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OPTIMIZATION OF SEVERAL WEED CONTROL TECHNOLOGICAL MEASURES BASED ON MODERATE INPUTS IN MAIZE CROP

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Abstract

The alternative weed control of maize crop, based on absent chemical products, consists in mechanical and manual hoeing weed control and is an ecological alternative. This alternative could be easily adopted in an integrated weed management system owing to the regional traditions and success all over the world. We studied a very importantcrop – maize, in 11 types: mechanical hoeing, manual hoeing and a combination of both. The results collected from 2009 to 2011, showed the best solution which has to be adopted in order to obtain a good yield both quantitatively and qualitatively. We measured the weed number between rows and the plant rows. The decrease in the weeding level resulted in an increased average grain yield, from 4410 kg/ha to 8775 kg/ha.

Key words: *maize, mechanical and manual practices, weed number, grain yield.*

INTRODUCTION

The application of effective crop technologies for the maximum use of the high productive potential resulting from the new cultivars is a basic element of agricultural production. The literature shows average production losses between 50 and 80%, sometimes even 100%, between the maize crop where high-quality hoeing was applied and the unhoed crops (Aldrich, 1984; Berca, 1996; Beraru, 1997).

Non-polluting modern crop technologies give consideration to weed identification and control in order to limit the damage. Maize, like other row crops, is highly affected by weeds, irrespective of the growing area (Berca, Ciorlaus, 1994). Sometimes, the high density of certain weeds, such as *Sorghum halepense*, can damage the maize grain yield up to 91.3% (Sarpe, 1987). Using environmentally friendly practices, i.e. mechanical and manual weeding, is an alternative for the ecological crop system (Ionescu et. al., 1996).

As known, the concept of integrated control appeared at the beginning of the 1970s, entailing the development of technologies that reunite all the prevention and control means whose application helps to achieve the best economic results (Berca, 2004).

The analysis of the research results on weed control shows that Romania mainly favours herbicides (Sarpe,1981; Budoi, 1994), compared to other measures. A brief summary of the weed control measures, other than the chemical ones, also refers to manual and mechanical hoeing (Ionescu, 2010). The concept of ecological agriculture excludes the use of chemicals, replacing them on several technological sequences with other methods, at least equally efficient in weed control.

MATERIALS AND METHODS

Research was carried out at SCDA Caracal and was focused on important issues related to the selection of the best agrotechnical methods, i.e. combinations between mechanical and manual hoeing that provide one of the ecological alternatives for weeding decrease in the maize crop.

To achieve this goal, between 2009 and 2011 we performed a complex experiment based on grain maize cultivation and a combination of hoeing practices for weed control, as presented in Table 1.

The experiments were based on the randomized block method applied in three replications.

The following presents several technological issues resulted from the three years of experimentation.

Thus, deep ploughing in autumn was followed by two disking in spring and complex fertilization in doses of 80kg/haN and 30kg/haP. Seeding was conducted at the beginning of May, using the maize hybrid LG 3330 at a density of 5.5pl/m^2. Weed sampling was performed in three phenophases, as follows:

- 20 days after emergence (20 ZDR);
- 40 days after emergence (40 ZDR);
- 60 days after emergence (60 ZDR).

Numerical and gravimetric analysis was performed on the space between the rows and on the rows, results being related to one linear metre (1m).

On-row analysis included 6 cm on both sides of the row, over a 1m distance. The six centimetres represent the plant protection area during mechanical hoeing.

The analysis on the space between rows included a distance of 58 cm, i.e. 70 cm (the technological distance between the rows) minus the protection area (6 cm on each side of the row), over a 1m distance.

Table 1. Experimental variants analyzed during the experiments carried out at SCDA Caracal

No. var	Treatments	Mechanical-ZDR days			Manual-ZDR days		
		20	40	60	20	40	60
1.	2Mec (I,II) Control	yes	yes				
2.	2man (I,II)				yes	yes	
3.	2Mec (I,II) +1man (II)	yes	yes			yes	
4.	1Mec (II) +2man (I,II)		yes		yes	yes	
5.	2Mec (I,II) +1man (I)	yes	yes		yes		
6.	1Mec (I) +2man (I,II)	yes			yes	yes	
7.	*2Mec (1,2) +2man (1,2)*	*yes*	*yes*		*yes*	*yes*	
8.	2Mec (I,II) +2man (I,II)	yes	yes		yes	yes	
9.	3Mec +2man (I,II)	yes	yes	yes	yes	yes	
10.	*3Mec +3man (1,2,3)*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
11.	3Mec + 3 man (I,II,III)	yes	yes	yes	yes	yes	yes

RESULTS AND DISCUSSIONS

The research performed at SCDA Caracal between 2009 and 2011 resulted in a wide range of resultson the influence of the manual and mechanical hoeing on weeding in the maize crop, partly presented in this paper.

1. Weed evolution on maize row depending on the mechanical and manual works applied.

The analysis of the data presented in Table 2 shows the evolution of weed density on the maize rows, prior to the three hoeing epochs (20 ZDR, 40 ZDR si 60 ZDR).

At 20 ZDR (days after emergence), the weed number varied between 19.9 plt./ml in variant V_7-2Mec (1,2) +2 man (1,2) and 25.2 in V_9-3Mec (I, II, III) +2 man (I, II), while the control 2 Mec I, II recorded 22.8 plt./m. Compared with the control, there were no significant differences between the experimental variants.

Before the second-epoch works (40 ZDR), the degree of weed infestation on the maize row ranged between 7.1 plt./ml in V_{11}-2Mec + 3 man (I, II, III) and 21.9 plt./ml la V_3-2Mec (I,II) +1 man (II). Except for variant V_3, all other variants showed a decrease in the degree of infestation, compared with the control.

At 60 ZDR, the weed number decreased to 4.8 plt./m in V_{11}-3Mec+3 man (I, II, III), recording significant differences for all combinations of mechanical and manual hoeing, compared with the control.

The analysis of the weed number as the mean for the three epochs of observation also showed the favourable effect of combining mechanical with manual works, the degree of infestation ranging between 49% and 76%, compared with the control.

For the mean values, it should be noted that weeding had a certain dynamics. The mean values included the dynamics, particularly due to reinfestation which is a natural phenomenon, given the biological characteristics of the plant species.

Table 2. Weed evolution in maize rows, 2009-2011

No.	*Variants* / Treatments	20 ZDR	40 ZDR	60 ZDR	Mean	
		No. plt./m	No. plt./m	No. plt./m	No. weeds	%
1.	**2Mec (I,II) Control**	22.8	20.4	27.1	23.4	100
2.	2man (I,II)	209	14.5^{00}	8.0^{000}	14.5^{000}	62
3.	2Mec (I,II) +1man (II)	20.4	21.9	11.1^{000}	17.8^{00}	76
4.	1Mec (II) +2man (I,II)	20.8	10.7^{000}	7.0^{000}	12.8^{000}	55
5.	2Mec (I,II) +1man (I)	23.8	10.7^{000}	13.4^{000}	16.0^{000}	68
6.	1Mec (I) +2man (I,II)	21.3	8.5^{00}	6.5^{000}	12.1^{000}	52
7.	*2Mec (1,2) +2man (1,2)*	19.9	13.4^{00}	6.0^{000}	13.1^{000}	56
8.	2Mec (I,II) +2man (I,II)	24.9	9.2^{000}	5.6^{000}	13.2^{000}	56
9.	3Mec +2man (I,II)	25.2	9.0^{000}	4.9^{000}	13.0^{000}	56
10.	*3Mec +3man (1,2,3)*	21.4	8.3^{000}	5.2^{000}	11.6^{000}	50
11.	3Mec + 3 man (I,II,III)	22.2	7.1^{000}	4.8^{000}	11.4^{000}	49
	DL 5%	3.4	3.9	2.4	3.23	
	DL 1%	4.8	5.5	3.2	4.50	
	DL 0,1%	6.7	7.7	4.1	6.17	

2. Effect of mechanical and manual works on the dynamics of weed number on the distance between the rows, mean 2009-2011

The analysis of the data presented in Table 3 shows the evolution of weed density on the spaces between the maize rows before the three-epoch hoeing (20 ZDR, 40 ZDR si 60 ZDR). At 20 ZDR the weed number varied between 37.3 plt./m in variant V_7- 2 Mec (1,2) + 2man (1,2) and 29.2 in V_6- 2 Mec (I, II) +2man (I, II), while the 2 Mec I, II control infestation recorded 30.7 plt./m. Compared with the control, there were significant differences between the experimental variants $V_{3,7,8,9}$.

Before the second-epoch works (40 ZDR), weed infestation of maize crop varied between 18.7 plt./ml in V_5- 2 Mec (I, II) +1 man (I) and 33.4 plt./m in V_2- 2 man (I, II). Except for variants $V_{3,4}$, all the other variants showed reduced infestation, compared with the control.

At 60 ZDR, weed number decreased to 10.4 plt./m in V_{11}- 3 Mec + 3 man (I, II, III), with highly significant differences from the control, in all combinations of mechanical and manual hoeing.

The analysis of weed number as mean for the three epochs also shows the favourable effect of combining mechanical with manual works, reducing infestation to 85%, compared with the mechanically weeded control.

Table 3. Weed evolution on maize interval between rows

No.	Variants / treatments	20 ZDR	40 ZDR	60 ZDR	Mean	
		No. plt./m	No. plt./m	No. plt./m	No. Weeds	%
1.	**2Mec (I,II) Martor**	30.7	29.1	16.1	25.3	100
2.	2man (I,II)	31.8	33.4*	42.5***	35.9***	142
3.	2Mec (I,II) +1man (II)	34.5*	26.7	13.3^{0}	24.8	98
4.	1Mec (II) +2man (I, II)	29.3	32.1	16.3	25.3	100
5.	2Mec (I,II) +1man (I)	33.4	18.7^{000}	12.9^{0}	21.7^{0}	86
6.	1Mec (I) +2man (I, II)	29.2	19.0^{000}	27.0***	25.1	99
7.	*2Mec (1,2) +2man (1, 2)*	37.3*	18.7^{000}	10.5^{000}	22.2	88
8.	2Mec (I,II) +2man (I, II)	33.7*	20.2^{000}	11.1^{000}	21.7^{0}	86
9.	3Mec +2man (I, II)	34.8*	20.7^{000}	10.8^{000}	22.1	87
10.	*3Mec +3man (1, 2, 3)*	32.6	20.4^{000}	11.7^{00}	21.6^{0}	85
11.	3Mec + 3 man (I, II, III)	34.6	19.6^{000}	10.4^{000}	21.5^{0}	85
	DL 5%	3.0	4.2	2.7	3.30	
	DL 1%	4.1	5.8	3.5	4.47	
	DL 0.1%	5.8	8.2	4.9	6.30	

3. Evolution of total weed number in maize crop, depending on manual and mechanical hoeing, mean 2009-2011

The analysis of the results presented in Table 4 shows the evolution of weed density on the entier maize-grown area before the three-epoch hoeing (20 ZDR, 40 ZDR and 60 ZDR). At 20 ZDR, weed number renaged between 50.1 plt./m in varianti V_4- 1 Mec (2) +2 man (1,2) and 60.0 plt./m in V_9- 3 Mec (I, II, III) + 2 man (I, II), with a degree of infestation of 53.5 plt./m in the control 2 Mec (I, II). Compared with the control, significant differences were recorded in the experimental variants $V_{8,9,11}$.

Before the second-epoch hoeing (40 ZDR), weed infestation of maize crop on the entire area varied between 26.7 plt./m in V_{11}- 3 Mec (I, II, III) +3 man (I, II, III) and 49.5 plt./m in V_1- 2 Mec (I, II). Except for variants $V_{2,3}$, all other variants recorded decreased infestation, compared with the control.

At 60 ZDR, weed number decreased to 15.2 plt./m in V_{11}- 3 Mec + 3 man (I, II, III), with highly significant differences compared with the control, for all combinations of mechanical and manual hoeing.

The analysis of weed number as mean for the three epochs of observation also shows the favourable effects of combining mechanical with manual works-V_3-V_{11}, infestation ranging between 68% and 87%, compared with the manually hoed control (I, II).

Table 4. Evolution of weed total number in maize crop

No.	Variants / treatments	20 ZDR	40 ZDR	60 ZDR	Mean	
		No. plt./m	No. plt./m	No. plt./m	No. weeds	%
1.	**2Mec (I, II) Control**	53.5	49.5	43.2	48.7	100
2.	2man (I, II)	52.7	47.9	50.5***	50.4	103
3.	2Mec (I,II) +1man (II)	54.9	48.6	24.4^{000}	42.6^{00}	87
4.	1Mec (II) +2man (I, II)	50.1	42.8^{00}	23.3^{000}	38.7^{000}	79
5.	2Mec (I,II) +1man (I)	57.2	29.4^{000}	26.3^{000}	37.6^{000}	77
6.	1Mec (I) +2man (I, II)	50.5	27.5^{000}	33.5^{000}	37.2^{000}	76
7.	*2Mec (1,2) +2man (1, 2)*	57.2	32.1^{000}	16.5^{000}	35.3^{000}	72
8.	2Mec (I,II) +2man (I, II)	58.6**	29.4^{000}	16.7^{000}	34.9^{000}	72
9.	3Mec +2man (I, II)	60.0***	29.7^{000}	15.7^{000}	35.1^{000}	72
10.	*3Mec +3man (1, 2, 3)*	54.0	28.7^{000}	16.9^{000}	33.2^{000}	68
11.	3Mec + 3 man (I, II, III)	56.8*	26.7^{000}	15.2^{000}	32.9^{000}	68
	DL 5%	3.2	4.1	2.6	3.30	
	DL 1%	4.5	5.7	3.4	4.53	
	DL 0.1%	6.3	8.0	4.5	6.27	

4. Maize grain yield, depending on manual and mechanical hoeing applied to the crop grown at SCDA Caracal

Table 5 presents the production data resulted from research. Data analysis shows that, in 2009, maize grain yield was 5219 kg in the control, and varied between 5957 kg/ha in V_2 and 9134 kg/ha in V_{11}. The yield increase, achieved by applying weed control measures in the experimental variants V_2-V_{11}, varied between 14 and 75% (highly significant).

In 2010, the yield increase recorded in variants V_2-V_4 was statistically assured as well (distinctly significant in V_2 and highly significant in V_3-V_{11}).

Yields varied between 3684 kg/ha in V_1 (control) and 8823 kg/ha in V_{11}.

In 2011, the control achieved a yield of 4326 kg/ha; compared with variants V_2 and V_3, production increases were recorded, although not statistically assured while variants V_4-V_{11} recorded statistically assured productiion increases.

Variant V_{11} recorded the highest production level in 2011 (8369 kg/ha).

The application of two-three mechanical hoeing works, together with two-three manual works, proves the most effective for obtaining high yields of maize.

Concerning the production data expressed as the mean for the three experimental years, the differences were singificant, compared with the control, the grain yields varying between 4410 kg/ha in variant V_1 (control) and 8775 kg/ha in variant V_{11}. The yield increase resulting from manual and mechanical hoeing ranged between 11 and 99%, depending on the number of works applied for weed control purposes.

Table 5. Results on grain maize yield obtained at SCDA Caracal depending on mechanical and manual hoeing, 2009-2011

No.	Variants/ treatments	Year 2009		Year 2010		Year 2011		Mean 2009-2011	
		kg.ha^{-1}	%	Kg.ha^{-1}	%	Kg.ha^{-1}	%	Kg.ha^{-1}	%
1	**2Mec (I,II) Control**	5219	100	3684	100	4326	100	4410	100
2	2man (I, II)	5957^{xxx}	114	4185^{xx}	114	4520	104	4887^{xx}	111
3	2Mec (I,II) +1man (II)	6433^{xxx}	123	4602^{xxx}	125	4634	107	5223^{xxx}	118
4	1Mec (II) +2man (I, II)	6889^{xxx}	132	5163^{xxx}	140	4893^{xx}	113	5648^{xxx}	128
5	2Mec (I,II) +1man (I)	7347^{xxx}	141	5723^{xxx}	155	5271^{xxx}	122	6114^{xxx}	139
6	1Mec (I) +2man (I, II)	7728^{xxx}	148	6179^{xxx}	168	5784^{xxx}	134	6564^{xxx}	149
7	*2Mec (1,2) +2man (1, 2)*	8244^{xxx}	158	7493^{xxx}	203	6720^{xxx}	155	7486^{xxx}	170
8	2Mec (I,II) +2man (I, II)	8630^{xxx}	165	7779^{xxx}	211	7224^{xxx}	167	7878^{xxx}	178
9	3Mec +2man (I, II)	8885^{xxx}	170	7899^{xxx}	214	7458^{xxx}	172	8081^{xxx}	183
10	*3Mec +3man (1, 2, 3)*	8950^{xxx}	171	8433^{xxx}	229	7892^{xxx}	182	8425^{xxx}	191
11	3Mec + 3 man I, II, III	9134^{xxx}	175	8823^{xxx}	239	8369^{xxx}	193	8775^{xxx}	199
	*DL 5%	285.5	12	343.6	9	345.8	8	324.9	9.76
	DL 1%	389.8	16	468.6	13	471.2	12	443.2	13.62
	DL 0.1%	528.4	23	634.1	17	641.7	19	601.4	19.62

CONCLUSIONS

Developing ecological weed control strategies is also based on substantiating efficient agrotechnical measures that can be applied for maintaining a low level of damage.

Our research shows that, given an above-average weeding (as was the case of the experimental area), combining mechanical and manual hoeing is the best weed control solution in the ecological agriculture system.

Variant $V_{11,}$ (3 Mec + 3 man I, II, III) was the most favourable technological sequence by its increased maize grain yield.

In 2009, the yield varied between 3684 kg in the control and 9134 kg/ha in variant V_{11}, resulting from the application of thrree mechanical and three manual hoeing works.

Research results can be used by the farmers located in the area of SCDE Caracal, particularly by those who turn to ecological agriculture, in order to select the technological variant that will provide weed control of the maize crop.

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