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Research Article

Determination of the *Amaranthus retroflexus* damage threshold in maize crop

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Abstract. Maize resilience when competing with different weed species is decisive when intervening with different control methods. *Amaranthus retroflexus* is of particular interest because of its occurence time (at the same time with maize, after its emergence, following the 7-leafs stage), height, biomass, growth rate, breeding capacity, dissemination and damage. Given the damage caused by *A. retroflexus*, the aim of this research was to determine the circumstances of weed-maize crop competition so as to identify the threshold for this species.

Key Words: weeds, maize, *Amaranthus retroflexus* threshold.

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Introduction

Maize (*Zea mays* L.) culture is among the most important agricultural sectors in Romania, having a wide range of local hybrids (Braşovean *et al* 2010). In order to improve the crop technologies, it is necessary to have knowledge both on weed species and their density (no. per sqm) when competing with crop plants (Knezevic *et al* 1994, 1995; Chirilă 2001; Silvertown 1982).

The damage threshold (DT) is the weed coverage of a crop, expressed through the total number of species, or the number of a certain species resulting in a quantitative and qualitative decrease equaling $DL_{5\%}$.

The most important characteristics of *Amaranthus retroflexus* L. in the competition with crop plants are the rapid growth rate and the large number of seeds per plant that is sometimes more than 1.5 million (Ionescu-Şişeşti & Staicu 1958; Gliessman 1989; Gîdea *et al* 2010; Damian 2011). We chose *A. retroflexus* because it emerges at the same time, or only some time later than maize plants and it has a strong competitive capacity in close proximity.

With a view to extending maize cultivation to more areas including south Romania, a good knowledge of the qualities displayed by maize in the competition with *A. retroflexus* is the first condition to ensure potential success. Compared to studies of Knezevic *et al* (1994, 1995), our study focused on interrelations between plants native to Romania (weeds from spontaneous flora and Olt maize hybrid).

Table 1. Treatments of the experiment "Determination of the *Amaranthus retroflexus* threshold in maize crop" (locality Milosesti 2009)

Treatments	Hoeing and plucking works	
	On the interrow	On the plants row
V_1 – **classic with three mechanical hoeings and two manuals hoeings without** *A. retroflexus*	3 hoeing	2 hoeing
V_2 – **unhoeing, unplucking**	-	-
V3 – mechanical hoeing	3 hoeing	-
V_4 – **1 plant** *A. retroflexus*. **mp**$^{-1}$	3 hoeing	plucking
V_5 – **2 plants** *A. retroflexus*.**mp**$^{-1}$	3 hoeing	plucking
V_6 – **3 plants** *A. retroflexus*.**mp**$^{-1}$	3 hoeing	plucking
V_7 – **4 plants** *A. retroflexus*.**mp**$^{-1}$	3 hoeing	plucking

Table 2. Dry weeds biomass in maize function of weed control works and the *Amaranthus retroflexus* number at 25.10.2009

Treatments	Control works		Weed biomass	Difference	%
	On interrow	On the row	(kg d.m. per ha)	kg d.m. per ha	
V_1 – classic, without *A. retroflexus*	3 hoeing	2 hoeing	520	-3230 000	14
V_2 – unhoeing, unplucking	-	-	3750	Control	100
V_3 – mechanical hoeing	3 hoeing	-	1665	-2085 000	44
V_4 – 1 plant *A. retroflexus*	3 hoeing	plucking	742	-3008 000	20
V_5 – 2 plants *A. retroflexus*	3 hoeing	plucking	1257	-2493 000	34
V_6 – 3 plants *A. retroflexus*	3 hoeing	plucking	1757	-1993 000	47
V_7 – 4 plants *A. retroflexus*	3 hoeing	plucking	1885	-1865 000	50

$DL_{5\%}$ =210 kg d.m. per ha;
$DL_{1\%}$=370 kg d.m. per ha;
$DL_{0.1\%}$=620 kg d.m. per ha.

Material and Method

The experiment had seven treatments (presented in the Tables 1 and 2). Weed density was measured on the row of maize plants, with a varying width of ± 12 cm. In order to ensure the presence of *A. retroflexus*, seeds from the previous year's harvest were spread on the ground two weeks before sowing. The aisles between the rows of maize plants were hoed in the treatments with *A. retroflexus*, and the targeted densities were reached by periodical plucking. According to the experimental scheme, the remaining plants were highlighted through red sticks in the first growth stage. Until harvesting, weed control on plant rows was performed through manual plucking in treatments V_4 - V_7. Before harvesting, weeds were cut from the collet, weighed as green mass, then samples were taken to be dried at 65ºC, so as to calculate weed biomass as dry matter. The agrotechnical works for maize (see Table 1), (plowing, preparing the field for sowing, sowing the Olt maize hybrid, hoeing etc) were the usual one in the area. The production output was processed through variance analysis and correlation calculations. The determination of the damage threshold is done according to a specific procedure based on the definition of the indicator.

Results and Discussion

The Table 2 presents weed coverage in maize crop in autumn, before harvesting.

Weed Coverage

The weed coverage in treatments V_1 and V_2 is represented by various weed populations, where the following species prevailed: yellow foxtail (*Setaria glauca*, Linnaeus, 1758, Pal.Beauv.), green bristlegrass (*Setaria viridis*, Linnaeus, 1758, Pal. Beauv.), cockspur grass (*Echinochloa crus galli*, Linnaeus, 1758, Pal. Beauv.), redroot pigweed (*Amaranthus retroflexus*, Linnaeus, 1758), common lambsquarters (*Chenopodium album*, Linnaeus, 1758), wild mustard (*Sinapis arvensis*, Linnaeus, 1758), field bindweed (*Convolvulus arvensis*, Linnaeus, 1758) and creeping thistle (*Cirsium arvense*, Linnaeus, 1758, Scop.).

In comparison with the maximum weed coverage recorded in the first treatment – unhoed, unplucked (3750 kg d.m. per ha), with no control measures, the classical system of ecological control with three mechanical hoeings and two manual hoeings resulted in 520 kg dry matter per ha, representing the weeds from the last stage of weed coverage (emerged after the last works). The treatment with three mechanical hoeings enabling weeds to remain on plant rows leads to a highly significant negative difference, of 2085 kg per ha, compared to the unhoed treatment.

The three mechanical hoeings associated with one plucking in one *A. retroflexus* treatment result in a weed biomass of 742 kg per ha accounting for 20% of the weed coverage in the witness and a highly significant decrease of 3008 kg per ha. The progressive increase of the number of *A. retroflexus* to two, three

Table 3. The dry weight of the *A. retroflexus* plants, depending of their density on the maize plant row

Treatments	Dry mater, g d.m. per sqm				
	Total (g)	On one plant *Amaranthus*			
		g	Difference	Significance	%
V_4 – 1 plant *A. retroflexus*	52	52	Control	-	100
V_5 – 2 plants *A. retroflexus*	88	44	-8	00	85
V_6 – 3 plants *A. retroflexus*	123	41	-11	000	79
V_7 – 4 plants *A. retroflexus*	99	25	-27	000	52

$DL_{5\%}$ = 3.5 g d.m. per sqm
$DL_{1\%}$ =5.7 g d.m. per sqm
$DL_{0.1\%}$=9.2 g d.m. per sqm

Table 4. Maize yield depending of *A. retroflexus* density and the weed control works in the year 2009

Treatment	Yield		Difference/Significance		Weed encrochment or *A. retroflexus*	
	kg per ha	(%)	kg per ha	%	kg per ha	%
V_1– classic, without *A. retroflexus*	5340	100	Control	-	520	14
V_2 – unhoeing, unplucking	780	15	-4560 000	85	3750	100 Control
V_3 – mechanical hoeing	3250	61	-2090 000	39	1665	44
V_4 – 1 plant *A. retroflexus*	5125	96	-215	4	742	20
V_5 – 2 plants *A. retroflexus*	4350	81	-990 000	19	1257	34
V_6 – 3 plants *A. retroflexus*	3900	73	-1440 000	27	1575	42
V_7 – 4 plants *A. retroflexus*	2710	51	-2630 000	49	1885	50

$DL_{5\%}$=304 kg per ha
$DL_{1\%}$=516 kg per ha
$DL_{0.1\%}$=910 kg per ha

and four plants leads to highly significant increases of the weed coverage, from 1257 kg per ha to 1885 kg per ha accounting for 34%, 47% and respectively 50% of the weed coverage in the witness treatment.
In comparison with the maximum weed coverage in V_2 represented by the local weed populations, the dry matter of *A. retroflexus* varied between 20% and 50%, according to its density and increased at the same time with the density of *A. retroflexus*. It is important to underline that there was no correlation between weight increase and the raise of plant number. The amplitude of the increase is reduced with each raise in plant numbers. For instance, in V_3 (treatment with one *A. retroflexus* plant) dry matter accounts for 20%. In addition, in V_5, the number of *A. retroflexus* plants per metre is doubles, but dry matter is of 34% etc.

The results of the measurements in the Table 3 represent the dry matter of one *A. retroflexus* plant, according to its density on the plant row. Their variation, namely the decrease in weight at the same time with the increase in density on the maize plant row (in this case from 52 g dry matter to 25 g/ *A. retroflexus* plant) highlights how the competition for life support takes place not only among *A. retroflexus* plants and maize plants. The biomass of an *A. retroflexus* plant decreased at least distinctly significantly from 100% to 48% once the density increased from one to four plants per square metre, which is also explained through the competion among the individuals belonging to the same species.

Production output

The data presented in Table 4 regarding production output provide the calculation basis for the damage threshold of *A. retroflexus* in maize crop. Starting from V_1 (classical witness) with three mechanical hoeings and two manual ones on plant rows and a production output of 5340 kg per ha, considered 100%, the following information results: production output decreased to 61%, when weeds were controlled only on the aisles between plant rows through three mechanical hoeings (V_3); it reduced to 15% when there were no weed control measures during maize plant growth (in V_2).

In treatments no. 4, 5, 6 and 7 where the number of *A. retroflexus* plants was different, raising from one to four plants per square metre, the production output reduced gradually from 96% (the treatment with one *A. retroflexus* plant in the row area) to 51% (treatment no. 7, with four *A. retroflexus* plants per row area). Thus, production output varied reversely, in comparison with

Table 5. Ratio between the maize yield and the dry matter of the weeds or of the *A. retroflexus*

Treatments	Dry mater weeds	Yield	Dry mater weeds and *A. retroflexus* /maize production ratio	Maize production / weeds and *A. retroflexus* ratio
	kg per ha			
V_1– classic, without *A. retroflexus*	520	5340	0.1	10.3
V_2 – unhoeing, unplucking	3750	780	4.8	0.21
V_3 – mechanical hoeing	1665	3250	0.51	1.95
V_4 – 1 plant *A. retroflexus*	742	5125	0.14	6.9
V_5 – 2 plants *A. retroflexus*	1257	4350	0.29	3.51
V_6 – 3 plants *A. retroflexus*	1757	3900	0.45	2.2
V_7 – 4 plants *A. retroflexus*	1885	2710	0.7	1.4

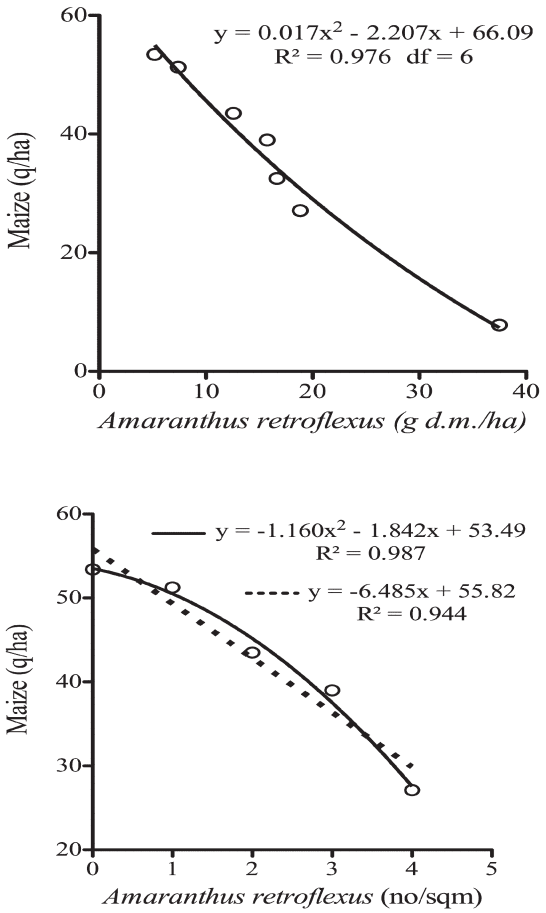

Figure 1. Maize production versus weed biomass (top); function of the weed number of *A. retroflexus* (bottom), solid line is function and dotted line is linear model.

the dry matter of different weeds or just *A. retroflexus* (Table 5). A quadratic regression was calculated between the dry biomass of weeds and production, the result being of statistical distinct significance (see Figure 1a). When weed density was low (represented by various weed populations from the last weed emergence stage, occurring after the last hoeings), for each kilogram of weed dry matter, maize production output reduced by 0.1 kilograms. When the weeds on the aisle between rows were hoed, and the weed density on maize plant rows was represented by various weed populations, for each kilogram of weed biomass, maize production output decreased by 0.5 kilograms. When weed density was represented by local weed populations (in treatment no. 2 where no control measure was applied), for each 4.8 kilograms of weeds maize production output was of 1 kilogram. The ratio between production output and weed biomass decreased from 10.3/1 to 1.95/1 when applying only mechanical hoeings and to 1.4/1 when four plants of *A. retroflexus* were present.

Determination of *A. retroflexus* damage threshold in maize crop

In the course of our experiment, as well as in similar research on other species, various weed densities were tested. In this case, four densities of *A. retroflexus* were tested. Figure 1b clearly show that the decrease in production output starts with the first plant of *A. retroflexus* and the correlations resulted in statistically significant differences.

In none of the tested treatments the difference from the production output in the witness treatment isn't identical with the value of DL5% (statistically calculated). In order to calculate the density of *A. retroflexus* plants corresponding with the the production whose difference from the witness equals DL5%, the treatment whose production output difference is closest value to DL5% is used. It is calculated as follows.

If the production output difference a is reached at density b, the value of DL5% will be reached at density x.

x = (value of $DL_{5\%}$ * b)/ a, where:
a is the production output difference of the treatment closest to the value of $DL_{5\%}$, statistically calculated;
b – weed density in the treatment whre the production output difference is a.

In our research (Table 4), the production output difference of 215 kg/ha is closest to the value of DL5%, of 304 kg/ha, and it belongs to treatment no. 3, where the density of *A. retroflexus* is of one plant per sqm. The value x corresponding to the damage threshold for *A. retroflexus* is:

$$x = \frac{304\,kg\,/\,ha * 1\,plant\,/\,sqm}{215\,kg\,/\,ha} = 1{,}41\,plant * ha^{-1}$$

The damage threshold in grain maize crop for *A. retroflexus* is reached at the density of 1.41 plants/sqm making it impossible to measure exactly, which means that the risk to decrease production starts with one plant of *A. retroflexus* per sqm.

Conclusions

The progressive rise in the numbers of *A. retroflexus* to two, three and four plant individuals led to a highly significant increase of the weed coverage from 1257 kg per ha to 1885 kg per ha accounting for 34%, 47% and respectively 50% of the weed coverage in the witness treatment. For each 1.0 kilogram of weeds present in the crop, maize production decreased by 0.1 and 0.5 kilograms respectively, corresponding with the application of a combination of mechanical and manual hoeings in the first case and only mechanical hoeing in the second case. The ratio between production and weed mass decreased from 10.3/1 to 1.95/1 when applying mechanical hoeings exclusively and from 1.4/1 to 4 plant individuals of *A. retroflexus*. In the conditions of the year 2009, maize production decreased and the number of *A. retroflexus* weed individuals/sqm increased, so that a production of 5340 kg per ha was recorded in the absence of this weed species and a weed coverage of 520 kg d.m. per ha resulted in a production drop to 3900 kg/ha at four *A. retroflexus* weed individuals per sqm. The damage threshold in grain maize crop for *A. retroflexus* is reached at the density of 1.41 plants per sqm.

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