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Dnipro State Agrarian and
 Economic University,
 25, Voroshylova st., 49027,
 Dnipro, Ukraine.
 Tel.: +38-050-454-97-33.
 E-mail:
 kolesnykova.kate@gmail.com

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Effectiveness of herbicides and plant growth regulators in corn crops

Y. Tkalich, K. Kolesnykova, M. Nazarenko

Dnipro State Agrarian and Economic University, Dnipro, Ukraine

Abstract. The objective of this study was determining the effectiveness of weed control and increasing the productivity of the DN Galatea corn hybrid when using modern herbicides, plant growth regulators and adjuvants. Indicators of the technical efficiency of herbicides differed according to the variants of the experiment, which generally characterizes the phytotoxic properties of the agents as a different indicator. At the initial stage of the development of the corn agrocoenosis, the highest efficiency was provided by: Task Extra(880g/ha) + Synergen SOC(0.25%) – 92%; Titus Extra(50 g/ha) + Synergen SOC(0.15%) – 39%; Titus Extra(100 g/ha) + Synergen SOC (0.25%) – 94%; Titus Extra(50 g/ha) + Prima(0.4 L/ha) + Synergen SOC(0.15%) – 94%. As can be seen from the figures, the corn crops in those variants were free of weeds during the phases of panicle shedding. Effective control of the invasion of weeds in corn, but with lower technical efficiency options, was demonstrated by Task Extra (440g/ha) + Trend 90 (0.1%) – 85%; Task Extra (440g/ha) + Synergen SOC (0.15%) – 89%; Titus Extra (50 g/ha) + Trend 90 (0.2%) – 86%; Titus Extra (100 g/ha) + Trend 90 (0.2%) – 88%. The application of the Master Power (1.5 L/ha) – 70% also caused a less significant effect; this was not the first year we observed this. Based on the results of the research in our laboratory, we can conclude that the Master Power is significantly inferior to the herbicide Master (150 g/ha) + Biopower (1.25 L/ha), which was more effective. The highest above-ground biomass of weeds in the air-dry state was traditionally recorded in the control version without the introduction of the agents – 109.7 g/m². The characteristics of the weed flora on the research plots are also given, as well as the evaluation of the elements of the structure of the corn hybrid crop with the use of the specified agents.

Keywords: herbicides; growth regulators; corn; *Zea mays*; invasive plants; weeds.

Introduction

The structure of the agroecosystem includes all the elements in the ecosystem and how they are functionally related to each other: that is, all types of crops, livestock, weeds, pests, soil animals, as well as all other plants, animals or microorganisms that are present. Agroecosystem structure is the result of individual crops and other components (weeds, pests, soil animals, microorganisms, etc.) in the agroecosystem, how these components are structured by farm management practices, and how these components are functionally related to each other (Marten, 1988). Studies of the impact of agriculture on the components of ecosystems are conducted all over the world, including the impact of weeds on crops, on soil properties, water in the soil, the possibilities of control and the effectiveness of preparations, etc. (Essman et al., 2021; Schramski et al., 2021; Zavalova et al., 2021; Bhattacharya et al., 2022; Dai et al., 2022; Guerra et al., 2022).

Weeds are considered as plants that coexist with cultivated plants, forming a single phytosystem in agrophytocoenosis (Fysyunov, 1984; Morderer et al., 2018). From the point of view of phytocoenology, weeds are natural components of agrophytocoenoses (Tuganaev, 1984). According to the ecological strategy of growth and development, commonest weeds are ruderal plants. The ecological purpose of this type of plants is to ensure the integrity of the plant cover due to the formation of phytocoenoses of the first stages of recovery after their destruction or disturbance by various natural factors (Rabotnov, 1983; Mirkin et al., 1989; Mosyakin, 2007; Morderer et al., 2018).

In the flora of higher plants, the share of weedy plants in different countries and regions ranges 6–19%. For Ukraine, this indicator is about 15% (Zuza, 2022).

Most common species of weeds are those that - according to the ecological coenotic strategy of growth and development - belong to ruderal plants. The ecological purpose of this type of plants is to ensure the integrity of the plant cover due to the phytocoenoses formation of

the first stages of recovery after destruction or disturbance by various natural factors (Rabotnov, 1983; Mirkin et al., 1989; Mosyakin, 2007; Morderer et al., 2018).

Weed plants can be very beneficial, even despite the significant damage they cause to agriculture, which can reach about 10% per year worldwide (Oerke, 2006). They play a significant role in stabilizing the soil, preserving its moisture and preventing erosion, help reduce nitrogen leaching, especially on lightly eroded soils (Importance, 2015). Weeds are a source of nectar and pollen for bees, and can be shelter and food for natural enemies of crop pests. Some types of weeds are a source of vegetable protein and are used as medicinal raw materials (Medicinal ..., 1992; Nizhko, 1997) and can also be used for soil phytoremediation (Guralchuk & Gudkov, 2005; Morderer et al., 2018).

While from the phytocoenotic perspective, the existence of weeds is completely natural, from the economic perspective, weed is a purely negative phenomenon, since they compete with cultivated plants for water, nutrients and living space, contribute to the spread of pests and diseases, complicate soil cultivation, crop care and harvesting (Morderer et al., 2018).

The objective of the study was determining the effectiveness of weed control in order to increase the productivity of the DN Galatea corn hybrid when using modern herbicides, plant growth regulators and adjuvants.

Materials and methods

Our research was conducted under commercial contracts with the Dolyna-Center LLC. Every year the research scheme was changed at the request of the customer, so the data are presented for individual years (2016, 2017).

Scheme of the experiment (2016):

1. Control. Task Extra (440 g/ha) + Par Trend (0.2 L/ha) (3–6 true leaves).

2. Task Extra(440 g/ha) + Par Trend (0.2 L/ha) + Vympel(500 g/ha) (7–8 true leaves).

3. Task Extra (440 g/ha) + Par Trend (0.2 L/ha) + Vympel-30 (1000 g/ha) (7–8 true leaves).

4. Control. Titus Extra(50 g/ha) + Par Trend (0.2 L/ha) (weed phase of 1–3 leaves).

5. Titus Extra (50 g/ha) + Par Trend (0.2 L/ha) + Vympel (500 g/ha) (weed phase of 1–3 leaves).

The duration of the corn growing season was 124 days. The seedlings grew in 12 days after the sowing. The phase of 9–11 leaves was noted on June 6, panicle shedding on July 1. The milk ripeness of the grain was recorded on July 13, the waxy state occurred on July 28, and its full ripeness was noted on August 25.

Scheme of the experiment (2017):

1. Task Extra (440 g/ha) + Trend 90 (0.1%) (6 leaves).

2. Task Extra (440 g/ha) + Synergen SOC (0.15%) (6 leaves).

3. Task Extra (880 g/ha) + Synergen SOC (0.25%) (6 leaves).

4. Task Extra (880 g/ha) + Trend 90 (0.2%) (6 leaves).

5. Titus Extra (50 g/ha) + Synergen SOC (0.15%) (6 leaves).

6. Titus Extra (50 g/ha) + Trend 90 (0.2%) (6 leaves).

7. Titus Extra (100 g/ha) + Trend 90 (0.2%) (6 leaves).

8. Titus Extra (100 g/ha) + Synergen SOC (0.15%) (6 leaves).

9. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%) (6 leaves).

10. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Trend 90 (0.2%) (6 leaves).

11. Master Power (1.5 g/ha) (6 leaves).

12. Control (without processing).

Corn was sown on April 27, 2017. The seedlings grew in 14 days after the sowing. The herbicides were applied on May 27. The phase of 10–11 leaves was noted on June 11, and panicles were released on July 4. The milk ripeness of grain was recorded on July 23, the waxy state was seen on August 9, and its full ripeness was observed on August 25. The duration of the corn growing season lasted for 123 days.

When applying the herbicides Task Extra and Titus Extra in the recommended doses, almost no damage to corn plants was observed. As with increase in the amount of the agents per 1 ha in 2 variants, the greatest inhibition of weeds was recorded in variant 4 – 16.1%.

It should be noted that compared with the use of the Trend agent, the number of damaged plants was 1.5–2.0% less in the variants where the Synergen adjuvant was used at the double rate. Damage to the corn was in the form of curling of the leaves, tilting of the stems; those plants were in an inhibited condition during the growing season, did not form a cob and were 70–100 cm tall.

When analyzing the plant community, its species composition was taken into account. The names of plant species and their systematic position are given according to Tarasov (2012). The ecological analysis of the weed flora was carried out according to the climate classification (Raunkier, 1937; Tarasov, 2012) and the ecological characteristics of species according to Belegard (1971). Climamorphs are also called life forms of plants according to Raunkier (1937) (Andrusevych & Zadorzhnaya, 2019).

Certain types of weeds inhabit certain areas with specific ecological conditions, depending on biological features or the way people use them. Therefore, weeds are divided into:

1) segetal (from the Latin *segetalis* – which grows among grains), or field species, which are common in agricultural crops;

2) ruderal (from the Latin *runderis* – garbage) – species that grow on developed, but not cultivated lands (on garbage dumps, near roads, housing, on the territory of industrial enterprises, etc.);

3) meadow weeds – undesirable species that are common on natural forage grounds, mainly near rivers, water bodies, where places are partially overmoistened;

4) pasture weeds – undesirable species, growing near streams, where they are used for cattle grazing (Zuz, 2022).

Results and discussion

Agrophytocoenosis is a plant grouping in which the active cultivation of plants, as the main goal of agriculture, is accompanied by spontaneous, constant compression, the invasion of wild flora species, mainly synanthropic, which have evolved over thousands of years

against the background of human cultivation of plants and are considered weeds. Agrophytocoenosis comprises cultivated plants with varying participation of weeds, or almost without them, which is formed on a certain more or less homogeneous area of cultivated (permanently, periodically or one-time) lands with characteristic relief, soil differences, hydrological conditions, exposure of slope to sunlight, etc. (Structure and development..., 2017).

As a result of the research, we determined that the taxonomic diversity of weed flora in corn crops was 11 species belonging to 8 families (Table 1). As a set of habitual traits that have developed in the course of adaptive evolution, the life forms of plants reflect complex relationships between plant species and environmental conditions (Semenova-Tian-Shanska, 1954). As a result of our research, we determined the following distribution of the species composition by life forms: the share of perennials was 9.1%, annuals – 90.9%.

In the formed stable plant communities, young plants are practically absent. Since the vegetation cover of agricultural land mainly exists for 6 to 10 months, each subsequent “creation” of phytocoenosis can be characterized as the initial stage of phytocoenosis development. According to (Felbaba-Klushina & Komendar, 2001), the initial stage of phytocoenosis development, which in turn is characterized by a set of random plant species, includes a significant share of annuals and rhizome perennials.

Climamorphs are life forms of plants that reflect the relationship between plants and climate. Such spectra are used in the analysis of life forms in different groups of the same climatic zone. We determined that the average share of participation of therophytes (plants that overwinter in the form of seeds or brood buds) was 81.8%, the share of geophytes (plants in which the wintering points of recovery are underground) was 9.1%, and the species of the Canadian slinky (*Coniza canadensis*) (according to Tarasov) appeared both as therophytes and hemicryptophytes (plants the regeneration buds of which are at soil level or in the litter).

A study focused on the representation of trophomorphs (according to Belgard (1971)) according to their ecological optimum in terms of soil trophicity (fertility), revealing that the structure of trophomorphs included mesotrophs (63.6%), oligomegatrophs (27.3%), and megatrophs (9.1%).

The composition of hygromorphs of research plot in the reclamation area contained mesoxerophytes (36.4%), xeromesophytes (36.4%), mesohygrophytes (18.2%), and mesophytes (9.1%).

Heliomorphs were represented by heliophytes and sciopheliophytes. The dominant position belonged to the sciogeliophytes (54.6%). The subordinate position was taken by heliophytes (45.5%).

Coenomorphs are forms of plants that are confined to one or another coenosis. They are functional entities with a consortial structure (Zhukov et al., 2010). Many species of ruderal plants are inhabitants of anthropogenic plant communities and reflect a significant disturbance of the vegetation cover. The taxonomic diversity of plants is represented by one coenomorph, i.e. ruderal plants.

Spring weeds include annual plants that germinate en masse in spring or early summer and complete their development cycle in one growing season. This biological group is divided into early and late spring weeds. The first begins to germinate at low positive temperatures (1–3 °C), and the other when the soil warms above 10–12 °C (Zuz, 2022).

The recorded species of weedy plants include 10 species (90.9%) are (4 species – early spring, 3 species – late spring, 3 species – winter), and 1 species (9.1%) is (rhizome).

At the beginning of the growing season of 2016, there were sufficiently favorable conditions for phytotoxic activity herbicides. The distribution of temperatures during the emergence of corn and weeds caused a sufficiently favorable situation regarding the synchronicity of the activation of their growth and the action of herbicides. The main number of weeds began to sprout starting from the corn's phase of 3–4 leaves. Against the background of a moderate thermal regime, the difference between the periods of emergence of weed seedlings of different biological properties became distinct.

At first, above-ground invasion with ragweed appeared, and over the interval of 9–10 days, the density of bent sedge and white quinoa increased. Dicotyledons turned out to be the main re-regulating elements, occupying 94.4% of the species structure, and monocotyledons accounted for 5.6%.

Table 1
Biological and ecological characteristics of recorded species of weed flora in corn crops

Class	Family	Species	Climamorphs	Trophomorphs	Hygromorphs	Heliomorphs	Coenomorphs
Magnoliopsida (Dicotyledones)	Asteraceae	<i>Ambrosia artemisifolia</i> L.	Th	Og-MgTr	MsKs	ScHe	Ru
		<i>Coniza canadensis</i> (L.) Cronq.	Th, H	Og-MgTr	MsKs	ScHe.	Ru
	Convolvulaceae	<i>Convolvulus arvensis</i> L.	G	MsTr	MsKs	ScHe	Ru
	Polygonaceae	<i>Persicaria hydropiper</i> L.	Th	MsTr	MsHg	ScHe	Ru
	Chenopodiaceae	<i>Chenopodium album</i> L. –	Th	MsTr	KsMs	ScHe	Ru
	Solanaceae	<i>Solanum nigrum</i> L.	Th	MsTr	Ms	He	Ru
		<i>Descurainia sophia</i> (L.) Webb. ex Prantl	Th	MsTr	KsMs	He	Ru
	Brassicaceae	<i>Thlaspi arvense</i> L.	Th	MsTr	KsMs	ScHe	Ru
Amaranthaceae	<i>Amaranthus retroflexus</i> L.	Th	MsTr	KsMs	He	Ru	
Monocotyledones	Poaceae	<i>Echinochloa crusgalli</i> (L.) P. Beauv	Th	Og-MgTr	MsHg	He	Ru
		<i>Setaria glauca</i> (L.) P. Beauv	Th	MgTr	MsKs	He	Ru

Notes: Raunkiaer's lifeforms: G – geophytes, H – hemicryptophytes, Th – therophytes; trophomorphs: OgTr – oligotrophs, MsTr – mesotrophs, MgTr – megatrophs; hygromorphs: Ks – xerophytes, MsKs – mesoxerophytes, KsMs – xeromesophytes, Ms – mesophytes, HgMs – hygromesophytes; heliomorphs: He – heliophytes, ScHe – scioheliophytes, HeSc – heliosciophytes; coenomorphs: Ru – weedyspecies.

Table 2
Agrobiological characteristics of recorded species of weed flora in corn crops

Latin Name	By life expectancy	Biological groups of weeds	Nature of distribution	Group	Main areas of spread	Quarantine
<i>Ambrosia artemisifolia</i> L.	yearling	early spring	adventive	segetal-ruderal	steppe and forest-steppe zones	+
<i>Chenopodium album</i> L.	yearling	early spring	native	segetal-ruderal	everywhere	–
<i>Descurainia sophia</i> (L.) Webb. ex Prantl	yearling	wintering	adventive	segetal-ruderal	everywhere	–
<i>Amaranthus retroflexus</i> L.	yearling	late spring	adventive	segetal	everywhere	–
<i>Echinochloa crusgalli</i> (L.) P. Beauv	yearling	late spring	adventive	segetal-ruderal	steppe and forest-steppe zones	–
<i>Solanum nigrum</i> L.	yearling	early spring	adventive	segetal-ruderal	steppe and forest-steppe zones	–
<i>Setaria glauca</i> (L.) P. Beauv	yearling	late spring	adventive	segetal-ruderal	everywhere	–
<i>Convolvulus arvensis</i> L.	perennial	rhizome	native	segetal-ruderal	everywhere	–
<i>Persicaria hydropiper</i> L.	yearling	early spring	native	segetal-ruderal	–	–
<i>Thlaspi arvense</i> L.	yearling	wintering	adventive	segetal-ruderal	everywhere	–
<i>Coniza canadensis</i> (L.) Cronq.	yearling	wintering	adventive	segetal-ruderal	everywhere	+

Weeds that spread most intensively and have extremely flexible mechanisms of adaptation in agrocenoses include ragweed. Ragweed emerges both spring and autumn. The share of weed was maintained at a high level, which significantly affected the structure of the phytocoenosis (Table 5). Before application of the Task Extra herbicide during the phase of 3–5 leaves of the corn, the weed invasion of crops was at the level of 51.8 ind/m², ragweed was in the cotyledon phase – 2 pairs of leaves, thistles were 8–10 cm high, simple flat 1–2 leaves. Twenty five days after the application of herbicide, we observed almost complete death of the weeds, the technical efficiency being at the level of 98.1%. Application of the same agent during the later stages of corn development (7–8 leaves) had a negative effect on cultivated plants. Therefore, after the simultaneous application of Tasks Extra + Vympel (500 g/ha), we observed suppression, and leaf curling, but only in 3.6% of plants; in the variant using Tasks Extra + Vympel 30 (1000 g/ha), this indicator changed to 2.3%. That is, Vympel, Vympel 30 agents acted not only as growth regulators, but also as anti-stress agents, which had a positive effect on the partial stress relief in corn. At the time of application of Task Extra + Vympel, ragweed was in the phase of 2–4 pairs of leaves, the thistles were 10–15 cm high, simple flat ordinary 3–4 leaves, therefore the herbicide did not fully control those weeds, the enzymes of which in those phases of development already give a certain resistance to the active substance of the drug. Therefore, the technical efficiency of variants 2 and 3 was 95.7% and 96.6%, respectively, but the weeds did not cause economic damage to the crop.

In the variant where the Titus Extra herbicide was applied during the phase of 1–3 leaves of the corn, the technical efficiency was at the level of 88.5–92.4%. This can be explained by the low phytotoxic effect of this agent on some weeds. Thus, the technical efficiency of the herbicide in relation to weeds was as follows: *Ambrosia artemisifolia* – 96%, *Solanum nigrum* – 28%, *Convolvulus arvensis* – 41%, *Persicaria hydropiper* – 49%, *Chenopodium album* – 15%, *Setaria glauca* and *Echinochloa crusgalli* – 100%. A similar pattern was observed in variant 5. The addition of the Vympel plant growth regulator improved the appearance of corn, which tolerated the herbicide load, was greener,

which later reflected in its productivity. Before harvesting the corn, the number of weeds increased in all the variants of the experiment, but their above-ground mass varied 18.4 to 46.4 g/m². This can be explained by heavy rainfall in June and high temperatures, promoting the germination of the second wave of weeds.

The research conducted in 2017 showed that there were sufficiently favorable conditions for the manifestation of the phytotoxic effect of herbicides and the development of weeds.

The results of monitoring the weed invasion revealed that at the first stage of corn ontogenesis (seedlings–phase 4–6 leaves), three biological groups and eleven species of weeds were found in crops, with subsequent occurrence according to Raunkier ($T=A/B*100\%$, where A is the number of accounting square in which this weed occurs, B is the total number of accounting squares (Table 5).

Young annual dicotyledons: *Ambrosia artemisifolia* (60%, i.e. with relatively frequent occurrence); *Persicaria hydropiper* (45%, quite often); *Chenopodium album* (48%, quite often); *Amaranthus retroflexus* (45%, quite often); young Poaceae: mainly *Setaria glauca* (27%, rare occurrence); perennial rhizomes: *Convolvulus arvensis* (16%, relatively rare).

Based on the conducted accounts of the invasion of corn, it can be stated that all the variants of the experiment exerted high phytotoxic effect on *Chenopodium album* (71–100%), *Amaranthus retroflexus* (85–99%), *Convolvulus arvensis* (95–100%), *Coniza canadensis* (100%), *Descurainia sophia* (100%), *Persicaria hydropiper* (85–100%).

The greatest inhibition of *Ambrosia artemisifolia* was produced by Task Extra (880 g/ha) + Synergen SOC (0.25%) – 94%, Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%) – 91%, Titus Extra (100 g/ha) + Synergen SOC (0.25%) – 86%, and the lowest effects were taken by Master Power (1.5 L/ha) – 13%, Task Extra (440g/ha) + Trend 90 (0.1%) – 72%. The increased resistance of ragweed to herbicides is explained by the presence of a fairly active SOD enzyme in its cells (superoxide dismutase, which catalyzes the dismutation reaction of superoxide anion into hydrogen peroxide and reduces

the effectiveness of the active substances of the herbicides. The technical efficiency of herbicides on black nightshade (13–80%) and yellow foxtail (38–75%) was low in almost all the variants of experiment. The adjuvant Synergen was 7–15% more efficient than Trend, as seen in almost all the variants. It is difficult to draw conclusions on this issue, because there is probably a difference in the structure of those agents.

At the initial stage of the development of the corn agroecosystem, the highest efficiency was provided by: Task Extra(880g/ha) + Synergen SOC(0.25%) – 92%; Titus Extra (50 g/ha) + Synergen SOC (0.15%) – 39%; Titus Extra (100 g/ha) + Synergen SOC (0.25%) – 94%; Titus Extra(50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%) – 94%. As can be seen from the figures, the corn crops in the phases of panicle shedding were free of weeds in those variants. Effective control of weed invasion in the corn, but with lower technical efficiency, was

produced by the variants: Task Extra (440g/ha) + Trend 90 (0.1%) – 85%; Task Extra (440g/ha) + Synergen SOC (0.15%) – 89%; Titus Extra (50 g/ha) + Trend 90 (0.2%) – 86%; Titus Extra (100 g/ha) + Trend 90 (0.2%) – 88%. Based on the results of laboratory research, we can conclude that Master Power is much less effective the herbicide Master (150g/ha) + Biopower (1.25L/ha). The highest above-ground biomass of weeds in the air-dry state was traditionally noted in the control variant without the introduction of preparations – 109.7 g/m² (Table 3).

Therefore, the multi-faceted evaluation of the phytocoenosis parameters of weeds in corn crops showed that with the existing arsenal of herbicides, there is an opportunity to increase the technical efficiency of the chemical method of weed control by selecting appropriate active substances of various preparations and adjuvants.

Table 3
Weed invasion of crops, survey results

Research variants	Number of weeds by biogroups, ind/m ²												Above-ground biomass of weeds in the air-dry state, g/m ²	Technical efficiency of herbicides, %
	before applying herbicides				25–30 days after spraying				before harvesting					
	annual		rhi-zomes	total	annual		rhi-zomes	total	annual		rhi-zomes	total		
	dicots	<i>Poa</i> species			dicots	<i>Poa</i> species			dicots	<i>Poa</i> species				
Control. Task Extra (440 g/ha) + Par Trend (0.2 L/ha) (3–6 real leaves)	45.5	3.5	2.8	51.8	1.0	0	0	1.0	15.0	0.0	1.0	16.0	18.4	98.1
Control. Titus Extra (50 g/ha) + Par Trend (0.2 L/ha) (weed phase 1–3 leaves)	63.7	5.7	2.0	71.4	4.6	0	0.8	5.4	26.2	2.8	0.0	28.2	33.6	92.4

Table 4
Technical effectiveness of herbicides against weeds 25 days after the application (%)

Research variants	The name of weeds										
	<i>Ambrosia artemisi- folia</i>	<i>Cheno- podium album</i>	<i>Descu- rainia sophia</i>	<i>Amaran- thus re- troflexus</i>	<i>Echi- nochloa crusgalli</i>	<i>Solanum nigrum</i>	<i>Setaria glauca</i>	<i>Convol- vulus arvensis</i>	<i>Persica- ria hydropi- per</i>	<i>Thlaspi arvense</i>	<i>Coniza cana- densis</i>
1. Task Extra (440g/ha) + Trend 90 (0.1%)	72	71	–	84	44	30	56	95	84	100	–
2. Task Extra (440g/ha) + Synergen SOC (0.15%)	79	92	–	93	–	13	67	100	84	–	–
3. Task Extra (880g/ha) + Synergen SOC (0.25%)	94	100	–	97	–	22	57	–	90	–	–
4. Task Extra (880 g/ha) + Trend 90 (0.2%)	75	97	–	92	100	75	38	–	85	–	100
5. Titus Extra (50 g/ha) + Synergen SOC (0.15%)	87	100	100	99	–	57	–	–	100	100	100
6. Titus Extra (50 g/ha) + Trend 90 (0.2%)	78	100	–	93	–	80	40	100	88	–	100
7. Titus Extra (100 g/ha) + Trend 90 (0.2%)	75	83	100	85	–	42	73	100	92	–	–
8. Titus Extra (100 g/ha) + Synergen SOC (0.25%)	86	100	–	99	100	56	75	–	100	–	–
9. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%)	91	96	–	96	–	54	–	100	93	–	–
10. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Trend 90 (0.2%)	83	86	100	85	100	–	73	100	100	–	100
11. Master Power (1.5 L/ha)	13	18	–	84	100	71	64	100	71	–	–

Indicators of the crop structure have a direct impact on the yield, its energy and nutritional value.

The indicators of the structure of the corn crop, namely the length of the cob and its diameter, were the highest after applying Task Extra (440 g/ha) + Synergen SOC (0.15%) (19.5 and 5.2 cm) and Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%) (19.7 and 5.2 cm), the indicator decreased by 7–8% in the variants with Task Extra (880 g/ha) + Trend 90 (0.2%), Task Extra (440 g/ha) + Trend 90 (0.1%), Titus Extra (100 g/ha) + Trend 90 (0.2%) (Table 6). This is explained by the double rate of the herbicide, which suppressed the corn plant, thereby reducing the indicators of the length and diameter of the cob. Those indicators were the lowest after using Master Power (1.5 L/ha) (16.4 and 4.4 cm) and the control plots. The number of rows of grain on the corn cob was the same in all the variants of the experiment, which is a varietal characteristic of the hybrid. The yield of grain

also slightly fluctuated according to the experimental variants (80.0–82.9), being the lowest in the control.

One of the important indicator of the formation of corn grain yield was the mass of 1,000 grains, which had a noticeable range of fluctuations depending on the studied factors. The weight of 1,000 grains depended on the biological properties of the hybrid, as well as the doses of herbicides. The inhibition of this element of the structure of the corn control crop progressed with the growth of the degree of weed invasion up to 104 g in the control plots. Application of Task Extra (440 g/ha) + Trend 90 (0.1%) reduced this indicator by 24 g compared with the use of Synergen SOC (0.15%). The highest mass of 1,000 grains was recorded in variants 2 and 9 – 231 and 231 g, respectively.

Based on our analysis, it can be stated that the length, diameter and coarseness of the grain are subject to effective regulation with the help of herbicides and play the role of one of the main factors in the forma-

tion of the yield. Thus, the indicators of the crop structure were strengthened or weakened depending on the effectiveness of herbicides and the degree of weed invasion. The highest biometric parameters were

recorded in variants with application of Task Extra (440 g/ha) + Synergen SOC (0.15%), and Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%).

Table 5
Dynamics of weed invasion of corn crops in 2017

Research variants	Number of weeds by biogroups, ind/m ²												Above-ground biomass of weeds in the air-dry state, g/m ²	Technical efficiency of herbicides, %
	before applying herbicides				25–30 days after spraying				before harvesting					
	annual				annual				annual					
	dicots	<i>Poa</i> species	rhizomes	total	dicots	<i>Poa</i> species	rhizomes	total	dicots	<i>Poa</i> species	rhizomes	total		
1. Task Extra (440g/ha) + Trend 90 (0.1%)	31.0	3.2	1.7	35.9	3.6	1.6	0.2	5.4	5.6	0.7	1.9	8.2	33.4	85
2. Task Extra (440g/ha) + Synergen SOC (0.15%)	35.7	0.9	1.7	38.3	3.9	0.3	0	4.2	2.8	0.3	0.7	3.8	22.1	89
3. Task Extra (880g/ha) + Synergen SOC (0.25%)	14.1	0.7	0	14.8	0.9	0.3	0	1.2	0.4	0.2	0.6	1.2	17.8	92
4. Task Extra (880 g/ha) + Trend 90 (0.2%)	26.5	1.0	1.2	28.7	4.9	0.5	0	3.1	3.7	0.5	1.1	5.3	28.1	89
5. Titus Extra (50 g/ha) + Synergen SOC (0.15%)	28.8	0	0.1	28.9	1.9	0	0	1.9	0.3	0	0.1	0.4	14.3	93
6. Titus Extra (50 g/ha) + Trend 90 (0.2%)	36.9	0.5	0.1	37.5	4.8	0.3	0	5.1	4.1	0.4	2.6	7.1	26.6	86
7. Titus Extra (100 g/ha) + Trend 90 (0.2%)	32.9	1.5	0.3	34.7	3.6	0.4	0	4.0	7.1	0.8	0.4	8.3	32.6	88
8. Titus Extra (100 g/ha + Synergen SOC (0.25%)	24.8	0.4	1.6	26.8	0.7	0.1	0.7	1.5	2.3	0.3	0.5	3.1	14.1	94
9. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%)	29.2	0.6	0.1	29.9	1.7	0	0	1.7	2.3	0.4	0.8	3.5	15.0	94
10. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Trend 90 (0.2%)	23.2	0.8	1.2	25.2	2.1	0	0	2.1	5.4	0	2.1	7.5	19.9	92
11. Master Power(1.5 L/ha)	27.2	1.2	0.4	28.8	8.3	0.4	0	8.7	12.3	1.0	0	13.3	65.9	70
12. Control (without treatment)	29.3	1.6	1.3	32.2	30.6	8.9	4.5	44.0	34.9	12.5	4.8	52.2	109.7	–

Table 6
Elements of the corn crop structure depending on the use of herbicides, 2017

Research variants	The length of the cob, cm	Number of rows, pcs	The diameter of the cob, cm	Grain yield, %	Weight of 1000 grains, g
1. Task Extra (440g/ha) + Trend 90(0.1%)	18.6	17	4.9	81.4	217
2. Task Extra (440g/ha) + Synergen SOC (0.15%)	19.5	17	5.2	82.9	231
3. Task Extra (880g/ha) + Synergen SOC (0.25%)	18.1	17	4.8	81.6	211
4. Task Extra (880 g/ha) + Trend 90 (0.2%)	17.9	17	4.6	81.8	203
5. Titus Extra (50 g/ha) + Synergen SOC (0.15%)	19.0	17	5.0	82.0	228
6. Titus Extra (50 g/ha) + Trend 90 (0.2%)	18.8	17	4.9	81.5	215
7. Titus Extra (100 g/ha) + Trend 90 (0.2%)	18.3	17	4.7	81.4	207
8. Titus Extra (100 g/ha) + Synergen SOC (0.25%)	18.2	17	4.9	82.3	209
9. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%)	19.7	17	5.2	82.6	231
10. Titus Extra (50 g/ha) + Prima – (0.4 L/ha) + Trend 90 (0.2%)	18.9	17	5.0	81.7	226
11. Master Power (1.5 L/ha)	16.4	17	4.4	80.0	194
12. Control (without treatment)	13.8	17	3.9	78.7	104

Taking into account the peculiarities of the soil and climatic conditions of the steppe zone, which are characterized by an unstable hydrothermal complex, in order to realize the yield potential of the corn hybrid, it is necessary to create technological support with high chances of overcoming lack of moisture and high degree of weed invasion.

Research on the technology of corn cultivation shows that the formation of the maximum yield of corn grain is possible only if the life support factors are optimized at all stages of organogenesis of the crop. With the existing amplitude development of climatic elements during the crop growing season, the effectiveness of technological methods is determined by the extent to which they are able to optimize agroecological regimes in agroecosystems. Weeds develop strongly under any conditions, which leads to the redistribution of nutrients and moisture in their favor, and this, in turn, causes a decrease in the yield of corn in the most inhibited condition.

The weather conditions of the growing season turned out to be similar, which significantly affected the yield of corn hybrids. The lack of weed control measurements led to a significant decrease in grain yield – 3.31 t/ha (Table 7). Task Extra (440g/ha) + Synergen SOC (0.15%) (6.12 t/ha) turned out to be effective means of controlling weeds; application of Task Extra (440g/ha) + Trend 90 (0.1%) reduced the yield by 0.27 t/ha, which was associated with a decrease in the phytotoxic effect of the Trend herbicide on weeds. The use of Titus Extra

(50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%) led to a high yield – 6.10 t/ha, and the application of Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Trend 90(0.2%) reduced this parameter by 0.29 t/ha, although it was within the experimental error.

Applying a double dose of Task Extra (880 g/ha) + Synergen SOC (0.25%) reduced the yield by 0.62 t/ha compared with variant 2. Because the crop was under stress and 15% of the plants were neutralized, the yield decreased even more (0.78 t/ha) after using Task Extra (880 g/ha) + Trend 90 (0.2%). A high yield was recorded in after using Titus Extra (50 g/ha) + Synergen SOC (0.15%) (5.91 t/ha). When the rate of herbicide was increased to 100 g/ha, the productivity decreased in the variant with Trend 90 (0.2%) – 0.38 t/ha, and Synergen SOC (0.25%) – 0.24 t/ha. The use of the herbicide Master Power (1.5 L/ha) led to an increase in weed invasion and a decrease in yield to 4.87 t/ha.

Conclusions

The problem of weed control is necessary components of the course on the EU plant production standards (Essman et al., 2021; Dilliot et al., 2022; Fluttert et al., 2022). First, a fairly broad range of weeds should be inhibited using a limited set of herbicides in the absence of residual chemical loading on agroecosystems (Zavialova et al., 2021). Secondly, the toxicity of the herbicides must be reduced

(Wang et al., 2022). Thirdly, there should be taken into account the possible negative physiological impact on the growth and development of the cultivated crops (Sun et al., 2022). It sometimes has a subthreshold value and synergy and is quite difficult to take into consideration

(Wang et al., 2022). Fourthly, the genetically determined features of varieties and hybrids of agricultural crops depend on the mechanism of interaction with weeds and the active substances of protection agents (Schramski et al., 2021; Poljuha et al., 2022).

Table 7
Yield of corn grain (t/ha) depending on crop treatment, 2017

Research variants	Repetition			Average
	I	II	III	
1. Task Extra (440 g/ha) + Trend 90 (0.1%)	5.53	5.88	6.14	5.85
2. Task Extra (440g/ha) + Synergen SOC (0.15%)	5.82	6.13	6.42	6.12
3. Task Extra (880g/ha) + Synergen SOC (0.25%)	5.01	5.78	5.70	5.50
4. Task Extra (880 g/ha) + Trend 90 (0.2%)	5.27	5.16	5.59	5.34
5. Titus Extra (50 g/ha) + Synergen SOC (0.15%)	5.80	5.91	6.01	5.91
6. Titus Extra (50 g/ha) + Trend 90 (0.2%)	5.73	5.73	5.87	5.78
7. Titus Extra (100 g/ha) + Trend 90 (0.2%)	5.69	5.78	5.14	5.53
8. Titus Extra (100 g/ha) + Synergen SOC (0.25%)	5.53	5.88	5.61	5.67
9. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Synergen SOC (0.15%)	5.95	6.25	6.11	6.10
10. Titus Extra (50 g/ha) + Prima (0.4 L/ha) + Trend 90 (0.2%)	5.83	5.62	5.97	5.81
11. Master Power (1.5 L/ha)	4.98	4.11	5.53	4.87
12. Control (without treatment)	3.09	3.60	3.24	3.31

We should also note that the agro-climatic features of the growing region as a zone of unstable agricultural practices are associated with numerous problems (Essman et al., 2021) – problems with moisture in critical periods of the development, heat resistance of plants (Dilliot et al., 2022), the formation of heat shock proteins (Guerra et al., 2022), sometimes leading to problems not predicted even by herbicide manufacturers (Guerra et al., 2022). Unfortunately, those issues could only be detected by constant monitoring of different cultivation options in the conditions of the region (Zhukov et al., 2010), while the common protocols when deciding on the registration of a herbicide and manufacturers' studies are quite often insufficient (Zavialova et al., 2021).

The leading European institutions are oriented at complete abandoning of the chemical means of plant protection by increasing the genetically determined tolerance of cultivated varieties and hybrids to weed invasion and the use of biologization of means of protection. Nonetheless, this goal is hardly achievable (Fluttert et al., 2022; Liu et al., 2022), taking into account, firstly, the problems with a significant seed bank of weed crops, which must first be eliminated, secondly, the level of development of agricultural practices in the territory of our country, and thirdly, the agroecological features of the growing region (Zhukov et al., 2010). A significant obstacle is the rapid growth of the necessary funds to solve the problem in such a paradigm (Polli et al., 2022) and some temporary decrease in the productivity of crops (Huang et al., 2022). In the EU countries, taking into account state programs to support the biologization of agriculture (Mobli et al., 2022) and the flexible price policy of the domestic market, it is possible to compensate for these factors not at the expense of reducing the profitability of agricultural producers. At the same time, we do not even have procedures for licensing and certification of the corresponding products (Dai et al., 2022), not to mention absence of the orientation of the consumer to a healthier diet and understanding the need to consume such products.

In the system of protection against a broad range of weeds in agroecosystems of corn, it is necessary to use the herbicide Task Extra (440 g/ha) + Par Trend (0.2 L/ha) in the phase of 5–6 leaves of the crop. To increase the yield and remove herbicide-caused stress, there may be used Vypmel and Vypmel 30 growth regulators during the later phases (7–8 leaves) of corn development. When protecting corn from weeds using the herbicide Titus Extra (50 g/ha) + Par Trend (0.2 L/ha), the species composition of weeds should be taken into account and spraying should be carried out during the early stages of their development. The herbicides Task Extra and Titus Extra in a tank mixture with the adjuvants Synergen and Trend showed the highest phytotoxic effect in almost all the variants of the experiment: on *Chenopodium album* (71–100), *Amaranthus retroflexus* (85–99%), *Convolvulus arvensis* (95–100), *Coniza canadensis* (100%), *Descurainia sophia* (100%), *Persicaria hydropiper* (85–100%). A high yield was recorded in the variant with Titus Extra (50 g/ha) + Synergen SOC (0.15%) (5.91 t/ha). However, when the rate of the herbicide was increased to 100 g/ha, the yield decreased in the variant with Trend 90 (0.2%) – 0.38 t/ha, and Synergen SOC (0.25%) – 0.24 t/ha, indicating the superiority of the latter.

The Vypmel growth stimulator and Oracle multicomplex and Oracle boron chelate microfertilizers were highly effective stimulators and anti-stress agents for on sunflower. When spraying plants, the productivity of photosynthesis, drought resistance, heat resistance and productivity increased, and herbicide-caused stress in plants was mitigated. To quickly remove the inhibition of plants by a herbicide and yellowing of the leaves, it is possible to apply the Express herbicide or Vypmel (0.5 L/ha) or Vypmel K, Oracle multicomplex and Oracle chelate boron microfertilizers during the phase of 2–3 pairs of leaves, which act as growth stimulants and microfertilizers, increasing the yield by 0.45 t/ha.

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