Journal of Agriculture and Crops
ISSN(e): 2412-6381, ISSN(p): 2413-886X
Vol. 9, Issue. 1, pp: 130-136, 2023
URL: https://arpgweb.com/journal/journal/14
DOI: https://doi.org/10.32861/jac.91.130.136

Academic Research Publishing Group

Original Research **Open Access**

Evaluation of the Effectiveness of the Combined Use of Humic Fertilizer and Herbicides in Spring Wheat Crops

E. P. Kondratenko (Corresponding Author)
Kuzbass State Agricultural Academy, Kemerovo, Russia
Email: e.p.kondratenko@mail.ru

O. M. Soboleva
Kemerovo State Medical University of the Ministry of Health of the Russian Federation, Kemerovo, Russia

N. V. Verbitskaya
Kuzbass State Agricultural Academy, Kemerovo, Russia

L. A. Filipovich
Kuzbass State Agricultural Academy, Kemerovo, Russia

Article History
Received: 10 October, 2022
Revised: 18 December, 2022
Accepted: 5 January, 2023
Published: 9 January, 2023

Abstract

The use of herbicides is a necessity of modern agricultural production. Adaptogenic compounds, such as humic substances, will help minimize the harm from their use. There are few studies on the combined use of herbicides and humates, so the purpose of the study was to evaluate the effectiveness of the combined use of humic fertilizer and herbicides in spring soft wheat crops and their effect on grain yield and quality indicators. The research was carried out in 2018-2020 in the Beregovoy agricultural production cooperative in the Kemerovo region of Russia. Variants of the experiment: 1. Treatment with Magnum Super herbicide, 10 g/ha + humic fertilizer “Healthy Harvest”, 1 l/ha. 2. Gorgon herbicide treatment, 0.17 l/ha + Healthy harvest, 1 l/ha. 3. Plugger herbicide treatment, 15 g/ha + Healthy crop, 1 l/ha. The high efficiency of treatment with the Plugger preparation together with the humic fertilizer “Healthy Harvest” was established. Two other drugs, Magnum Super and Gorgon, effectively reduced the infection of wheat crops with bedstraw, beautiful pikulnik, white goosefoot, Tatar buckwheat. Yield increase ranged from 1.8 t/ha (Magnum Super) to 2.9 t/ha (Plugger). Herbicides and humic fertilizer did not affect the content of raw gluten and increased grain vitreousness by 1-2%. Thus, the study proved the effectiveness of the combined use of herbicides and humic compounds on wheat crops.

Keywords: Spring wheat; Weeds; Humic fertilizer “Healthy Harvest”; Efficiency; Productivity; Grain quality.

How to Cite: E. P. Kondratenko, O. M. Soboleva, N. V. Verbitskaya, L. A. Filipovich, 2022. "Evaluation of the Effectiveness of the Combined Use of Humic Fertilizer and Herbicides in Spring Wheat Crops." *Journal of Agriculture and Crops*, vol. 9, pp. 130-136.

1. Introduction

One of the factors hindering obtaining of high and stable yields of spring wheat grain is the infestation of crops [1]. Weeds are a constant worldwide problem in the production of crops [2], increasing production costs while reducing crop yields [3]. Worldwide, crop losses due to weed infestation are usually higher than losses due to other negative factors [4-6]. Herbicides are the most widely used weed control in commercial crops [7] but weeds have now developed resistance to 23 of 26 known herbicide targets [8], thereby limiting chemical control options, increasing economic losses and threatening agricultural sustainability. This threat comes at a time when global population growth is demanding increased agricultural productivity for food sustainability and environmental concerns have led to significant restrictions on the use of many herbicides.

Continuous use of a single herbicide for several years in a particular location may not provide effective control of different types of weeds and therefore a combination of herbicides is needed to control broad-spectrum weeds in wheat [9, 10]. The use of herbicide combinations not only reduces weed density but also increases wheat nutrient uptake and reduces nutrient loss due to weeds. Herbicides and tillage play an important role in weed control [11-13]. Herbicides effectively control weeds. Their application is not very laborious, but herbicides are not a complete solution to the complex problem that weeds present. Herbicide-resistant weeds are rapidly evolving as a natural response to the selection pressure exerted by agricultural management activities [10, 14]. Weed resistance to herbicides limits control options, thereby increasing economic losses and threatening agricultural sustainability in cereal production.

A number of works show positive trends from the combined use of herbicides and humic preparations, which consist in reducing the pesticide pressure on the soil microbiota, increasing adaptability and increasing the yield of various agricultural crops [15-17]. There are indications that humic acids are able to adsorb pesticides in water, which does not exclude similar processes in soils [18].

Evaluation of means of agricultural crop protection from weeds is important for their application in local conditions. The purpose of our research was to test the effect of herbicides on weeds and the humic fertilizer “Healthy Harvest” on the yield and quality of grain under the conditions of agricultural production.

2. Materials and Methods

The studies were carried out in 2018-2020 on crops of spring soft wheat of the Iren variety in the agricultural production cooperative “Beregovoy” of the Kemerovo region of Russia. Grain quality was determined in the testing laboratory of the branch of the Federal State Budgetary Institution “Rosselkhoztsentr” in the Kemerovo region, located in the southeast of Western Siberia in Russia.

The weather conditions during the years of research were typical for the zone and favorable for wheat cultivation. The soil of the experimental plot is leached heavy loamy chernozem. The plot area is 10 ha. An untreated plot was taken as control.

Soil preparation included autumn plowing by PN-8-35 to a depth of 35 cm, disking by TAD-7.2. In the spring, when the physical ripeness of the soil was reached, cultivation was carried out with “Smaragd 8” to a depth of 12 cm and harrowing with VELES BS 15. The sowing time was the second decade of May.

According to the temperature regime and moisture conditions, the years of the research differed markedly from each other and had their own characteristic features. In May 2018, unstable weather was observed, with sharp fluctuations in temperature from +2°C to +4°C, with frequent precipitation in the form of rain. Moisture in a meter layer of soil was the optimal amount of 160 mm, 70% of the lowest moisture capacity. June was very warm and moderately humid. In July, the average daily air temperature was +17°C…+18°C, which is 1°C below the norm. Precipitation was 60 mm per month, which is 87% of the norm. Warm weather also prevailed in August. The average daily air temperature was +15°C ... +20°C. May 2019 was cold and dry. There was a shortage of precipitation, 11% of the ten-day norm. The average temperature in June was at the level of the long-term average, precipitation for the month was 54 mm, 81% of the ten-day norm. The reserves of productive moisture in the soil layer were 0-100 cm - 115 mm (slightly insufficient moisture). July was warm and humid. In August, in the first decade, the weather was dry and sunny. The average ten-day air temperature was 4°C higher, and 12 mm of precipitation fell in total, 50% of the ten-day norm. The average air temperature for May 2020 was +13°C, which is 2°C above the norm, there was little precipitation, 3% of the ten-day norm. A meter layer of soil was in strong insufficient moisture. Moisture reserves did not exceed 111 mm. Hot, dry weather (+16°C) prevailed in June, and was at the level of the long-term average, with heavy rain showers in the second ten-day period, and practically no precipitation in the third decade. July was warm (+20°C), which is 1°C above the norm, and quite humid. The amount of precipitation was 122 mm, 245% of the ten-day norm. In August, the weather remained warm with heavy rains. The reserves of productive moisture in the meter layer of soil were 101 mm, 43% of the lowest moisture capacity. In general, hydrothermal conditions in 2018-2020 reflected the features of the sharply continental climate of the southeast of Western Siberia.

Under the conditions of the economy, the content of humus in the soil cover is 4.9%. The content of nitrogen in leached chernozem is 80 mg/kg of soil, P2O5 is 159 mg/kg of soil, K2O is 130 mg/kg of soil, pH = 5.7. In general, these soils are favorable for the cultivation of spring wheat and make it possible to obtain high yields with the implementation of appropriate agricultural technology.

The Iren variety was bred in the Krasnoufimsk breeding center of the State Scientific Institution Ural Research Institute of Agriculture. It was included in the State Register of Breeding Achievements in 1998. It is a variety of milturum, early ripening, ripens in 70-87 days, the yield in the competitive test is 3.7-5.7 t/ha.

Sowing was carried out by the Russian sowing complex "Tom", designed for sowing without preliminary soil preparation (direct sowing), which minimally disturbs the protective mulch layer on the soil surface and allows preserving its natural structure. The complexes are equipped with an electronic control system, which allows quickly receiving accurate information about the drive of the sowing units, the level of material in the hopper, the pressure in the sowing pneumatic system, the passage of material to the coulters, etc. Precise sowing on zero technology (No Till). The complex provides accurate dosing of seeds and fertilizers and their placement in the soil, due to high-quality copying of the field surface. The sowing time for wheat in the studies is the first, the beginning of the second decade of May, with a seeding rate of 5 million per piece of germinating seeds per 1 hectare. Seeding depth is 6.0 cm. Predecessors are alfalfa, peas. Before sowing, seeds were treated with Vial Tras, a water-suspension concentrate - a complex fungicidal seed treater for grain crops with anti-stress components (Active ingredient: thiabendazole + tebuconazole. Chemical class: Benzimidazoles + triazoles. Manufacturer: JSC "August"). The norm of application of the preparation is 0.3 l/t, the flow rate of the working fluid is 10 l/t, against a complex of wheat diseases, with a dressing machine - a chamber dresser PK-20 Super. Herbicidal treatment against weeds was carried out with a John Deere sprayer. This high-performance compact trailed self-propelled sprayer can move quickly and safely on the roads; convenient, error-free and time-saving dosing of applied agents, as well as accurate and environmentally friendly work in the field. Spraying of spring wheat crops against annual (2-6 leaves) and perennial dicotyledonous (leaf rosette 10-20 cm) weeds was carried out in the tillering phase of wheat before budding (recommended period). Chemical weeding and foliar treatment with humic fertilizer "Healthy Harvest" were carried out with a working fluid consumption rate of 150 l/ha. Fertilizers were not applied. Harvesting was carried out in the full ripeness of wheat, from the second decade of August to the first decade of September, by direct combining with Russian Akros-530 combines. Yield data is based on 14% moisture and 100% purity.

Field experiments on the study of herbicides included 4 options. From herbicides on crops of spring wheat were applied: Magnum super, Gorgon and Plugger. In the control variant (without herbicides), only agrotechnical measures were carried out. The infestation of wheat crops was studied in the field according to the guidelines for conducting production tests of herbicides.

All herbicides used in the experiments were produced by JSC "August".

The predecessor is alfalfa. The experiment was carried out in accordance with the methodological guidelines for conducting production tests of herbicides [19].

Variants of the experiment:

1. Treatment with herbicide Magnum Super, water dispersible granules with a consumption rate of 10 g/ha + Healthy Harvest, 1 l/ha.

Magnum super herbicide, preparative form water-dispersion granules, active ingredients: tribenuron-methyl + metsulfuron-methyl (450 + 300 g/kg). Magnum Super is a two-component herbicide for the control of annual and some perennial dicotyledonous weeds, including those resistant to 2,4-D and 2-methyl-4-chlorophenoxyacetic acid in grain crops. The consumption rate of the drug is 10 g/ha. Consumption of working fluid is 200 l/ha.

2. Treatment with herbicide Gorgon, water soluble concentrate, 0.17 l/ha + Healthy Harvest, 1 l/ha.

Gorgon herbicide, water-soluble concentrate, active ingredient 2-methyl-4chlorophenoxyacetic acid + picloram (350 g/l 2-methyl-4chlorophenoxyacetic acid to + 150 g/l picloram. Chemical class: aryloxyalkanecarboxylic acids + pyridine derivatives. Gorgon is systemic herbicide for control with creeping bitterweed and other persistent dicotyledonous weeds.The consumption rate of the drug is 0.17 l/ha, the consumption of the working fluid is 200 l/ha.3. Treatment with herbicide Plugger, water dispersible granules, 15 g/ha + Healthy Harvest, 1 l/ha.

Control was without treatment.

Fertilizer “Healthy Harvest” is a liquid complex fertilizer based on natural humic acids. It is used for root and foliar top dressing both in pure form and in tank mixtures with pesticides on grain, tilled, industrial, vegetable crops, potatoes. The developer is Agrotekh Gumat LLC (Russia). The manufacturer is the branch of the Federal State Budgetary Institution “Rosselkhoztsentr” in the Kemerovo region of Russia.

A test was carried out under the conditions of agricultural production of the action of the tank mixture of herbicide + humic fertilizer "Healthy Harvest" and their effect on weediness and yield. Liquid complex fertilizer is based on natural humic acids "Healthy Harvest". It was manufactured by the branch of the federal state budgetary institution “Rosselkhozcenter” in the Kemerovo region of Russia and was developed by the LLC "AGROTECH HUMAT". Liquid complex fertilizer contains salts of humic acids 78-82%, 8 microelements Si, Fe, Mn, Mo, B, Co, Zn, Cu and 5 macronutrients N, P, K, S, Mg, meets the requirements of technical regulations. It is used for soaking seeds, root and foliar top dressing, both in pure form and in tank mixtures with pesticides on cereals.

Herbicide treatment of spring wheat crops against annual (2-leaves) and perennial dicotyledonous (leaf rosette 10-20 cm) weeds was carried out in the tillering phase of wheat. Chemical weeding and foliar treatment with humic fertilizer “Healthy Harvest” were carried out with a John Deere sprayer (United States), the flow rate of the working fluid was 150 l/ha.

Sheaves were selected before harvesting and the biological yield per 1 m^2 was taken into account. Harvesting was carried out in the phase of full ripeness of wheat.

The biological effectiveness of herbicides was calculated by the formula [20]:

$$BE = C – B / C \times 100, \quad (1)$$

where C is the number of weeds before processing; B - the number of weeds after processing; multiplied by 100 and received the percentage of biological effectiveness.

When calculating economic efficiency, the cost of yield increase was taken into account, divided by costs and multiplied by 100 percent.

3. Results

Before field trials, the species composition of weeds in the experimental field was characterized. The infestation of crops of spring soft wheat was high. There were dicotyledonous juveniles (163 pcs/m^2), dicotyledonous perennials (256 pcs/m^2), dicotyledonous biennials (57 pcs/m^2) in crops. At the end of the first decade of June, 11 species of weeds belonging to 9 families were identified in spring wheat crops. Dicotyledonous perennials (Table 1) from the Asteraceae family (251 pcs/m^2) and dicotyledonous juveniles from the Amaranthaceae family (118 pcs/m^2) had the greatest distribution. The dominant species from these families were yellow thistle and white gauze. Weeds Euphorbia virgate, Conolvulus arvensis, Taraxacum officinale, Fagopyrium tataricum, Fagopyrium tataricum had the minimum distribution from 1 piece/m^2 to 8 pieces/m^2.

Table-1. Species composition of weeds in spring wheat crops before herbicide treatment

Weed species	Biological group	Family	Quantity (pcs/m^2)
Dicotyledonous juveniles (total 163 pcs/m^2)			
Tartary buckwheat (Fagopyrium tataricum)	Early spring	(Polygonaceae)	6
White goosefoot (Chenopodium album)	Early spring	(Chenopodiaceae)	118
Bedstraw (Galium aparine)	Early spring	(Rubiaceae)	18
Beautiful pikulnik or Edmonton hempnettle (Galeopsis speciosa)	Early spring	(Lamiaceae)	21
Dicotyledonous biennials (total 57 pcs/m^2)			
The bladder campion or maidenstears (Silene vulgaris)	Optional biennial	(Caryophyllaceae)	8
Drug fumitory (Fumaria offcinalis)	Optional biennial	(Fumaracae)	49
Dicotyledonous biennials (total 256 pcs/m^2)			
Field bindweed (Conolvulus arvensis)	Root shoots	(Conolvulaceae)	4
Creeping thistle (Cirsium arvense)	Root shoots	(Asteraceae)	20
Common dandelion (Taraxacum officinale)	Root shoots	(Asteraceae)	4
Field milk thistle (Sonchus arvensis)	Root shoots	(Asteraceae)	227
Leafy spurge (Euphorbia virgate)	Root shoots	(Euphorbiaceae)	1
Total			476

Wolgarie bur (Fumaria offcinalis) dominated among the optional biennial weeds. Dicotyledonous annual weeds accounted for 29.6%, dicotyledonous biennials –10.4%, dicotyledonous perennials – 60%.

Weeds cause the greatest harm to spring wheat plants in the tillering phase of the crop. It is in this phase that the use of herbicides is most effective. 20 days after herbicide treatment and foliar treatment with humic fertilizer "Healthy Harvest", the first count of weeds was carried out (Table 2).

Table-2. Species composition of weeds in spring wheat crops 20 days after herbicide treatment (pcs/m^2)

Type of weeds	Before treatment	Control	Variant 1	Variant 2	Variant 3
Dicotyledonous juveniles					
Tartary buckwheat	6	0	0	3	3
White goosefoot	118	1	0	5	0
Bedstraw	18	0	0	0	0
Edmonton hempnettle	21	1	0	0	3
Dicotyledonous biennials					
The bladder campion or maidenstears	8	0	2	0	2
Drug fumitory	49	7	4	18	0
Dicotyledonous perennials					
Field bindweed	4	0	3	0	0
Creeping thistle	20	0	8	20	2
Common dandelion	4	0	0	6	0
Field milk thistle	227	109	75	36	71
Leafy spurge	1	0	1	1	0
Total	476	118	93	89	81

The biological effectiveness against young weeds when treated with Magnum Super, 10 g/ha + Healthy Harvest, 1 l/ha was high and amounted to 100%. The maximum against perennials was in the variants with the use of Gorgon, 0.17 l/ha + Healthy Harvest, 1 l/ha and Plugger, 15 g/ha + Healthy Harvest, 1 l/ha and was 74 .1% and 76.1%, respectively. Weeds in the seedling phase died, and those in later phases stopped growing. They showed chloroticity and leaf curl. The bedstraw died in all variants among the dicotyledonous juvenile weeds and Edmonton hempnettle died in the first and second variants. Field bindweed and common dandelion died in the second and third variants among the dicotyledonous perennial species.

The second count of the number of weeds in wheat crops was carried out on the 30th day (Table 3) after herbicide treatment with the use of humic fertilizer "Healthy Harvest". In the variants of the experiment, a change in the number and species composition of weeds was observed.

Tartary buckwheat (the dicotyledonous juveniles) was not found in the first and second variants. White goosefoot and bedstraw were not found in the first and third variants. The dicotyledonous perennial such as common dandelion was not found in the first and second variants. Field milk thistle was preserved in all variants of the experiment. Although the growth of weeds was observed, they no longer competed with spring wheat plants.

Table-3. Species composition of weeds in spring wheat crops 30 days after herbicide treatment (pcs/m^2)

Type of weeds	Before treatment	Control	Variant 1	Variant 2	Variant 3
Dicotyledonous juveniles					
Tartary buckwheat	6	0	0	0	2
White goosefoot	118	0	0	0	
Bedstraw	18	0	0	0	0
Edmonton hempnettle	21	1	10	0	0
Dicotyledonous biennials					
The bladder campion or maidenstears	8	0	1	0	0
Drug fumitory	49	29	0	1	1
Dicotyledonous perennials					
Field bindweed	4	1	0	1	0
Creeping thistle	20	0	0	1	0
Common dandelion	4	0	0	0	1
Field milk thistle	227	74	16	83	62
Leafy spurge	1	0	1	1	0
Total	476	105	28	87	66

Biological efficiency (Table 4) against young weeds was maximum in the second and third variants of the experiment and amounted to 100% and 98.7%, respectively. Biological efficiency against perennials was maximum in the first variant and was 94.2%, in the second – 72.2%, in the third variant – 79.5%. The third count of the species composition of weeds was carried out before harvesting. It was found based on this accounting and analysis of weeds, that Tartary buckwheat, bedstraw, beautiful pikulnik died among dicotyledonous juveniles in all variants of the experiment; among dicotyledonous biennials – drug fumitory, among perennials – leafy spurge and dandelion in the second and third variants.

Table-4. The effectiveness of the use of herbicides in spring wheat crops (average data for 2018-2020)

Variant	Before harvesting			
	Number of weeds, pcs/m^2		Efficiency, %	
	juveniles	perennials	juveniles	perennials
Control	265.0	413.3	—	—
Magnum Super, water dispersible granules, 10g/ha + liquid complex fertilizer, 1 l/ha	4	31	97.5	90.1
Gorgon, water soluble concentrate, 0.17 l/ha + liquid complex fertilizer, 1 l/ha	1	32	99.3	89.8
Plugger, water dispersible granules, 15 g/ha + liquid complex fertilizer, 1 l/ha	0	29	100	90.7

Biological efficiency against young weeds before harvesting according to the variants of the experiment was: Magnum Super, 10 g/ha + Healthy Harvest, 1 l/ha – 97.5%, Gorgon, 0.17 l/ha + Healthy Harvest, 1 l/ha – 99.3%, Plugger, 15 g/ha + Healthy Harvest, 1 l/ha – 100%. The biological efficiency against perennial weeds was lower and, according to the variants of the experiment, was 90.1%, 89.8% and 90.7%, respectively.

The maximum biological yield of spring wheat for harvesting in the third variant with the use of Plugger herbicide and humic fertilizer "Healthy Harvest" was revealed. This treatment showed both the greatest yield increase and the greatest economic efficiency.

There were no negative effects of treatment on the quality indicators of spring wheat grain using the studied herbicides and humic fertilizer, subject to the regulations according to the research results. The crude gluten content was 30%, the vitreousness increased from 54% to 56%.

4. Discussion

The data obtained as a result of studying the effectiveness of the combined use of a tank mixture of humic fertilizer and herbicides in crops of spring soft wheat of the Iren variety made it possible to identify promising herbicides that can be used by commodity producers to successfully control weeds without harming wheat plants. Our findings are consistent with the findings of foreign and domestic researchers. Many foreign researchers [12-14], as well as Bezuglova, *et al.* [21], show a positive effect of using a combination of herbicides and humic preparations and believe that they are aimed at reducing pesticide stress on soil microbiota and increasing wheat adaptability. Stimulation of plants with humic preparations in tank mixtures with herbicides is indicated for a wide range of crops, and there are publications that indicate that such treatment has a more pronounced effect on monocots compared to dicots [22]. The positive effect of humic acids on plants and microorganisms is manifested in those experiments where plants are exposed to a stress factor. This is well shown in [23], the researchers note that humic acids have a protective effect when used together with the herbicide picloram. Also, in a recent work, the ability of humic acids to adsorb various classes of pesticides was established [24].

5. Conclusion

It was found on the basis of the conducted studies, that 12 species of weeds, typical for the territory of the Kemerovo region of Russia, were identified in the spring wheat crops in the tillering phase. The bulk of weeds was represented by perennial and juvenile species. White goosefoot, beautiful pikulnik, tartary buckwheat, bedstraw predominated among the juvenile species. Field milk thistle predominated among the perennial species, belonging to the root off spring biological group. It is effective to use the herbicide Plugger, water dispersible granules, in the tillering phase of wheat with a consumption rate of 15 g/ha together with the humic fertilizer Healthy Harvest, 1 l/ha for the control of dicotyledonous juvenile and perennial weeds. The biological effectiveness of the use of this herbicide in spring wheat crops against young weeds was 100%, against perennial weeds 90.7%. The use of humic fertilizer increased the grain yield of spring wheat by 2.9 t/ha compared to the control. The biological efficiency of treatment before harvesting spring wheat against juveniles was: in the first variant – 97.5%, in the second variant – 99.3%, in the third variant – 100% and against perennials 90.1%, 89.8% and 90, 7% respectively. The economic efficiency of the combined use of herbicides and humic fertilizer varied from 76% to 122.4%. It has been established that the joint herbicidal treatment with humic fertilizer does not reduce the studied indicators of wheat grain quality, but, on the contrary, increases grain vitreousness by 1–2%.

References

[1] Chauhan, B. S., Singh, R. G., and Mahajan, G., 2012. "Ecology and management of weeds under conservation agriculture: A review." *Crop Protection,* vol. 38, pp. 57-65. Available: https://doi.org/10.1016/j.cropro.2012.03.010

[2] Mwendwa, J. M., Brown, W. B., Weidenhamer, J. D., Weston, P. A., Quinn, J. C., Wu, H., and Weston, L. A., 2020. "Evaluation of commercial wheat cultivars for canopy architecture, early vigour, weed suppression, and yield." *Agronomy,* vol. 10, p. 983. Available: https://doi.org/10.3390/agronomy10070983

[3] Wu, H., 2015. *Integrating belowground non-chemical approaches for future weed management. In: I. S. Travlos, D. Bilalis and D. Chachalis (Eds.), Weed and pest control: Molecular biology, practices and environmental impact*. Hauppauge: Nova Science Publishers, Inc., pp. 55-84.

[4] Jabran, K., Mahajan, G., Sardana, V., and Chauhan, B. S., 2015. "Allelopathy for weed control in agricultural systems." *Crop Protection,* vol. 72, pp. 57-65. Available: https://doi.org/10.1016/j.cropro.2015.03.004

[5] Pinchuk, L., Pjanyh, A., and Yakovchenko, M., 2019. "Productivity of winter rye in terms of the use of bio-organic nano-fertilizer Nagro." In *IOP Conference Series: Earth and Environmental Science.*

[6] Sherer, D. V. and Chumanova, N. N., 2017. "Soil tillage as a factor of soil conservation." In *IOP Conference Series: Earth and Environmental Science.*

[7] Yadav, H. L., Gupta, A. K., Kumar, S., and Gupta, S., 2019. "Comparative efficacy of herbicides applied in wheat and their residual effect on the succeeding crops." *International Journal of Current Microbiology and Applied Sciences,* vol. 8, pp. 1866-1874. Available: http://dx.doi.org/10.20546/ijcmas.2019.804.218

[8] Heap, I., 2014. *Herbicide resistant weeds. In: D. Pimentel and R. Peshin (Eds.), Integrated pest management*. Dordrecht: Springer. pp. 281-301.

[9] Głowicka-Wołoszyn, R., Kozera, A. B., and Stanisławska, J., 2020. "The problem of weed resistance to herbicides and the economic efficiency of wheat protection on the example of a large-scale agricultural farm." *Annals of the Polish Association of Agricultural and Agribusiness Economists,* vol. 22, pp. 85-94. Available: https://doi.org/10.22004/ag.econ.302905

[10] Verma, S. K., Bhatnagar, G. S., Shukla, A. K., Singh, R. K., and Meena, R. K., 2021. "Integrated weed management in wheat (Triticum aestivum L.): A review." *Current Research in Agriculture and Farming,* vol. 2, pp. 1-4. Available: https://doi.org/10.18782/2582-7146.132

[11] Gianess, L. P., 2013. "The increasing importance of herbicides in worldwide crop production." *Pest Management Science,* vol. 69, pp. 1099-1105. Available: https://doi.org/10.1002/ps.3598

[12] Kondratenko, E. P., Soboleva, O. M., and Sergeeva, I. A., 2022. "Influence of weather conditions and weediness on barley (Hordeum vulgare) yield." *Research on Crops,* vol. 23, pp. 33-39. Available: http://dx.doi.org/10.31830/2348-7542.2022.006

[13] Norsworthy, J. K., Ward, S. M., Shaw, D. R., Llewellyn, R., Nichols, R., Webster, T., Bradley, K. W., Frisvold, G., Powles, S. B., *et al.*, 2012. "Reducing the risks of herbicide resistance: Best management practices and recommendations." *Weed Science,* vol. 60, pp. 31-62. Available: https://doi.org/10.1614/WS-D-11-00155.1

[14] Harker, K. N. and O'Donovan, J. T., 2013. "Recent weed control, weed management, and integrated weed management." *Weed Technology,* vol. 27, pp. 1-11. Available: https://doi.org/10.1614/WT-D-12-00109.1

[15] Aydin, M., Arslan, E., Yigider, E., Taspinar, M. S., and Agar, G., 2021. "Protection of phaseolus vulgaris l. From herbicide 2, 4-d results from exposing seeds to humic acid." *Arabian Journal for Science and Engineering,* vol. 46, pp. 163-173. Available: https://doi.org/10.1007/s13369-020-04893-w

[16] Gorovtsov, A. V., Bezuglova, O. S., Polienko, E. A., Grinko, A. V., Naimi, O. I., Lykhman, V. A., Dubinina, M. N., and Patrikeev, E. S., 2021. "The effect of the tank mixtures of humic substances and herbicides on the abundance of microbial communities in chernozem during chickpea cultivation." In *IOP Conference Series: Earth and Environmental Science.*

[17] Korotkova, I., Marenych, M., Hanhur, V., Laslo, O., Chetveryk, O., and Liashenko, V., 2021. "Weed control and winter wheat crop yield with the application of herbicides, nitrogen fertilizers, and their mixtures with humic growth regulators." *Acta Agrobotanica*, vol. 74, p. 748. Available: https://doi.org/10.5586/aa.748

[18] Vrantsi, E., Lakka, A., Bozinou, E., Athanasiadis, V., Papadaki, E. S., Dourtoglou, V. G., and Lalas, S. I., 2021. "Humic and fulvic acids as specific sorbents of herbicides in Water." *CLEAN–Soil, Air, Water*, vol. 49, p. 2000467. Available: https://doi.org/10.1002/clen.202000467

[19] Spiridonov, Y. Y., Shestakov, V. G., Raskin, M. S., Nikitin, N. V., Larina, G. E., Protasova, L. D., Spiridonova, G. S., and Cherkashin, V. I., 2004. *Guidelines for conducting production tests of herbicides*. Moscow: Protection and Quarantine of Plants. p. 23.

[20] Abbott, W. S., 1925. "A method of computing the effectiveness of an insecticide." *J. Econ. Entomol*, vol. 18, pp. 265-267. Available: https://doi.org/10.1093/jee/18.2.265a

[21] Bezuglova, O. S., Gorovtsov, A. V., Polienko, E. A., Zinchenko, V. E., Grinko, A. V., Lykhman, V. A., Naimi, O. I., and Dubinina, M. N., 2019. "Influence of a humic preparation on the productivity of winter wheat and the rhizosphere microbial community under herbicide stress." Actual issues of the development of agricultural sectors: theory and practice." In *Conference proceedings: Rostov-on-Don, Rassvet, 1-3 October, 2019.* pp. 8-18.

[22] Canellas, L. P., Olivares, F. L., Aguiar, N. O., Jones, D. L., Nebbioso, A., Mazzei, P., and Piccolo, A., 2015. "Humic and fulvic acids as biostimulants in horticulture." *Scientia Horticulturae*, vol. 196, pp. 15-27. Available: https://doi.org/10.1016/j.scienta.2015.09.013

[23] Taspinar, M. S., Aydin, M., Sigmaz, B., Yildirim, N., and Agar, G., 2017. "Protective role of humic acids against picloram-induced genomic instability and DNA methylation in Phaseolus vulgaris." *Environmental Science and Pollution Research*, vol. 24, pp. 22948-22953. Available: https://doi.org/10.1007/s11356-017-9936-y

[24] Ćwieląg-Piasecka, I., Medyńska-Juraszek, A., Jerzykiewicz, M., Dębicka, M., Bekier, J., Jamroz, E., and Kawałko, D., 2018. "Humic acid and biochar as specific sorbents of pesticides." *Journal of Soils and Sediments*, vol. 18, pp. 2692-2702. Available: https://doi.org/10.1007/s11368-018-1976-5