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# INFLUENCE OF POST-EMERGENCE HERBICIDES ON YIELD OF MAIZE (*Zea mays* L.)

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**Summary:** The influence of two post-emergence herbicides - foramsulfuron and tembotrione on yield, plant height and ear length in hybrid maize Kneja-530 (*Zea mays* L.) was analyzed by means of dispersion analysis. The experimental design was randomized block with three replicates. The results revealed that both active ingredients had high efficiency on the annual monocotyledonous and dicotyledonous weeds. Significant differences in the response to both herbicides were found for the studied characters.

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**Keywords:** maize; post-emergence herbicides; tembotrione; foramsulfuron; weeds; yields.

## INTRODUCTION

Maize (corn) is one of the world's topic crops that provide fast-foods and staple foods for human consumption. Also, maize grain is a basic livestock of feed, and the corn stalks; once separating the cobs, it can be used as animal fodder. Over recent years maize has been increasingly used as a feedstock for the production of biofuels (Blanco-Canqui and Lal, 2007). In Bulgaria, maize is the most important grain crop and it is produced throughout the country under diverse environments (Kraptchev et al., 2010; www.mzh.government.bg).

The successful cultivation of maize depends largely on the efficacy of weed control. Annual yield losses occur as a result of weed infestation of cultivated crops. The annual yield loss in maize because of weed problems is estimated to be approximately 37%. The loss occurs as a result of weed competition for nutrients, water and light (Oerke and Dehne, 2004). Weeds can be removed mechanically or by using chemical liquids, granules or gases to kill germinating or growing weeds, or even weed seeds. There are a great number of pre-emergence or post-emergence herbicides with different efficacy against weeds. One of the new herbicides is foramsulfuron which applied alone controls *Setaria faberi* Herrm., *Panicum dichotomiflorum* Michx. and *Amaranthus retroflexus* L. by 88, 99 и 99%, respectively on the 28$^{th}$ d after treatment. Good efficiency of its active ingredients

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was also established against *Xanthium strumarium L., Abutilon theophrasti* (L.) Rusby and *Chenopodium album* L. (Bunting et al., 2005) and other specific weeds for agrocenosis, thus ensuring a prolonged lack of weeds (Nurse et al., 2007). Foramsulfuron acts on the weeds both via the foliage and the soil, with predominance of foliar action. After pre-emergence application broadleaf and grass weeds are susceptible to the activity of foramsulfuron. After uptake the substance shows limited translocation to nontreated parts. Susceptible plants cease to grow almost immediately after post-emergence application and the symptoms include the appearance of chlorotic patches, followed by slow shoot necrosis. Weeds are completely killed 1 to 4 weeks after application. Foramsulfuron causes the inhibition of acetolactate synthase ALS (acetohydroxyacid synthase) (Tomlin, 2009).

Tembotrione is a herbicide for post-emergence use in corn. It has shown quite satisfactory results on weed control, particularly for monocotyledonous species. It inhibits the enzyme 4-hydroxy - phenylpyruvate dioxygenase (HPPD) and the formation of carotenoids is disrupted. Depletion of carotenoids deprives chlorophyll, the sites of photosynthesis, of its protection against an overdose of light resulting in chlorophyll oxidation. The development of bleaching starts at the youngest tissues of the aerial plants parts. This process is rapid, as the herbicide exerts its full effect within a few days (Santel, 2009). Commercial formulation of tembotrione includes the poorer isoxadifen-ethyl, granting higher selectivity to corn and popcorn crops (Waddington and Young, 2006). Field tests of crop tolerance provided by mezotrion, topramezone and tembotrione application in maize showed that tembotrione caused the least crop injury and poorest phytotoxicity when compared with mezotrion and topramezone (Bollman et al., 2008). It was demonstrated that tembotrione applied at a rate of 92 $gha^{-1}$ was effective against several dicotyledonous and monocotyledonous weeds: *Amaranthus retroflexus* L., *Chenopodium album* L., *Ambrosia artemisifolia* L., *Abutilon theophrasti* Medic., *Setaria faberi* Herrm, *Echinochloa crusgalli* (L.) Beauv, and *Eriochloa villosa* (Thunb.) Kunth (Hinz et al., 2005; Lamore et al., 2006).

The aim of the present study was to evaluate the weed control efficacy of a.i. foramsulfuron (trade name Equip OD) and a.i. tembotrione (trade name Laudis OD) on plant height, ear length and grain yield of maize plants.

## MATERIALS AND METHODS

The late maize (*Zea mays* L.) hybrid Kneja 530 was used in this study. The experiments were carried out at the Experimental Field of the University of Forestry, Sofia, Bulgaria (42°50´N, 23° 40´E, 552 m above the sea level) during three consecutive years (2009, 2010, 2011). The soil type in Sofia is fluvisol, slightly stony, slightly acidic (0-15 cm, top soil). Month mean temperatures and average rainfall occurring from April to September according to the State Meteorology Department are presented in Table 1.

The scheme of the experiment was the following: V1 - without herbicides, but weeding control; V2 - a.i. foramsulfuron

**Table 1.** Month mean temperature and amount of rainfall according to the State Meteorology Department.

| Month | 2009 | | 2010 | | 2011 | |
|---|---|---|---|---|---|---|
| | Mean temp., °C | Amount of rainfall, l/m² | Mean temp., °C | Amount of rainfall, l/m² | Mean temp., °C | Amount of rainfall, l/m² |
| April | 11.3 | 49.3 | 10.7 | 54.4 | 9.9 | 15.8 |
| May | 16.3 | 67.0 | 15.6 | 66.1 | 14.7 | 30.1 |
| June | 19.1 | 47.1 | 18.6 | 76.5 | 19.0 | 13.6 |
| July | 21.4 | 79.6 | 21.1 | 52.8 | 21.8 | 110.6 |
| August | 20.8 | 124.2 | 22.5 | 41.3 | 21.4 | 44.9 |
| September | 16.4 | 60.5 | 16.5 | 47.1 | 19.5 | 23.6 |

(Equip OD applied at a rate of 200 ml/da), V3 - a.i. foramsulfuron (Equip OD applied at a rate of 250 ml/da), V4 - a.i. tembotrione (Laudis OD applied at a rate of 200 ml/da), V5 - a.i. tembotrione (Laudis OD applied at a rate of 225 ml/da). Treatment with post-emergence herbicides was applied at 3-4 leaf stage of the crop and 2-4 leaf of the annual weeds, respectively.

Each trial was laid out in a randomized block-design with three replications. The sowing was performed in the second half of April. Seeds from each sample were sown in 8 cm depth by hand in 3 m x 8 m plots. The scheme of sowing was 70 x 30 cm. Every plot included 4 rows of maize. Standard agronomic practices use monocultivation with sprinkle irrigation. Ten randomly selected plants from each replication were used for recording plant height (cm), ear length (cm) and grain yield (kg/da). The number of weeds before treatment and on the 14$^{th}$ and 28$^{th}$ days after treatment with herbicides was analyzed.

Data were subjected to statistical analysis using dispersion method. Means were separated by application of Duncan's multiple range test at $p \leq 0.05$.

## RESULTS AND DISCUSSION

### Influence of post-emergence herbicides on weeds

Data on the weed community composition evidenced during the growing period are given in Tables 2-4. The naturally occurring weed communities consisted of 11 annual grassy and broad-leaved species that are typical for the weed flora in cultivated fields of Sofia region: cockspur (*Echinochloa crus-galli* L. Beauv.), green bristlegrass (*Setaria viridis* L. Beauv.), yellow bristle-grass (*Setaria glauca* L. Beauv.), red finger-grass (*Digitaria sanguinalis* (L.) Scop.), gallant soldier (*Galinsoga parviflora* Cav.), prostrate knotweed (*Polygonum aviculare* L.), purslane (*Portulaca oleracea* L.), rough cockle-bur (*Xanthium strumarium* L.), white goosefoot *(Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.) and creeping thistle (*Cirsium arvense* (L.) Scop.).

After 14$^{th}$ day of treatment, the number of annual monocotyledonous weeds remained unchanged compared to the control (Table 2). Meanwhile, the general influence of post-emergence herbicides was evidenced by the appearance of

**Table 2.** Average number of weeds in 1 $m^2$ before treatment with post-emergence herbicides.

| Weed species | Untreated control | Foramsulfuron - 200 ml/da | Foramsulfuron - 250 ml/da | Tembotrione - 200 ml/da | Tembotrione - 225 ml/da |
|---|---|---|---|---|---|
| *Echinochloa crus galli* | 26.0 | 9.0 | 6.7 | 10.0 | 8.7 |
| *Setaria viridis* | 20.0 | 3.3 | 1.0 | 5.0 | 3.3 |
| *Setaria glauca* | 6.7 | 0.0 | 0.0 | 4.0 | 2.0 |
| *Digitaria sanguinalis* | 3.0 | 0.7 | 0.3 | 0.0 | 0.0 |
| *Galinsoga parviflora* | 8.7 | 2.7 | 2.0 | 0.0 | 0.0 |
| *Polygonum aviqulare* | 3.3 | 1.0 | 1.0 | 0.0 | 0.0 |
| *Portulaca oleracea* | 1.3 | 0.7 | 1.0 | 0.0 | 0.0 |
| *Xanthium strumarium* | 26.0 | 14.0 | 4.3 | 9.0 | 7.0 |
| *Chenopodium album* | 17.0 | 11.3 | 21.7 | 10.3 | 9.0 |
| *Amaranthus retroflexus* | 20.0 | 2.0 | 0.3 | 5.0 | 4.5 |
| *Cirsium arvense* | 8.0 | 0.3 | 0.7 | 0.0 | 0.0 |

anthocyan colored seedlings after treatment with Equip OD or necrosis after treatment with Laudis OD, respectively. The sterongest effect of herbicides on annual monocotyledonous weeds was established in species *Galinsoga parviflora*, *Polygonum aviculare* and *Portulaca oleracea*. The average number of weeds per square meter of *Xanthium strumarium, Chenopodium album* and *Amaranthus retroflexus* remained unchanged but the herbicide caused chlorosis and partial necrosis. Also, the average number of perennial dicotyledonous weeds was

**Table 3.** Average number of weeds in 1$m^2$ on the 14$^{th}$ day after treatment with post-emergence herbicides.

| Weed species | Untreated control | Foramsulfuron - 200 ml/da | Foramsulfuron - 250 ml/da | Tembotrione - 200 ml/da | Tembotrione - 225 ml/da |
|---|---|---|---|---|---|
| *Echinochloa crus galli* | 26.0$^a$ | 9.0$^b$ | 6.7$^b$ | 10.0$^b$ | 8.7$^b$ |
| *Setaria viridis* | 20.0$^a$ | 3.3$^b$ | 1.0$^b$ | 5.0$^b$ | 3.3$^b$ |
| *Setaria glauca* | 6.7$^a$ | 0.0$^c$ | 0.0$^c$ | 4.0$^b$ | 2.0$^b$ |
| *Digitaria sanguinalis* | 3.0$^a$ | 0.7$^b$ | 0.3$^b$ | 0.0$^c$ | 0.0$^c$ |
| *Galinsoga parviflora* | 8.7$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Polygonum aviculare* | 3.3$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Portulaca oleracea* | 1.3$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Xanthium strumarium* | 26.0$^a$ | 14.0$^b$ | 4.3$^c$ | 9.0$^b$ | 7.0$^c$ |
| *Chenopodium album* | 17.0$^a$ | 11.3$^b$ | 21.7$^a$ | 10.3$^b$ | 9.0$^b$ |
| *Amaranthus retroflexus* | 20.0$^a$ | 2.0$^c$ | 0.3$^c$ | 5.0$^b$ | 4.5$^b$ |
| *Cisium arvense* | 8.0$^a$ | 0.3$^b$ | 0.7$^b$ | 0.0$^b$ | 0.0$^b$ |

Means with the same letter in each column are not significantly different using Duncan's multiple range test ($p \leq 0.05$).

not influenced by treatment with post-emergence herbicides. Significant differences in the average number of weeds in 1m$^2$ between untreated control and treated with post-emergence herbicides variants were observed.

After 28 days of treatment, the applied post-emergence herbicides affected to the highest extent the monocotyledonous species *Galinsoga parviflora, Polygonum aviqulare* and *Portulaca oleracaea* in both treatments with Equip OD and Laudis OD (Table 4). A. i. tembotrione exerted successful control of weed species *Xanthium strumarium* and *Chenopodium album.* Single numbers in particular replications of weed species *Amaranthus retroflexus* were observed in which there was delayed growth. In the variants treated with Equip OD we found a decrease in the number of the other annual dicotyledonous weeds in which herbicide efficacy was between 80 and 90%. These results were similar to data reported by other authors (Nurse et al., 2007; Kir and Doğan, 2009).

Mathematical processing of dispersion analysis for statistical differences between all variants is presented in Table 5.

## Influence of post-emergence herbicides on yield

The results obtained after gathering crop showed that the yield of grain was highest in the variant treated with Laudis OD at a rate of 200 ml/da followed by the variant treated with the same herbicide at a rate of 225 ml/da. The yield obtained after treatment with Equip OD was twice lower. Higher yield was obtained by using the higher rate of foramsulfuron (250 ml/da). The same results were obtained for the investigated biometric indicators, plant height and ear length. The highest values for both indicators were obtained in the variants treated with tembotrione followed by the variants treated with foramsulfuron. The lowest values were obtained for the untreated control (Tables 2, 3).

**Table 4.** Average number of weeds in 1 m$^2$ on the 28$^{th}$ day after treatment with post-emergence herbicides.

| Weed species | Untreated control | Foramsulfuron - 200 ml/da | Foramsulfuron - 250 ml/da | Tembotrione - 200 ml/da | Tembotrione - 225 ml/da |
|---|---|---|---|---|---|
| *Echinochloa crus galli* | 31.0$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Setaria viridis* | 27.0$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Setaria glauca* | 9.3$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Digitaria sanguinalis* | 5.7$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Galinsoga parviflora* | 21.7$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Polygonum aviqulare* | 8.3$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Portulaca oleracaea* | 2.3$^a$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Xanthium strumarium* | 27.7$^a$ | 6.3$^b$ | 4.0$^b$ | 0.0$^b$ | 0.0$^b$ |
| *Chenopodium album* | 20.0$^a$ | 2.7$^b$ | 2.3$^b$ | 0.0$^c$ | 0.0$^c$ |
| *Amaranthus retroflexus* | 25.0$^a$ | 0.7$^b$ | 0.3$^b$ | 1.3$^b$ | 0.3$^b$ |
| *Cisium arvense* | 10.0$^a$ | 0.3$^b$ | 0.7$^b$ | 0.0$^b$ | 0.0$^b$ |

Means with the same letter in each column are not significantly different using Duncan's multiple range test ($p \leq 0.05$).

**Table 5.** Average biometric and economic values (2009-2011).

| Variants | Average plant height, cm | Average ear length, cm | Average grain yield, kg/da |
|---|---|---|---|
| 1 | 127.0[c] | 6.23[c] | 71.72[c] |
| 2 | 170.0[b] | 9.57[b] | 211.27[b] |
| 3 | 165.4[b] | 10.63[b] | 222.18[b] |
| 4 | 216.0[a] | 15.17[a] | 492.98[a] |
| 5 | 211.0[a] | 14.60[a] | 397.73[a] |

Means with the same letter in each column are not significantly different using Duncan's multiple range test ($p \leq 0.05$).

**Statistical analysis**

A significant difference in the investigated indicators (plant height, ear length, yields) was observed between treatments with post-emergence herbicides. Plant height was similar in variants 2 and 3 treated with the two rates of Equip OD and in variants 4 and 5 treated with the two rates of Laudis OD. Plant height differed significantly between treatmented and control plants. Similar results were obtained for the other investigated indicators, ear length and grain yields. A significant difference in average yields was observed between treated variants and control. The differences between the variants were reliable. For establishing statistically significant differences between the tested variants Duncan`s test was performed (Table 5). The yield in V4 (Laudis OD at a rate of 200 ml/da) was 6.9 times higher than the yield in V1 (untreated control). The yield in V2 (Equip OD at a rate of 200 ml/da) was lowest compared with the other treatments. It was 2.9 times higher than the yield in V1. The statistical analysis of data helped to make a conclusion that all investigated signs obtained after treatment with the post-emergence herbicides Equip OD and Laudis OD at both tested rates differred statistically from the control.

## CONCLUSIONS

1. Treatment with foramsulfuron (Equip OD applied at rates of 200 ml/da and 250 ml/da) warranted 100% efficiency towards annual monocotyledonous weeds and some annual dicotyledonous weeds.
2. Our results showed very good herbicide efficiency against the annual monocotyledonous and dicotyledonous weeds after treatment with tembotrione (Laudis OD applied at rates of 200 ml/da and 225 ml/da).
3. Grain yields were highest in the variant treated with Laudis OD applied at rates of 200 ml/da and 225 ml/da, the difference between the two rates being insignificant.
4. The highest values for plant height and ear length of maize were obtained after treatment with Laudis OD applied at the two tested rates followed by treatment with the two rates of Equip OD.
5. The post-emergence herbicides used in this study showed very high efficiency towards the weed species present in the maize agrocenosis in the investigated area and helped to increase grain yield.

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