Resource-saving method of chemical treatment of tilled crops

I B Borisenko, A S Ovchinnikov, M V Meznikova, S D Fomin, V S Bocharkov, A F Rogachev and E I Ulybina
Volgograd State Agrarian University, 26, University Avenue, Volgograd, Russian

E-mail: fsd_58@mail.ru

Abstract. The article discusses the state of natural resources as a result of the use of traditional tillage technologies, suggests ways to solve them by switching to the resource-saving strip-till cultivation technology. Analyzed production costs for chemical processing and identified the shortcomings of serial machines for chemical processing of plants. The proposed technology and technical solution for the use of band spraying with the redistribution of working solutions for the objects of impact, taking into account the phase of crop development, which allows accurately making the active substance on the object of impact, which reduces hectare application rates and stresses of cultivated plants, saves money on chemical processing solving environmental problems by reducing the chemical load on the soil. An algorithm has been developed to recalculate the rate of application, as well as a calculator has been upgraded to select the nozzle number at the optimum pressure in the system, taking into account the hectare consumption and the speed of the unit in relation to the resource-saving method of chemical treatment of plants. As a result of the calculations, when using a resource-saving method of chemical processing of tilled crops, the consumption of the working solution is reduced compared to a continuous spraying when applied to crops with a row spacing of 0.7 m by 31.4%, with a row spacing of 0.9 m by 38.9%. This method allows adding a set of machines for mechanical tillage in the framework of the Strip-till strip technology.

1. Introduction
The primary task of the producer of agricultural products is to provide food for the population, the need for which is constantly growing, along with a clear decrease in soil fertility. Obtaining a crop in sufficient quantity while meeting quality requirements in the face of financial difficulties becomes a feasible task only for competent business executives who are striving for continuous self-development and personal growth, able to keep up with the development of modern technologies, in which resource-saving technologies occupy a key place. It is important for a modern agricultural producer to take care of the state of the soil at all stages of production [1,2].

One of the technologies that help in solving the above problems is the promising technology of strip-till strip-farming [3]. In the last decade in Russia to this technology and technical means for its implementation has grown significantly scientifically-based interest [4,5]. This is due to the possibility, through the use of this technology, not only to obtain good yields, reduce production costs and reduce the composition of MTPs in the economy, but also simultaneously solve a number of environmental problems. As you know, in recent years, global warming has been having a particularly negative effect on the effects of all natural systems [6]. The reason lies in the release of greenhouse gases, as a negative consequence of human activity. The functioning of agriculture leads to the release into the atmosphere of about 25% of all greenhouse gases due to microbial oxidation as a result of soil treatment. For Russia,
this figure is 290 million tons per year (from the report of L.V. Orlova, President of the National Movement for Conservation Agriculture Non-Profit Partnership, I International Scientific and Practical Conference “Climate, Soil Fertility, Agrotechnologies” on June 5, 2018 Samara, Russia). The use of the strip technology makes it possible to reduce greenhouse gas emissions into the atmosphere in proportion to the processed share of the bands, which is at least 24%. Of the total amount, this amounts to about 70 million tons.

2. A summary of the purpose and methodology
To test the scientific hypothesis, we made and installed a laboratory setup, which allows carrying out a series of laboratory studies on the spray process and spray pattern. The main working body of the installation is a device type “Dropleg” with slot nozzles. To determine the parameters of the spray cones of nozzles, the technical characteristics used a serial calculator developed by the Danish agro-industrial company “HARDY”. Processing of the results was performed using computer programs.

3. Research results, discussion
At the first stage, the performance check and the determination of the parameters of the spray cones of the nozzles were carried out to the technical characteristics, which were carried out using the HARDY calculator. The results showed that the performance and uniformity of spray nozzles complies with the technical specifications declared by the manufacturer.

At the second stage of research, we studied the parameters of the spray pattern. The dependence of the geometrical parameters of the flame cone on the pressure value for different nozzle sizes is presented in Figure 1.

As it can be seen from the graph, taking into account the approximation to the horizontal surface of the installation, the spray cone has a stable coefficient of expansion. At the same time, at a height of 450-500 mm from the beginning of the spray cone, it smoothly narrows to a vertical drop of drops.

At the third stage of research, we began a series of experiments to study the fusion of working fluid flows from oppositely located nozzles with lateral spray cones. Preliminary studies have shown the implementation of the process of merging flows from the nozzles with the lateral cones of spray.

In terms of further research, it is supposed to study and test the hypothesis about the merging of the streams with the formation of a new vertical stream with stable geometric characteristics, taking into account the studied factors.

Any production technology allows getting the best results if each of the operations and the applied technical means are aimed at achieving the goal, developed taking into account the features of this technology, while complementing each other and do not violate the technical process. The modern complex of technologies includes the operations of mechanical tillage and chemical in the form of plant protection and nutrition [7]. Moreover, with an increase in the intensity of the technology, as a rule, the chemical load increases. Conducting research and analysis of known technical means for the mechanical treatment of soil in the framework of the Strip-tills technology, we found that a significant article in the cost of production are the costs of plant protection and nutrition [8,9]. These activities are high-cost, in terms of monetary investments in chemical products. Chemical processing with the Strip-till technology takes 20-30% in the cost structure.

At the same time, the problem of reducing the chemical impact on the soil is urgent and necessary for creating a favorable ecological climate on our planet [10]. Therefore, with the obvious advantages of the Strip-till technology, one of the ways to improve it is to reduce the chemical load on the soil due to redistribution and accurate, band-wise application by target.

As a rule, the technological processes of plant protection in field cultivation are carried out by spraying liquid working solutions. Recently, more and more application is found in foliar feeding with the introduction of liquid complex fertilizers and a urea-ammonia mixture in small doses. The main advantage of liquid fertilizers is their rational use by plants [11].
Figure 1. Effect of pressure on the geometric parameters of the spray cone.

Analysis of the structure of technological processes of using a sprayer in the cultivation of sunflower makes it possible to notice that it is more expedient to carry out the treatment for soil herbicide application, protection from weeds, pests and diseases using the continuous spraying technology (Figure 2) on cultivated crops. In this regard, it is important to substantiate the technological process of chemical treatment of plants, taking into account the specific crop and the phase of its development [12].

To reduce the distance between the tops of the plants and the sprayers, it is necessary to choose nozzles with a large spray angle. However, this leads to an increase in the non-uniformity of the width of the treated strip with a vertical oscillation of the sprayer boom.

So, for the distance between the nozzle and the soil surface is 800 mm, when choosing the spray angle of the nozzle is 80°, the width of the treated strip is 1331 mm, and when the rod oscillates by 300 mm, respectively 829 mm (Figure 3a).
Figure 3. Changing the width of the treated strip sprayer: (a) for a serial sprayer; (b) for an advanced sprayer with a spray cone angle of 65°; (c) for an advanced sprayer with a spray cone angle of 80°.

For nozzles with a spray angle of 65°, the width of the treated strip is 1018 and 634 mm, respectively. That is, variations in the size of the treated strip vary within 38%. And although the spray angle of the 80° nozzle gives a better coverage of the plant in its upper part, which makes it possible to reduce the distance from the nozzle to the plant, but an increase in the angle leads to an increase in the irregularity of the application of chemistry. Therefore, one of the ways to improve the technological process of chemical treatment of plants is the redistribution of the working solution along the strips, taking into account their purpose. Sheet top dressing is advisable to carry out only for culture. Herbicides are advisable to use only between the rows, where weed vegetation grows. When making chemical solutions for diseases and pests, it is important to influence the lesions, that is, selectively process only the desired band. As a result, it is expected to reduce the cost of chemical treatment of plants.

The use of this technological approach allows the point of redistribution of the working solution with the active substance, which as a result reduces hectare norms, while the rate of application for the objects remains the same. In addition, the use of a differentiated approach to the introduction of chemistry will reduce the stressful effects on cultivated plants.

In this regard, we propose to improve the well-known technological process and the design of the boom sprayer, adapting it for processing along the lanes where the growth bands of cultivated plants alternate with row spacing with weeds [4,5]. To this end, it is proposed to redistribute the working solution in strips with simultaneous coverage of the plant over the entire surface in a vertical plane due to the use of lateral nozzles with oriented spray necks towards each other (Figure 3b). Side nozzles
should be located above the aisles. During the spraying of the working solution between the upper edges of the spray cones, an intersection zone with a spray angle of less than 180 degrees is formed, and the lower edges are located in the outline zone of the projection of a number of plants onto the soil.

The use of this method of side spray contributes to the conversion of spray streams from each nozzle into a new, more stable flow when they merge. That is, the proposed method makes it possible to achieve a constant distribution (density) of the working solution within the treated strip, regardless of the vertical oscillations of the rod (Figure 3c).

The developed technical solution allows quickly adjusting the sprayer to the technology of continuous and strip distribution of the working solution by switching between the housings for several sprayers.

The economic effect is expected to be achieved by concentrating the working solution at the target site through the redistribution of the working solutions along the lanes. As well as reducing the influence of vertical oscillations of the rod on the density of the distribution of the working solution across the width of the treated strip.

Using the method of stripe chemical treatment of plants, it is possible to reduce the hectare rate of chemical plant care products within 35 ... 45% with respect to continuous processing, without reducing the rate and quality of processing of objects of impact.

In connection with the change in the spraying process, it is important to make adjustments to the method of calculating the rate of fluid flow, taking into account the changed area of the treated lanes within the band spraying.

In this case, the consumption rate \( R_L \) in the treated lanes is assumed to be equal to the value of the consumption rate for continuous spraying, which is also expressed in l / ha, and the minute consumption \( q_l \) in l / min for each treated strip is determined from the relationship:

\[
Q_L = R_L \cdot b \cdot v \cdot 600
\]

where \( b \) is the width of the processed lanes (m), \( v \) is the speed of the unit, (km / h);

The total volume of working fluid required for the entire field \( Q_p \) (l / field) can be calculated by the following formula:

\[
Q_p = F_p \cdot b \cdot R_L \cdot r
\]

where \( F_p \) – area, ha; \( r \) – width of row-spacing, [m].

Using the above formulas, it is easy to pre-configure the sprayers on the flow rate with a given rate [12].

Within the framework of the cooperation agreement between the Volgograd State Agrarian University and the French holding company “EXEL Industries”, with the placement of an assembly plant in the Volgograd Region, in 2018, work began on the adaptation of the sprayers produced for the effective use of strip farming in agricultural technologies.

Monitoring of the technological problem of band spraying showed that today the volume of sown areas occupied by tilled crops in the Volgograd region is within 900 thousand hectares. The stipulated standard annual load on one sprayer, equal to 360 ha/year, clearly indicates that for the chemical treatment of plants by the most efficient and rational methods, more than 2.5 thousand modernized sprayers can be demanded by the most efficient and rational methods in our region. The solution to this problem is feasible for the company “EXEL Industries”.

For the correct selection of the size of the nozzle and recalculation of the pouring rate of the outflow during the transition to strip processing, we have proposed an improved calculator for sprayers from HARDY [9]. Figure 5 shows the algorithm for working with a calculator: the first stage is the recalculation of the rate of hectare associated with the re-equipment of the sprayer, by changing the distance between the bodies of the sprayers from 0.5 to 0.35 meters; at the second stage, the use of strip processing, taking into account the angle of the spray cone (65 and 80 degrees), for the row spacing of 0.7 m.
Figure 4. Algorithm for selecting the nozzle number at the optimum pressure in the system, taking into account the hectare flow and the speed of the unit.

From Figure 4 it can be seen that taking the rate of continuous introduction of the working solution of 200 l/ha taking into account the speed of the unit 8 km/h when recalculated for changing the distance between the nozzles from 0.5 to 0.35 meters, the norm on the sprayer computer should be set to 140 l/ha and, accordingly, the nozzle numbers 03 and 025 are selected with an optimal pressure in the system of 1.5-4.0 bar. When band processing, respectively, at 8 km/h: application rate of 96 l/ha; a capacity of 0.65 l/ha provides nozzle numbers 0.2 at a system pressure of 2.0 bar, and a nozzle number 0.15 at a pressure of 3.6 bar. Analysis of the calculations shows that band spraying at the accepted indicators allows reducing the hectare consumption of the working solution by 140/96 = 1.46 times.

4. Conclusion

On the basis of the obtained results, it can be argued that the use of the process under investigation of band spraying with side nozzles in the cultivation of tilled crops reduces the standards and improves the efficiency of treatment with liquid substances while maintaining the application rate for the objects, reducing the cost of chemical treatment, reducing the hectare consumption of chemical care products plants up to 45% relatively complete processing. All this ultimately contributes to the improvement of environmental and resource-saving principles and the further development of Strip-till technology.

For precise pre-setting of the sprayer on the flow rate with a given rate, the calculation method is given, taking into account the area of the treated lanes.

Based on theoretical calculations, taking into account the data obtained during laboratory tests, the reduction in the consumption of the working solution in the processing of crops with a row spacing of 0.7 m is 31.4%, and with a row spacing of 0.9 m – 38.9%.

It is recommended to choose sprayers for band application of herbicides as part of the strip effect of a slit injection type and sprayers with a hollow spray cone.
For the correct choice of the nozzle number and recalculation of the per-hectare pour-out rate when using the resource-saving method of chemical treatment of tilled crops, an improved calculator HARDY has been proposed.

Taking into account the fact that today work is being done on organizing cotton cultivation in the Volgograd region, which is also a row crop, but with a row spacing of 0.9 m, EXEL Industries is considering the possibility of adapting its machines for successful use in cotton production.

References
[1] Balashov A V 2018 Science in Central Russia 31(1) 14–20
[2] Belenkov A I, Tyumakov Yu A and Sabo M U 2015 Bulletin of the Altai State Agrarian University 126(4) 5–10
[3] Jaskulska I, Gałęzewski L, Piekarczyk M and Jaskulski D 2018 Italian J. of Agron. 13(3) 194–199
[4] Borisenko I B and Meznikova M V 2015 Proc. of the Orenburg State Agrarian Univ. 56(6) 82–84
[5] Borisenko I B, Shaprov M N, Dotsenko A E and Borisenko P I. 2015 Proc. of the Orenburg State Agrarian Univ. 56(6) 76–79
[6] Canales E, Bergtold J and Williams J. 2018 Agricultural and Resource Economics Review 47 (1) 90-117
[7] Borisenko I B, Shaprov M N and Borisenko P I 2013 News of the Nizhnevolzhsky Agrouniversity Complex: Science and Higher Professional Education 32(4) 193–197
[8] Borisenko I B, Chamurliev O G, Chamurliev G O and Meznikova M V 2018 Bulletin of Peoples’ Friendship University of Russia. Series: Agronomy and livestock breeding 13(3) 194–206
[9] Lukmenev V P 2015 Proceedings of the Orenburg State Agrarian University 51(1) 41-46
[10] Melnik V I 2015 Zemledelie 1 8-12
[11] Zavrazhmov A I, Balashov A V, Dyachkov S V, Omarov A N and Strykin S P 2017 Achievements of science and technology in the AIC 1 52-55
[12] Zubarev Yu N 2014 Perm Agrarian Bulletin 7(3) 17-21