JOURNAL OF PLANT PROTECTION RESEARCH
Vol. 47, No. 4 (2007)

# ASSESSMENT OF THE TANK MIXTURE OF MESOTRIONE AND PETHOXAMID PLUS TERBUTHYLAZINE EFFICACY FOR WEED CONTROL IN MAIZE (*ZEA MAYS* L.)

*Grzegorz. A. Skrzypczak*, Jerzy A. Pudełko, Wojciech Waniorek*

Agricultural University of Poznań
Soil and Plant Cultivation Department
Mazowiecka 45/46, 60-623 Poznań, Poland

*Received: August 7, 2007*
*Accepted: October 28, 2007*

**Abstract:** The evaluation of effect of the grass and broadleaf weed control of different mixture rates of mesotrione plus pethoxamid and terbuthylazine applied postemergence in maize was conducted in the field experiments during the 2005 and 2006 growing seasons. There was no phytotoxicity observed on maize after herbicide treatments. Herbicide mixture provided higher levels of *Echinochloa crus-galii* (L.) Beauv. control than mesotrione used alone. In the postemergence trials, the broadleaf weeds, except *Ch*enopodium *album* L., were not well controlled by the mesotrione-alone treatment. The addition of pethoxamid plus terbuthylazine to mesotrione significantly improved the control of broadleaf weeds. Mesotrione and mesotrione plus pethoxamid and terbuthylazine treated plots were always among the highest yielding as compared to untreated plots. Any reductions in cob and grain yield were always associated with high weed fresh matter yields indicating that it was the weed competition that led to reduced yield and not herbicide phytotoxicity.

**Key words:** weed control, thank-mix, mesotrione, pethoxamid and terbuthylazine, maize, *Zea mays*

## INTRODUCTION

Weeds are one of the most important limiting factors in maize (*Zea mays* L.) production. Therefore, weed control is an important management practice for maize production that should be carried out to ensure optimum grain yield (Adamczewski *et al.* 1997; Skrzypczak *et al.* 1995, 2005; Skrzypczak and Pudełko 1993). Mesotrione is a new callistemone herbicide that inhibits the HPPD enzyme (p-hydroxyphenylpyruvate dioxygenase), a component of the biochemical pathway that converts tyrosine to

*Corresponding address:
gsweed@au.poznan.pl

plastoquinone and $\alpha$-tocopherol (Cornes 2005; Lee *et al.* 1988). Following treatment, in sensitive plants carotenoid biosynthesis is disrupted in the chlorophyll pathway, resulting in a bleaching effect (Wichert *et al.* 1999). It is a member of the benzoylcyclohexane-1,3-dione family of herbicides, which are chemically derived from a natural phytotoxin obtained from the *Callistemon citrinus* (Curtis) Skeels plants. Mesotrione has been shown to be effective for both pre- and postemergence control of weeds in maize (Armel *et al.* 2003b; Gołębiowska and Rola 2003, 2005; Paradowski and Praczyk 2005; Sutton *et al.* 1999). However, as it is a weak acid, mesotrione has been found to be highly adsorbed by soil organic matter in acid soils, thus requiring higher rates when applied preemergence in these environments (Wichert *et al.* 1999). It can be used in both conventional and no-till maize as well as to control glyphosate tolerant weeds in glyphosate-resistant maize (Armel *et al.* 2003a, 2003c).

Mesotrione provides control of the major broad-leaved weeds, and it can be used in integrated weed management programmes depending on the grower's preferred weed control strategy. At postemergence rates mesotrione provides naturally selective control of key species that may show triazine resistance e.g. *C. album*, *Amaranthus* spp., *Solanum nigrum* L., as well as species of weed that show resistance to acetolactase synthase (ALS) inhibitors e.g. *Xanthium strumarium* L., and *Sonchus* spp. and introduces a new naturally selective tool into weed management programmes for use in maize (Mitchell *et al.* 2001; Sutton *et al.* 2002). Maize is tolerant to mesotrione as a consequence of slower uptake and selective metabolism by the crop plant. In all cases, a grass herbicide is still needed.

Pethoxamid, a new chloroacetamide compound appears to inhibit the biosynthesis of fatty acids, and terbuthylazine well known chlorotriazine herbicide compatible with most herbicide formulations except very strong acid/alkaline formulations, can be used for grass and broadleaf weed control in maize (Dhareesank *et al.* 2005; Kidd 2001; Okamoto *et al.* 1991). Up to now according to regulations of UE in some cases both herbicides may replace the use of atrazine.

The objective of this research was to determine the effect of the grass and broadleaf weed control by different mixture rates of mesotrione and pethoxamid plus terbuthylazine applied postemergence in maize.

## MATERIALS AND METHODS

Field trials were conducted using maize (cv. Fido) grown at the Brody Research and Education Station of Agricultural University of Poznań, during the 2005 and 2006 growing seasons. The soil type was luvisoil with pH range from 5.8 to 6.1. Fertiliser and agronomic practices were applied according to State Soil Testing Laboratory recommendations. The trials were set up as complete, randomised block design with four replicates and individual plot size of 2.8 m x 10 m. Each plot contained four rows of maize planted at 70 cm row spacing. Mesotrione (Callisto 100 SC – Syngenta) and pethoxamid + terbuthylazine (Successor T, 550 SE (300+250 g/l) – supplied by Arysta LifeScience) as the tank-mix were used at different rates (150+1650, 100+1650, 100+1375 g/ha and 150 g/ha mesotrione only). Treatments were applied at 4–6 leaves (BBCH 14–16) of the maize growth with bicycle mounted sprayer equipped with fan nozzles type Lurmark 02110 delivering 230 l/ha of spray solution at 220 kPa pressure.

Grass and broadleaf weed control as well as selectivity assessment to maize were done 2 weeks after postemergence treatments using visual estimations. Every year at the beginning of July (8–10 weeks after planting) the analysis of fresh matter of weeds was done and weed control efficacy was calculated. Weed fresh matter was determined by cutting and collecting weeds at ground level in two middle rows, randomly selected from 0.5 $m^2$ frame placed on each plot. The collected weeds were separated into grass and broadleaf species and weighed. Cobs as well as grain yield were taken each year from the two central rows of plots. Maize grain from each plot was weighed and seed moisture was determined using grain moisture tester. Yield was adjusted to 15.5% moisture. Data of weed control and yield of maize were subjected to the analysis of variance and treatment means were compared with a least significant difference test at 5% of probability.

## RESULTS AND DISCUSSION

Maize plants in all the trials showed good tolerance to mesotrione. There was no phytotoxicity observed on maize after herbicide treatments. Also papers presented by James *et al.* (2006), Gołębiowska and Rola (2003, 2005); Paradowski and Praczyk (2005) as well as Sulewska *et al.* (2005) indicated that maize plants in all the conducted trials showed good tolerance to mesotrione. No phytotoxic symptoms were observed in any of the mesotrione alone or combination treatments. The study done by Waligóra and Duhr (2004) showed no phytotoxicity to sweet maize in case of the tank mixture of mesotrione and atrazine.

The main weeds present in the untreated plots in all trials included *E. cruss-galli*, *C. album*, *Viola arvensis* Murray, *Geranium pusillum* L., *Polygonum aviculare* L., *Polygonum convolvulus* L. and *Veronica hederifolia* L. Herbicide mixture provided higher levels of *E. crus-galli* control (98–100%) than mesotrione used alone (86%). According to works of James *et al.* (2006) and Armel *et al.* (2003a, 2003b) the grass weeds were not well controlled by the mesotrione-alone treatments. The addition of e.g. primisulfuron, acetochlor or s-metolachlor gave better both grass and broadleaf weed control. James *et. al.* (2006) also indicated that in the postemergence trials the grass weeds present were not well controlled by the mesotrione-alone treatments. The addition of atrazine to mesotrione significantly improved the control of grass weeds. *Digitaria sanquinalis* (L.) Scop. and *Eleusine indica* (L.) Gaertn. were more susceptible to mesotrione than *Panicum dichotomiflorum* Michx. Presented data of grass weed control were analysed and no significant difference was found between 100+1375 or 1650 g/ha rates of mesotrione plus pethoxamid and terbuthylazine (Table 1).

In the postemergence trials, the broadleaf weeds, except *C. album,* were not well controlled by the mesotrione-alone treatment. The addition of pethoxamid and terbuthylazine to mesotrione significantly improved the control of broadleaf weeds. Control of *G. pusillum* was effective with lower rates of mesotrione plus pethoxamid and terbuthylazine (100+1 375 g/ha). Also Sulewska *et al.* (2005) reported that mesotrione needs a partner herbicide to be more effective against *G. pusillum* control. Mesotrione applied alone was less effective on *P. arvensis* and *P. convolvulus* (50 and 63% control, respectively). Understandably, herbicide mixtures provided higher levels of both species control than mesotrione used alone. Results indicated 88–90% control of *P. arvensis* and 98–100% control of *P. convolvulus* when mesotrione and pethoxamid plus therbuthylazine ware applied at the rate 100+1 375 g/ha only. *V. arvensis* was more effectively controlled when mesotrione and pethoxamid plus therbuthylazine tank mixture were used at higher rates e.g. 150+1 650 g/ha, respectively (Table 1).

Table 1. Weed control efficacy in applied treatments (2005–2006)

| Treatment | Rate [g/ha] | Weed control efficacy [%] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | ECHCG | CHEAL | VIOAR | GERPU | POLAV | POLCO | VERHE |
| Mesotrione | 150 | 86 | 100 | 80 | 60 | 50 | 63 | 70 |
| Mesotrione +pethoxamid and terbuthylazine | 150 +1650 | 100 | 100 | 100 | 100 | 88 | 100 | 100 |
| Mesotrione +pethoxamid and terbuthylazine | 100 + 1650 | 98 | 100 | 90 | 100 | 90 | 98 | 88 |
| Mesotrione +pethoxamid and terbuthylazine | 100 + 1375 | 98 | 100 | 91 | 100 | 90 | 98 | 88 |
| Untreated control (weeds g/m$^2$) | – | 223 | 1547 | 320 | 105 | 80 | 15 | 15 |
| LSD (0.05) | – | 10.6 | n.s. | 8.8 | 15.2 | 9.8 | 5.9 | 5.9 |

ECHCG – *Echinochloa crus-galli*, CHEAL – *Chenopodium album*, VIOAR – *Viola arvensis*, GERPU – *Geranium pusillum*, POLAV – *Polygonum aviculare*, POLCO – *Polygonum convolvulus*, VERHE – *Veronica hederifolia*
n.s. – not significant difference

Table 2. Cob and grain yield of maize as influenced by herbicide treatments (2005–2006)

| Treatment | Rate [g/ha] | Yield [t/ha] | |
|---|---|---|---|
| | | cobs | grain |
| Mesotrione | 150 | 11.7 | 8.70 |
| Mesotrione +pethoxamid and terbuthylazine | 150 +1650 | 11.1 | 8.80 |
| Mesotrione +pethoxamid and terbuthylazine | 100 +1650 | 11.7 | 8.63 |
| Mesotrione +pethoxamid and terbuthylazine | 100 +1375 | 13.0 | 9.38 |
| Untreated control | 0 | 4.7 | 3.32 |
| LSD (0.05) | – | 2.79 | 1.17 |

Sulewska and Koziara (2006) also obtained better results of broadleaf weeds control when mesotrione was applied as tank-mix with atrazine. They observed complete weed control of such species as: *C. album, V. arvensis, Capsella bursa-pastoris* L., *Lamium purpureum* L. as well as *P. convolvulus*. James *et. al.* (2006) reported that all the broadleaf weeds present were significantly reduced by mesotrione, with the exception of *Portulaca oleracea* L. Portulaca was well controlled by atrazine, dicamba and nicosulfuron. The work of Lingenfelter *et al.* (2002) has shown that mesotrione applied postemergence provided > 90% control of *C. album*, *Abutilon theophrasti* Medik. and *Amaranthus hybridus* L. but *Ambrosia artemisiifolia* L. and *P. convolvulus* control was improved by the addition of atrazine.

Mesotrione and mesotrione plus pethoxamid and terbuthylazine treated plots were always among the highest yielding as compared to untreated plots. Any reductions in cob and grain yield were always associated with high weed fresh matter yields indicating that it was the weed competition that led to reduced yield and not herbicide phytotoxicity (Table 2).

## CONCLUSIONS

Results presented here demonstrate mesotrione to be an effective herbicide for post-emergence control of weeds in maize especially broadleaf weeds. Therefore, to ensure effective control of all weeds, mesotrione should be used in combination with an herbicide that has more activity on grass weeds. Using a combination of postemergence herbicides overcomes many of potential problems and also provides the best strategy for avoiding herbicide resistance. Selection will mainly depend on weed spectrum, cost, and use of restrictions.

## ACKNOWLEDGEMENTS

Research was supported by the Polish Ministry of Science and Higher Education as the part of project number 508-03-3 at the August Cieszkowski Agriculture University in Poznań. The authors thank mgr B. Skrzypczak and inż. M. Żurowska for field research and technical assistance.

## REFERENCES

Adamczewski K., Skrzypczak G., Lisowicz F., Bubniewicz P. 1997. Aktualne problemy ochrony kukurydzy w Polsce. Zesz. Probl. Post. Nauk Rol. 450: 63–78.

Armel G.R., Wilson H.P., Richardson R.J., Hines T.E. 2003a. Mesotrione combinations in no-till corn (*Zea mays*). Weed Technol. 17: 111–116.

Armel G.R., Wilson H.P., Richardson R.J., Hines T.E. 2003b. Mesotrione, acetochlor, and atrazine for weed management in corn (*Zea mays*). Weed Technol. 17: 284–290.

Armel G.R., Wilson H.P., Richardson R.J., Hines T.E. 2003c. Mesotrione alone and in mixtures with glyphosate in glyphosate-resistant corn (*Zea mays*). Weed Technol. 17: 680–685.

Cornes D. 2005. Callisto: a very successful maize herbicide inspired by allelochemistry. http://www.regional.org.au/au/allelopathy/2005/2/7/2636_cornesd.htm

Dhareesank A., Kobayashi K., Usui K. 2005. Phytotoxic activity of pethoxamid in soil under different moisture conditions. Weed Biol. Manage. 5: 197–202.

Gołębiowska H., Rola H. 2003. Ocena skuteczności działania herbicydu Callisto 100 SC w zwalczaniu chwastów jedno- i dwuliściennych na plantacji kukurydzy. Prog. Plant Protection/Post. Ochr. Roślin 43: 643–647.

Gołębiowska H., Rola H. 2005. Ocena zastosowania herbicydów Mustang 306 SE i Callisto 100 SC w kukurydzy do zwalczania chwastów w rejonie Dolnego Śląska. Prog. Plant Protection/Post. Ochr. Roślin 45: 675–679.

James T.K., Rahman A., Hicking J. 2006. Mesotrione – a new herbicide for weed control in maize. NZ Plant Protection 59: 242–249.

Kidd H. 2001. Conference report – weeds 2001. Pestic. Outlook 12: 212–213.

Lee D.L., Knudsen C.G., Michaelay W.J., Chin H., Nguyen N.H., Carter C.G., Cromartie T.J., Lake B.H., Shribbs J.M., Fraser T. 1988. The structure-activity relationships of the triketone class of HPPD herbicides. Pestic. Sci. 54: 377–384.

Lindenfelter D.D., Curran W.S., Handwerk K. 2002. Isoxaflutole vs. mesotrione: the battle of the bleachers. Proc. NEWSS 56. p. 24.

Mitchell G., Bartlett D.W., Fraser T.E.M., Hawkes T.R., Holt D.C., Townson J.K., Wichert R.A. 2001. Mesotrione: a new selective herbicide for use in maize. Pest Manage. Sci. 57: 120–128.

Okamoto H., Kato S., Kobutani T., Ogasawara M., Konnai M., Takematsu T. 1991. Herbicidally active N-(1-arylethеyl)-2-chloroacetamides bearing an alkyloxyalkyl moiety. Agric. Biol. Chem. 55: 2737–2743.

Paradowski A., Praczyk T. 2005. Ocena działania mezotrionu (Callisto 100 SC) na chwasty w uprawie kukurydzy. Prog. Plant Protection/Post. Ochr. Roślin 45: 978–981.

Skrzypczak G., Pudełko J. 1993. Assessment and economic aspect of herbicides used for weed control in maize (*Zea mays* L.). 8th EWRS Symposium. Braunschweig, 14–16 June 1993: 267–273.

Skrzypczak G., Pudełko J., Blecharczyk A., Woźnica Z. 1995. Adjuvants and herbicides in maize (*Zea mays* L.) production. 9th EWRS Symposium. Budapeszt, 10–12 July 1995: 315–319.

Skrzypczak G., Pudełko J., Waniorek W. 2005. Ocena skuteczności herbicydów do zwalczania *Echinochloa crus-galli* w uprawie kukurydzy. Prog. Plant Protection/Post. Ochr. Roślin 45: 1078–1080.

Sulewska H., Ptaszyńska G., Jazic P., Waligóra H. 2005. Ocena zachwaszczenia kukurydzy po powschodowym użyciu wybranych herbicydów. Prog. Plant Protection/Post. Ochr. Roślin 45: 1120–1122.

Sulewska H., Koziara W. 2006. Skuteczność wybranych herbicydów stosowanych powschodowo w kukurydzy. Prog. Plant Protection/Post. Ochr. Roślin 46 (2): 243–245.

Sutton P.B., Foxon G.A., Beraud J-M., Anderdon J., Wichert R. 1999. Integrated weed management systems for maize using mesotrione, nicosulfuron and acetochlor. The BCPC Conference – Weeds 1: 225–230.

Sutton P., Richards C., Buren L., Glasgow L. 2002. Activity of mesotrione on resistant weeds in maize. Pest Manage. Sci. 58: 981–984.

Waligóra H., Duhr E. 2004. Skuteczność chwastobójcza preparatów Callisto 100 SC, Titus Plus DF i Emblem 20 WP w kukurydzy cukrowej. Prog. Plant Protection/Post. Ochr. Roślin 44: 1183–1186.

Wichert R., Townson J.K., Bartlett D.W., Foxon G.A. 1999. Technical review of mesotrione, a new maize herbicide. The BCPC Conference – Weeds 1: 105–110.

## POLISH SUMMARY

## OCENA SKUTECZNOŚCI CHWASTOBÓJCZEJ HERBICYDU MEZOTRION W MIESZANCE Z PETHOXAMIDEM I TERBUTYLOAZYNĄ W UPRAWIE KUKURYDZY (*ZEA MAYS* L.)

W latach 2005–2006 wykonano badania, których celem było określenie skuteczności chwastobójczej różnych dawek herbicydu Callisto 100 SC (mezotrion) stosowanego w mieszance z herbicydem Successor T 550 SE (pethoxamid + terbutyloazyna) w uprawie kukurydzy na ziarno. Doświadczenia przeprowadzono w ZDD Brody należącym do Akademii Rolniczej w Poznaniu na glebie płowej o pH 5,8–6,1. Kukurydzę odmiany Fido wysiewano w rozstawie 19x70 cm na poletkach o wymiarach 2,8 m x 10 m.

Badania założono jako jednoczynnikowe w 4 powtórzeniach. Kombinacje herbicydowe stosowano po wschodach kukurydzy w fazie 4–6 liści (BBCH 14–16) używając opryskiwacza rowerowego o wydatku cieczy roboczej 230 l/ha.

Ocenę fitotoksyczności wykonano 2 tygodnie po zabiegu, a ocenę skuteczności chwastobójczej przedstawiono jako procent zniszczenia występujących gatunków chwastów wyrażoną obniżeniem ich świeżej masy na jednostce powierzchni.

Nie stwierdzono fitotoksycznego działania na rośliny kukurydzy żadnej z zastosowanych kombinacji herbicydowych. Głównymi gatunkami chwastów występującymi na obiektach kontrolnych były: *Echinochloa cruss-galli* (ECHCG), *Chenopodium album* (CHEAL), *Viola arvensis* (VIOAR), *Geranium pusillum* (GERPU), *Polygonum aviculare* (POLAV), *Polygonum convolvulus* (POLCO) i *Veronica hederifolia* (VERHE). Mieszanki herbicydowe skuteczniej zwalczały chwasty jednoliścienne w tym dominujący gatunek ECHCG w porównaniu do stosowania samego mezotrionu. Również mieszanki okazały się skuteczniejsze w zwalczaniu CHEAL oraz rdestów (POLSP). Pozostałe gatunki dwuliścienne, poza VIOAR, dobrze były niszczone po zastosowaniu niższych dawek herbicydów stosowanych w mieszankach. Wyższe dawki wymagane były do skutecznego zwalczania gatunku VIOAR. Wszystkie kombinacje herbicydowe poprzez wysoką skuteczność chwastobójczą przyczyniły się do istotnego zwiększenia plonów zarówno kolb jak i ziarna kukurydzy.