Taxonomic composition of weed vegetation in the southern and middle Urals and zonal features of its control in maize crops

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Abstract. As a result of expeditionary-route studies, the impoverishment of the composition of the segetal flora in maize crops was established when moving from the North-West to the South-East of the Ural region: from 37 species in the forest-meadow and mountain-forest zones to 10 in the steppe zone. Zonal features of the composition of weed communities associated with the hydrothermal gradient consist in the mutual substitution of annual monocotyledonous and dicotyledonous species with a stable contribution of perennial dicotyledons, as well as the replacement of mesophytic weeds with xerophytic species of the same families. A comparison of cross-spectrum herbicides effectiveness in the forest-steppe and forest-meadow zones showed the advantages of a post-emergent preparation with soil effect of Meister Power. In temperate soil fertility in the Southern area of the region, it is economically feasible to use post-emergent herbicides without soil effect, in Northern areas with stable moisture – soil ones.

1 Introduction

The promotion of maize to the Northern regions of Russia is accompanied by an increase in its infestation, which hinders the expansion of this crop, in particular, in the Ural region. High maize infestation is associated with the influence of two main factors. One of them is the use of early-season hybrids of the FAO group from 120 to 170, characterized by a relatively small plant habit and low projective cover [31,10]. In addition, modern hybrids of this group are mostly three-line and double interline with weakly expressed dynamics of biomass and leaf surface growth [8]. These features of the hybrids creates a competitive advantage for weeds and extend maize herb-critical period. If in the Southern regions it usually continues from germination to the formation of 7-8 leaves [9,1], then in the Urals – to the phases of grain formation and milk ripeness [5].

The second factor, the influence of which leads to increased weeding of crops, is a short growing season, which causes maize to be sown at the earliest possible time, and slow warming of the soil during the pre-sowing period [10,11,24]. As a result, sprouts of most types of weeds appear after sowing, and often after the crop sprouts. This dramatically re-

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duces the effectiveness of preventive measures to control weeds, for example, the destruction of weeds in the process of pre-sowing tillage or pre-sowing use of general-purpose herbicides [27], leads to increased weeding of crops and increases the harmfulness of segetal vegetation. Thus, in traditional (southern) maize growing zones, weed damage ranges from 8 to 24 percent [22, 13, 26], while in the Urals, typical infestation reduce maize yield by 7-15 times [19,25,5].

The harmfulness of weeds in the conditions of the Ural region is realized through several channels. The most important of them, the most relevant for the Southern regions, is the alienation of water resources. In weeded maize crops, an increase in total water consumption by 5-7% and an increase in the evapotranspiration coefficient by 3-4 times was revealed [20]. In the Northern regions, larger damage is caused by the removal of mineral nutrition elements by weeds. It is established that monocotyledonous weed species carry 1.5-2 times more nitrogen, phosphorus and potassium than maize, dicotyledonous – 2-2.5 times; at the same time, weeds can account for up to 75-80% of the total removal of macronutrients in agrocenosis[28]. Solar radiation is not usually considered as a factor limiting the growth and development of maize in the Urals, but research of Sinitsyna and Kazakova (2011) found a decrease in the content of chlorophyll in the parenchyma of maize leaves from 0.17-0.32% in clean crops to 0.10-0.19% in weeded ones, which reduces the efficiency of light resources use.

In most cases, three biological groups of weeds are observed in maize crops: perennial and annual dicotyledons, as well as annual monocotyledons. In addition, perennial monocotyledonous and spore-bearing weed species are found in limited areas [14]. The group and species composition of weeds is largely determined by soil and climatic conditions and can significantly change in the meridional and latitudinal directions and in connection with vertical zoning [33, 23]. Thus, in the Western part of the Urals (the Republic of Bashkortostan), a regular increase in the share of xerophytes in the steppe zone compared to the forest-steppe zone was found [15,16].

The complexity and geographical conditionality of the infestation composition require a zonal approach to the justification of its control. It is based on the direct study of segetal communities of various soil and climatic zones, as well as the identification of the effectiveness of plant protection techniques against weeds in connection with soil and hydrothermal conditions.

The control of annual monocotyledonous weeds is the most difficult in maize crops. This is due to the abundant supply of seeds in the soil, their different quality, and the presence of species with different responses to soil temperature [4,20,5]. As a result, this group is characterized by extended periods of emergence, and their suppression requires technological schemes with a long protective period. In particular, two-time spraying is effective: with a soil herbicide before sowing or before germination and post-emergent - in the period from 3 to 5 leaves in the crop in combination with one or two row spacing cultivations [36,21,17,29,35]. The disadvantage of such schemes is their organizational and economic tension and the high risk of deviation from the optimal timing of operations.

More technologically advanced plant protection schemes can be implemented using post-emergent herbicides that have both translaminar and screen effects, which, after spraying of vegetating weeds, are able to control their subsequent waves. These properties are characteristic of the thienicarbazone-methylol compound, which belongs to the class of ALS-inhibitors – sulfonyl-amino-carbonyl-triazolinones and is part of the Adengo and Meister Power preparations. Their effectiveness was revealed in various soil and climatic conditions [37,17,30,1,6,2].

The choice of the herbicide type in each case depends on the complex of soil-climatic, phytocenotic and organizational and economic conditions. To justify zonal approaches to this choice, in 2014-2016, 2018, and 2019, the effectiveness of herbicides of various classes

was studied in two soil-climatic zones: the forest–steppe of the Chelyabinsk region and the forest-meadow of the Sverdlovsk region.

The **research objective** is to identify the zonal features of weed communities and the influence of cross-spectrum herbicides with different types of action on the infestation and maize yield.

2 Materials and methods

Research methods – expedition-route, quantitative-weight, field experience. Studies of taxonomic diversity of weeds held in 2019 in the production maize crops in five soil-climatic zones of Southern and Middle Urals (in the administrative boundaries of the Kurgan, Sverdlovsk, Chelyabinsk regions and the Republic of Bashkortostan): steppe, Southern forest-steppe (4 locations), Northern forest-steppe (5 locations), forest-meadow (3 locations) and mountain-forest (1 locations). To determine the species composition, number and mass of weed vegetation in the surveyed fields, 12 accounting sites with an area of 0.25 m² were allocated. The moisture content in the tops of weeds was determined by gravimetric method.

Field experiments to study the effectiveness of cross-spectrum herbicides were conducted against the background of zonal technologies for maize cultivation: in the forest-steppe zone on ordinary chernozem, typical medium-dry medium-humus medium-loamy, in the forest-meadow zone – on dark gray forest heavy-loamy soil. The experiments used a hybrid of maize Obsky 140 SV. The scheme of the experiment is presented in table 1.

Table1. Experience scheme (2014-2016, 2018-2019)

Variant	Preparation composition (active ingredients)	Consumption rate of the preparation	Agrotechnical time of application
Control	Without herbicides		
Merlin	isoxaflutole, 750 g/kg	0.15 kg/ha	before sprouting
Meister	foramsulfuron, 300 g/kg + iodosulfuron-methyl-sodium, 10 g/kg	0.15 kg/ha	by sprouts (3-5 leaves)
Meister Power	foramsulfuron, 31.5 g/l + iodosulfuron-methyl-sodium, 1.0 g/l + thiencarbazone-methyl, 10 g/l	1.5 l/ha	by sprouts (3-5 leaves)

The choice of variants in the experiment is associated with the different nature of the action of the studied objects: the Merlin preparation is a group of soil herbicides, Meister – post-emergent, Meister Power - post-emergent with a soil effect due to the presence of the active substance *thiencarbazone-methyl*. Therefore, these preparations can be considered as models for identifying zonal features of their influence on weeds. The total area of the plot is 84 m², the accounting area is 42 m², the experience is repeated three times.

Statistical hypotheses were tested using the method of variance analysis. The significance of differences between the mean values for the variants was judged by the Fisher criterion (F) and the least significant difference (LSD). The significance level of critical values of statistical parameters is p = 0.05.

3 Results and discussions

Taxonomic composition of weeds

As a result of the expedition-route study, zonal features of the taxonomic composition of weeds were established (table 2). Moving from the North to the South of the region, the number of botanical families decreased from 18 in the forest-meadow and mountain-forest zones to 10 in the steppe zone. In terms of species composition, the greatest diversity (37

species) was also revealed for the most humid North-Western part of the surveyed territory, while their number decreased to 17 in the arid steppe.

Table 2. Taxonomic diversity of weeds in the Southern and Middle Urals

Soil and climate zone	Number of	
	families	species
Forest-meadow and mountain-forest	18	37
Northern forest-steppe	14	23
Southern forest-steppe	13	20
Steppe	10	17

As noted above, typical infestation of maize in the Urals is formed by species belonging to three economic and biological groups: perennial and annual dicotyledons, as well as annual monocotyledons. The contribution of these groups to the total segetal phytomass depended on the nature of moisture (figure 1). The longevity and low mobility of populations of perennial dicotyledonous weeds caused a weak variation in their share in the phytomass, which ranged from 22 to 24% across zones.

Fig. 1. Zonal features of the segetal phytomass structure in the Ural region (A - annual dicotyledons, B - annual monocotyledons, C – perennial dicotyledonous weeds)

Changes related to the hydrothermal gradient related to the species composition within this group: moving from the North-West to the South-East was accompanied by an increase in the contribution of *Cirsium vulgare* (Savi) Ten. and *Euphorbia virgata* W. K., a decrease in the share of *Convolvulus arvensis* L. and mesophytic species (*Equisetum arvense* L., *Persicaria amphibia* (L.) Delarbre, *Lamium album* L., *Mentha arvensis* L., *Lathyrus tuberosus* L.). *Sonchus arvensis* L. took a relatively constant part in the formation of infestation.

The contribution of annual dicotyledonous and monocotyledonous species is strongly dependent on climatic conditions. The steppe zone is characterized by a predominance of cereals, mainly late spring species: *Echinochloa crus-galli* (L.) Beauv., *Panicum miliaceum* subsp. *ruderales* (Kitag.) Tzvel. and *Setaria viridis* (L.) Beauv.; *Avena fatua* L. occurs sporadically regardless of zonal conditions. In the forest-meadow and mountain-forest zones, these species are partially replaced by annual dicotyledonous plants.

As the climate aridizes from the North-West to the South-East, mesophyticbiennial

weeds are replaced by xerophytic species of the same families. For example, in the Asteraceae family, the species *Centaurea cyanus* L., which occurs in forest-meadow and mountain-forest zones, is replaced in the forest-steppe zone by the species *Tripleurospermum nodosum* (L.) Sch. Bip., in the steppe zone - by *Erigeron canadensis* L. The Amaranthaceae family is characterized by the following species change: *Amaranthus retroflexus* L. – *Amaranthus albus* L.; Chenopodiaceae: *Atriplex tatarica* L. – *Chenopodium album* L.; Salsolaiberica (Sennen&Pau) Botsch.; Caryophyllaceae: *Stellaria media* L. – *Silene vulgaris* (Moench) Garcke – *Stellaria graminea* L. – *Gypsophila paniculata* L.

The presented material allows us to conclude that, despite the dependence of the taxonomic composition of weed plants on hydrothermal factors and its impoverishment when moving from the forest-meadow and mountain-forest zones to the forest-steppe and steppe, the entire territory of maize cultivation in the Ural region preserves the economic and biological diversity of weeds, which implies the use of effective methods of their control in technologies.

Effectiveness of cross-spectrum herbicides in maize crops

Due to the consistently high infestation of maize crops associated with the climatic and phytocenotic conditions of the Urals, protective measures are based on the use of cross-spectrum herbicides [30]. The problem is to choose the optimal herbicide model, considering the composition of infestation and the zonal nature of territory moistening. As already noted, the current range of herbicides is distributed among three groups (soil, post-emergent and post-emergence with soil action), which differ in the nature of action and distribution relative to plant organs. Studies conducted in the forest-steppe and forest-meadow zones of the Urals revealed the zonal features of the influence of three model preparations on the infestation and maize yield.

The initial infestation of both experimental sites was typical for the corresponding natural zones. In the forest-steppe, from 19 to 20-24% of segetal biomass was accounted for perennial dicotyledonous species, from 49 to 61 % - for cereal species. The minimal contribution was made by biennial dicotyledonous species due to the small number of plants and weak competitive ability in relation to weeds of the first two groups [34]. In the forest-meadow zone, the core of weed vegetation was dicotyledonous species, while the proportion of cereal species ranged from 29 to 49 %.

The level of crop infestation is also typical for the region. Both in the forest-steppe and forest-meadow zones, weed plants formed a significant biomass: 378 and 391 g/m², respectively, which is comparable to the mass of cultivated plants (table 3).

Table 3. Influence of herbicides on the maize infestation, on average over 2014-2016, 2018-2019

Variant	Weight of weeds, g/m ²		Biological effectiveness, %	
	Forest-steppe zone	Forest-meadow zone	Forest-steppe zone	Forest-meadow zone
Control	377.6	391.0	-	-
Merlin before sprouting	162.7	107.9	56.9	72.4
Meister by sprouting	58.4	111.1	84.5	71.6
Meister Power by sprouting	24.6	39.2	93.5	90.0
LSD ₀₅	4.8	9.1	-	-

In both zones, the minimum contamination and maximum biological efficiency were achieved in the variant with the use of the Meister Power preparation due to the combination of translaminar and soil action and, as a result, a long-term protective effect that ensured weed control throughout the entire vegetation period. Zonal features are established in relation to the action of soil (Merlin) and post-emergent (Meister) herbicides. In the for-

est-steppe zone, the effectiveness of the soil preparation was limited by unstable moisture, which led to a relatively low biological efficiency, on average, not exceeding 60 %. Post-emergent preparation by this parameter was close to the best variant. In the forest-meadow zone on a more humid background, both herbicides are comparable in their effectiveness on weeds; in these conditions, the biological effectiveness of Merlin exceeded the same indicator for the forest-steppe by an average of 12 percentage points. On the contrary, for the Meister preparation, there was a decrease in effectiveness compared to the forest-steppe zone by 13 points. The reason is the high probability of secondary infestation of crops and the lack of a prolonged effect on weed sprouts that appear after its use.

The variation in the yield of dry maize mass by variants was closely related to the infestation (table 4). High infestation led to extremely low yields in the control – from 1.1 to 5.5 t/ha in the forest-steppe zone and from 2.0 to 6.4 t/ha in the forest-meadow zone. In both natural zones, the maximum and stable yield was shown by the preparation with the soil action of Meister Power during post-emergence application. The effectiveness of the other two preparations was strongly dependent on the conditions of use: in the forest-steppe the best yield variant was approaching the post-emergent herbicide Meister, in the forest-meadow zone - soil Merlin. It is necessary to note a wide variation in yield against the background of soil preparation in the forest-steppe zone, characterized by pronounced lows in 2014, 2015 and 2019. This circumstance excludes the use of this herbicide in the South of the Ural region, despite its periodically high economic efficiency.

Table 4. Yield of dry maize mass (t/ha) under the influence of herbicides of various types of action, on average for 2014-2016, 2018-2019

Variant	Year of research					On average
	2014	2015	2016	2018	2019	
Forest-steppe zone						
Control	1.1	2.0	1.8	5.2	2.3	2.5
Merlin before sprouting	3.6	6.6	12.0	12.5	2.8	7.1
Meister by sprouting	6.5	11.4	9.3	13.2	7.5	9.6
Meister Power by sprouting	7.1	14.1	10.9	15.3	9.1	11.3
LSD ₀₅	0.8	2.3	1.2	1.5	0.6	0.4
Forest-meadow zone						
Control	3.9	2.0	5.6	6.4	5.1	4.6
Merlin before sprouting	12.2	10.9	12.1	8.9	6.2	10.1
Meister by sprouting	11.8	8.5	10.8	7.7	5.5	8.5
Meister Power by sprouting	10.6	12.0	16.8	8.3	7.0	11.0
LSD ₀₅	1.8	1.3	2.0	1.4	1.1	0.5

A significant factor influencing the choice of herbicide is the costs associated with its purchase. In the prices of 2020, the cost of a hectare norm of the Meister Power preparation is 5.9 thousand rubles, which ensures its high payback only against the background of intensive technologies, including the cultivation of highly productive hybrids and the introduction of optimal doses of mineral fertilizers. In moderate agricultural zones, the high costs of using a herbicide are often not justified [7]. In these situations, in the Southern part of the Ural region, it is advisable to use post-emergence herbicides, while in the Northern regions with stable moisture – soil, the cost of which, on the example of the Meister and Merlin preparations is 3.4 and 3.1 thousand rubles, respectively.

4 Conclusions

As a result of expeditionary-route studies, the impoverishment of the taxonomic composition of the segetal flora in maize crops was established when moving from the North-West to the South-East of the Ural region: with respect to botanical families - from 18 in the forest-meadow and mountain-forest zones to 10 in the steppe zone. The greatest diversity of species composition (37 species) was also found for the most humid North-Western part of the surveyed territory, while their number decreased to 10 in the arid steppe.

Typical infestation of maize in the Urals is formed by species belonging to three economic and biological groups: perennial and annual dicotyledons, as well as annual monocotyledons. Zonal features of the group composition associated with the hydrothermal gradient consist in the mutual substitution of annual monocotyledonous and dicotyledonous species with a stable contribution of perennial dicotyledons. In addition, climate aridization is accompanied by the replacement of mesophytic annual weeds with xerophytic species of the same families. As a result, despite the dependence of the taxonomic composition of weeds on hydrothermal factors, the entire territory of maize cultivation in the Ural region preserves the economic and biological diversity of weeds, which implies the use of effective methods of their control in technologies.

A comparison of cross-spectrum herbicides effectiveness in the forest-steppe and forest-meadow zones of the Southern and Middle Urals showed the advantages of a post-emergent preparation with soil effect of Meister Power, the use of which is justified against the background of intensive maize cultivation technologies, characterized by a high return on the cost of chemicalization. In temperate soil fertility in the Southern area of the region, it is economically feasible to use post-emergent herbicides without soil effect, in Northern areas with stable moisture – soil ones, introduced after crop sowing (before germination).

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