Research of garden sprayer machines of near-stem and inter-stem strips of orchards

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Abstract. The article presents the results of experimental studies of industrial application in the trunk and interstem strips of orchards of a chemical treatment machine with spray sections, which are equipped with additional sprayers directed in the direction of the location of the protective and interstem strips. The authors reproduced an experiment to determine the density of the coating of droplets on the surface of cultivation depending on the distance relative to the centerline of a number of trees with a full cycle of cultivation of the trunk and trunk strip at work: section sprayers; additional spray; all sprayers section. The authors confirmed the technological capabilities of the developed machine in comparison with modern chemical treatment of stem and interstitial strips, in terms of reducing the cost of the active protective chemical. The optimal parameters of additional sprayers are set. The authors in the article confirmed that the spray sections work in three modes depending on the required width of the treatment of the stem and interstore strip. The width of the treated strip during the operation of the section with one spray is 0.5-1.0, with two 1.0-1.5, with three is 1.5-2.0 m. In addition, the quality assurance of the technological operation of the chemical processing of orchards.

1. Introduction

Weed control in the area of the root system of trees is one of the main prerequisites for obtaining products in a competitive volume [1] and quality [2]. The negative impact of weeds on cultivated plants is explained by the fact that they compete with them in the fight for moisture [3] and nutrients [4], promote the development of diseases and pests [5], create favorable conditions for the spread of rodents that damage plants in winter [6].
The use of traditional means of mechanical tillage of interstitial strips in intensive gardens is ineffective [7]. First, it is difficult to ensure the mechanical treatment of interstitial strips when the trees in a row at a distance of 2 meters or less [8], and secondly, such treatment is complicated by the possibility of mechanical damage to the root system of trees obtained using vegetatively propagated rootstocks [9]. Therefore, the use of herbicides as the main means of weed control in these cases is the most rational solution to this problem [10], as evidenced by world experience [11]. Analysis of the state of the means of performing this technological operation showed that most of them are hung on the frame of a tractor or sprayer [12] and have a rod structure at the end of which is a spray section [13]. The bar has the device for change of length that allows to carry out technological operation in gardens with various width of interrows [14].

The quality of such devices [15], which are mostly made in the workshops by the efforts of machine operators themselves in most cases does not meet agricultural requirements due to [16], as a rule, exceeding the rate of consumption of the chemical [17] or uneven distribution on the surface of the strip being treated [18]. Therefore, their common disadvantage is the insufficient quality and low productivity of this technological operation [19], and hence low efficiency [20]. In order to determine the influence of design and technical parameters of the spraying section of the device on the quality of its work, an experimental sample of a device for applying herbicides to the stem-interstitial strips of the garden with two spraying sections was attached and mounted on the front of the tractor frame.

2. Materials and methods

The spray section (figure 1) consists of a rear 1 and front 2 protective covers connected by a frame 3, which in turn is attached to the mechanism for holding the section in the desired position. To increase the width of cultivation and ensure the necessary uniformity of distribution of the chemical, two sprayers 4 (figure 1) are installed in the upper part of the section at a height $h_1$ above the soil surface and the angle of the saw $\alpha$ relative to the horizontal plane. To process the interstitial strip, the section is equipped with an additional sprayer 5 (figure 1).

![Figure 1. Scheme of the spraying section (side view) and placement of sprayers relative to the horizontal plane (surface of treatment): 1, 2 – protective casings; 3 – connecting frame; 4 – section sprays; 5 – additional spray.](image)

The quality of the device was determined by the parameters of density and uneven coverage of the surface to be treated. The study was performed in the field using indicator paper Spray test paper from the Dutch company Hardy. The coating density (pcs/cm$^2$) was determined by counting 200–300 μm droplets on indicator paper using a microscope.

The dispersion of the spray was determined visually by comparing the droplet size with their sample of known size. The degree of non-uniformity of the coating was evaluated by the coefficient of variation. During the research, the indicator strips were placed on a straight perpendicular axis line of a number of plants at a distance of 0.10 m from each other, and the distance between the extremes was 1.90 m.
As a result, it was found that the density and unevenness, and therefore the quality of treatment of liquid droplets of zone "a" (figure 2) depends on the type of sprayers, their performance, location on the working section, direction of spraying and pressure of working fluid.

The required quality of processing, namely the effective density of the coating of the treatment plane with drops of test size (200–300 μm) provide the following components: type of spray – flat jet; cut angle – 110°; productivity at a pressure of working liquid of 0.2 MPas – about 1 l/min; speed of movement of a tractor (working section) – 1.0–1.3 m/s; height of placement of sprays above the plane of processing (h1) – 0.25 m; the angle of the sawing direction relative to the horizontal plane (α) – 40°; the distance between the sprayers (b) – 0.35 m; the width of the working section (a) – 0.8 m.

![Axial line of a number of trees](image)

**Figure 2.** Scheme of the spray section (top view) and its location relative to the centerline of a number of trees.

### 3. Results

As can be seen from the presented material (figure 3, curve 1), the density of coating drops of the test size of the processing plane, which is within the zone "a", in compliance with the above parameters, is in the range of 80–120 pcs/cm² (minimum agricultural requirements), coating density –30 pcs/cm², which is sufficient to ensure the required quality of the technological operation.

To ensure the treatment of the entire stem-interstitial strip, the spray section must be equipped with an additional spray directed in the direction of the location of the protective and interstore zone "c". Its optimal parameters are:

- Type of spray – flat jet;
- Cutting angle – 110°;
- Productivity at a pressure of working liquid of 0.2 MPas – about 0.5 l/min;
- Height of placement above the plane of processing – 0.13 m;
- Angle of the sawing direction relative to the horizontal plane – 25–35°;
• The angle of inclination of the plane of the spray torch relative to the horizontal plane – 10°.

Curve 2 (figure 3) characterizes the distribution of the density of the droplet coating of the surface of the interstitial strip by an additional spray.

Accordingly, curves 3 and 4 (figure 3) correspond to the distribution of the drop density of the surface of the other half of the stem-interstitial strip, which occurs when the unit moves along the adjacent row spacing in the opposite direction, respectively, additional and main sprays section.

Curve 5 (figure 3) is the result of the distribution of the density of the coating of the drug stem-interstitial strip (that part of which was observed) when performing the spray section of the full cycle of treatment.

**Figure 3.** Density of coating of drops of a surface of processing depending on distance concerning an axial line of a number of trees at a full cycle of processing of a trunk and inter-trunk strip: 1, 4 – operation of sprayers of section (zone a); 2, 3 – operation of an additional spray (zone c); 5 – operation of all sprayers of section.

4. Discussion

According to the results of experimental studies, it is confirmed that the developed device in compliance with the optimal parameters [21] and modes of operation provides the required quality of the technological operation [22]. The density of the coating with test drops of the treatment plane is in the range of 100–120 pcs/cm², and the unevenness of the coating (coefficient of variation) does not exceed 6% [23, 24].

The authors confirmed that the dispersion of the spray is also satisfactory [25]. About 90% of the total liquid covered by the treatment surface settled in the form of droplets [26], the size of which is in the range of 100–300 μm, which is optimal for this process [27]. To ensure the required efficiency of use of the device in gardens of both intensive and traditional types [28], the section sprayers are connected to the pressure line individually and can be, if necessary, disconnected from it [29].

Therefore, the section can operate in three modes depending on the required processing width of the stem-interstitial strip [30]. The width of the treated strip during the operation of the section with one sprayer is 0.5–1.0, with two 1.0–1.5, with three – 1.5–2.0 m. Production tests were carried out in the experimental plantations of the orchards of National University of Life and Environmental Sciences of Ukraine. The total area of the cultivated garden was about 10 hectares. Age of trees is 5–12 years, width between rows is 4–5 m. Keeping the soil between rows is a natural turfing.
The use of the developed device in comparison with the existing means of chemical treatment of the stem and inter-stem bands allows to reduce the cost of the active chemical substance by 30–40% [31]. Application of Roundup with a dose of 5 l/ha of the treated area gave the treatment efficiency of 96%.

5. Conclusion

Ensuring the treatment of the entire stem and inter-stem strip of orchards is carried out by a chemical treatment machine with spray sections, which are equipped with additional sprayers directed in the direction of the location of the protective and stem stem. The optimal parameters of such additional sprays are: type of spray – flat jet; cutting angle – 110°; productivity at a pressure of working liquid of 0.2 MPas – about 0.5 l/min; height of placement above the plane of processing – 0.13 m; angle of the sawing direction relative to the horizontal plane – 25–35°; the angle of inclination of the plane of the spray torch relative to the horizontal plane – 10°.

The density of the coating with test drops of the plane of treatment by a chemical treatment machine with spray sections are in the range of 100-120 pcs/cm$^2$, and the non-uniformity of the coating does not exceed 6%. The dispersion of the spray is satisfactory. About 90% of all protective chemical liquid, which covers the surface of the treatment, settled in the form of droplets, the size of which is in the range of 100-300 μm.

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