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Review

Achievements and problems in the weed control in grain maize (Zea Mays L.)

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Abstract. Chemical control has emerged as the most efficient method of weed control. Herbicides combinations and tank mixtures of herbicides with adjuvants, fertilizers, growth regulators, fungicides, insecticides, are more effective than when they are applied alone in maize crops. Their combined use often leads to high synergistic effect on yield. There are maize hybrids resistant to imidazolone for Clearfield technology, but they have not yet been introduced in Bulgaria. Data regarding herbicide for chemical control of perennial graminaceous weeds in maize crops are quite scarce even worldwide. The problem is the persistence of some herbicides used in the predecessors on succeeding crops, which is directly related to the weather conditions during their degradation. Most of the information in maize relates to conventional technology for weed control. There is not information about the new Duo system technology in grain maize and the hybrids used are resistant to cycloxydim. A serious problem is also the volunteers of the Clearfield and Express sun sunflower. They have resistance to herbicides different from that of conventional sunflower hybrids. There is no information yet in scientific literature about control of these volunteers.

Keywords: maize, herbicides, weeds control, grain yield, grain quality

Introduction

Weeds are one of the main limiting factors for the production of maize (Zink and Hurte, 1990; Petkova et al., 1990; Rapparini et al., 1994; Sinzar and Tesic, 1995; Zhalnov et al., 1996; Sinzar et al., 1998; Markovic et al., 1998 and 2000; Drazic et al., 1999; Milivojevic, 2001; Michel, 2001; Pacanoski et al., 2007; Simic and Stefanovic, 2007; Vancetovic et al., 2010; Dragičević et al., 2010). Kees and Lutz (1991) reported high resistance to triazine herbicides in weeds Chenopodium album L., Solanum nigrum L., Amaranthus retroflexus L., Galinsoga parviflora Cav., Senecio vernalis L., etc. Many authors found positive influence of properly applied weed control on the grain yield of maize (Gus et al., 1986; Stefanovic and Sinzar, 1988; Legesse et al., 1988; Stefanovic and Zaric, 1991; Jablonkai and Hatziou, 1994; Walton and Casida, 1995; Markovic et al., 1998, 2000; Hiraki et al., 2000; Panfilov, 2002; Mikova and Stoimenova, 2006; Tasko et al., 2006; Christ, 2007, 2008; Korpanov et al., 2010; Dragičević et al., 2012; Simic et al., 2008, 2010, 2012).

Weed control in maize crops

From an economic and environmental viewpoint the combination of chemical and mechanical weed control is very positive. Limiting the soil treatments for mechanical weed control reduces the risk of soil erosion, especially in hilly areas and reducing herbicide reduces contamination of soil and water (Estler et al., 1992; Zadorozhniy, 2002; Sánchez-Martín et al., 2004; Pajić et al., 2009).

Garcia and Mejia (2005) investigated the influence of several herbicide mixes for weed control in maize without vegetation treatments: paraquat + diuron, paraquat + diuron + acetochlor + fluohloridon, paraquat + diuron + metolachlor, paraquat + diuron + pendimethalin + atrazine, paraquat + diuron + nicosulfuron + atrazine, paraquat + diuron + nicosulfuron + bentazon + MCPA, glyphosate-trimezium, glyphosate-trimezium + acetochlor + fluohloridon, glyphosate-trimezium + metolachlor, glyphosate-trimezium + pendimethalin + atrazine, glyphosate-trimezium + nicosulfuron + atrazine, glyphosate-trimezium + nicosulfuron + bentazon + MCPA. According to the authors when used alone soil herbicides cannot control all weeds. They must necessarily be combined with vegetation herbicides. The best results are obtained when combining non-selective herbicide used after the predecessor + soil herbicide used after sowing before emergence + foliar herbicide used during vegetation, as well as when combining soil herbicide + two foliar herbicides.

Kogotko et al. (2006) investigated the effectiveness of four herbicides - Titus, Basis, Callisto and Secator turbo and found that Secator turbo and Basis showed the highest biological efficacy against weeds - 95.5% and 94.6%, respectively. The highest grain yields and green mass were obtained after the use of Secator turbo. Herbicides Primetra gold and Milargo also showed high herbicidal efficacy against annual weeds (Shlarunov and Sholtanyuk, 2005).

Khan et al. (1993, 2002) investigated combinations of soil herbicides Stomp (pendimethalin) Primetra (atrazine + metolachlor) Inong (atrazine), Dual Gold (S-metolachlor) and Treflan (trifluralin) with foliar herbicide Banvel (dicamba + 2,4-D). The most effective is the combination Stomp + Banvel, followed by Primetra + Banvel.

Tank herbicidal mixtures acetochlor + atrazine, alachlor + atrazine and acetochlor + dicamba are more efficient than independent use of these herbicides (Sarpe and Mihalcea, 1999). Grain yield increased by 65% and 55%, respectively.

According to Moosavi et al. (1995) herbicide Stomp
(pendimethalin) controls 77 graminaceous and 69 broadleaf weeds in maize phytocenoses. The high efficiency of foliar herbicides bentazon, bromoxynil, dicamba, pyridate and soil herbicides fluorochloridone, pendimethalin, metobromuron, metolachlor, atrazine is reported.

Gimesi (1992) establishes the following descending order of selectivity of three herbicides in maize: amidosulfuron, trasulfuron, chlorsulfuron. With regard to the herbicidal effect the order is reversed: chlorsulfuron, trasulfuron, amidosulfuron. According to the author the addition of an antidote to chlorsulfuron will increase its selectivity for maize and will allow introducing the scheme "cereal after cereal" in production, i.e. continuous rotation wheat-maize-barley.

According to Green and Ulrich (1993), Molnar et al. (2001) and Milivojevic et al. (2003) most of the investigated over 100 maize hybrids are highly tolerant to sulfonyleurea herbicides rimsulfuron, nicosulfuron, primisulfuron and thifensulfuron. Herbicides Guardian (acetoxychlor) and Gezaprim (atrazine) used for weed control in maize, increased grain yield by 53-90% compared to weeded check (Dawoud et al., 2006). The combination of alachlor and parquat increased grain yield by 33-38%, while with single application of the herbicides yield increases only by 11-18% (Pornchai, 1997).

Soil introduction of pendimethalin and vegetation treatment with bromoxynil octanoate provide control of weeds throughout the growing season (Lesnik, 2000). Similar results were obtained with soil application of isoxaflutole and S-metolachlor and foliar application of dicamba and rimsulfuron (Lesnik, 2003). The new herbicide surkrotion controls a wide range of annual and perennial broadleaf weeds. The herbicide has high selectivity to maize (Matić et al., 2011). Leyehe et al. (1994) reported high herbicidal efficacy and selectivity of Lontrel for maize.

According to Ammon et al. (1992) treatment of stubble after harvest of the predecessor with glyphosate (Roundup) and vegetation crop treatment with rimsulfuron (Titus) provides full weed control for maize.

Kopmanis and Gail (2008, 2010) reported that in highly mixed weed infestation with graminaceous and broadleaf weeds the highest herbicide efficacy is shown by tank mixtures Titus + Arat and Titus + Harmony.

According to Asadi et al. (2009) herbicide Eradikan controls 100% of the Sorghum helenense Pers. from seeds and rhizomes. The herbicidal combination Eradikan + Atrazine controls practically all the weeds in maize crops (Jovovic et al., 1999).

Volunteers of sunflower are a big problem in maize crops. The herbicides used for their control are 100% effective only on young plants to stage first pair of true leaves. Later treatment only slows the sunflower volunteer, but plants survive, albeit with slowed initial growth (Marisavljevic and Pavlovic, 2006).

Maize productivity

The use of herbicides in the early development of maize is essential to achieve high yields. The basic herbicide used in maize crops is triazine, especially atrazine. The highest grain yield at direct sowing of maize is obtained by presowing treatment with total herbicide Roundup bioactive plus vegetation treatment of the crop with the herbicide Banvel C. In this variant the yield is higher by 12.4% than the standard herbicide combination Lentagan + Mikado treated as tank mixture (Hnat, 2002). Miklaszewskas et al. (2000) reported that the preparation Olbras 88 used as adjuvant to 28 herbicides in maize and winter canola increases their efficiency more than adjuvants Tislovet, Adbios, Atpol and Atplus. According to Hoppe (1992), the efficacy of herbicides can be improved by the addition of paraffin oil (PAH), but doing so increases the risk of phytotoxicity on some maize hybrids.

According to Hassan and Amer (1987), the addition of superphosphate to powdered formulations of herbicides Gezaprime, Primextra, Bladex and Igran increases their efficiency under irrigation.

Malzloja et al. (1998, 2009) investigated the interaction between herbicides primisulfuron-methyl, rimsulfuron, nicosulfuron, thifensulfuron-methyl and prosulfuron and insecticides terbufos, phorate, malathion + fenitrothion, carbofuran and carbosulfan. The interaction of the insecticide terbufos with five sulfonylurea herbicides leads to high phytotoxicity. It is most pronounced in high rainfall before or after application of insecticides and herbicides.

In high rainfall after application of Merlin (isoxaflutole) occurrence of phytotoxicity is possible. It is expressed in graying of part of the leaves and stems of plants and temporary inhibition of growth. This phytotoxicity does not affect grain yield. No significant differences were found between the different tested doses of this herbicide (Soukup et al., 2004).

According to Đurić (2010) herbicides rimsulfuron, primisulfuron and prosulfuron are dissolved more easily by soil microorganisms compared to nicosulfuron and foramsulfuron.

Zand et al. (2009) investigated the persistence of several herbicides containing sulfonyleurea used in wheat on subsequent in rotation maize, sunflower, canola, chickpeas and soybeans. The herbicides Apirus (sulfosulfuron), Megaton (chlorsulfuron), Bromcside + Topic (bromoxynil + MCPA + clodinafop-propargil), Total (sulfosulfuron + mesosulfuron) and Atlantis (mesosulfuron + iodosulfuron) were studied. The authors found that herbicides Total and Atlantis reduced maize production by 28% and 13%, respectively.

Some phytotoxicity may occur in maize hybrids under the influence of herbicides Titus, Meister and Milargo in adverse weather conditions (Golebiowska, 2002; Golebiowska and Rola, 2008). The herbicides isoxaflutole and terbutilizan used on maize crops are characterized by the longest persistence in the soil (Rapparini et al., 2000).

Stefanovic and Simic (2007, 2008) and Stefanovic et al. (2010) investigated the selectivity of herbicides isoxaflutole (Merlin), nicosulfuron (Motivel), foramsulfuron (Erip), dicamba + rimsulfuron (Tarot plus), mesotrine (Callisto) and thifensulfuron-methyl (Grid). They were applied in 2-3 leaf of maize. Phytotoxic effect of herbicides on the grain yield of maize is assessed by a 9-point scale of EWRS (European Weed Research Society). Maize hybrids show different sensitivity to the applied herbicides. The lowest is the selectivity of herbicides Tarot plus and Grid, in which the lowest values of maize grain yield were registered.

In maize and wheat resistance to the herbicide chlorosulfuron is determined by the dominant condition of a particular gene and sensitivity - by the recessive condition of this gene (Yang and Wu, 1994).

Walgora et al. (2008a, 2008b) investigated the response of 10 sweet maize hybrids to herbicides Azorpin (atrazine), Meister (formasulfuron + iodosulfuron), Dual Gold (S-metolachlor), Hvastox Turbo (MCPA + dicamba), Aminopilik Gold (fluroxypyr + 2.4-D ), Mustang (florasulam + 2.4-D), Titus (rimsulfuron), Emblem (bromoxynil), Cady star (isoxaflutole + flufenacet), Suxesor (pethoxamide) and Pledge (flumioxazin). Tank mixtures of these herbicides were also studied. The herbicides and their mixtures were applied in dose recommended for each of them at stage 3-4 leaf of maize. Not all of the investigated herbicides are selective to
sweet maize. Herbicide Titus is not selective to it. The highest yield of cobs is obtained after treatment with the combination Meister + Aminopielik Gold. Lowered yield of cobs was observed after application of herbicides Dual Gold and Hvastox Turbo.

To be able to be used in sweet corn without danger of phytotoxicity, herbicide Dual Gold (S-metolachlor) should be used together with the herbicide antidote benoxacor. In other types of maize is not necessary (Roy et al., 2002).

Wright and Penner (1998) reported about selection of maize hybrids resistant to imidazolinones through interspecific hybridization.

Zheliazkov et al. (2010) investigated the effect of four herbicides for weed control in maize crops on yield and quality of the subsequent crops - barley and fodder beet. The herbicides used on maize crops are isoxaflutole (Merlin), acetochlor (Guardian), 2,4-D ester (Maton) and nicosulfuron (Mistral). The highest yields of barley and fodder beet are obtained in cases where maize was treated with herbicides Guardian and Maton in the previous year.

Quality characteristics of maize grain

Elimination of competition of weeds by improving the conditions for intensive development of the maize plant not only increases grain yield, but increases the 1000 grain weight, too (Janjic et al., 1983).

Hussein et al. (1998) reported that soil herbicides Stomp and Primextra increased plant height and 1000 grain weight in addition to grain yield. Ivanovic et al. (1998) reported that foliar sulfonylurea herbicides Tarot (rimsulfuron), Tel (primsulfuron-methyl), Ring (prosulfuron + primsulfuron-methyl) and Motivel (nicosulfuron) have a retarding effect - increased grain yield, but decreased plant height. Stefanovic et al. (2001, 2006), however, reported an increase in the maize height under the influence of nicosulfuron, rimsulfuron and primsulfuron-methyl.

According to Sredojevic et al. (2006, 2006) alachlor reduces root length and coleoptile length during seed germination of 14 inbred lines of maize, but atrazine increases their length.

Conclusion

Literature review demonstrates the views of the cited authors formulated a series of laws. Chemical control has emerged as the most efficient method of weed control. Herbicide combinations and tank mixtures of herbicides with adjuvants, fertilizers, growth regulators, fungicides, insecticides, are more effective than when they are applied alone in maize crops. Their combined use often leads to high synergistic effect on yield. There are maize hybrids resistant to imidazolinone for Clearfield technology, but they have not yet been introduced in Bulgaria. Although without claim to be an exhaustive literature review, it should be noted, that data regarding herbicides for chemical control of perennial graminaceous weeds in maize crops are quite scarce even worldwide. The problem is the persistence of some herbicides used in the predecessors on the succeeding crops, which is directly related to the weather conditions during their decomposition. Most of the information in maize relates to conventional technology for weed control. On some issues there are contrary opinions published due primarily to the different conditions under which the experiments were conducted and also the biological characteristics of the investigated cultivars and hybrids. There is no information about the new Duo system technology in grain maize and the hybrids used that are resistant to cycloxydim. A serious problem is also the volunteers of the Clearfield and Express sun sunflower. They have resistance to herbicides different from that of conventional sunflower hybrids. There is yet no information in specialized literature as to the control of these volunteers.

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Review

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G. Delchev, M. Georgiev

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N. Neykov, T. Mokreva

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B. Dyulgerova, D. Valcheva, N. Dyulgerov

Phenotypic diversity in six-rowed winter barley (Hordeum sativum L.) varieties
N. Dyulgerov, B. Dyulgerova

Evaluation of rye specimens in maturity stage on the base of mathematical – statistical analysis
V. Kuneva, E. Valchinova, A. Stoyanova

Evaluation of lentil cultivars and lines for resistance to Fusarium oxysporum f.sp. lentis
M. Koleva, Y. Stanoeva, I. Kiryakov, A. Ivanova, P. Chamurlyiski

Registration of a new sunflower hybrid - Sevar
P. Peevska, M. Drumeva, G. Georgiev

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The effect of novel xylanase on feeding value of diet containing cereal by-products for broilers
J.M. Abdulla, S.P. Rose, V. Pirgozliev

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H. Lukanov, I. Pavlova, A. Genchev

Slaughter traits of Pharaoh Japanese quails
A. Genchev, H. Lukanov, I. Penchev

Blood count in dogs with mammary gland carcinoma
Ts. Hristov, R. Binev

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Economic efficiency of fattening on different genotypes slow-growing and fast-growing broiler chickens
M. Oblakova, Y. Popova, P. Hristakieva, N. Mincheva, M. Lalev
Effect of nutmeg extract supplementation on some productive traits and economic efficiency of common carp (*Cyprinus carpio* L.) cultivated in recirculation system
G. Zhelyazkov, S. Stoyanova, I. Sirakov, K. Velichkova, Y. Staykov

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Influence of biomanipulation on the living communities and the water quality in the Strezhevo hydroecosystem, R. Macedonia
R. Nastova, V. Kostov, N. Gjorgovska, V. Levkov

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Residue analysis of difenoconazole in apple fruits grown in Republic of Macedonia
V. Jankuloska, I. Karov, G. Pavlovsk

Organooleptic properties of white yam (*Dioscorea rotundata* poir) as affected by autoclaving time
M. Ahmed, Y.B. Kiri, M.S. Abubakar

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