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RESEARCH ON THE SELECTIVITY AND THE EFFICACY OF HERBICIDES IN CONTROLLING WEEDS FOR THE MAIZE CROP

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ABSTRACT

The maize is an important crop, affected by many of the weeds that, fortunately can be effectively controlled by specific herbicide applications.

The main objective of this paper is to investigate the selectivity and the efficacy of five herbicides applied in different stage: pre-emergence (BBCH 00-09), early post-emergence (stage of development for maize crop 2-4 leaves; stage of development of weeds 1-3 leaves) and post-emergence (stage of development for the maize crop 4-6 leaves and stage of development for mono weeds BBCH 11 -14 and dicotyledons weeds - BBCH 11-15) for the control of the annual and perennial monocotyledonous and dicotyledonous weeds from the maize crop.

The paper present the results obtained for the herbicide treatments: Dual Gold (s-metalaclor); Adengo (isoxaflutol 225 g/l + tiencarbazon-metil 90 g/l + ciprosulfamide (safener) 150 g/l; Adengo [isoxaflutol 225 g/l + tiencarbazon-metil 90 g/l + ciprosulfamide (safener) clopiralid] + Lontrel (300 g/l clopyralid); Nicogan 40 (40 g/l nicosulfuron) + Lontrel (300 g/l clopyralid) + Tomigan (250 g/l fluroxipir).

The study was performed in the experimental fields on cambic chernozem soil of the National Agriculture Research and Development Institute from Fundulea in the years 2015-2017.

Keywords: maize, herbicides, time of application, selectivity, efficacy, weed species.

INTRODUCTION

Maize ranks third in the world in terms of area (after wheat and rice) and first in terms of production, being used in human nutrition, animal feed, raw material in industry and, more recently, for the production of fuels to replace gasoline and diesel. In Romania, maize holds the most important place, having the largest contribution to the total production of grain cereals, although the cultivated area represents about 49-52% of the area sown with cereals.

Maize is considered a weed-sensitive plant, due to its slow growth in the early stages of vegetation and low density (4-7 plants/m^2). The large number of weeds/m^2, which are much more rapacious in terms of light, food and water than maize plants, can cause very high damage (over 30-80% production losses) (Petcu and Martura, 2018).

In general in Romania, the areas cultivated with maize show a strong degree of infestation (over 80%) with annual and perennial monocotyledonous and dicotyledonous weeds, extremely differentiated, depending on the zonal pedoclimatic conditions. The most representative weed species are: monocotyledonous [*Setaria* sp., *Echinochloa crus-galli, Sorghum halepense (from seed and rhizomes), Elymus repens, Eriochloa villosa*] and dicotyledonous *(Amaranthus retroflexus, Chenopodium album, Solanum nigrum, Xanthium strumarium, Sinapis arvensis, Raphanus raphanistrum, Stellaria media, Thlaspi arvensis, Hibiscus trionum, Datura stramonium, Abutilon theophrasti, Cirsium arvense, Convolvulus arvensis, Sonchus arvensis)* (Popescu et al., 2009).

In agriculture, the damage caused by weeds is large, irrecoverable, and diversified. The damage caused by weeds is of several types: quantitative damage (reducing the

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level of production), qualitative damage (by depreciating the quality of crops) and by increasing production costs (technological links are affected in value). Crops of agricultural plants are reduced quantitatively with values between 20% and 60%, sometimes until the compromise of agricultural crops (Penescu and Ciontu, 2001).

Chemical control is one of the most useful means of fighting weeds in our country and has the prospect of becoming more and more profitable. In a broader sense by herbicide we mean a chemical capable - depending on the concentration at which it is used and in the presence of a constellation of favorable natural factors - to exert completely or selectively on the tissues or metabolism of plants with which it comes into contact, a negative effect that can lead to their death (Anghel et al., 1972).

Herbicide is one of the most valuable works in the entire complex of works performed in plant protection actions and is the most expensive and demanding technological link (Berca, 2004; Petcu et al., 2015).

It is difficult to deny the importance of herbicides for cultivation. In most developed countries, agriculture involves the widespread use of herbicides to control weeds and in developing countries, mass migration from rural to urban areas reduces the pool of force for unloading and other labor (Peterson et al., 2017). Herbicides have not only had a profound impact on weed control in agriculture but have also played an important role in expanding the understanding of fundamental plant processes (Dayan et al., 2010).

The rich assortment of herbicides approved for the conditions of Romania, at the optimal doses and times depending on the soil type, the degree of infestation, the spectrum and the dominance of the weeds and last but not least, the climatic conditions allowed the establishment of "optimal strategies for weed control in the maize crop", on agricultural areas, obtaining superior results in the control of weeds from this culture (over 90%) (Popescu, 2007).

In the last years, numerous researches have been carried out regarding the application of the new types of herbicides combined (based on 2-3 active substances), applied early post-emergently (maize 2-4 leaves), with the effect of combating the annual weeds, under the conditions of the optimum phase, weed developments at the time of treatment (Popescu, 2007; Petcu et al., 2015).

The purpose of the work carried out during the research period was to identify technological solutions regarding weed control for maize crop by applying herbicides (combinations and associations of herbicides), with the objective of broadening the control spectrum, synergism, persistence and without negative impact on the environment.

MATERIAL AND METHODS

The research took place in the period 2015-2017, at the NARDI Fundulea, being studied the application of herbicide treatments (simple, combined and combinations of herbicides) to control weed species existing in the maize crop. The researches were carried out in the experimental field from NARDI Fundulea. The maize experiment was placed on a type of soil: cambic chernozem with a pH of 6.5, a clay content of 37% and a humus content of 3.2%. The maize experiment was in randomized block design in 4 replications. The size of the experimental plot was 25 m^2 (3.20 x 7.80 m), using the water volume 400 l/ha.

The experiments were sown in the optimal time, for their development in the experimental field, the biological material we used was the Olt corn hybrid, part of the FAO 450-500 group, with a vegetation period of 135-138 days. It is resistant to breaking and falling, resistant to drought and heat, resistant to corn smut (*Ustilago maydis)*, European corn borer (*Ostrinia nubilalis)* and *Helicoverpa zeae*.

In all three experimental years, the monthly average air temperatures (except those from April - May) were above the long-term average (LTA), but in 2017 the maximum difference was less than one standard deviation. In 2015 the germination and emergence of maize (and weeds) were advantaged by a high soil moisture

content. In May - June 2015 the cumulated precipitation was with 90 mm bellow LTA. Also, in March - Mai 2016 the rainfalls were with 66 mm higher than LTA level, but the next 2 months were with 71 mm lower than LTA. Even if the vegetation season for corn started quite dry in 2017, that year may be consider as favorable due to the generous amount of precipitation above the LTA (171 mm) for March - August.

The objective of this study was to assess the degree of selectivity for the corn crop and the effectiveness in controlling weed species of five herbicide treatments: Dual Gold (s-metalachlor); Adengo [isoxaflutol 225 g/l + tiencarbazon-metil 90 g/l + ciprosulfamide (safener) 150 g/l]; Adengo [isoxaflutol 225 g/l + tiencarbazon-metil 90 g/l + ciprosulfamide (safener) 150 g/l) + Lontrel (clopyralid)]; Nicogan 40 (40 g/l nicosulfuron) + Lontrel 300 (300 g/l clopyralid) + Tomigan (250 g/l fluroxipir).

Table 1. The applied herbicide treatments in the maize crop.
Experimental variants

No. var.	Herbicide treatments	Active ingredient	Dose (l/ha)	Time of application
1	*Untreated*	-	-	-
2	Dual Gold	960 g/l s-metolaclor	1.5	Pre-emergence BBCH 00-09
3	Adengo	isoxaflutol 225 g/l + tiencarbazon-metil 90 g/l + ciprosulfamide (safener) 150 g/l	0.4	
4	Adengo	isoxaflutol 225 g/l + tiencarbazon-metil 90 g/l + ciprosulfamide (safener) 150 g/l	0.35	Early Postem BBCH 12-14
5	Adengo + Lontrel	isoxaflutol 225 g/l + tiencarbazon-metil 90 g/l + ciprosulfamide (safener) 150 g/l + 300 g/l clopyralid	0.35 + 0.4	
6	Nicogan 40 + Lontrel + Tomigan	40 g/l nicosulfuron + 300 g/l clopiralid + 250 g/l fluroxipir	1.0 + 0.5 + 0.6	Postem BBCH 14-16

The herbicide treatments, mentioned in Table 1, were applied at the time:

- pre-emergent (BBCH 00-09), for the variant two and three;
- early post-emergent (stage development corn crop: BBCH 12-14, 2-4 leaves and stage of weed development: 1-3 leaves), for the variants four and five;
- post-emergent (stage development of corn crop: BBCH 14-16, 4-6 leaves and stage of weed development: mono - BBCH 11 -14; for dicots - BBCH 11-15), for the last variant (Nicogan 40 + Lontrel + Tomigan).

Following the application of herbicide treatments, the observations were made regarding the degree of selectivity (%) at intervals of 7-14-28 days after treatment and the degree of control (%) of weeds at intervals of 14-28-56 days from treatment.

RESULTS AND DISCUSSION

In the three years of research, in the experimental field, all the selectivity observations made for the cultivated hybrid Olt were not recorded phytotoxic phenomena (EWRS scale = 0), under the conditions of observing the optimum application phase. Data on the degree of selectivity of tested herbicides was particularly good (no phytotoxic symptom was recorded in any treatment in any of the three experimentation years).

The experience of maize realized in the experimental field showed an infestation degree of 80% (with mono- and dicotyledonous weeds ratio of 55:45), in the culture being present the monocotyledonous and dicotyledonous annual and perennial weeds extremely diversified, depending on: the pre-emergent plant, the local pedo-climatic conditions.

During the years of experimentation, the maize crop presented in the experimental field from Fundulea various of annual and perennial weed species. In the corn experiment, there was a diversified weed species:

- annual and perennial monocotyledonous *Setaria viridis, Echinochloa crus–galli, Sorghum halepense* (seeds and rhizomes)*;*

➢ annual dicots: *Amaranthus retroflexus, Solanum nigrum, Chenopodium album, Xanthium strumarium, Polygonum convolvulus, Sinapis arvensis;*

➢ *perennial dicots: Cirsium arvense, Convolvulus arvensis, Rubus caesius.*

In the maize crop, the present weed reserve appears even before the emergence of crops were simultaneously with the crop plant, leading to: water loss, nutrient consumption, stress on the cultivated plant). In the early stages of weed development of about 70%, it is necessary to apply herbicide treatments in time. An important link will always be the application of combined herbicide treatments, both simple, selective and systemic with an increased spectrum of destruction, with action on annual and perennial weed species and last but not least an important attention for resistant weeds.

In the mentioned infestation conditions and of optimal humidity after treatment, when applying herbicide treatments (combined and herbicide combinations) good results were obtained regarding the control effect of annual and perennial weed species, depending on the degree of infestation, the spectrum and the dominance of the species present in the maize crop and last but not least the climatic conditions (precipitation recorded before and after treatment).

During the research period are presented the average results obtained (3 years) of the experimental variants: Dual Gold 1.5 l/ha; Adengo 0.4 l/ha; Adengo 0.35 l/ha; Adengo 0.35 l/ha + Lontrel 0.4 l/ha; Nicogan 40 1.0 l/ha + Lontrel 0.5 l/ha + Tomigan 0.6 l/ha. The influence of the application of herbicide treatments highlights a significant control of annual and perennial weed species in the treated variants, in accordance with the products used, compared to the untreated plot.

In 2015 and 2017 the application of Dual Gold herbicide at the dose of 1.5 l/ha showed a good efficacy (79-73%) for monocotyledons *Setaria viridis, Echinochloa crus-galli* and *Sorghum halepense* and for the research year 2016 a good effect on the annual monocotyledonous weeds *Setaria viridis* of 80% and *Echinochloa crus - galli* of 75%, these having close efficacy values. The annual dicotyledons *Amaranthus retroflexus* and *Chenopodium album* showed an efficacy of 81% and 80%, respectively. In this experimental variant the annual and perennial uncontrolled weeds: *Solanum nigrum, Xanthium strumarium, Polygonum convolvulus, Sinapis arvensis, Cirsium arvense, Convolvulus arvensis, Rubus caesius.*

Dual Gold is a simple herbicide that provides good control for grass weeds but also for broadleaf species. Based on the research carried out, the average efficacy results obtained for this product showed similar efficacy values for monocotyledonous species: *Setaria viridis, Echinochloa crus - galli, Sorghum halepense.* The annual dicotyledonous weeds *Amaranthus retroflexus* and *Chenopodium album* showed an efficiency of 80-75% (Figure 1).

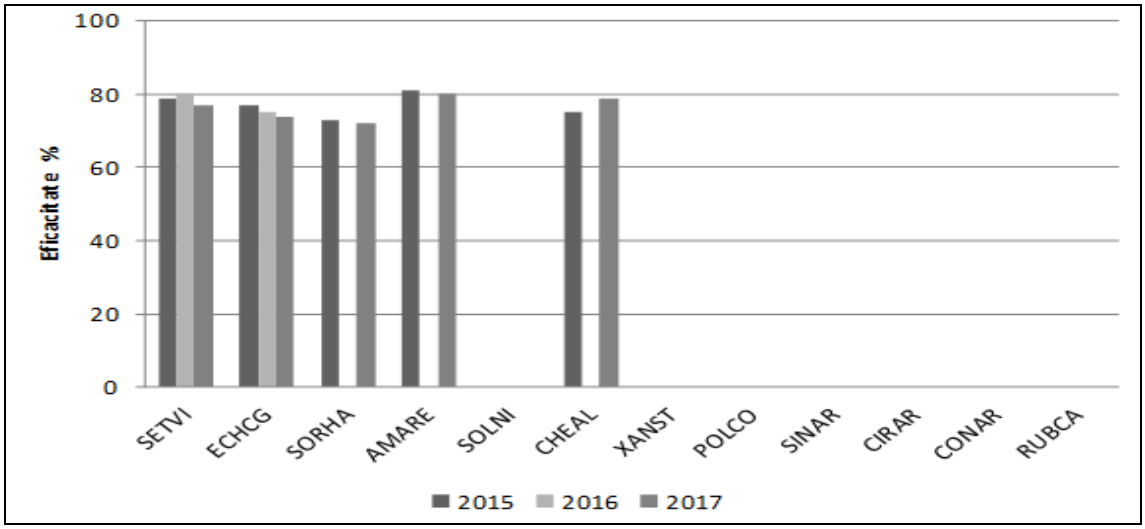

Figure 1. The efficacy of Dual Gold (1.5 l/ha) herbicide applied in pre-emergence

Compared to Dual Gold 1.5 l/ha herbicide, the Adengo 0.4 l/ha combined treatment showed a much more effective control against monocotyledonous and dicotyledonous weeds. In the three years of experimentation, the monocotyledonous weeds *Setaria viridis, Echinochloa crus - galli* and *Sorghum halepense*, in all three experimental variants showed a good control effect, respectively 80%. The effect of combined herbicide treatments (Figure 2) on the annual dicotyledonous weed species *Amaranthus retroflexus* and *Chenopodium album* had a good efficacy, respectively for 2015 and 2017. The annual dicotyledonous species *Polygonum convolvulus* showed a good efficacy of over 80% in the three years of research. In the experimental variants treated with the combined herbicides, the uncontrolled weeds were *Xanthium strumarium, Sinapis arvensis, Cirsium arvense, Convolvulus arvensis, Rubus caesius*.

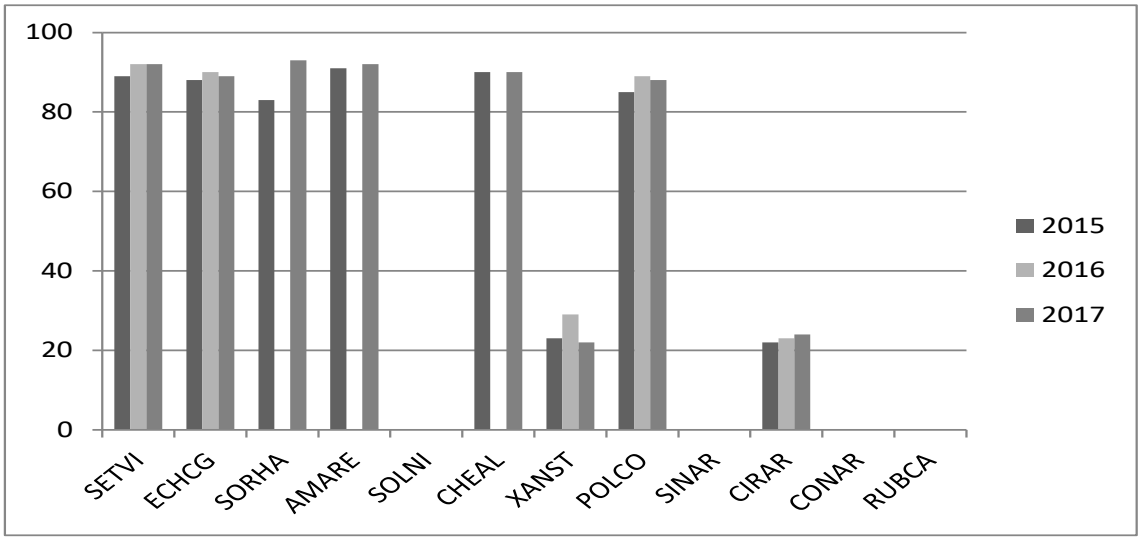

Figure 2. The efficacy of Adengo (0.4 l/ha) herbicide applied in pre-emergence

The combined herbicides and the combination of herbicides were applied in the early post-emergence period (BBCH 12-14, 2-4 leaf corn). The most prominent product was the combination of Adengo herbicides 0.35 l/ha + Lontrel 0.4 l/ha, followed by Adengo which showed a good degree of control for weed species, characteristic of each experimental year. In the three years of experimentation, the monocotyledonous weeds *Setaria viridis, Echinochloa crus - galli* and *Sorghum halepense*, at the combination of herbicides Adengo + Lontrel showed a degree of control, respectively 90%. The annual dicotyledonous *weeds Amaranthus retroflexus, Chenopodium album, Polygonum convolvulus, Xanthium strumarium, Solanum nigrum, Sinapis arvensis* had a good efficacy, for each year of research where these weed species were present. Perennial dicotyledonous weed, resistant to *Cirsium arvense*, was present during the three years in the corn crop, showing a good control effect of 93% (Figure 3).

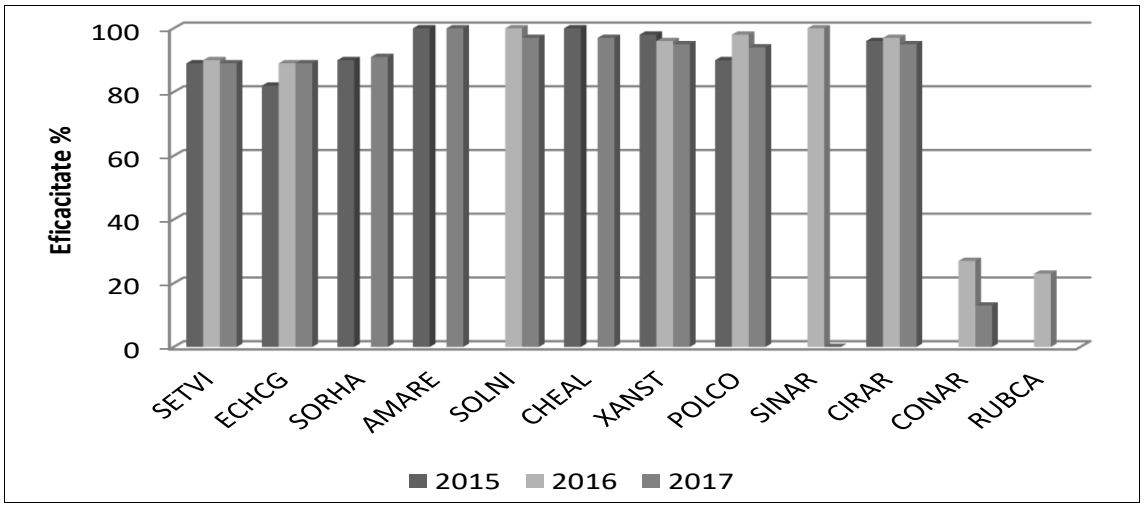

Figure 3. The efficacy (%) of the herbicide associations: Adengo (0.35 l/ha) + Lontrel (0.4 l/ha) applied in early post-emergence

Figure 4 shows the average efficacy results (%) obtained in the early post-emergence application of Adengo herbicide (0.35 l). The results show a control effect greater than 90-98% for the annual monocotyledons *Setaria viridis (SET), Echinochloa crus-galli (ECHCG), Sorghum halepense (SORHA*) and annual dicotyledons *Amaranthus retroflexus (AMARE), Solanum nigrum, Chenopodium album (CHEAL), Xanthium strumarium (XANST), Sinapis arvensis (SINAR) Polygonum convolvulus (POLCO).*

Except for the species of perennial weeds, resistant *Cirsium arvense (CIRAR), Convolvulus arvenses (CONAR), Rubus caesius (RUBCA),* these being uncontrolled (40%).

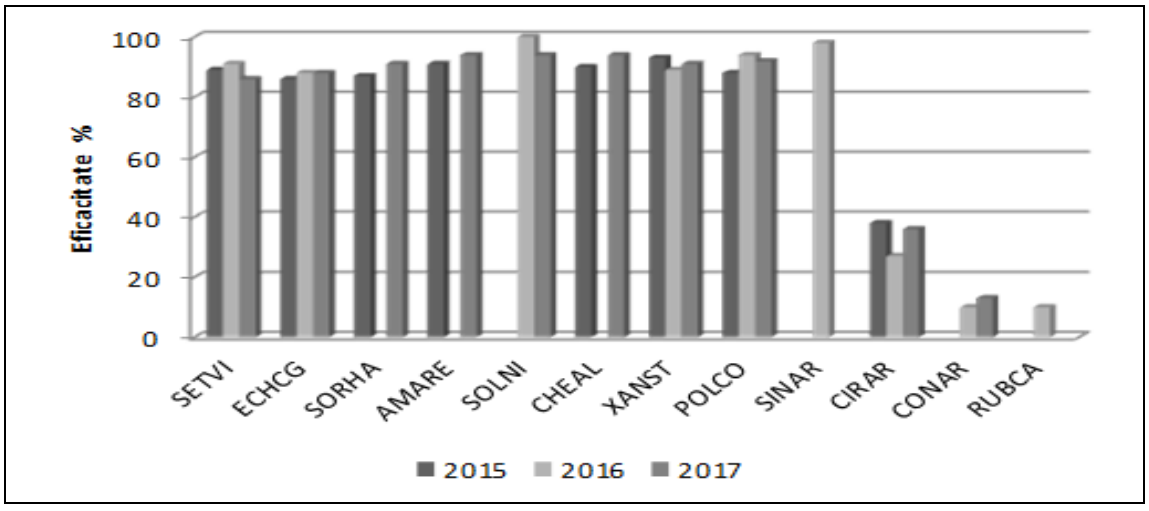

Figure 4. The efficacy of Adengo (0.35 l/ha) herbicide applied in early post-emergence

The average efficacy results of the combination of herbicides Nicogan + Lontrel + Tomigan, showed a good degree of control to control weed species, characteristic of each experimental year. In the three years of experimentation (2015-2017) the monocotyledonous weeds *Setaria viridis, Echinochloa crus - galli* and *Sorghum halepense*, at the combination of herbicides Nicogan + Lontrel + Tomigan showed a good degree of control, respectively 93%. The annual dicotyledonous weeds *Amaranthus retroflexus, Chenopodium album, Polygonum convolvulus, Xanthium strumarium, Solanum nigrum, Sinapis arvensis* had a good efficacy, for each year of research where these weed species were present. Also, the perennial dicotyledons *Cirsium arvense, Convolvulus arvenses* and *Rubus caesius* showed a high degree of control (Figure 5).

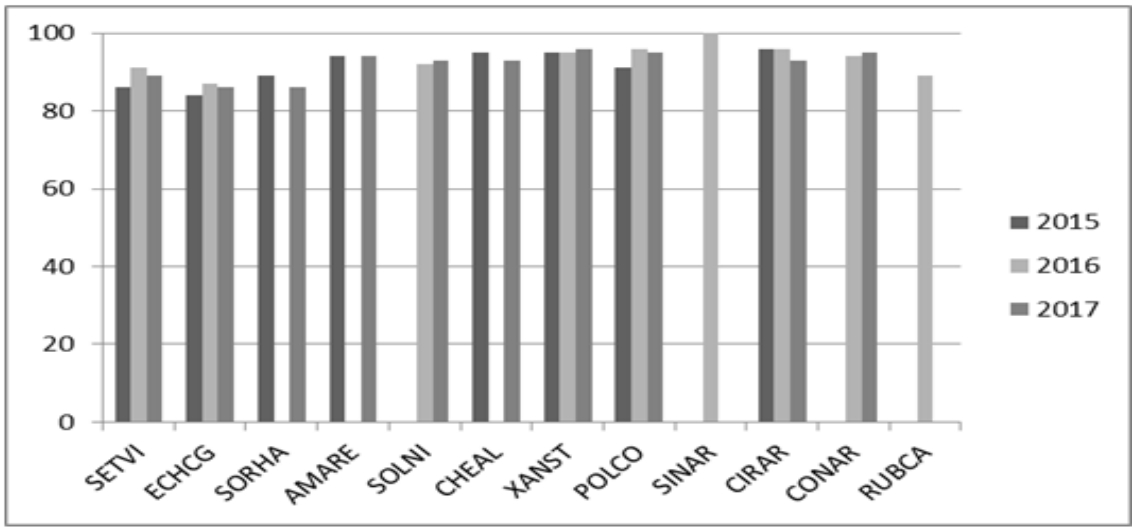

Figure 5. The efficacy of Nicogan 40 (1.0 l/ha) + Lontrel (0.5 l /ha) + Tomigan (0.6 l/ha) herbicides applied post-emergently

The influence of herbicide treatments on the height of plants and maize yields

In generally, the maize is a sensitive plant. Based on research conducted both in our country and abroad, they highlight the level of crop losses caused by weeds. The production losses are characterized differently, these being determined by the degree of infestation, by the dominance and the spectrum of the weeds, the registered climatic conditions. The productions obtained from the maize crop have different variations with the level of the degree of effectiveness of the weed species, carried out by each chemical technology with significant variations. The yields obtained from the maize cultivation is influenced by several factors, including the level of soil fertility and its physico-chemical properties.

For the crop plant, measurements were made regarding the height of the corn plants. These measurements differed from year to year for each treatment applied (Figure 6).

The measurements were made before harvesting, revealed significant differences in maize crop waist. These measurements were closely correlated with herbicide efficiency, yields and, climatic conditions.

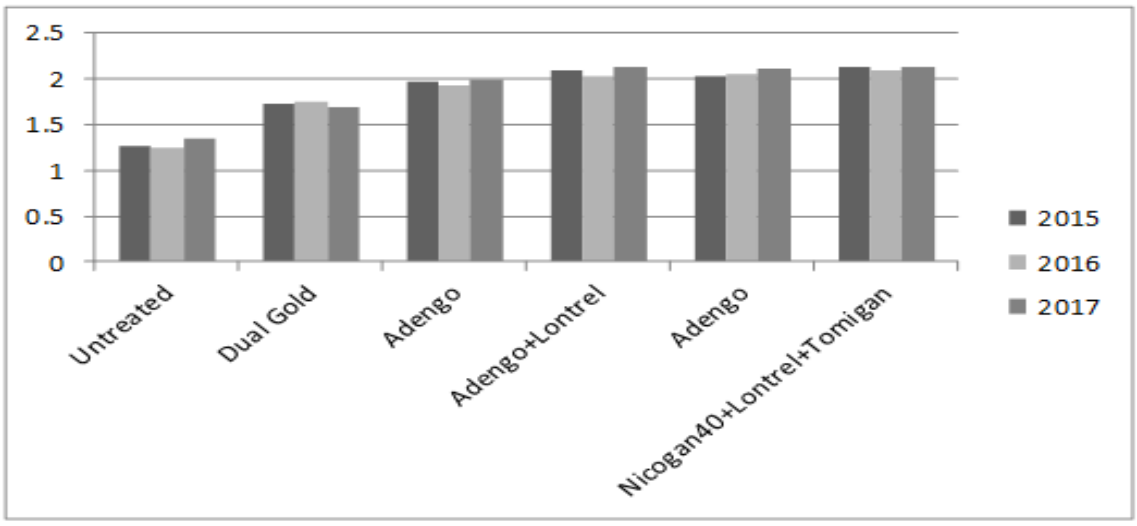

Figure 6. The influence of herbicide treatments on the height of maize plants of the maize crop

All herbicide treatments applied to the maize crop ensured a high and qualitative increase in production compared to the untreated control (Table 2). The most representative herbicide treatments that registered a high production increase were: Adengo 0.4/ha - 7238 kg/ha, Adengo 0.35 l/ha + Lontrel 0.4 l/ha - 9422 kg/ha, Nicogan 1.0 l/ha + Lontrel 0.5 l/ha + Tomigan 0.6 l/ha - 9768 kg/ha.

Table 2. The average yields achieved for the maize crop from 2015-2017

Herbicide treatments	**Dose (l/ha)**	**Yields (kg/ha) 2015-2017**			
		2015	**2016**	**2017**	**Average**
Untreated	-	*1650*	*1510*	*1580*	*1580*
Dual Gold	1.5	4870	4625	4103	4502
Adengo	0.4	7120	6910	7685	7238
Adengo + Lontrel	0.35 + 0.4	9540	9311	9416	9422
Adengo	0.35	8220	8070	8975	8422
Nicogan + Lontrel + Tomigan	1.0 + 0.5 + 0.6	9767	9683	9854	9768

The chemical control of the weed species existing in the maize culture, on the type of cambic chernozem soil from Fundulea, represents an especially important and necessary technological measure.

CONCLUSIONS

- All herbicide treatments (simple, combinations and combinations of herbicides) had a good selectivity for the crop plants, for the commercial hybrid maize - Olt.
- The cause of the appearance of different weed species are correlated with the climatic aspects, with the reserve of seeds in the soil and the low power of the maize plant to compete with them.
- The combined herbicides and the combination of herbicides applied early postemergently (corn, BBCH 12-14) showed a good control effect, highlighting through a single application period.
- The combination of Adengo + Lontrel herbicides with application in early post-emergence (corn, 2-4 leaves) obtained a superior efficacy over 95% for annual and perennial weed species.
- The combination of herbicides: Nicogan (1.0 l) + Lontrel (0.5 l) + Tomigan (0.6 l) applied post-emergently (corn, BBCH 14-16) obtained a superior efficacy of 95-100%, both for monocotyledonous weeds (*Setaria viridis, Echinochloa crus-galli, Sorghum halepense*) and annual dicotyledonous weeds (*Xanthium strumarium, Sinapis arvensis, Solanum nigrum*, and for perennial dicotyledonous: *Cirsium arvense, Convolvulus arvensis, Rubus caesius*).
- The maize yields achieved in the three years of study was noted for herbicide treatments: Adengo 0.4 l/ha - 7238 kg/ha, Adengo 0.35 l/ha + Lontrel 0.4 l/ha - 9422 kg/ha, Nicogan (1.0 l/ha) + Lontrel (0.5 l/ha) + Tomigan (0.6 l/ha) - 9768 kg/ha.
- In all variants treated with herbicides, maize yields were higher compared to the non-herbicide control variant (1580 kg/ha).
- The effectiveness of herbicide application depends on the level of infestation, dominance, weed spectrum, applied dose and climatic conditions.

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