf and later on without protection, 4. chemical weeding.

The mechanical cultivation of the maize stands was accomplished in 14-day interval. The interrows were weeded and the space among plants was treated by hoeing. The postemergent stand treatment by herbicides was made by 0.4 l/ha Banvel 480 SL (dicamba 480 g/l), 15 g/ha Harmony extra (50% thifensulfuron methyl), 0.3 l/ha Lontrel 300 (clopyralid 300 g/l), 1.5 l/ha Milagro (nicosulfuron 40 g/l).

Pre-harvest testing (height of plants, stalk diameter 0.1 m above the ground, number of fully developed ears per plant, height of ear insertion, number of leaves per plant, number of dry leaves per plant) was accomplished on 10 through plants from each plot. The time of harvest was milk-waxy maturity. The stand density and dry mass yield per ha were established. Five plants were sampled from each plot for analyses. The mass of individual plant parts was established (stalks, leaves, ears, husks).

RESULTS AND DISCUSSION

The stand density and dry mass yield

The dry mass yield is, according to many authors (Gonzales-Ponce and Salas 1995, Gyuricza et al. 1999, Anderson 2000), significantly affected by the intensity of weed infestation. The yield decreases due to the weed infestation throughout the whole vegetation period by 65% (Tollenaar et al. 1994). Our results also show (Table 2) the significant decrease of yield in the check variant (34% decrease in comparison with the chemically treated variant). The interrow tillage in the beginning of vegetation significantly increased the yield per ha of dry matter in comparison with the check variant, but did not reach the yield levels of mechanically treated stand throughout the vegetation period. The highest dry matter yield was obtained in the variant of interrow tillage during the whole vegetation season. Two compared permanently outweeded variants (herbicide treatment, cultivation throughout the vegetation) gave higher yields in the mechanical treatment. It is evident, that the

Table 2. Effect of the way of stand treatment and year on the number of plants and dry mass yield per ha in 1999–2001, one-way and multifactor analysis of variance

		No. of plants/ha	Yield 1999 (t/ha)	Yield 2000 (t/ha)	Yield 2001 (t/ha)	Yield 1999–2001 (t/ha)
Variant	1	76 667	7.80	8.68	7.78	8.09
	2	82 444	11.20	10.85	17.67	13.24
	3	79 556	9.99	9.49	14.90	11.46
	4	80 111	10.72	10.65	15.64	12.34
	D_{min} (α = 0.05)		1.785	1.632	3.994	1.408
	D_{min} (α = 0.01)		2.313	2.115	5.176	1.747
	F-test	1.30	12.55	6.95	20.64	37.08
	P-value	0.2885	0.0005	0.0058	0.0000	0.0000
Year	1999	80 417				9.93
	2000	84 167				9.92
	2001	74 500				14.00
	D_{min} (α = 0.05)	6 231				1.107
	D_{min} (α = 0.01)	7 927				1.408
	F-test	7.31				54.02
	P-value	0.0022				0.0000
	variant × year					
	F-test	0.54				8.13
	P-value	0.7753				0.0000

cultivation supported more favourable conditions for the development of maize root system and thus a better water and nutrient use.

There was no visible influence of stand treatment on the number of maize plants (Table 2). But it was possible to prove a lower number of plants in the variants infested by weeds throughout the whole vegetation period in comparison with the mechanical or chemical weed regulation. The low number of plants was found in the variants 1 and 3, in 2001. It was the reason of a negative effect on the stand density.

The effect of the year was statistically significant in both studied parameters. It was mostly caused by unfavourable weather conditions. The warm half-year in 1998/1999 and 1999/2000 was

Table 3. Significance in the differences for the number of plants and dry mass yield depending on the variant and year

	No. of plants			Yield 1999			Yield 2000			Yield 2001			Yield 1999–2001		
Variant	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1	ns	ns	ns	**	*	**	**	ns	*	**	**	**	**	**	**
2		ns	ns		ns	ns		ns	ns		ns	ns		**	ns
3			ns			ns			ns			ns			ns
Year	2000	2001											2000	2001	
1999	ns	ns											ns	**	
2000		**												**	

ns – not significant, * significant at α = 0.05, ** significant at α = 0.01

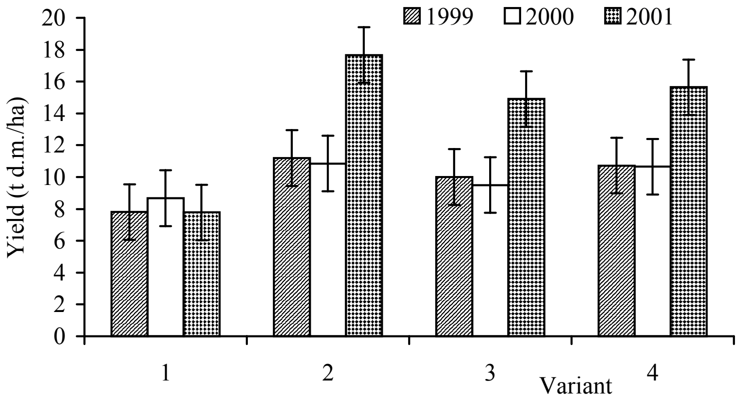

Figure 1. Interactions between the variant and year in the dry mass maize yield in 1999–2001, Tukey (α = 0.05)

highly above the normal and below the normal in precipitations, the year 2000/2001 was normal, both in temperature and precipitations. The non standard development of climatic conditions in 1998/1999 and 1999/2000 namely the lack of precipitations during the vegetation period caused a negative decrease in yields (Figure 1). The year 2001 was different in the absolute values of yields and number of plants, but in the relative values the results were comparable. The significant differences are presented in Table 3.

Morphological parameters

The first studied factor was the height of silage maize plants before harvesting. All the studied variants differed significantly in this character.

Table 4. Effect of stand protection and the year on morphological parameters of maize plants in 1999–2001, multifactor analysis of variance

		Height of plants (m)	Stalk diameter (mm)	Total no. of leaves	No. of dry leaves	Number of ears	Height of ear insertion (m)
Variant	1	1.96	15.0	12.0	6.1	0.85	0.89
	2	2.42	18.7	12.1	5.0	0.97	1.02
	3	2.23	17.9	12.0	5.0	0.93	0.97
	4	2.35	18.9	12.1	5.4	0.98	1.00
	D_{min} (α = 0.05)	0.059	0.860		0.437	0.078	0.040
	D_{min} (α = 0.01)	0.072	1.042		0.529	0.094	0.049
	F-test	153.56	60.03	1.28	19.06	7.78	28.50
	P-value	0.0000	0.0000	0.2810	0.0000	0.0000	0.0000
Year	1999	2.39	17.5	12.1	5.2	0.84	1.13
	2000	1.94	16.5	12.0	7.6	1.00	0.75
	2001	2.38	18.9	12.0	3.4	0.96	1.02
	D_{min} (α = 0.05)	0.047	0.679		0.345	0.061	0.032
	D_{min} (α = 0.01)	0.058	0.845		0.429	0.076	0.038
	F-test	336.30	35.55	2.58	410.51	21.34	439.41
	P-value	0.0000	0.0000	0.0767	0.0000	0.0000	0.0000
	variant × year						
	F-test	12.57	11.59	3.43	14.52	2.71	14.43
	P-value	0.0000	0.0000	0.0025	0.0000	0.0134	0.0000

Table 5. Significance of differences for morphological maize parameters depending on variant and year

	Height of plants			Stalk diameter			Total no. of leaves			No. of dry leaves			Number of ears			Height of ear insertion		
Variant	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1	**	**	**	**	**	**	ns	ns	ns	**	**	**	**	*	**	**	**	**
2		**	*		ns	ns		ns	ns		ns	ns		ns	ns		**	ns
3			**			*			ns			ns			ns			ns
Year	2000	2001		2000	2001		2000	2001		2000	2001		2000	2001		2000	2001	
1999	**	ns		**	**		ns	ns		**	**		**	**		**	**	
2000		**			**			ns			**			ns			**	

ns – not significant, * significant at $\alpha = 0.05$, ** significant at $\alpha = 0.01$

According to Begna et al. (2001) the weed infestation decreases the height of plants in classical hybrids by 0.26 m. The values obtained in our experiment prove the decrease in the height of plants by 0.39 m in the check variant compared with the chemical one. The significantly highest plants were found in the stand mechanically cultivated throughout the vegetation period (Table 4).

Similar results in the negative effect caused by weeds were also observed in the stalk diameter 0.1 m above the ground. The check variant showed significantly lower values in the stalk diameter compared with the chemically treated variant. The weeding in the beginning of vegetation period (var. 3) increased the stalk diameter on the level of the weeded variants 2 and 4.

The way of stand treatment did not affect the total number of leaves, which was also proved by Vafabakhsh et al. (1996) in their field study concerning chemical and mechanical weed regulation and its influence on the morphological characters. Number of leaves is therefore limited by genetic properties of the used hybrid (Ford and Pleasant 1994, Robertson 1994). The significantly higher number of dry leaves in the check variant was evidently affected by the water consumption by weeds. Yield looses can reach 50 or more percent (Yao et al. 1991).

The total number of ears on the maize plant is a genetic expression of the hybrid. One fully developed ear was found as a mean in weeded stands. In the permanent weed infestation there appeared significant reduction in ear number (0.85 ears per plant). The height of ear insertion was negatively affected by the weed infestation too. The significantly ($\alpha = 0.01$) lowest ears were found in the check variant (0.89 m). The weeded variants 2 and 4 showed similar parameters, but there was a significant difference between the 2 and 3 variants (Table 4).

The effect of the year was found as statistically significant in all characters, besides the number of leaves per plant (Table 5). The year 1999/2000 subnormal in precipitations, caused the lower plant height, stalk diameter 0.1 m above the ground, height of ear insertion and number of dry leaves. Berzsenyi et al. (1998) found in the studies concerning the height of plants, leaf area, leaf and stalk mass creation that the effect of the year is higher in comparison with the other parameters, i.e. date of sowing or hybrid earliness. The lower number of fully developed ears in the first experimental year was significantly different compared with the other years, due to the higher weed infestation, affected by the high number of weed seeds in the soil.

The proportion of individual maize plant parts

The maize stand weed infestation caused the significant decrease in the total plant mass; there were no significant differences between weeded variants 2 and 4 (Table 6). Similar relations were found among individual plant parts, for the weed infestation reduces their mass. The percentage of individual parts of plants was not affected by the way of protection. The proportion of ears in the total mass was 51.2% (var. 1) to 53.7% (var. 3.), proportion of stalks 21.1% (var. 1) to 22.8% (var. 2), proportion of leaves 17.3% (var. 2) to 21.6% (var. 1) and the proportion of husks 6.2% (var. 3) to 7.8% (var. 2).

The dependence of ears on the total plant mass was evaluated by the simple regression and correlation analysis (Figure 2). High dependence ($r = 0.98$) was proved. The ear mass was explained (95%) by the linear equation $y = 0.384627 + 0.522972x$ (F-test 903.4, P-value 0.0000). Revilla et al. (1999) present the 36% regression dependence of grain mass on the dependence of maize plant mass.

Table 6. Effect of the way of stand treatment and year on the mass of individual maize plant parts (g of dry mass) in 1999–2001, multifactor analysis of variance

		Stalk mass (g)	Leaf mass (g)	Ear mass (g)	Husks mass (g)	Total plant mass (g)
Variant	1	21.4	21.9	51.9	6.3	101.4
	2	46.2	35.0	105.4	15.8	202.3
	3	33.6	29.7	84.5	9.7	157.5
	4	42.5	32.9	100.0	14.1	189.4
	D_{min} (α = 0.05)	8.882	4.094	12.983	3.115	25.807
	D_{min} (α = 0.01)	11.023	5.081	16.113	3.866	32.029
	F-test	22.42	28.53	49.89	27.73	44.09
	P-value	0.0000	0.0000	0.0000	0.0000	0.0000
Year	1999	37.4	28.5	72.1	10.1	148.1
	2000	26.4	27.3	81.3	8.9	143.9
	2001	43.9	33.8	103.0	15.4	196.0
	D_{min} (α = 0.05)	6.981	3.218	10.205	2.448	20.285
	D_{min} (α = 0.01)	8.882	4.094	12.983	3.115	25.807
	F-test	19.21	13.69	28.88	23.53	24.38
	P-value	0.0000	0.0000	0.0000	0.0000	0.0000
	variant × year					
	F-test	3.11	3.62	7.94	4.90	6.54
	P-value	0.0148	0.0065	0.0000	0.0009	0.0001

The significant unfavourable development of the years 1998/1999 and 1999/2000 was proved in the studied parameters, as well as in the dry mass yield. Gyenesne et al. (2002) and Knežević et al. (2003) presented statistically significant effect of the year on the ear yield. Significant differences among studied factors are given in the Table 7.

The results show that the mechanical stand cultivation in the beginning of vegetation period till the phase of 5th leaf cannot prevent the yield depression caused by weed infestation and the evaluated parameters do not reach the level of the fully weeded variants. Maximum values in yield components were obtained only in the maize

Table 7. Significance of differences in the mass of individual maize plant parts depending on the variant and year

	Stalk mass			Leaf mass			Ear mass			Husks mass			Total plant mass		
Variant	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1	**	**	**	**	**	**	**	**	**	**	*	**	**	**	**
2		**	ns		**	ns		**	ns		**	ns		**	ns
3			*			ns			*			**			*
Year	2000	2001		2000	2001		2000	2001		2000	2001		2000	2001	
1999	**	ns		ns	**		ns	**		ns	**		ns	**	
2000		**			**			**			**			**	

ns – not significant, * significant at α = 0.05, ** significant at α = 0.01

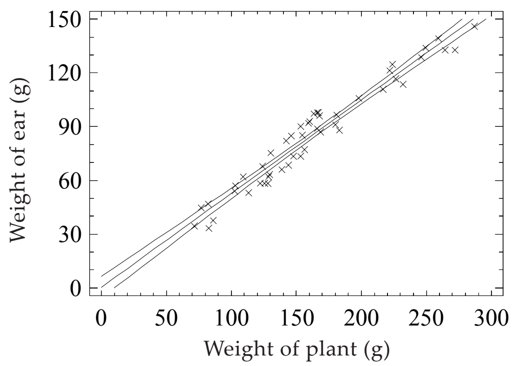

Figure 2. Dependence of ear mass on the mass of total plant (g of dry mass) in the mean of 1999–2001, simple regression, linear model, confidence level 99%

stands without weed population throughout the whole vegetation period. This can be reached by the herbicide application only, in the large-scale production at the present time. The mechanical stand cultivation throughout the whole vegetation period also ensures the favourable growth conditions, besides the weeding effect. This type of treatment guarantees the highest values in most of the studied parameters, which are not statistically significant from the herbicide treatment ones.

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ABSTRAKT

Vliv zaplevelení na morfologické parametry kukuřice (*Zea mays* L.)

V letech 1999 až 2001 byl sledován vliv různého způsobu regulace zaplevelení porostu silážní kukuřice. Byly porovnávány čtyři varianty: 1. porost bez ošetření proti plevelům (kontrolní), 2. porost odplevelován mechanicky po celou dobu vegetace, 3. porost odplevelen mechanicky na počátku vegetace do fáze 5. listu kukuřice, později ponechán zaplevelen, 4. porost ošetřen chemicky proti plevelům. Z hodnocení výnosu sušiny a morfologických charakteristik (výška rostlin, průměr stébla, počet palic na rostlině aj.) vyplývá výrazně negativní vliv zaplevelení na sledované ukazatele. U kontrolní varianty dosahoval výnos 8,09 t/ha, u 2. varianty 13,24 t/ha, u 3. varianty 11,46 t/ha a u 4. varianty 12,34 t/ha. Dochází rovněž ke snížení hmotnosti jednotlivých částí rostliny, jejich procentuální podíly však nejsou stupněm zaplevelení ovlivněny. Byla prokázána vysoká závislost (α = 0,01) mezi hmotností celé rostliny a hmotností palice (r = 0,98). Celkový počet listů nebyl způsobem ošetřování ovlivněn. Z výsledků vyplývá, že mechanická kultivace porostu pouze na počátku vegetace nedokáže zabránit výnosové depresi vlivem zaplevelení a hodnocené parametry nedosahují úrovně plně odplevelených variant.

Klíčová slova: kukuřice; zaplevelení; chemické ošetření; mechanické ošetření; výnos; morfologické parametry

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