Ukrainian Journal of Ecology

Ukrainian Journal of Ecology 2020, 10(2), 112-117, doi: 10.15421/2020_72

RESEARCH ARTICLE *UDC 633.14 «324»:632.51 (477.41/.42)*

Species Composition and Noxiousness of Segetal Vegetation in Winter Rye Agrocoenoses in the Central Ukrainian Polissia

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Received: 10.04.2020. Accepted: 10.05.2020

Competing with cultivated plants for the main life factors, weeds absorb a significant amount of nutrients and moisture from the soil, shade out crops and hinder their vegetation. In addition, they differ from cultivated plants; they have a lower level of requirements for growth factors; they are characterized by the strong development of root systems, which determines their higher competitive ability in the struggle for living conditions. Therefore, crop protection against weediness plays a leading role in the system of measures aimed at obtaining high yields of winter rye. The purpose of our study was to look into the species composition and noxiousness of the weed component of winter rye agrocoenoses in the Ukrainian Polissia. Field studies were conducted during 2016–2019 with an organic crop rotation (vetch and oat mix – winter rye – field beans – white mustard – winter spelt – buckwheat) at the experimental field of Polissia National University. The results of the studies showed that 13 weed species were found in the winter rye agrocoenoses. Annual weeds are represented by various biological groups: ephemera, early spring, late spring, overwintering. Perennial weeds are represented by three species: milk gowan, field bindweed, and field milk thistle. *Centaurea cyanus* (All.) Dost., *Stellaria media* (L.) Vill., *Sonchus arvensis* L., and *Convolvulus arvensis* L. dominated in the winter rye agrocoenosis; their share of the total weeds was 19.5, 18.0, 11, 3, 9.8% respectively. Other weed species were small in number, ranging from 0.1 to 0.9 pc/m^2. According to the results of correlation-regression analysis, a close inverse relationship between the grain yield indices and the number of weeds in winter rye crops was established. Thus, with increasing crop weediness, there is a direct correlation between the decrease in yield (r=-0.74). If weeds, especially perennial, exceed the economic threshold of noxiousness, the grain yield is reduced at a rate of 3.5 kg/ha for one species. Thus, 18,2% of the grain yield fluctuations are caused by changes in the level of crop weediness. Prospects for further research will be aimed at the improvement and substantiation of ecologically safe systems of protection of winter rye against spreading of segetal vegetation in crops.

Keywords: Winter rye; Species composition of weeds; Weediness; Agrocoenosis; Noxiousness

Introduction

Winter rye is one of the valuable food and forage crops. The grain is used to produce baker's flour; it is also used as a fodder for farm animals, as well as for the production of alcohol, starch and malt (Hospodarenko & Ptashnyk, 2015). Products obtained from the grain contain the necessary nutrients for the human body: carbohydrates, proteins, fats and minerals. Baked bread contains vitamins B1, B2, PP, E; with them a human receives from 30 to 50% of all energy required for life, up to 40% of protein demand, up to 60% of B vitamins, up to 80% of vitamin E (Zuza, 2002).

However, the presence of segetal vegetation in agrophytocoenoses of winter rye is a limiting factor that reduces the crop yield and quality of its grain. The high level of weediness in the fields is formed due to human economic activity, biological properties of the weeds and of the crop, in particular. Weeds are competitors of cultivated plants for moisture and nutrients. In addition, they are intermediate or major hosts of many pathogens and crop pests. They are especially dangerous at the early stages of vegetation.

Foreign and domestic scientists are studying the problem of dispersal of segetal vegetation in winter rye agrocoenoses. Scientific achievements of M. R. Ryan, S. B. Mirskyi, D. A. Mortensen, O. I. Savchuk, V. V. Gurel, N. A. Koshytska, G. M. Kochyk and others played an important role in the study of this issue (Kochyk, 2012; Matthew et al., 2011; Savchuk et al., 2005). However, the question of the species composition of the weed component and its harmfulness in winter rye agrocoenoses has not been sufficiently investigated and needs an in-depth study.

Currently, approximately 30,000 weed species have been studied, more than 1.8 thousand of which cause serious economic losses each year. Most crops are forced to compete with 200 weed species (Siddiqui et al., 2010). Losses caused by weeds can reach between 10 and 70% of the crop (Zakharenko & Zakharenko, 2004; Ivashchenko, 2001). Therefore, protection against them is a technological and economic necessity when cultivating winter rye.

In view of this, there is a need for a mandatory phytocenotic analysis of weed groups, determination of their species composition and noxiousness. For this reason, the purpose of our research was to study the species composition and noxiousness of segetal vegetation in agrocoenoses of winter rye of the Central Ukrainian Polissia.

Materials and Methods

Field studies were conducted during 2016–2019 with an organic crop rotation (vetch and oat mix – winter rye – field beans – white mustard – winter spelt – buckwheat) at the experimental field of Polissia National University (Cherniakhiv raion, Zhytomyr region).
The experimental areas have grey forest light loamy soil. Field beans were the preceding crop of winter rye. Organic technology for growing winter rye included treating seeds with a mixture of biological preparation Agat-25K, PA (with a consumption rate 0.04 kg/t) and plant growth regulator Ekostim-1, PK (0.05 l/t). At the 21st stage of development (tillering phase), there was foliar fertilizing with the preparation Ekostim-1, PK (0.05 l/ha); and at the 30th stage (stem-extention stage), the crops were sprayed with biological preparation Agat-25K, PA (0.03 kg/ha) to reduce the development of fungal diseases and increase crop productivity. In order to protect against weeds and to destroy a soil crust, winter rye sowing was harrowed twice.
The weather conditions in the period 2016–2019 were susceptible to growing winter rye and were characterized by uneven temperature and rainfall during growth, which contributed to obtaining reliable data. In terms of hydrothermal conditions, 2017 was characterized by high air temperature and no precipitation. 2018 was unstable: Hot and cold days, rainy periods and drought took turns; 2019 was unstable and warm. The ocular estimate method and the quantitative methods were used to determine the actual weediness of winter rye crops.
The ocular estimate method was used to determine the dominant weed species. The degree of weediness was determined using the scale of O. I. Maltceva (Maltceva, 1936) (Table 1).

Table 1. Scale of ocular estimate of weediness.

How much the soil is covered with weeds, point	Degree of soil coverage, %	Number of weeds, pcs/m^2	Crop dominance
1	<1	<3	Complete
2	<5	3–5	High
3	5–20	6–15	Moderate
4	21–50	16–30	Average
5	51–70	31–75	Week
6	71–100	<5	Absent, complete weediness

The quantitative method was used to determine the number of weeds at the investigated sites (50 × 50 cm). The accounting frame was used, where one of the lines of the crop was diagonal (Zuza, 2006). Then, the number of weeds at the site was counted, the number of cultivated plants was determined, which was taken as 100%. The weediness point was determined using the scale shown in Table 2.

Table 2. Scale to determine the degree of weediness of winter rye crops.

Weediness points	degree	Weeds, psc/m^2
1	Weak	<2
2–3	Noticeable	2–5
4–5	Average	6–8
6–7	High	9–11
8–9	Very high	>11

The statistical processing of the experimental data obtained was performed by the analysis of variance method using the computer programs Microsoft Excel and Statistica 10. (Dospekhov, 1985).

Results and Discussion

An important indicator of the coenotic role and competitiveness of weed plants in agrophytocoenoses is the level of their noxiousness. Cultivated and weed plants that form agrophytocoenoses need the same life factors, which are usually limited in a competitive biotope. Because the relationships between these components of the community are manifested in the form of competition for light, moisture, minerals, etc. By creating more favorable conditions for the growth of cultivated plants and by increasing their competitiveness, we contribute to the suppression of weeds and increase in the productivity of crops and, conversely, under favorable conditions, the growth of weeds inevitably reduces the crop yield (Zakharenko & Kiraev, 2000; Bazdyrev & Safonov, 1990). The noxiousness of the weed component of agrophytocoenoses may vary depending on how long they co-grow with cultivated plants (Wilde et al., 2018; Ladenov et al., 2004), and also on the abundance and species composition of weeds (Smith & Kallenbach, 2006), biological features of their growth and development (Matthew R. Ryan, 2011), soil and climatic conditions and other factors (Wilde et al., 2018).
It has been established that the seeds of annual weeds sprout from the soil layer up to 5 cm. The number of similar seeds in different species and fields varies from 100–200 to 10–12 thousand/m^2 (Jabran, 2017).
From 10 to 15 weed species can grow on a separate field, and up to 40 weed species can be found in each farm. Their adverse effect on crops is observed from the first days of vegetation and increases proportionally to the number and species composition.
In order to successfully implement a weed control system in specific crops, it is important to have sufficient information on their species composition. For this reason, monitoring of weed dispersal is one of the means of controlling the weediness of crops.
Currently, according to the concept of integrated plant protection, as noted by academician V. A. Zakharenko (2000), scientists have proposed different criteria for determining threshold levels of weediness (Zakharenko & Zakharenko, 2004). The following threshold levels are offered: biological threshold of weed noxiousness – the number of weeds, which causes risk of crop loss, is by 25% above the confidence level of its identification in the experimental conditions. Weeding will be used in the most rational way if the economic threshold of harmfulness (ETH) is taken into account when weeding (Jordan, 1993). ETH refers to the density of a pest population or the degree of weediness of crops, which may cause significant economic damage to the crop. In our country, a 3%

loss of high-yielding crops and 5% loss of low-yielding crops is considered to be a tangible economic loss (Kononov & Takunov 1997). The economic threshold of weed harmfulness is the amount at which weeds cause crop losses, in value terms, they equal to the cost of taking protective measures (Shabolkyna et al., 2018; Tanskii, 1982).

The negative effect of weeds on the growth and development of winter rye is due to many reasons. They shade out the crop, lower the temperature of the soil, consume large amount of water and nutrients, and create sites of pests and diseases (Kuzminykh & Pashkova, 2016). Winter rye is particularly significantly damaged in the dry years, when moisture is low, because water is used to create weed biomass; accordingly, this determines the amount of the yield.

Various types of weeds have a different effect on the crop. Their impact is determined by the noxiousness that leads to a decrease in yield and deterioration of grain quality.

Change in the species composition of weeds depends on the technology of cultivation: tillage method, agricultural crop rotation, the use of fertilizers, application of plant protection agents, etc.

As a result of the study, 13 weed species of different biological groups and classes were identified in winter rye agrocoenoses (Figure 1).

Species	**Scientific name**	**Family**	**Biological group**
A N N U A L			
Chickweed	*Stellaria media* (L.) Vill.	Caryophyllaceae	Ephemera
Black bindweed	*Fallopia convolvulus L.*	Polygonaceae	Early spring
Field mustard	*Sinapis ararvensis* L.	Brassicaceae	
Common fumitory	*Fumaria officinalis* L	Fumariaceae	
Lamb's quarters	*Chenopodium album* L.	Chenopodiaceae	Late spring
Green foxtail	*Setaria glauca* L.	Poaceae (Gramineae)	
Redroot pigweed	*Amaranthus retroflexus* L.	Amaranthaceae	
Cornflower	*Centaurea cyanus* (All.) Dost.	Asteraceae	Wintering
Shepherd's purse	*Capsella bursa-pastoris* L.	Cruciferae	
Field poppy	*Papaver rhoeas* L.	Papaveraceae	
Scentless mayweed	*Tripleurospermum maritimum* L.	Asteraceae	
P E R E N N I A L			
Common dandelion	*Taraxacum officinale* Wigg.	Asteraceae	Taproot
Field bindweed	*Convolvulus arvensis* L.	Convolvulaceae	Sucker
Field milk thistle	*Sonchus arvensis* L.	Asteraceae	

Figure 1. Species composition of weeds in winter rye agrocoenoses in the Central Ukrainian Polissia.

Annual weeds are represented by different biological groups: ephemera, early spring, late spring, wintering. Ephemera are represented by only one species, *Stellaria media* (L.) Vill. Early spring weeds are not numerous: *Fallopia convolvulus* L., *Sinapis ararvensis* L. and *Fumaria officinalis* L.

A special feature of the way, in which *Sinapis ararvensis* L. spreads, is that the seeds have the ability to germinate in the autumn, although the majority of seedlings appear in the spring. The seeds do not lose their germination ability even when they are not ripe. Seedlings are resistant to frost (up to -3.8°C).
The most harmful late spring weeds are *Chenopodium album* L., *Setaria glauca* L., *Amaranthus retroflexus* L.
It should be noted that some scientists classify *Chenopodium album* L. as an early spring weed, because the duration of the seedling stage varies greatly (from March to October). Flowering begins in July and lasts until September, and the plant bears fruit from August to October. The breeding power reaches up to 1,000,000 galls. Ripe seeds in arid years are more similar than with sufficient moisture. However, the immature ones do not germinate at all. Seeds in soil retain viability up to 38 years.
The following wintering weeds dominate in winter rye crops: *Centaurea cyanus* (All.) Dost., *Capsella bursa-pastoris* L., *Papaver rhoeas* L., *Tripleurospermum maritimum* L.
Capsella bursa-pastoris L. is the most harmful species because it blooms from spring to autumn, develops 2–3 generations, has spring and winter forms. Its breeding power reaches 274 thousand seeds. It keeps viability up to 35 years.
Perennial weeds are represented by three species: *Taraxacum officinale* Wigg., *Convolvulus arvensis* L., *Sonchus arvensis* L.
A special feature of the way, in which *Convolvulus arvensis* L. spreads, is that the plant climbs very quickly and becomes visible only after the flowers appear. The maximum breeding power is 9800 seeds, and their viability is up to 50 years.
Species composition of weed populations in winter rye agrocoenoses in the Central Ukrainian Polissia is represented by *Centaurea cyanus* (All.) Dost.), *Tripleurospermum maritimum* L., *Convolvulus arvensis* L., *Chenopodium album* L., *Stellaria media* (L.) Vill., *Sonchus arvensis* L., *Papaver rhoeas* L., *Sinapis ararvensis* L. (Figure 2).

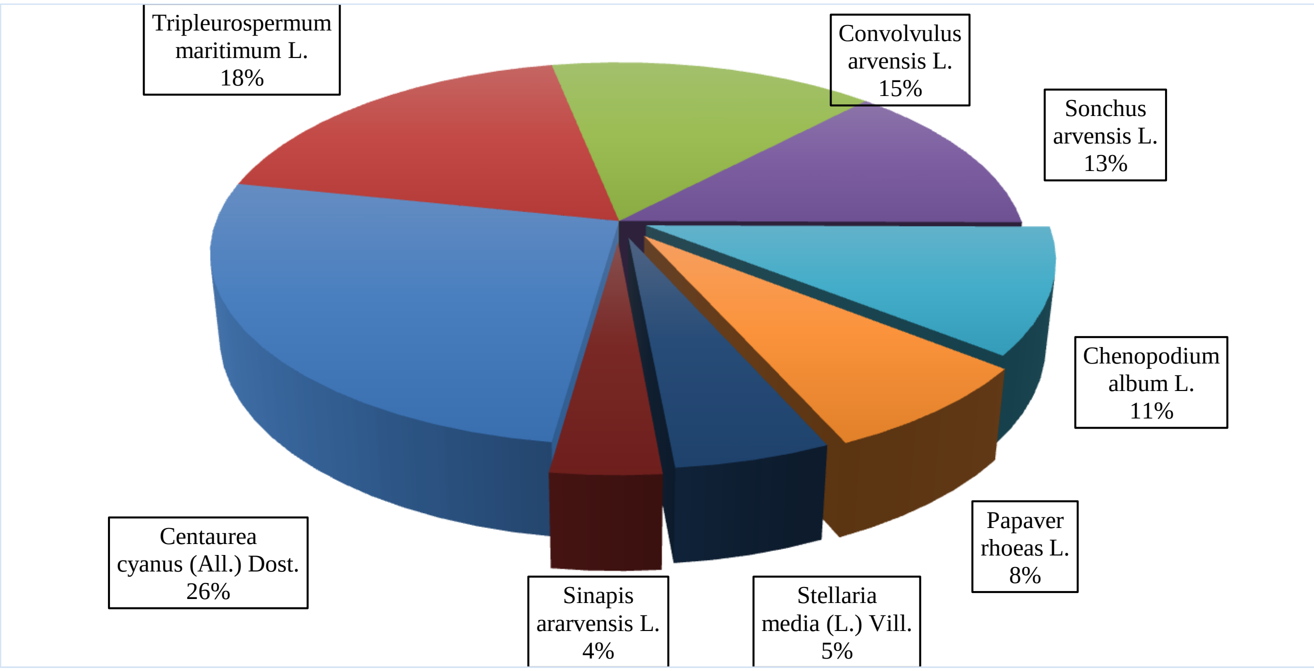

Figure 2. Species composition of weed populations in winter rye agrocoenoses in the Central Ukrainian Polissia, 2016–2019.

Species *Centaurea cyanus* (All.) Dost. (26%), *Tripleurospermum maritimum* L. (18%), *Convolvulus arvensis* L. (15%) and *Sonchus arvensis* L. (13%) were numerous in winter rye agrocoenoses. However, these weeds sprout covered by well-developed winter rye in the spring, so they are unable to form a significant competitive mass.
The percentage of other weeds ranged from 4 to 11%. *Stellaria media* (L.) Vill. and *Sinapis ararvensis* L. accounted for the smallest share, 5% and 4%, respectively.
An important reserve to increase the yield of winter rye is to protect crops from weeds. When there are not enough protection measures against weeds, grain producers lose 10–35% of the yield, and in very weedy areas these losses increase by 1.5–2 times. The decrease in grain yield and deterioration of its quality is due to competition between weeds and cultivated plants for water, light, nutrients.
According to the results of the experiment, the density of the weeds in the experimental plots was 13.3 pcs/m^2. The presented number is 1 point by the degree of weediness (Table 3).
Centaurea cyanus (All.) Dost., Stellaria media (L.) Vill., Sonchus arvensis L. and Convolvulus arvensis L. dominated in winter rye agrocoenosis; their share of the total number of weeds was 19.5, 18.0, 11.3 9.8%, respectively.
Other weed species were small in number, ranging from 0.1 to 0.9 pcs/m^2.
It should be noted that the degree of winter rye weediness was significantly influenced by the weather conditions of the vegetative period of the field crop and, above all, the content of productive moisture.
However, under unstable moisture conditions in 2016–2020, all weed species (both annual and perennial) grew and developed with moderate intensity. At the same time, they were in the lower layer and were well suppressed by winter rye plants and, as a consequence, did not pose a great risk to the crop yield. According to the results of correlation-regression analysis, a close inverse relationship between the grain yield indices and the number of weeds in winter rye crops was established (Table 4).
Thus, if crop weediness increases, there is a direct correlation between the decrease in yield (r= -0.74).
When the number of weeds exceeds the economic threshold of harmfulness, grain yield decreases at a rate of 3.5 kg/ha per one weed species, as shown by the regression coefficient. The percentage (%) of the change in the yield of winter rye grain depending on the weediness of crops is determined by the determination coefficient (Dxy). Therefore, 18.2% of the fluctuation in grain yield is caused by changes in the level of crop weediness.

Table 3. Weediness of winter rye crops before gathering, 2016–2019.

Species	Number, psc/m^2	Weediness point
Amaranthus retroflexus L.	0.4	1
Capsella bursa-pastoris L.	0.2	1
Centaurea cyanus (All.) Dost.	2.6	2
Chenopodium album L.	0.9	1
Convolvulus arvensis L.	1.3	1
Fallopia convolvulus L.	0.7	1
Fumaria officinalis L.	0.3	1
Papaver rhoeas L.	0.8	1
Setaria glauca L.	0.2	1
Sinapis ararvensis L.	0.8	1
Sonchus arvensis L.	1.5	1
Stellaria media (L.) Vill.	2.4	2
Taraxacum officinale Wigg.	0.3	1
Tripleurospermum maritimum L.	0.9	1
Total	13.3	
HIP05	1.23	

Table 4. Influence of weediness on the yield of winter rye grain.

	r	Rxy	Dxy
Winter rye	-0.74	0.035	18.2

R – Correlation coefficient; Rxy – Regression coefficient; Dxy – Determination coefficient.

Conclusion

Climate change causes substantial disorder of the self-regulation processes in winter rye agrocoenoses. As a result, the degree of weediness increases, and the ecological equilibrium is upset, which results in significant losses of crop yields.
The ecological and geographical approach was used to determine the species composition of weeds in winter rye crops, taking into account the area of their dispersal. *Centaurea cyanus* (All.) Dost., *Stellaria media* (L.) Vill., *Sonchus arvensis* L., and *Convolvulus arvensis* L. dominated in winter rye agrocoenosis; their share of the total weeds was 19.5%, 18.0%, 11.3%, 9.8%, respectively.
It has been established that when the number of weeds, especially perennial ones, exceeds the economic threshold of harmfulness, grain yield decreases at a rate of 3.5 kg/ha per one weed species. Therefore, 18.2% of the fluctuation in grain yield is caused by changes in the level of crop weediness.
The main prerequisite for improving the productivity and quality of winter rye grain products, as well as reducing the level of biological contamination of agroecosystems by harmful organisms, is the development and improvement of environmentally safe systems of protection, which are based on the rational combination of organizational, economic, agrotechnical, immunological, biological and other methods taking into account ETH and growing technology.
Prospects for further research will be directed towards the improvement and substantiation of environmentally safe systems of protection of winter rye against dispersal of segetal vegetation in the crops.

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Citation:
Kliuchevych, M.M., Stoliar, S.H., Hrytsenko, O.Yu., Retman, S.V., Tkalenko, H.M., Bilotserkivska, L.V. (2020). Species Composition and Noxiousness of Segetal Vegetation in Winter Rye Agrocoenoses in the Central Ukrainian Polissia. *Ukrainian Journal of Ecology, 10* (2), 112-117.