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# THE IMPACT OF SOIL HERBICIDES ON THE YIELD AND QUALITY OF LAVENDER (*Lavandula angustifolia* Mill.) ESSENTIAL OIL

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**Abstract**

During the period 2014 – 2015 the herbicidal effect and the selectivity of isoxaflutole (Merlin 750 WG), oxadiargyl (Raft 400 SC), imazamox (Pulsar 40) and flumioxazine (Pledge 50 VP) were studied on lavender fields, Hemus and Jubilejna varieties.

The present work focuses on the influence of low doses of the applied preparations on the yield and composition of the essential oil compared with untreated control.

The results of two-year studies show that the treated variants have a higher yield on average of 0.7-1.6 kg / dka.

The odoriferous ingredients range in the limits: linalyl acetate (20.0 - 38.6 %); linalool (20.6 - 46.2 %); lavandulyl acetate (1.9 - 5.9 %); 1,8 cineole (0,4 - 4,9 %) and camphor (0,2 - 0,6 %).

Applying oxidiarigil results in greater changes in the composition of the Jubilejna variety, whereas the Hemus variety has the most influence by isoxaflutole.

**Keywords:** *Lavandula angustifolia* Mill, varieties, herbicides, essential oil composition

## INTRODUCTION

*Lavandula angustifolia* Mill. is one of the world's most common essential oil crops. Until recently, the lead producer of lavender oil was France. Due to continuing problems with pests and diseases in the lavender fields, the country has gradually stepped down from the leadership position in favor of Bulgaria after 2006. Only for 2016 the Bulgarian production has reached 280-300 tons of oil (Grebenicharski, St. 2016). The most intensive creation of plantations between 2012-2015, when the total area was approaching 7,000 ha. as a structure, the Bulgarian varieties Hemus, Jubilejna, Sevthopolis and Hebar dominated. One of the main limiting factors for the yield and the quality of production is weed control. Weeds absorb significant amounts of the productive moisture and nutrients from the soil and are serious competitors of the culture in terms of light as a vegetative factor. The deficit of light results the number of flower stems and the flowers yield decreased. The amount of linalyl acetate in them has also lowered (Atanassov et al., 2008). In this connection, tackling weeds of that culture has an important agricultural and economic function (Bassino & Blanc, 1980). Furthermore, the application of herbicides may affect the biology of the crop itself or the microbiological status of the soil micro-organisms (Lisnevskaya et al., 1984; Nikolova & Baeva, 2000). This in turn affects the physiology of the plant and the production of essential oil. An important aspect of the treatment is the results for the yield and the changes in the scent ingredients (Angelova & Dobreva, 2011). The main components of lavender oil are limited to an international standard ISO 3515: 2002, but some relationships between them are of great importance (Ognyanov, 1984). Along with its strong antimicrobial action, certain components demonstrate a potential toxic or allergenic effect and are subject of monitoring (Di Sotto et al., 2011; IFRA Code of Practice, 2018; Prashar et al., 2004; Regulation (EC) No 1223/2009).

The aim of this study was to trace the influence of the soil herbicides on the quantity and quality of essential oil of the lavender varieties Hemus and Jubilejna.

## MATERIALS AND METHODS

A two-year field project with herbicides was conducted on the five-year plantings of *Lavandula angustifolia* Mill. (Hemus and Jubilejna varieties). The experiment had been placed by the randomized block method, the same area, four replicates, in the following variants:

Control - untreated and no digging;

Variant 1 - treated with isoxaflutole (Merlin 750 WG) at a dose of 3.8 g/da;

Variant 2 – treated with oxadiargyl (Raft 400 SC) - 48 g/da;

Variant 3 - imazamox (Pulsar 40) - 6 g/da;

Variant 4 - flumioxazine (Pledge 50 VP) - 15 g/da.

The herbicides were imported early in the spring, before the vegetation of lavender. Their effectiveness was established by the quantitative method.

The experiment was conducted in a plantation with predominantly annual weeds, as green foxtail (*Setaria viridis* L.), common lambsquarters (*Chenopodium album* L.), goose grass (*Polygonum aviculare* L.), shepherd's purse (*Capsella bursa-pastoris* L.) and perennial weeds (*Cynodon dactylon* L.), the palm tree (*Cirsium arvense* L.) and the bark beetle (*Convolvulus arvensis* L.).

The following indicators were examined: the essential oil yield (kg/da) and the chemical composition of essential oil. The results were statistically processed, the differences between the individual variants being determined by a single factor dispersion analysis (Zapryanov and Marinkov, 1978).

The essential oil was obtained by steam distillation in laboratory conditions, at the lavender-approved parameters. The chemical composition was determined by gas chromatography under the conditions of ISO 3515: 2002. (Oil of Lavender).

## RESULTS AND DISCUSSION

Isoxaflutole at a dose of 3,8 g/da showed herbicidal effect up to 74% for the variety Hemus and up to 64% for the variety Jubilejna against common weed infestation (Fig. 1). It is more efficient against *Chenopodium album* L. and *Capsella bursa-pastoris* L. On average for the two years of the study, oxadiargyl and imazamox showed a utility up to 75% for the Hemus variety and over 65% for the Jubilejna variety, compared to the untreated control. The herbicides successfully managed the *Chenopodium album* L., *Amaranthus retroflexus* L., *Capsella bursa-pastoris* L. and *Setaria viridis* L. After application of oxadiargyl, *Convolvulus arvensis* L. of deciduous perennials was much more affected and depressed in it. Sensitive to imazamox was *Cirsium arvense* L. The best effect (78%) in the Hemus test area against total weed number was achieved with flumioxazine. The herbicide reduced the population of *Amaranthus retroflexus* L., *Sinapis arvensis* L., *Chenopodium album* L., *Polygonum aviculare* L. and *Portulaca oleracea* L. There are no external symptoms of phytotoxicity and visible disturbances in the development of lavender plants after the herbicide treatment.

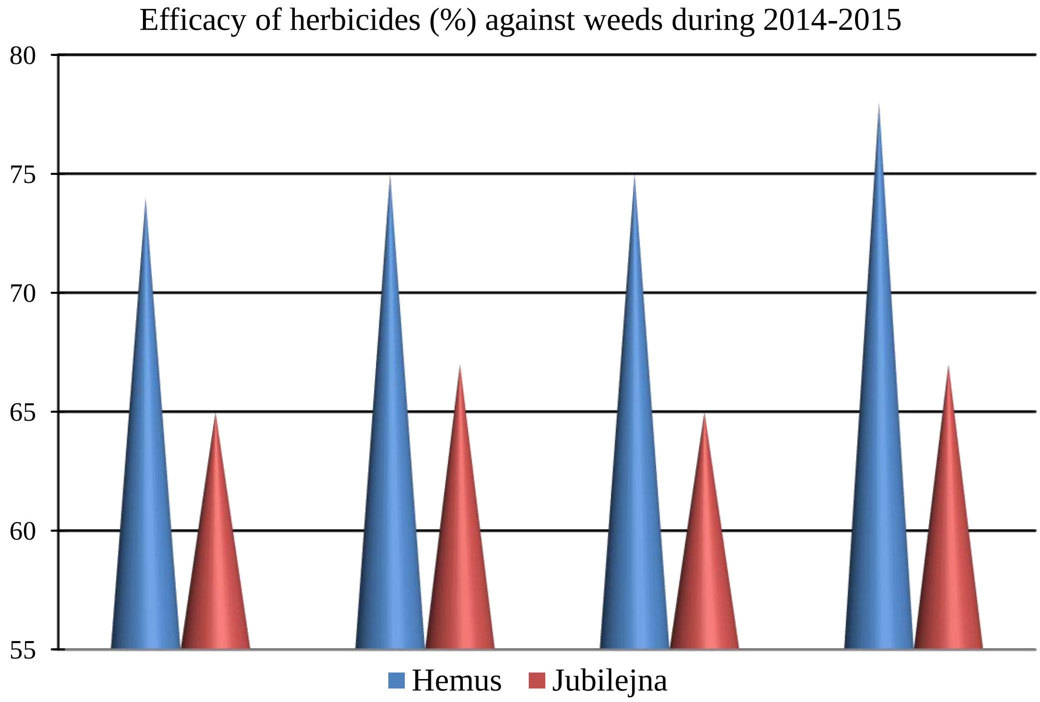


**Figure 1.** Efficacy of herbicides (%) against weeds during 2014-2015

**Table 1.** Influence of the herbicides on the yield of lavender essential oil of the variety Hemus during the period 2014-2015

| Variants | Yield, kg/da | Difference | Warranted |
|---|---|---|---|
| Untreated control | 7,1 | - | n.s. |
| Isoxaflutole | 7,4 | 0,3 | n.s. |
| Oxadiargyl | 8,1 | 1,0 | *** |
| Imazamox | 8,2 | 1,1 | *** |
| Flumioxazine | 8,7 | 1,6 | *** |
| Gd 5 % = 0,4 Gd 1 % = 0,6 Gd 0,1 % = 0,8 | | | |

The essential oil yield is shown in Tables 1 and 2. The quantity depends on both the yield of flowers and the oil percentage in it. It was found that the herbicide variants exceeded the untreated control with 0.3 to 1.6 kg/da for the Hemus variety and with 0.7 to 1.5 kg/da for the Jubilejna variety. The highest yield of lavender oil for the Hemus variety was obtained with flumioxazine (8,7 kg/da) and for the Jubilejna variety - with flumioxazine and oxadiargyl - 9,2 kg/da. The data were statistically proven at 0.1% for oxadiargyl, imazamox and flumioxazine, and at P 1% for isoxaflutole.

**Table 2.** Influence of the herbicides on the yield of lavender essential oil of the variety Jubilejna during the period 2014-2015

| Variants | Yield, kg/da | Difference | Warranted |
|---|---|---|---|
| Untreated control | 7,7 | - | n.s. |
| Isoxaflutole | 8,4 | 0,7 | ** |
| Oxadiargyl | 9,2 | 1,5 | *** |
| Imazamox | 8,8 | 1,1 | *** |
| Flumioxazine | 9,2 | 1,5 | *** |
| Gd 5 % = 0,5 Gd 1 % = 0,7 Gd 0,1 % = 1,0 | | | |

The components of the essential oil are secondary metabolites and their genesis in the secretory organs of the plant depends on abiotic and biotic factors. The year conditions strongly modulated terpene biosynthesis, so the effect of herbicides was compared to a control for each year of study. The results of the chemical analysis are shown in Tables 3 and 4.

**Table 3.** Influence of the herbicides on the essential oil composition of *Lavandula angustifolia* Mill. (variety Hemus) for 2014 and 2015 years

| Chemical profile-main and characteristic compounds, % | Variant | | | | |
|---|---|---|---|---|---|
| | Control - untreated | Isoxaflutole | Oxadiargyl | Imazamox | Flumioxazine |
| 1,8 cineole - 2014 | 2,6 | 4,9 | 3 | 4,6 | 3,2 |
| 1,8 cineole - 2015 | 1,5 | 1,5 | 1,6 | 1,7 | 2 |
| Cis-β-ocimene - 2014 | 1,9 | 1,7 | 2 | 3,1 | 2,3 |
| Cis-β-ocimene - 2015 | 1,7 | 1,7 | 1,9 | 1,7 | 1,7 |
| Trans-β-ocimene -2014 | 1,4 | 1,3 | 1,5 | 1,2 | 1,5 |
| Trans-β-ocimene -2015 | 1,5 | 1,4 | 1,9 | 1,5 | 1,4 |
| Linalool -2014 | 36,8 | 32,1 | 36,4 | 34 | 33,9 |
| Linalool -2015 | 45 | 39,6 | 43,2 | 43,5 | 46,2 |
| Camphor -2014 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 |
| Camphor -2015 | 0,2 | 0,3 | 0,2 | 0,6 | 0,2 |
| Lavandulol -2014 | 0,5 | 0,6 | 0,5 | 0,6 | 0,6 |
| Lavandulol -2015 | 0,4 | 0,3 | 0,4 | 0,5 | 0,5 |
| Terpinen-4-ol -2014 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 |
| Terpinen-4-ol -2015 | 0,2 | 0,2 | 0,2 | 0,3 | 0,2 |
| Linalyl acetate -2014 | 36,1 | 37,3 | 36,8 | 34,9 | 36,6 |
| Linalyl acetate -2015 | 23,3 | 34,6 | 23,8 | 26,2 | 22,7 |
| Lavandulyl acetate -2014 | 1,9 | 2,1 | 1,9 | 2,2 | 2,1 |
| Lavandulyl acetate -2015 | 2,7 | 2,3 | 2,4 | 2,4 | 2,6 |

**Table 4.** Influence of the herbicides on the essential oil composition of *Lavandula angustifolia* Mill. (variety Jubilejna) for 2014 and 2015 years

| Chemical profile-main and characteristic compounds, % | Variant | | | | |
|---|---|---|---|---|---|
| | Control - untreated | Isoxaflutole | Oxadiargyl | Imazamox | Flumioxazine |
| 1,8 cineole - 2014 | 0,8 | 0,7 | 1 | 0,8 | 0,8 |
| 1,8 cineole - 2015 | 0,4 | 0,5 | 0,6 | 0,6 | 0,4 |
| Cis-β-ocimene - 2014 | 3,8 | 6,3 | 6,0 | 3,9 | 3,9 |
| Cis-β-ocimene - 2015 | 5,4 | 5,1 | 6,5 | 4,9 | 6,1 |
| Trans-β-ocimene -2014 | 2,0 | 4,2 | 4,1 | 2,1 | 2,4 |
| Trans-β-ocimene -2015 | 3,7 | 3,6 | 4,9 | 3,2 | 3,9 |
| Linalool -2014 | 27,5 | 26,5 | 20,6 | 27,9 | 26,5 |
| Linalool -2015 | 32,2 | 32,8 | 26,7 | 32,2 | 31,5 |
| Camphor -2014 | 0,4 | 0,3 | 0,3 | 0,4 | 0.3 |
| Camphor -2015 | 0,2 | 0,2 | 0,2 | 0,3 | 0,2 |
| Lavandulol -2014 | 0,3 | 0,2 | 0,3 | 0,3 | 0,6 |
| Lavandulol -2015 | 0,2 | 0,1 | 0,2 | 0,2 | 0,1 |
| Terpinen-4-ol -2014 | 7,8 | 7,5 | 6,7 | 8,0 | 2,9 |
| Terpinen-4-ol -2015 | 7,9 | 8,7 | 6,7 | 7,5 | 7,9 |
| Linalyl acetate -2014 | 32,7 | 32 | 38,4 | 32,6 | 38,6 |
| Linalyl acetate -2015 | 21 | 22,7 | 29 | 23,2 | 23,1 |
| Lavandulyl acetate -2014 | 4,1 | 4,2 | 4,4 | 4,1 | 3 |
| Lavandulyl acetate -2015 | 5,6 | 5,1 | 5,9 | 5,5 | 5,2 |

The high content of esters is a sign of quality. The data show that for both varieties there were no losses of linalyl acetate and lavendyl acetate in the treated variants, their levels being either equivalent or higher than those of the control (with one exception). Both typical and main ingredients are linyl acetate and linalool. In the international standard, their amounts vary widely, with the ratio between them being below and above 1, i.e., the linalyl acetate may be more or less than the linalool but the usual proportion is above 1, i.e., the first component is predominant. This dependence can be used as a criterion for the influence of various factors on the quality of the essential oil (Ognyanov, 1984). Its values revealed interesting information (Fig. 2 and 3).

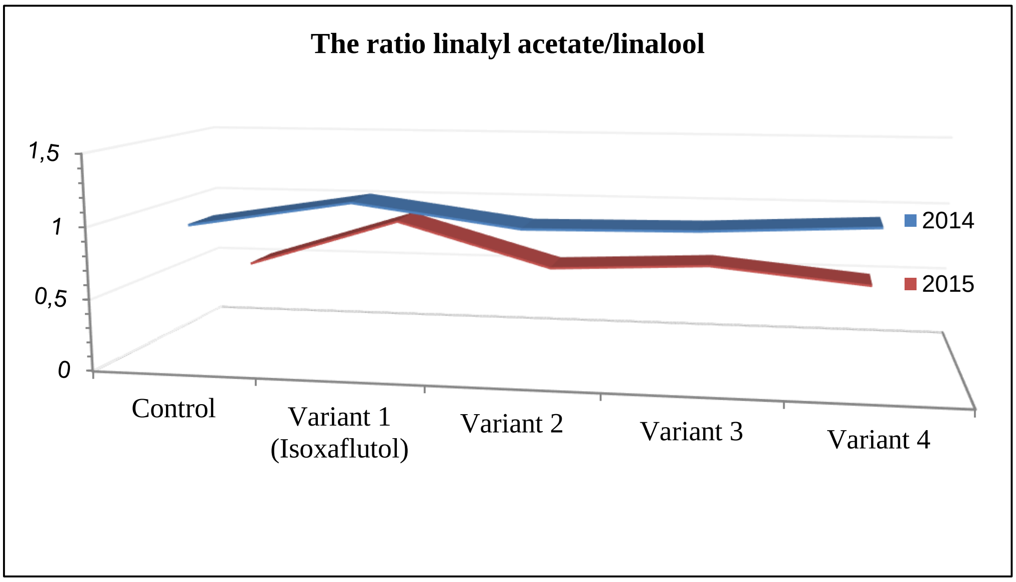


**Figure 2.** Influence of the herbicides on the main components ratio in the essential oil of *Lavandula angustifolia* Mill. (variety Hemus)

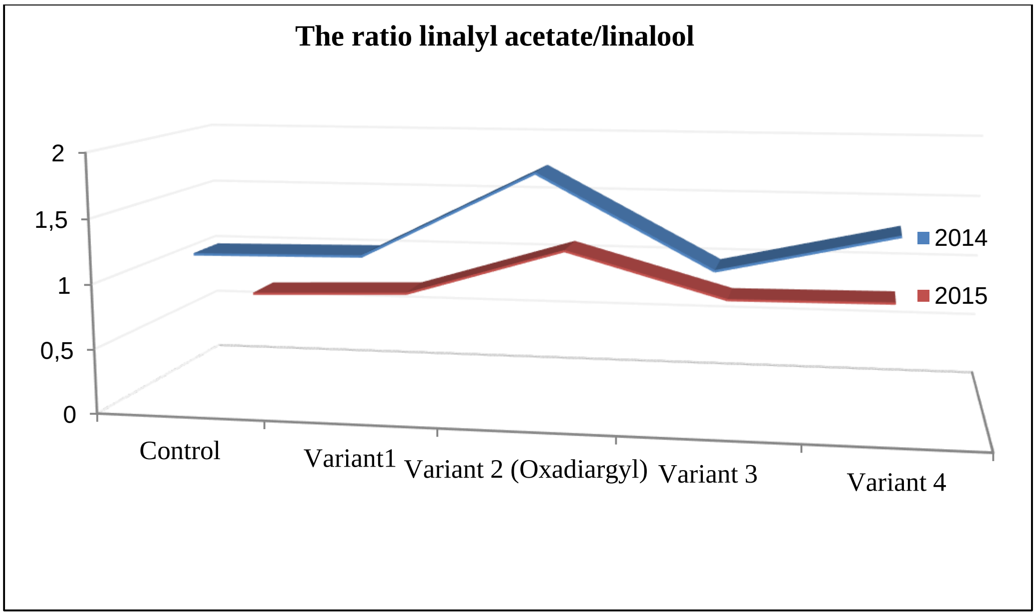


**Figure 3.** Influence of the herbicides on the main components ratio in the essential oil of *Lavandula angustifolia* Mill. (variety Jubilejna).

There were a definite positive correlation between the values of the linalyl acetate/ linalool ratio and herbicide (active substance), for both varieties and years of the study. For the Hemus variety isoxaflutole (Variant1) increases the ratio for 2014 and 2015 up to 18% and 68%, respectively. The other types of herbicides did not show significant changes.

For the Jubilejna variety, the use of oxadiargyl (Variant 2) resulted in an increase of 57% and 67% over the control for both years of the study. The other herbicides did not report a significant impact. The fact can be explained by the varietal specificity.

Camphor, 1,8-cineol and terpene 4-ol are undesirable scent ingredients. The first two are characteristic of the hybrid lavender (lavandin), while the third element is a carrier of a non-specific grassy note (Georgiev and Stoyanova, 2006; Ognyanov, 1984). Moreover 1,8 cineole and terpinene-4-ol are associated with a certain toxic effect and should be monitored (Hayes et al., 1997). In the case of Hemus, an increase of 1,8 cineol in the treated variants (up to twice) is noted, but this rise is negligible in relation to the total oil composition. For the Jubilejna variety there is no such dynamics and the ingredient retains control levels or the changes are within the analytical method error.

Terpinene-4-ol reveals another feature of the varieties. For Hemus the content is stable and low in both controls and treated variants. Jubilejna is characterized by a high content level of the component (Raev and Boyadjieva, 1988). Assuming the 100% values in the control, in the treated variants its content varies from 37% to 110%, i.e., decreases or practically no increase.

## CONCLUSION

1. For the two years of the study, after herbicide treated weeds in lavender plantations, a proven higher yield of essential oil is achieved compared to the untreated control. For the Hemus variety, the yield reaches a maximum of 22% at flumioxazine with a dose of 15 g/da. For the cultivar Jubilejna the largest increase was recorded after the administration of Oxadiargyl at a dose 48 g/da and Flumioxazine at a dose 15 g/da - on average 19% more than that of the control.

2. The application of the tested herbicides did not lead to negative changes in the composition of the essential oil. Weed treatment with isoxaflutole at a dose 3.8 g/da for Hemus resulted in an increase in the quality, reported by the ratio of linalyl acetate/ linalool. For Jubilejna the administration of oxadiargyl at a dose of 48 g/da had the same positive impact with 57% and 67% rise compared with the control.

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