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Herbicides in Winter Wheat of Early Growth Stages Enhance Crop Productivity

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1. Introduction

Herbicides are chemical substances destroying undesirable plants (weeds) or suppressing their growth.

Wheat (*Triticum* spp.) is a cereal that is cultivated worldwide. It is the most important human food grain (Hanee M. Al-Dmoor, 2008). Traditionally, herbicides in winter wheat are applied from two leaf stage till the end of tillering (Triasulphuron - *Logran*) and in spring at tillering (Propoxycarbazone-sodium - *Atribut*, Sulphosulphuron - *Monitor*, Iodosulphuron-methyl-sodium - *Husar*) and from tillering till booting (Florasulam + 2.4-D 2-ethylhexyl ester - *Mustang*). *Atribut, Monitor and Husar* best fit for control of annual monocotyledonous weeds as *Apera spica-venti, Avena fatua, Poa pratensis* etc. and some annual dicotyledonous weeds as *Galium aparine, Tripleurospermum perforatum, Viola spp., Lamium spp*. etc. *Logran* best fits for control of annual dicotyledonous weeds as *Sinapis spp., Capsella bursa-pastoris, Thlaspi arvense* and etc. while *Mustang* is designed for control of dicotyledonous weeds as *Chenopodium album, Centaurea cyanus, Myosotis arvensis, Sonchus arvensis, Cirsium arvense* and others (Rimavičienė, 2005). Appropriate selected and in time applied herbicides destroy spreading weeds in crop or suppress weed growth and new seed production. Crop weediness is considerably reduced when soil is adequately cultivated, herbicides are applied and crop rotations are practiced (Barberi et al., 1997). It was determined that the field crops of cultured plants are plant associations or so called agrophytocenoses, and that the total biomass of a crop stand (crop and weed biomass) is more or less constant and that the crop yield is inversely proportional to the weed biomass (Lazauskas, 1990, 1993). Effectiveness of chemical weed control is determined by three main specifications: selection of an adequate herbicide, its optimal norm and duration of application. In the process of weed control it should be remembered that wet climate, cold spring weather, long autumn are the factors that help them grow and develop. Another important factor is the ratio of weed biological groups. The prevailing weeds in Lithuania are short-lived annual dicotyledons that comprise 70-90% of all the weeds (Pilipavičius, 2005). Many annual weeds successfully survive till spring because of climate warming; however, they were naturally frozen during winter time just 10-15 years ago. Global warming is the increase in the average temperature of the Earth's near-surface air and the oceans since the mid-twentieth century and its projected continuation. Including uncertainties in future greenhouse gas concentrations and climate sensitivity, the IPCC, scientific intergovernmental body set up by the World Meteorological Organization (WMO) and by the

United Nations Environment Programme (UNEP), anticipates a warming of 1.1°C to 6.4°C by the end of the 21st century, relative to 1980–1999 (Summary for policymakers, Climate change, 2007). Conventionally herbicides are used in spring for weed control in winter cereals, therefore, perennial and winter annual weeds have favourable conditions to grow and compete with cereals when vegetation in spring is renewing. Winter wheat *Triticum aestivum* L. is sensitive to weed competition in early stages of growth and development. Therefore, intensive agricultural systems seek to destroy all growing weeds in crops and avoid of weed seed bank replenishment with new matured weed seeds that can survive in soil for decades (Koch & Hurle, 1978; Niemann, 1981). Weed seed bank in the soil changes in two directions: regularly cleans from seeds and is replenished by them. Balance between these processes decides seed bank change dynamics in the soil (Pilipavičius, 2004, 2007b). Many researchers (House, 1989; Faravani & Khaghani, 2004; Sikkemaa et al., 2007; Stasinskis, 2009) have investigated the effect of herbicide application on field weediness of wheat crops. However, there are reported data on conventional standard time of use of pre-emergence herbicides in autumn or post-emergence herbicides in spring. The potential use of herbicides at early stages of development of winter wheat in autumn has not been clearly considered, and published research data are still insufficient. Intensive use of herbicides following the traditional crop growing technologies, however, does not entirely solve the problem of weediness.

The work hypothesis: application of herbicides in autumn will control weeds that survive during winter time and winter wheat will not be damaged and better conditions for crop competition in spring after renewing of vegetation would be created.

The aim of this work was to evaluate various herbicide active substance applications in autumn at early stages of winter wheat *Triticum aestivum* L. development, its influence on crop weediness and productivity.

2. Chemical weed control development in winter wheat

The research was carried out in Kaunas county, Prienai district, Ašminta region, Strielčiai village. Winter wheat fore-crop was black fallow. Experimental field was ploughed in autumn using semi-helical plough Overum 4 to the depth of 24 cm, cultivated using a cultivator with comb harrow KPŠ-15 to the depth of 10 cm and the surface of soil was levelled off with a roller PP-7. The field was fertilized in autumn (10 September, 2005) by amofos 100 kg ha^{-1} and potassium chloride 200 kg ha^{-1}. Winter wheat cv. Ada was sown on 12 September, 2005. The sowing-machine SPU – 6 (inter-beds 12.5 cm) was used. The amount of seeds comprised 240 kg ha^{-1} and they were sown in the depth of 4-5 cm. Winter wheat cv. Ada develops well on all soils growing it by the conventional technologies. Cultivar Ada has high overwintering qualities evaluated by 8-9 points from 9. It is resistant to frost, when at tillering node temperature subsides till minus 14^{0}C died just 6% of plants. Average productivity 6.36 t ha^{-1}; stem medium high 90-94 cm (Characteristics of wheat varieties ..., 2011; Lithuanian national list of plant varieties, 2011). The investigated active substances of herbicides according to the scheme of research were applied in autumn at BBCH 14-15 of winter wheat (7 October, 2005).

Experimental design:

1. Control treatment, not sprayed with herbicides in autumn*
2. Monitor 75% g. (Sulphosulphuron 750 g kg^{-1}), 26.7 g ha^{-1}

3. Atribut 70% w.s.g. (Propoxycarbazone-sodium 700 g kg^{-1}), 0.120 g ha^{-1}
4. Mustang 458.75 g L^{-1} c.s. (Florasulam + 2.4-D 2-ethylhexyl ester 6.25 + 452.5 g L^{-1}), 0.5 L ha^{-1}
5. Logran 20% w.s.g. (Triasulphuron 200 g kg^{-1}), 0.03 g ha^{-1}
6. Husar 5% w.s.g. (Iodosulphuron-methyl-sodium 50 g kg^{-1}), 0.200 g ha^{-1}.

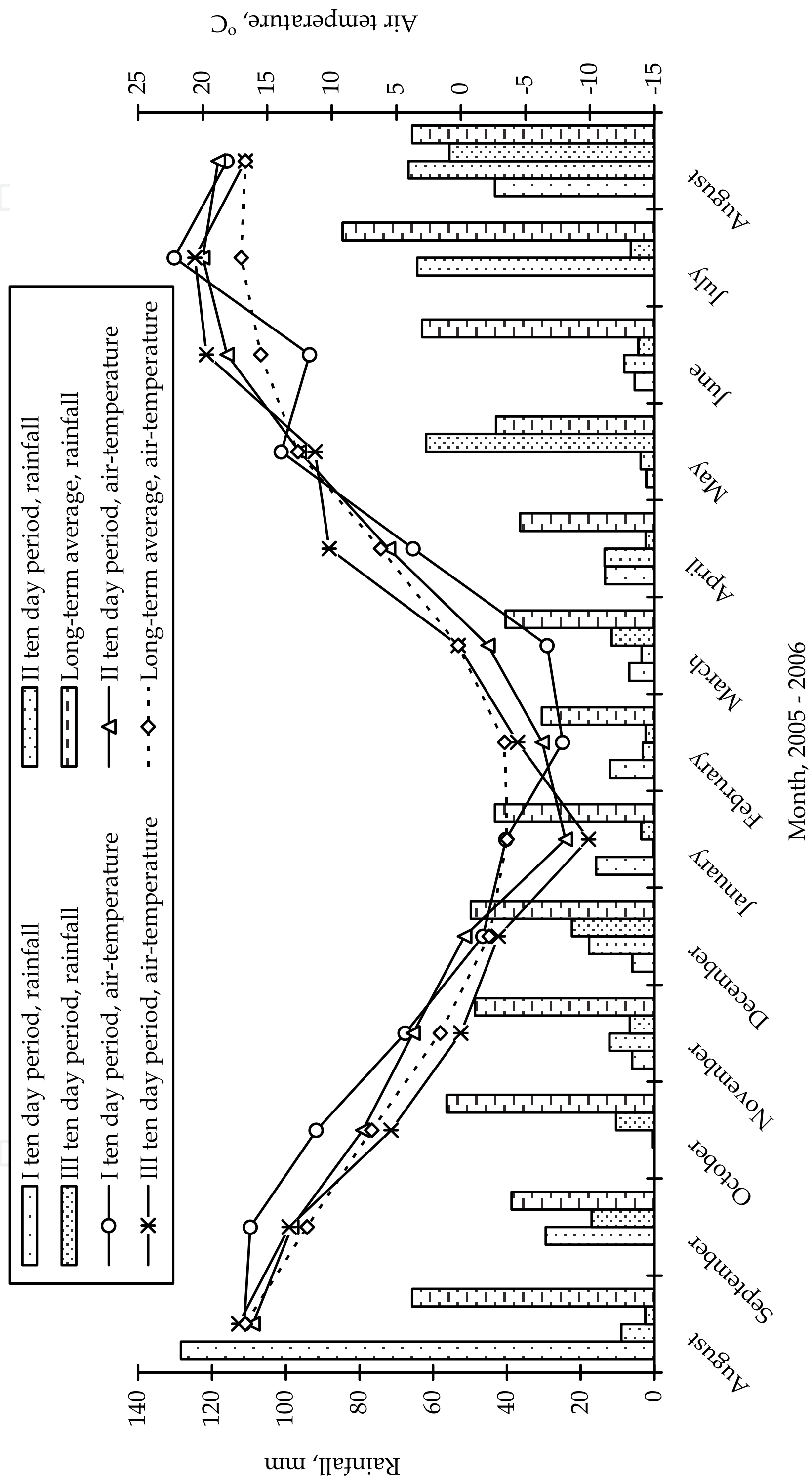
Note: g – granules; w.s.g. – water-soluble granules; g L^{-1} c.s. – grams in a litre of concentrated suspension.

The experiment was carried out in four replications. The experimental data were evaluated using analysis of variance by *Selekcija* (Tarakanovas, 1997) and correlation-regression analysis by *SigmaPlot 8.0* (SPSS Sciences, 2000).

For the first fertilization in spring (12 April, 2006) 250 kg ha^{-1} of ammonium nitrate was used and for the second fertilization (8 May, 2006) 200 kg ha^{-1} of ammonium nitrate was applied. A *composite of herbicides Sekator 300 g ha^{-1} and MCPA 1 L ha^{-1} with a growth regulator Cycocel 1.5 L ha^{-1} was used for conventional spraying at BBCH 22-23 (2 May, 2006, sprayed all experimental field, standard technology). At the beginning of winter wheat stem elongation (25 May, 2006) the composite of insecticide Fastak 100 g ha^{-1}, fungicide Folikur 0.75 L ha^{-1} and complex fertilizer Wuxal 5 L ha^{-1} were sprayed.

2.1 Meteorological conditions

Lithuanian territory occupies intermediate geographical position between west Europe oceanic climate and Eurasian continental climate. Climate of the Lithuania territory forms in different radiation and circulation conditions. Differences in these conditions hardly cross the boundaries of microclimatic differences; therefore, Lithuania belongs to western region of the Atlantic Ocean continental climatic area (Basalykas et al., 1958). During 2005-2006 meteorological conditions were favourable for winter wheat crop establishment. Autumn of 2005 was warm and rainy, i.e. suitable for crop emergence and early growth. The beginning of winter delivered well balanced conditions for wintering, however, during January – March 2006 the temperatures were rather low with insufficient snow cover on the soil. April – June 2006 was cool with high variation of rainfall which principally did not exceed the long-term average. Significant increase of rainfall in August resulted in complicated conditions for winter wheat maturing and harvesting (Pilipavičius et al., 2010b). Meteorological conditions during vegetation of winter wheat crop experiment are summarised in figure 1. September of 2005 was enough warm, average air temperature during the second ten day period was higher by 2^{0}C comparing with long-term average. However, the first ten day period of September was very rainy with rainfall of 68.3 mm while during the second ten day period it compounded 21.5 mm and the third ten day period pasted without rainfall. The first ten day period of October was warm but already at the second and the third ten day periods average air temperatures dropped to 8^{0}C which were by 1.1^{0}C and 1.4 ^{0}C warmer comparing with long-term average, accordingly. Rainfall during the first ten day period in October reached 31.3 mm while during the second and the third ten day periods decreased till 6.0 mm and 10.4 mm, accordingly. Hence, warm and humid first ten day period in October formed favourable conditions for winter wheat tillering. During November average air temperatures decreased till 1.6^{0}C, 5.6^{0}C and 6.1^{0}C and amount of rainfall consisted of 6.1 mm, 12.2 mm and 6.7 mm. Gradual decrease of temperatures and rainfall was adequately fitting biological needs of winter wheat. During December average air temperatures fell down below 0, i.e. till -1.7^{0}C while long-term average was -2.2^{0}C. Precipitation consisted 6.0 mm at the first ten day period of December, 17.7 mm at the second and 22.4 mm at the third. It was lower than long-term average and formed proper conditions for winter wheat cv. Ada wintering.



Note. Long-term average of rainfall (600.4 mm) and average air temperature (6.8°C) by ten day periods during 1974-2004, Kaunas Hidrometeorological station

Fig. 1. Meteorological conditions, rainfall and average air temperature by ten day periods during vegetation of winter wheat crop, Kaunas county, Prienai district, Lithuania.

Meteorological conditions during January, February and March were very unfavourable for winter wheat overwintering, because there was few precipitation formed insufficient snow cover with rather low average air temperatures of -7.2^{0}C, -6.3^{0}C and -2.7^{0}C accordingly. During January and February precipitation was by 54% and 42% lower comparing with long-term average. April weather was cool, just at the second ten day period it started to warm till +10.2^{0}C with rainfall of 29.3 mm while long-term average was 36.4 mm. During May average air temperatures reached 12.5^{0}C that was slightly lower than long-term average of 12.6^{0}C. The third ten day period of May was very rainy reaching 61.9 mm that consisted 83% of the whole month standard comparing with long-term norm average. The first ten day period in June was cool 11.7^{0}C comparing with long-term average 15.5^{0}C while during the second and the third ten day periods average air temperatures reached 18.1^{0}C and 19.7^{0}C accordingly. June was very dry with 18 mm rainfall when long-term average is 63 mm. It was by 71% lower than long-term average and it was very inappropriate for winter wheat growth and development (Fig. 1). As a consequence, average winter wheat grain yield 2.46 t ha^{-1} in Lithuania in 2006 was the lowest comparing with 2005-2010 (Statistics Lithuania, 2011). July was warm with average air temperature of 20.9^{0}C and 64.3 mm of rainfall that was by 20.3 mm lower than long-term average. The rainiest month during winter wheat vegetation was August with 165.6 mm rainfall exceeding long-term average by 99.9 mm and created very unfavourable conditions for winter wheat grain maturing and wet soil aggravated grain harvesting.

2.2 Soil weed seed bank

2.2.1 Soil agrochemical characteristics

Soil samples for agrochemical analysis and establishment of weed seed bank, seed varietal composition and quantity, were taken from 0-20 cm soil layer at the end of September from 10 sites of all treatments and their replications, making combined samples. Soil agrochemical characteristics were established in the Centre of Agrochemical Research, Lithuanian Agricultural Institute and weed seed bank composition was established at the Lithuanian University of Agriculture. Experimental field soil was *Gleyic Cambisols CMg*. Topsoil layer was alkaline, average in humus, rich in phosphorus and average rich in potassium (Table 1).

Agrochemical soil properties			
pH	Humus %	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}
7.1	2.17	152	146

Table 1. Experimental field soil agrochemical characteristics of 0–20 cm soil layer.

2.2.2 Weed seed bank

Weed seeds from soil samples were washed through 0.25 mm sieve and separated by saturated solution of high specific mass of NaCl (Rabotnov, 1958; Warwick, 1984, Pilipavičius, 2004). Seeds of 12 weed species (10 annual and 2 perennial) were identified in the soil weed seed bank. Annual weed seeds dominated with 88.0%-95.7% of weed seed bank, from them winter annual weed seeds (*Viola arvensis*, *Tripleurospermum perforatum*, *Thlaspi arvense* etc.) comprised 21%-60% (36%-54% from the whole seed bank). Seeds of the perennial weeds (*Cirsium arvense*, *Rumex crispus*) were in the minority with 4.3%-12.0% from the whole soil weed seed bank (Table 2). In winter wheat crop perennial weeds were in the minority as well (Fig. 3 & 4). From separated weed seed species, the seeds of *Chenopodium album* prevailed in the soil seed bank. They comprised 34%-48% of the whole soil weed seed bank. However, *Chenopodium album* was recessive weed in the crop as it is summer annual weed and consequently is freezing during winter time (see subchapter 2.3). *Viola arvensis* was the other dominant weed in the soil seed bank that covered 16%-30% of seed bank (Table 2). The main change in the number of weed species was influenced by appearance and disappearance of weed seeds that were low in number. It was either actual for the crop.

Weeds	Treatment					
	Control	Monitor	Atribut	Mustang	Logran	Husar
	Weed seeds					
Chenopodium album L.	3.0	2.0	4.25	2.75	4.0	4.75
Cirsium arvense (L.) Scop.	0.0	0.0	0.25	0.0	0.0	0.0
Fallopia convolvulus L.	0.0	0.0	0.0	0.0	0.5	0.0
Galeopsis tetrahit L.	0.0	0.0	0.25	0.0	0.0	0.0
Myosotis arvensis (L.) Hill.	0.0	0.25	0.25	1.0	0.25	1.75
Persicaria lapathifolia L.	0.0	0.0	0.0	0.0	0.0	0.25
Rumex crispus L.	0.75	0.25	1.0	0.75	0.75	1.5
Sinapis arvensis L.	0.25	1.0	0.0	0.25	0.25	0.25
Stellaria media (L.) Vill.	0.75	0.5	1.75	0.0	0.5	1.75
Thlaspi arvense L.	0.0	0.0	0.25	0.5	0.25	0.25
Tripleurospermum perforatum (Merat) M. Lainz	0.50	0.5	0.75	0.0	0.0	0.0
Viola arvensis Murray	1.0	1.25	3.75	2.0	2.5	2.75
All weed seeds	6.25	5.75	12.5*	7.25	9.0	13.25*
LSD_{05}	4.34					

Note. * - essential differences at 95% level of probability, compared to control treatment

Table 2. Weed seed bank in winter wheat crop soil of 0–20 cm layer, weed seeds in 100 g of air-dry soil (Pilipavičius et al., 2010a).

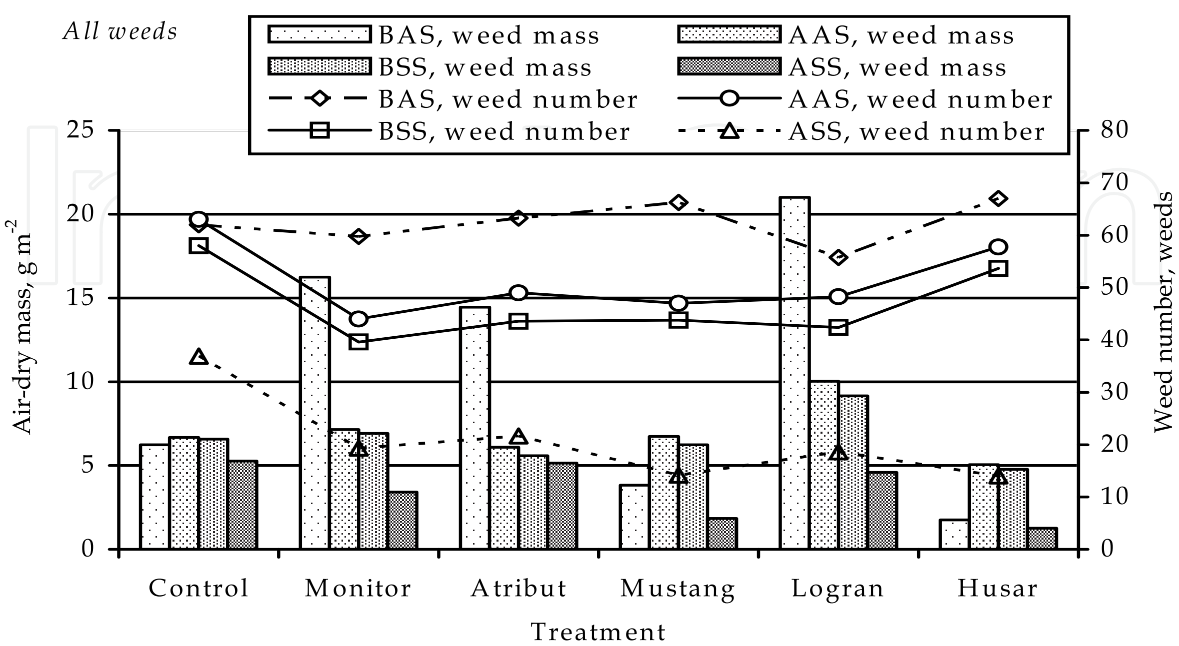
Direct chemical soil weed seed bank control is rather indeterminable, therefore ecological and cultural weed control methods should be applied for weed seed control. One of possibilities to control weed seed bank is harvesting cereal at earlier stage of maturity for the whole plant silage. It is essentially important factor, decreasing the amount of coming new weed seeds to the soil terminating weed seed rain while only a small part of weed seeds pours at milk or milk–dough stages of cereal maturity (Pilipavičius & Lazauskas, 2000, Pilipavičius, 2002, 2006) and delivering more fodder for animals from the same plot area (Pilipavičius, 2007b, 2012). When the amount of new weed seeds getting into the soil decreases, soil is cleaning quicker from them (Pilipavičius, 2004). Another important factor is weed seed position in the soil. The more weed propagation rudiments are decreased in the top soil layer, the less is weediness of the crop – the number and the mass of weeds (Pilipavičius, 2007a, Pilipavičius et al., 2009). Existing weed seed bank and vegetative weed parts in soil can be managed in non-chemical way. According to theoretical preconditions and data of the experiments, it is proved that total turnover of the arable soil layer in organic agriculture is a very important means of weed control decreasing weediness of the crop and increasing harvest. Comparing technological ploughing processes and ploughs, it was concluded that two layer ploughs can help to carry out this process the most effectively in organic agriculture (Lazauskas & Pilipavičius, 2004) and can be successfully applied in conventional agriculture.

2.3 Crop weediness

Weediness of winter wheat crop was established by a quantitative-weight method. Four samples with wire rim 50 x 50 cm (0.25 m^2) were taken from each experimental plot to establish weed density and mass (Pilipavičius, 2005) in autumn and spring during the winter wheat tillering before and after spraying with herbicides. Collected weeds were air-dried and distributed into species. Nomenclature of Latin plant names was based on the Institute of Botany's edition *Vascular plants of Lithuania* (Gudžinskas, 1999).

Twenty weed species in experimental field were established in autumn before spraying with herbicides. Seventeen of them were annual and three perennial ones. After autumn spraying with herbicides number of established weed species increased by one annual and one perennial, however, weed biomass essentially decreased (Fig. 2).

After overwintering the number of weed species in the crop principally did not change while after conventional spring spraying with herbicides it decreased by one annual weed species. The main change in the number of weed species was influenced by appearance and disappearance of weeds as *Chenopodium album* L., *Erysimum cheiranthoides* L., *Sinapis arvensis* L., *Myosotis arvensis* (L.) Hill, *Veronica arvensis* L., *Cerastium arvense* L., *Fumaria officinalis* L., *Viola arvensis* Murray, *Galeopsis tetrahit* L., *Polygonum aviculare* L. and some other weeds that were low in number. It was confirmed that more weed species were established in the crop (Fig. 3 & 4) than in soil weed seed bank (Table 2). Before autumn application of herbicides there were no considerable differences in weediness of winter wheat but after herbicide spraying the number of weeds decreased by 15.4 – 28.4% and their air-dry biomass lessened even up to 56.8% (Fig. 2). Monitor (Sulphosulphuron) was the most effective herbicide in destroying weeds in winter wheat crop in autumn compared to the control treatment with no herbicide application in autumn and other herbicides used. Crop weediness decreased by 18 weeds in m^{-2} and by 9.5 g m^{-2} of air-dry mass; the reduction comprised 28.4% and 56.8% respectively. Assessing the effectiveness of different herbicide active substances, it was established that after autumn spraying the number of weeds decreased from 32.4% to 91.7% compared to not sprayed by herbicides in autumn control. Assessing winter wheat crop in spring, it was determined that autumn herbicide application resulted in reduced weediness also after crop wintering. It was established that herbicide application in autumn at early stages of winter wheat development significantly decreased crop weediness as well in spring vegetation after over-wintering (Fig. 2). Later, Latvian researchers received analogous results while winter wheat crop in plots where herbicides were applied in autumn was more even, denser and better developed than in plots just with spring herbicide application. In the spring-treated plots the crops became thin and in open places weed plants that were not controlled by the herbicides could regrow and develop well during the growing season up to harvest time (Vanaga et al., 2010).

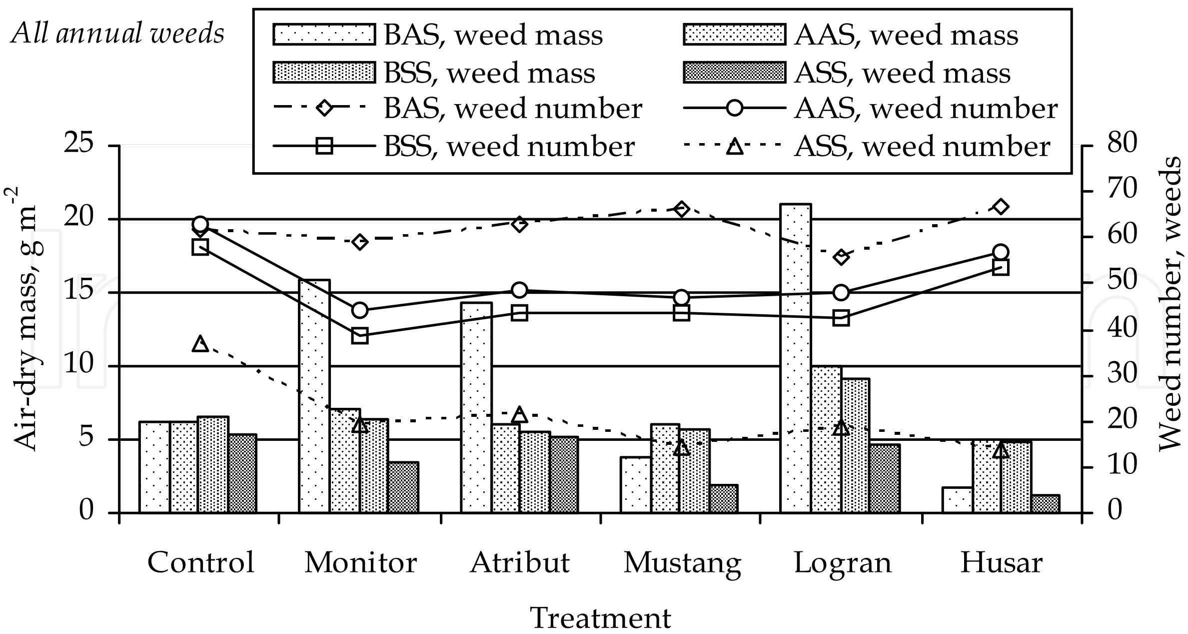


Note. LSD_{05}=24.18 for air-dry weed mass g m^{-2} before autumn application of herbicides; LSD_{05}=7.34 for air-dry weed mass g m^{-2} after autumn application of herbicides; LSD_{05}=22.85 for weed number before autumn application of herbicides; LSD_{05}=23.28 for weed number after autumn application of herbicides; BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

Fig. 2. Winter wheat crop weediness before and after autumn and spring application of herbicides.

Annual weeds such as *Centaurea cyanus* (Fig. 6), *Raphanus raphanistrum* (Fig. 8), *Thlaspi arvense* (Fig. 11) and *Tripleurospermum perforatum* (Fig. 12) prevailed in winter wheat crop whereas among perennial weeds only of *Sonchus arvensis* and *Plantago major* and a few plants of *Antennaria dioica* and *Poa trivialis* emerged in the crop (Fig. 4). Short-lived annual weeds in the crop of winter wheat in autumn and after application of the intended herbicides comprised 96%-100% and 93%-100% respectively, whereas in spring before and after application of background spring herbicides they comprised 89%-100% and 99%-100% respectively (Pilipavičius et al., 2010a) (Fig. 2 & 3).

This means that perennial weeds are better adapted to wintering than the short-lived ones because the increase of air-dry biomass up to 11% of perennial weeds was established in spring before the application of chemical weed control measures (Fig. 4). Assessing the effectiveness of diverse herbicides, it was established that the number of weeds after spraying in autumn decreased by 32–91% compared to the control treatment plot not sprayed in autumn. Assessing winter wheat crop in spring, it was determined that autumn application of herbicides resulted in lessened crop weediness after its wintering even before spring spraying (Pilipavičius et al., 2010a). The number of weeds decreased by 70–92% compared to the control (Fig. 2) with no autumn herbicide application.

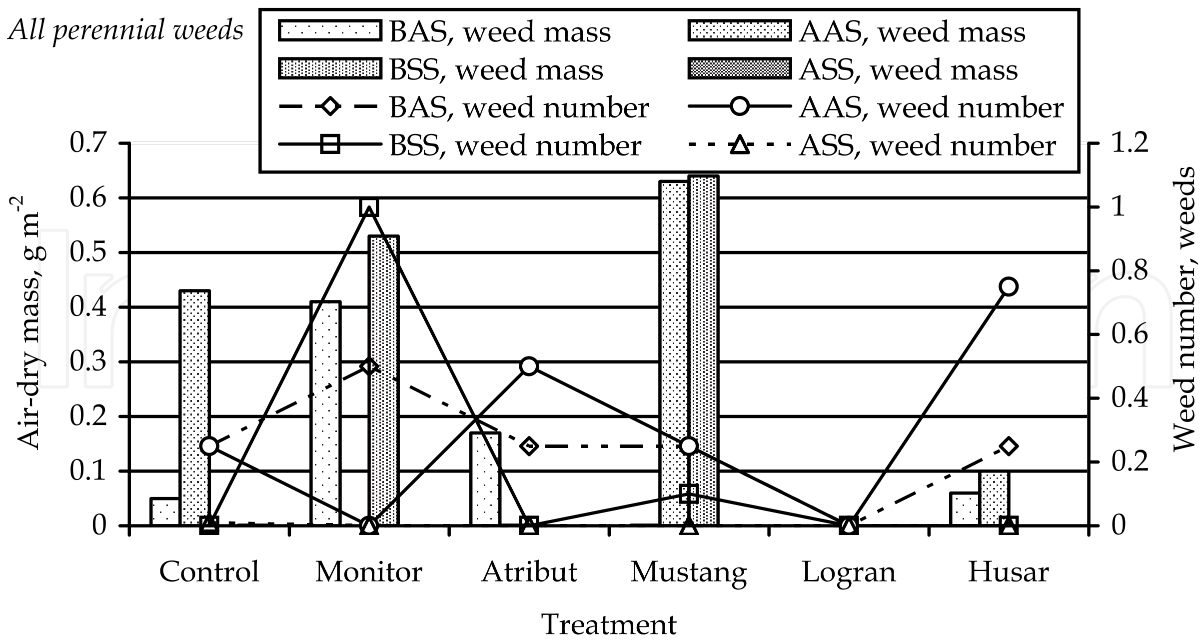


Note: Annual weed species: *Capsella bursa-pastoris* (L.) Medik (Fig. 5), *Centaurea cyanus* L. (Fig. 6), *Galium aparine* L. (Fig. 7), *Raphanus raphanistrum* L. (Fig. 8), *Raphanus sativus* L. (Fig. 9), *Stellaria media* (L.)Vill (Fig. 10), *Thlaspi arvense* L. (Fig. 11), *Tripleurospermum perforatum* (Merat) M.Lainz (Fig. 12), other annual weeds - *Chenopodium album* L., *Erysimum cheiranthoides* L., *Sinapis arvensis* L., *Myosotis arvensis* (L.) Hill, *Veronica arvensis* L., *Cerastium arvense* L., *Fumaria officinalis* L., *Viola arvensis* Murray, *Galeopsis tetrahit* L., *Polygonum aviculare* L.;
BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

Fig. 3. Annual weeds in winter wheat crop before and after autumn and spring application of herbicides.

Comparing weed over-wintering possibilities as crop weediness change dynamics, is important to pay attention for the development of one average weed plant air-dry mass (g per plant). In our experiment, it was shown that short-lived annual weeds successfully survived winter frosts even increasing its average one weed plant mass (Table 3).

Though, moderated increase of annual weed mass during winter time was in conformity with the research hypothesis that many annual weeds successfully survive winter time as earlier was not usual. Naturally, perennial weeds have the highest tolerance to winter frosts as biologically well adapted to over-wintering. The highest mass of one its over-wintered plant before spring application of herbicides reaches 6.4 gram increasing it from 2.52 gram in autumn. However, perennial weeds were rare in our experimental field (Fig. 4) and even were not present in some experimental plots overall (Table 3). Received analogous cereal crop weediness variations mostly depend on experimental field weediness heterogenity especially in intensive operating fields with low weediness as each weed observation is made randomly (Pilipavičius, 2005). Similar trend of annual and perennial weed populations has been noticed by Geisselbrecht-Taferner et al., 1997; Colbach et al., 2000; Rew et al., 2001 and other researchers. Dominating annual weeds in the winter wheat crop directly influenced all weed average plant mass that remained analogous to average annual weed plant mass (Table 3).



Note. Perennial weed species - *Antennaria dioica* L., *Plantago major* L., *Poa trivialis* L., *Sonchus arvensis* L.; BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying.

Fig. 4. Perennial weeds in winter wheat crop before and after autumn and spring application of herbicides

Spring spraying with composite of herbicides *Sekator* and *MCPA* was low effective as standard technology in control treatment (average weed plant mass increase from 0.10 gram in autumn till 0.14 gram in spring after application). Winter wheat crop spring spraying with herbicides was either low effective as average weed plant mass has tendency to increase comparing weed average mass in autumn after experimental application of herbicides or in spring before application of standard chemical weed control technology with average weed one plant mass after spring application of herbicides (Table 3).

Weed air-dry biomass in the crop before spraying by herbicides in spring regularly depended on left weed air-dry mass in the crop after autumn spraying by herbicides r = 0.608** using chemical weed control (according to the experimental design) in early winter wheat growth and development stages. The reliable linear dependence (1) best described this regularity.

$$y = 4.077 + 0.335\ x;\ P = 0.0016 \quad (1)$$

Weeds left in the crop after autumn spraying by herbicides reliably increased crop weediness in spring before conventional spraying. Weed air-dry biomass of 1 g m^{-2} left in winter wheat crop in autumn increased crop weediness by 0.335 g m^{-2} in spring after renewing of vegetation (Pilipavičius et al., 2010b). Other researchers (Spiridonov et al., 2006) have affirmed high biological and economical efficiency of autumn application of herbicide (*Difezan*) in winter wheat crop in comparison with the conventional spring period of treatment. The successful post emergence control of weeds in the winter cereal crops at the BBCH 11-25 in autumn with herbicide *Atlantis* was reported by Brink and Zollkau 2004.

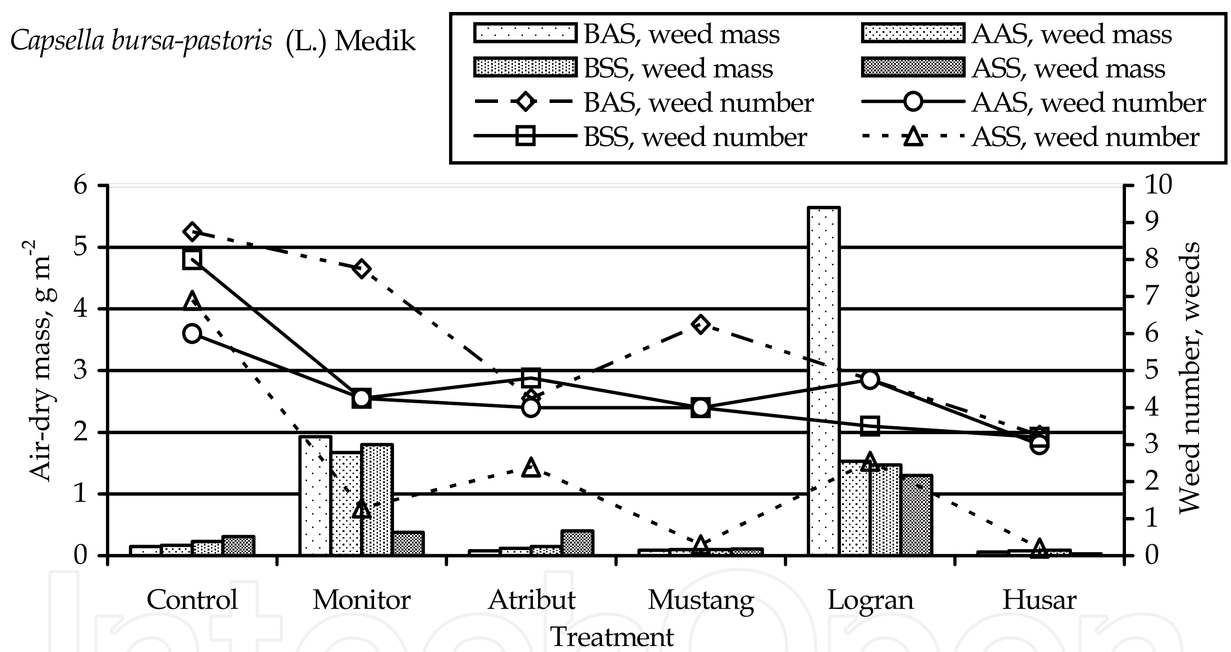
Treatment	Crop weediness average one weed plant air-dry mass, g per weed			
	Before autumn application of herbicides	After autumn application of herbicides	Before spring application of herbicides	* After spring application of herbicides *Sekator* 300 g ha^{-1} and *MCPA* 1 L ha^{-1} composite
	All annual weeds			
Control	0.10	0.11	0.11	0.14
Monitor	0.27	0.16	0.17	0.18
Atribut	0.23	0.13	0.13	0.24
Mustang	0.06	0.13	0.13	0.13
Logran	0.38	0.21	0.22	0.25
Husar	0.03	0.09	0.09	0.09
	All perennial weeds			
Control	0.20	1.72	-	0.10
Monitor	0.82	-	0.53	-
Atribut	0.68	-	-	-
Mustang	-	2.52	6.4	-
Logran	-	-	-	-
Husar	0.24	0.13	-	-
	All weeds			
Control	0.10	0.11	0.11	0.14
Monitor	0.27	0.16	0.17	0.18
Atribut	0.23	0.12	0.13	0.24
Mustang	0.06	0.14	0.14	0.13
Logran	0.38	0.21	0.22	0.25
Husar	0.03	0.09	0.09	0.09

Note. See experimental design.

Table 3. Average one weed plant air-dry mass change in winter wheat crop with autumn and spring applications of herbicides.

Separate weed species of winter wheat crop responded adequately to the autumn application of herbicides as the whole crop weed community. Winter annual weed *Capsella bursa-pastoris* (Fig. 5) was moderate in density and mass, however, it had tendency to increase in winter wheat crop without autumn application of herbicides. However, higher initial *Capsella bursa-pastoris* population in plots of *Monitor* and *Logran* treatments was inhibited and decreased with modern autumn application of herbicides (Fig. 5). Winter annual weed *Centaurea cyanus* (Fig. 6) was dominant in winter wheat crop agrophytocenoses before autumn application of herbicides. It comprised 4.4%-8.4% of weed density and 1.6%-17.3% of total weed biomass.

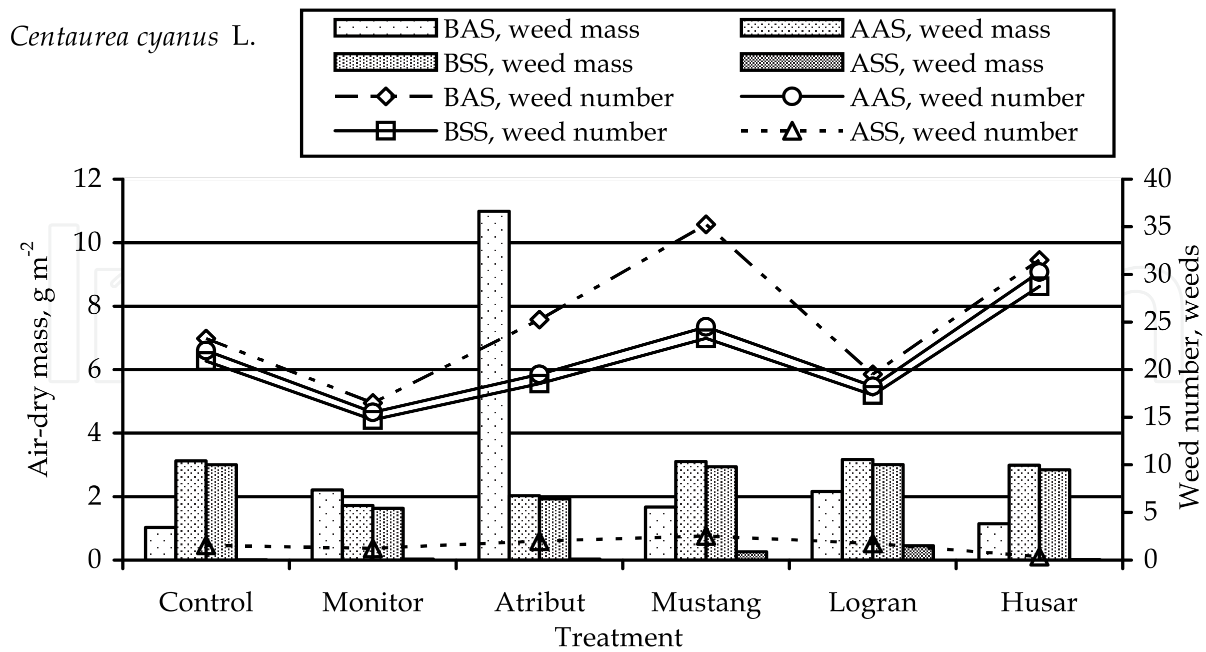
Density and mass of *Centaurea cyanus* had tendency to decrease after herbicide application in autumn. In overwintered crop *Centaurea cyanus* decreased by 5% in density and by 79.6%-19.8% in mass comparing it with the crop before winter time. Decrease of *Centaurea cyanus* density was similar in control treatment without autumn application of herbicides, however its mass decreased just by 3.8%, i.e. the *Centaurea cyanus* mass decrease after overwintering was by 5.2-20.9 times lower than in plots with autumn chemical weed control (Fig. 6). The other winter annual weed *Galium aparine* (Fig. 7) in winter wheat was less numerous and less in biomass comparing to *Centaurea cyanus* (Fig. 6), *Capsella bursa-pastoris* (Fig. 5) or *Raphanus raphanistrum* (Fig. 8). During wintering *Galiun aparine* without autumn herbicide application, density in the crop increased in mass by 56.5% and in density by 16.7%. It formed more competitive weed community against winter wheat in spring. Autumn application of herbicides subserved effectively *Galium aparine* control (Fig. 7). Summer annual weed *Raphanus raphanistrum* (Fig. 8) initial population made 3.2-9.8 weeds per square meter and 1.6-8.2 g m^{-2} of air-dry mass. It comprised 0.9%-2.6% of total weed density and 2.5%-13.1% of total weed mass. After autumn application of herbicides, *Raphanus raphanistrum* density and mass decreased by 21.9%-36.2% and 38.1%-65.5% accordingly.



Note. BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

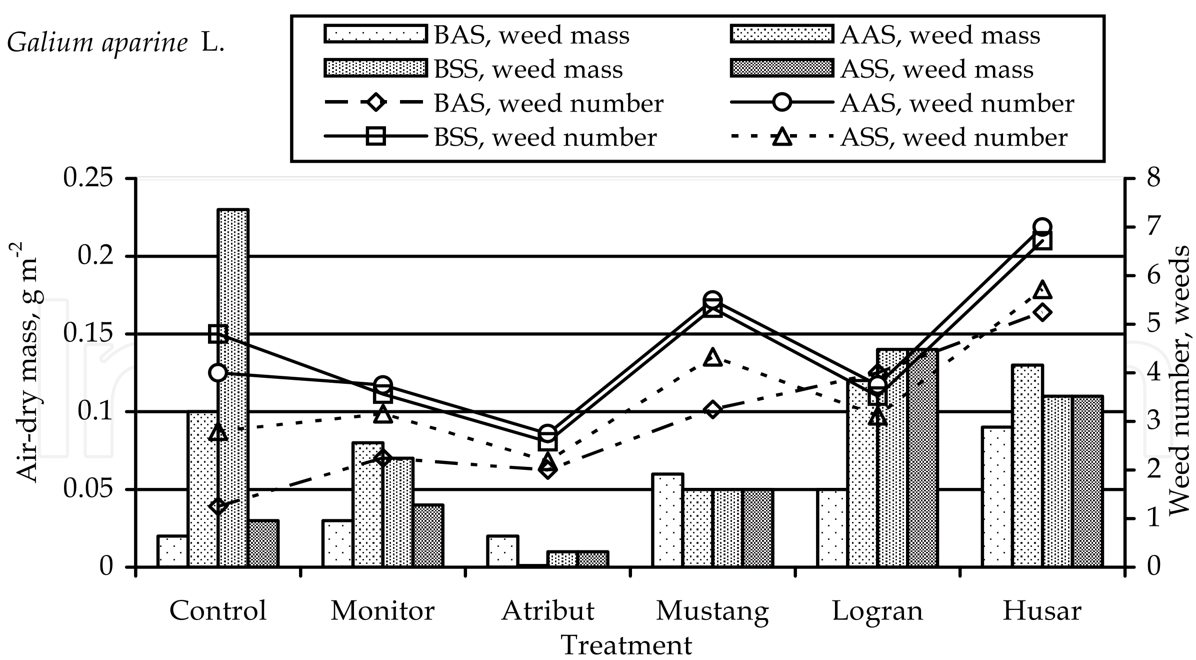
Fig. 5. *Capsella bursa-pastoris* (L.) Medik in winter wheat crop before and after autumn and spring application of herbicides.

In spring, renewing crop vegetation, *Raphanus raphanistrum* plants made 0.8%-1.9% of total weed density and 2.2%-6.2% of total weed mass. It was visible decrease of this weed population, hence, it showed that biologically summer annual weeds already can successfully survive during winter while conventionally it should not happen (Fig. 8). Other winter wheat crop weed belonging to *Brassicaceae* family, *Raphanus* genus was *Raphanus sativus* (Fig. 9). *Raphanus sativus* was present just in one treatment, was low in number and biomass. *Raphanus sativus* separately had no substantial effect on crop weediness and belonged to temporal weed flora element in the crop.



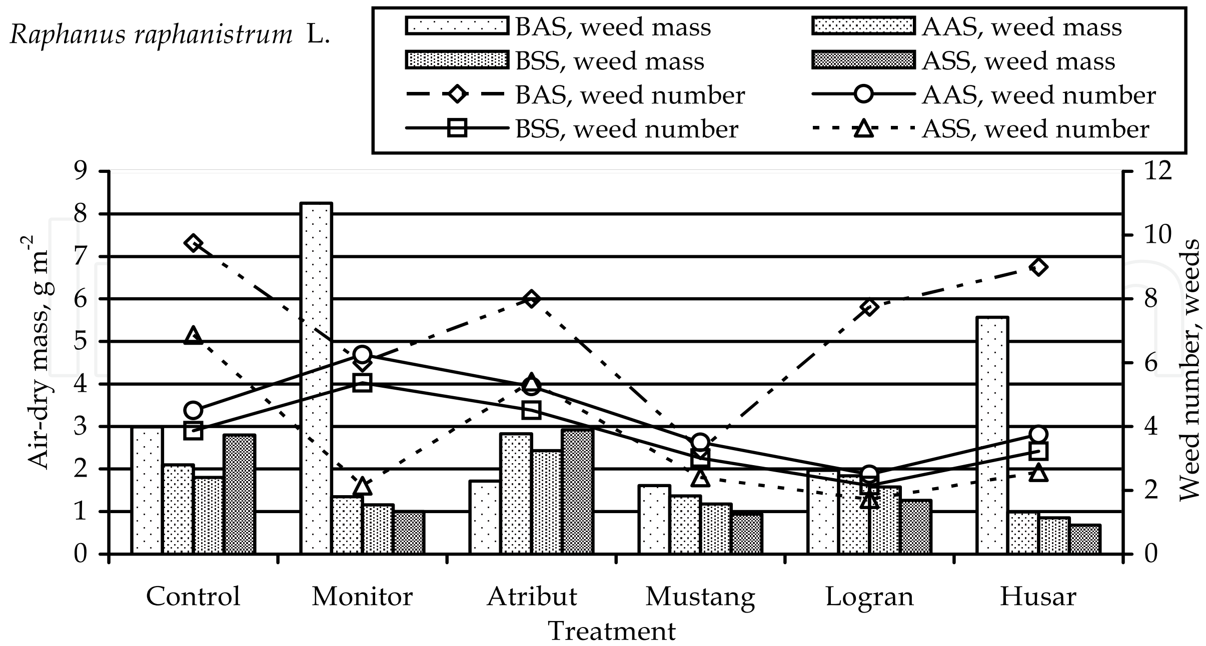
Note. BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

Fig. 6. *Centaurea cyanus* L. in winter wheat crop before and after autumn and spring application of herbicides.



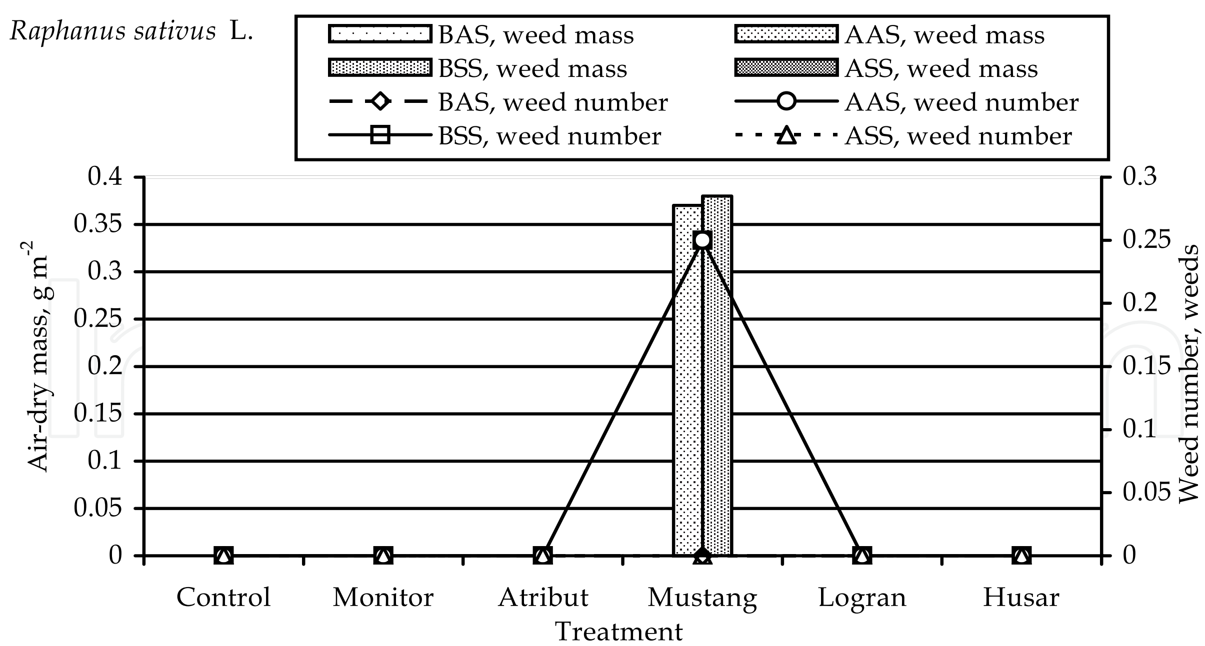
Note. BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

Fig. 7. *Galium aparine* L. in winter wheat crop before and after autumn and spring application of herbicides.



Note. BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

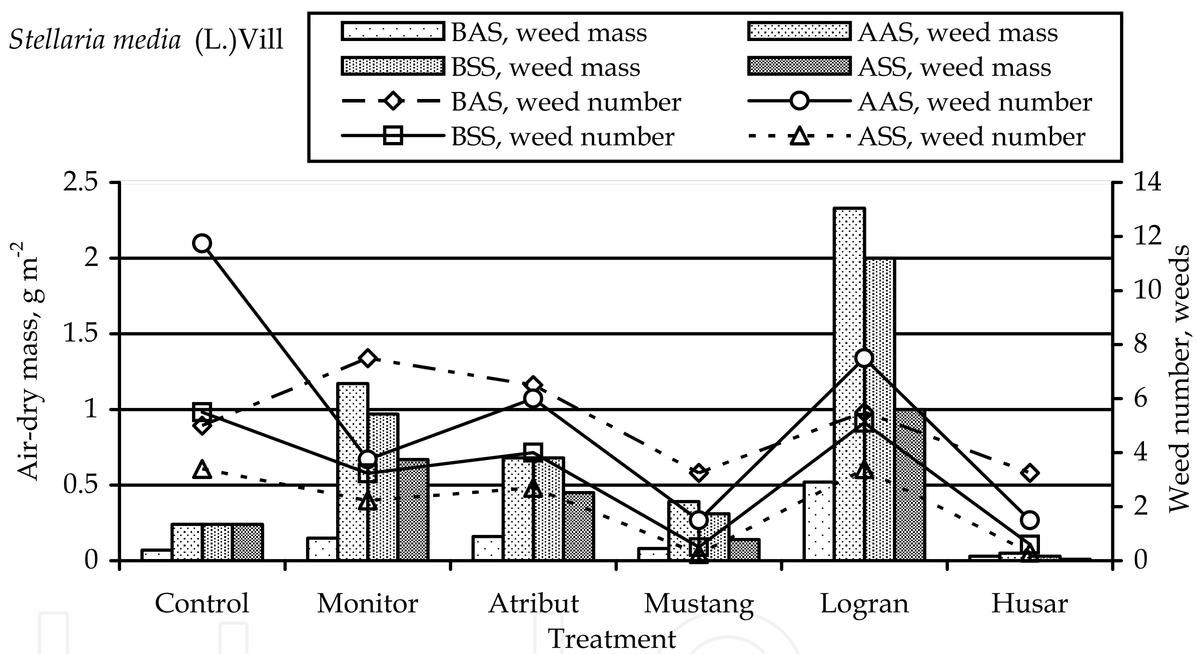
Fig. 8. *Raphanus raphanistrum* L. in winter wheat crop before and after autumn and spring application of herbicides.



Note. BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

Fig. 9. *Raphanus sativus* L. in winter wheat crop before and after autumn and spring application of herbicides.

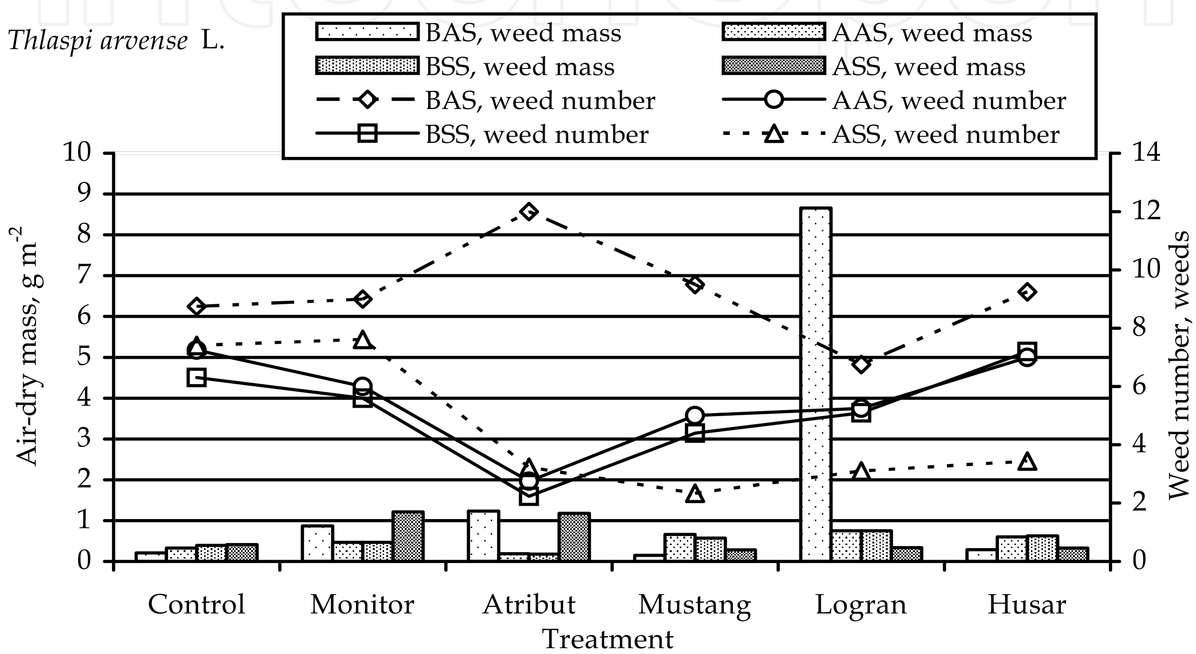
More important winter wheat crop weed was *Stellaria media* (Fig. 10). Biologically belonging to the summer annual ephemeral weeds *Stellaria media* showed ability to survive during winter (either as *Raphanus raphanistrum*) that was not usual for the conventional Lithuanian conditions (Aleksandravičiūtė et al., 1961). *Stellaria media* overwintering was not effected even by the unfavourable wintering conditions (see meteorological conditions, subchapter 2.1). Chemical weed control, especially in autumn was not successful for control of this weed. On the contrary, *Stellaria media* was initiated to growth after herbicide application in autumn (Fig. 10). It could be influenced by the *Stellaria media* biological quality to launch new branches (stems and roots) from each damaged or fresh node. Consequently, it makes *Stellaria media* control and evaluation even more complicated.



Note. BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

Fig. 10. *Stellaria media* (L.)Vill in winter wheat crop before and after autumn and spring application of herbicides.

Winter annual weed *Thlaspi arvense* made 1.8%-3.2% of total weed density and 0.23%-13.6% (the highest excess in *Logran* treatment plot) of total crop weed mass before autumn herbicide application (Fig. 11). After autumn chemical weed control applied in winter wheat crop it had tendency to decrease in number by 2.4-1.6 times and till 11 times in mass. Over wintered *Thlaspi arvense* has trivial increase in mass of control and *Husar* treatments, trivial decrease in *Mustang* treatment and sustained autumn level in other treatment plots. Autumn application of herbicides as *Mustang*, *Logran* and *Husar* in winter wheat crop lead to decease of *Thlaspi arvense* mass after spring spraying while after autumn application of *Monitor* and *Atribut Thlaspi arvense* mass increased 1.6 and 6.6 times after spring spraying accordingly. In mentioned last two autumn treatment cases (*Monitor* and *Atribut*) standard spring application of herbicides was ineffective.

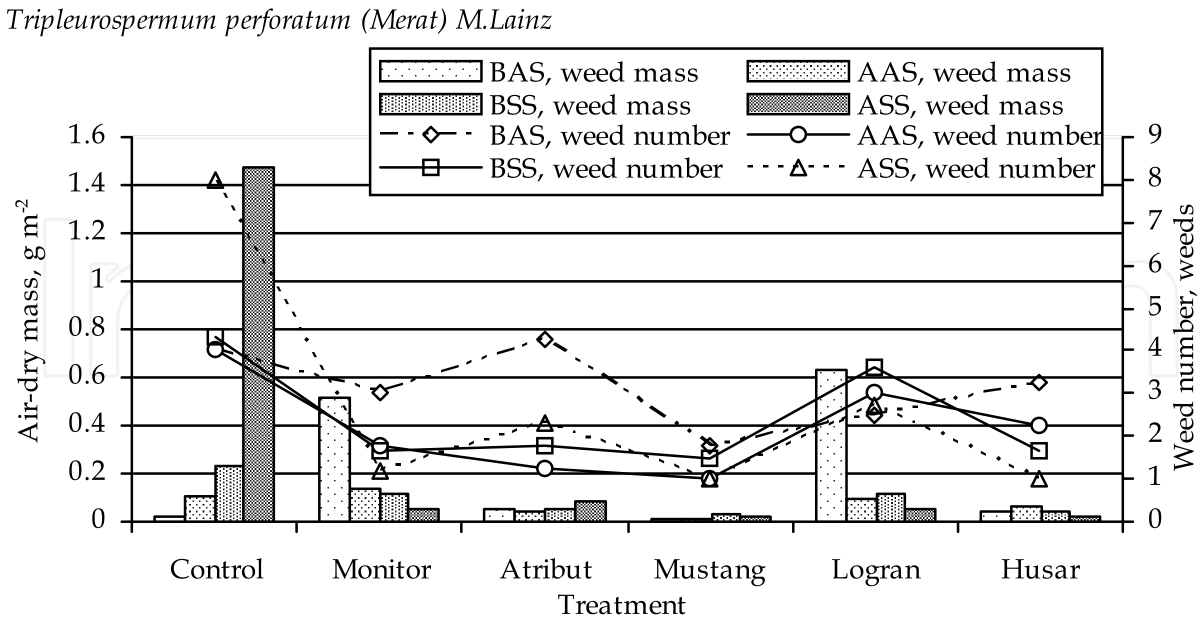


Note. BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

Fig. 11. *Thlaspi arvense* L. in winter wheat crop before and after autumn and spring application of herbicides.

Winter annual weed *Tripleurospermum perforatum* was spread enough homogenously in the experimental field except two excesses in *Monitor* and *Logran* treatments at early winter wheat crop development stages in autumn before applying chemical weed control means, that was reduced till averagely general *Tripleurospermum perforatum* weediness in the autumn crop after herbicides application (Fig. 12).

In spring *Tripleurospermum perforatum* plant development was limited by standard spring herbicide application (composite of herbicides Sekator 300 g ha^{-1} and MCPA 1 L ha^{-1} with a winter wheat growth regulator Cycocel 1.5 L ha^{-1} at BBCH 22-23) while in control treatment without autumn herbicide application it was not effective. It could be concluded that even without significant crop weediness decrease in autumn growth period of winter wheat weeds are damaged and weaken what is essentially highlighted at conventional spring application of herbicides in winter cereals.



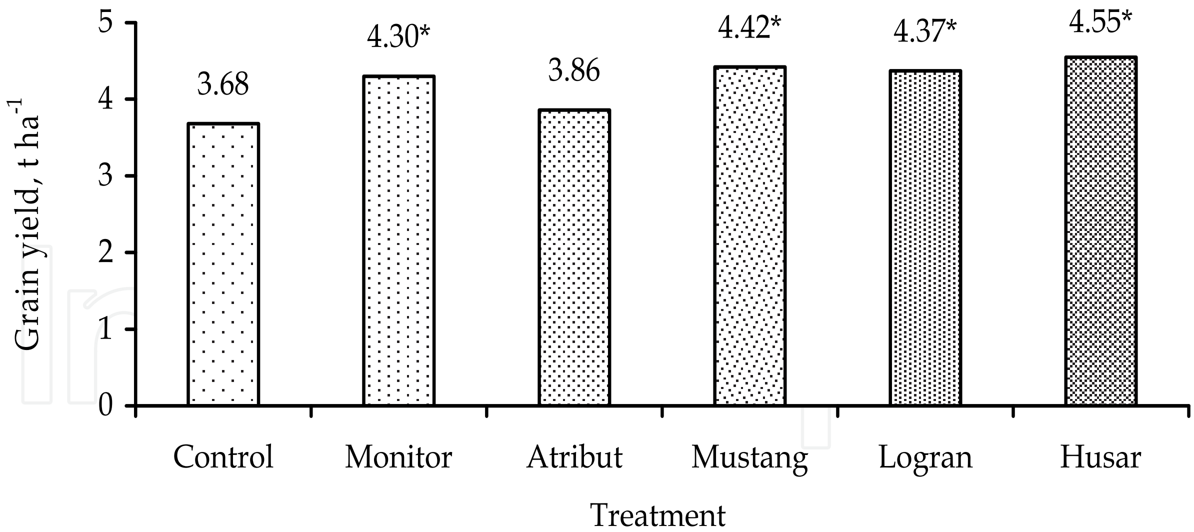
Note. BAS – before autumn spraying, AAS – after autumn spraying, BSS – before spring spraying, ASS – after spring spraying

Fig. 12. *Tripleurospermum perforatum* (Merat) M.Lainz in winter wheat crop before and after autumn and spring application of herbicides.

2.4 Crop productivity

Winter wheat grain yield was expressed in moisture of 14% and absolutely clean mass. Grain moisture was established by drying grains in a thermostat at the temperature of 105 ^{0}C until they reached the constant weight. The biggest winter wheat yield 4.55 t ha^{-1} was got using *Husar* (Iodosulphuron-methyl-sodium) in autumn and the least one 3.68 t ha^{-1} in control treatment without autumn application of herbicides (Fig. 13). Average winter wheat grain yield in Lithuania in the same year was 2.46 t ha^{-1} (Statistics Lithuania, 2011). Average winter wheat grain yield in Lithuania in 2006 comparing it with 2005 decreased by 35% and general yield by 43.6% (Market research, 2007). Modern technologies of herbicide application at early stages of winter wheat development in autumn are very promising while comparing winter wheat grain yield in our experiment with average winter wheat yield in Lithuania. During 2005-2010 the highest winter wheat grain average yield was 4.76 t ha^{-1} in 2008 (Statistics Lithuania, 2011), i.e. just by 4.4% higher than in our best treatment. Though, winter wheat vegetation 2007-2008 meteorological conditions for winter wheat growing were better than during 2005-2006 vegetation.

In our experiments (Pilipavičius et al., 2010b) essential winter wheat grain yield increase by 0.62-0.87 t ha^{-1} was established after use of *Monitor* (Sulphosulphuron), *Mustang* (Florasulam + 2.4-D 2-ethylhexyl ester), *Logran* (Triasulphuron) and *Husar* (Iodosulphuron-methyl-sodium) compared with in autumn unsprayed control. Winter wheat grain yield increase reached 25%, 20%, 19% and 24% accordingly, and after spraying by *Atribut* (Propoxycarbazone-sodium) grain yield had tendency to increase (Fig. 13).



Note. LSD_{05}=0.372; * - essential differences from control treatment

Fig. 13. Winter wheat grain yield of crop with autumn application of herbicides. (Pilipavičius et al., 2010b)

Evaluating grain chemical composition (Table 4), it was established that independently of used herbicides, nutritional composition of grain was not radically different. The amount of crude protein in winter wheat grain changed from 8.9% to 9.9% and there was found from 1.43% to 2.1% of crude fat, from 1.93% to 2.67% of crude fibre and from 1.2% to 1.7% of crude ash (Pilipavičius et al., 2010b).

Treatment	in grain dry matter							
	Crude protein		Crude fat		Crude fibre		Crude ash	
	%	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}
Control	8.9	0.328	1.53	0.056	2.23	0.082	1.2	0.044
Monitor	9.4	0.404	1.43	0.061	2.7	0.116	1.5	0.064
Atribut	9.1	0.351	1.69	0.065	2.59	0.099	1.2	0.046
Mustang	9.9	0.437	2.1	0.092	2.43	0.107	1.3	0.057
Logran	9.3	0.406	2.00	0.087	1.93	0.084	1.7	0.74
Husar	9.5	0.432	1.82	0.082	2.67	0.120	1.7	0.077

Table 4. Grain chemical composition of winter wheat crop with autumn application of herbicides (Pilipavičius et al., 2010b).

A statistically reliable reverse linear correlation r = -0.565** (Pilipavičius et al., 2010b) was established between crop weed number after spring spraying by herbicides and winter wheat grain yield (2).

$$y = 4.517 - 0.091\,x;\ P = 0.004 \qquad (2)$$

Evaluating dependence between weed air-dry biomass after herbicide application in spring and winter wheat grain yield (3), it was established statistically reliable reverse linear correlation r = -0.438* (Pilipavičius et al., 2010b).

$$y = 4.454 - 0.0128\,x;\ P = 0.032 \qquad (3)$$

It was in conformity as dependence of winter wheat grain yield on weed density (2) and coincided (3) with the law of crop productivity (Lazauskas, 1990, 1993; Pilipavičius et al., 2009).

3. Conclusion

Winter wheat *Triticum aestivum* L. is sensitive to weed competition in early stages of growth and development. In conventional technologies herbicides in winter cereals are applied in spring. Therefore, perennial and annual (especially winter annual) weeds over-wintered successfully in cereals have favourable conditions to grow and compete with cereals when vegetation in spring is renewing.

Perennial weeds are well adapted to over-wintering biologically while their air-dry mass increases till 11% during wintering. Conventionally, it is opposite to annual weeds. However, it was established that during winter time in winter wheat crop annual weeds, even some summer annual ones, had increase adaptivity of successful surviving winter frosts and accumulated higher one plant average mass by 5-6%during winter time. Moderated increase of annual weed mass during winter time was in conformity with the research hypothesis that many annual weeds successfully survive winter time as earlier was not usual.

Separate weed species of winter wheat crop responded adequately to the autumn application of herbicides as the whole crop weed community. Standard spring spraying as conventional technology with composite of herbicides is insufficient effective while average weed plant mass increase from 0.10 gram in autumn till 0.14 gram in spring after herbicide application, i.e. increase make 40%. Weeds had tendency to spread in winter wheat crop without autumn application of herbicides and formed more competitive weed community against winter wheat in spring. It can be concluded that even without significant crop general weediness decrease in autumn by herbicides weeds are damaged and weaken what is essentially highlighted at conventional spring application of herbicides in winter cereals. Weeds left in the crop after autumn spraying by herbicides reliably by 33.5% increased crop weediness in spring before conventional spraying, as described in regression equation $y = 4.077 + 0.335\ x$.

Winter wheat yield and its agrophytocenoses weed air-dry mass in spring crop was in conformity with the law of crop productivity. Winter wheat grain yield depended on weed air-dry mass and was described by the reverse linear correlation $r = -0.438^*$ and regression $y = 4.45 – 0.013x$ analyses.

Modern technologies of herbicide application at early stages of winter wheat development in autumn are very promising while in our experiment it gives increase in grain yield till 25% and comparing it with average winter wheat yield in Republic of Lithuania during the same period it was got increase in grain yield from 50% to 85%.

For the best weed control and winter wheat yield results herbicides should be applied in autumn, especially when the weather is favourable for prolonged development of weeds even at low density of perennial ones in the crop.

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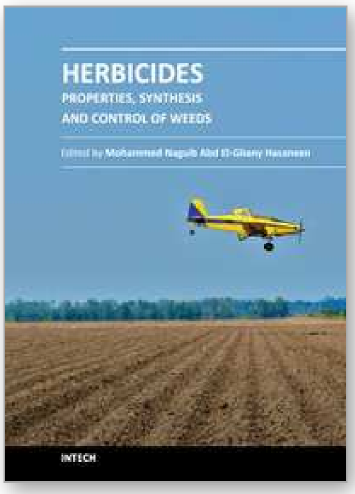

Herbicides - Properties, Synthesis and Control of Weeds
Edited by Dr. Mohammed Nagib Hasaneen

ISBN 978-953-307-803-8
Hard cover, 492 pages
Publisher InTech
Published online 13, January, 2012
Published in print edition January, 2012

This book is divided into two sections namely: synthesis and properties of herbicides and herbicidal control of weeds. Chapters 1 to 11 deal with the study of different synthetic pathways of certain herbicides and the physical and chemical properties of other synthesized herbicides. The other 14 chapters (12-25) discussed the different methods by which each herbicide controls specific weed population. The overall purpose of the book, is to show properties and characterization of herbicides, the physical and chemical properties of selected types of herbicides, and the influence of certain herbicides on soil physical and chemical properties on microflora. In addition, an evaluation of the degree of contamination of either soils and/or crops by herbicides is discussed alongside an investigation into the performance and photochemistry of herbicides and the fate of excess herbicides in soils and field crops.

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