A device for harvesting and utilization of non-grain part of crop and fertilization

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Abstract. An effective method of harvesting grain crops using straw for fertilization, which can be carried out by installing a device on the harvester for spraying the crushed straw mass with a working liquid using a pneumatic slot sprayer designed in Kuban State Agrarian University. The device and the process of operation of this device with pneumatic slotted sprayers of working fluid are considered. Various parameters of sprayers have been studied: the air pressure supplied to the spray jet and the position of the equalizing tank that regulate the static pressure of fertilizers for setting the specified flow rate.

The high efficiency of mechanized technology of using straw for fertilization has proved by long-term researches of scientific institutions of the region. It allows you to stop the degradation of Kuban chernozems, contributes to increasing crop yields by 15-20% and production efficiency.

However, a successful solution of the problem of using straw should be considered in connection with the harvesting of grain crops, which defines the role of the harvester in this process.

In these recommendations, we offer the most effective options for harvesting grain crops using straw for fertilization and straw harvesting, taking into account the agrotechnical and zootechnical requirements.

Periodic application of straw in a year in the amount of 5 t / ha on non-fertilized soil restrained the loss of humus, but did not completely prevent them. Application of straw 5 t / ha in combination with mineral fertilizers (N90P52K36) provided a deficit-free balance of humus in the soil.

It was also noted that the use of straw restrains soil acidification and improves the quality of humus, as well as traditional organic fertilizers and manure Fig. 1.

The researches have also shown that straw plowing in 5 t/ha without additional nitrogen did not significantly affect the yield of crop rotation, and adding it with nitrogen significantly increases the yield of agricultural crops.

A combined harvesting process is recommended to reduce the energy consumption spent on the process of harvesting grain crops with shredding straw and further restoration of the soil fertility by applying fertilizers to the straw and then embedding it in the soil. It is based on the modernization of the harvester with the installation of a device for crushed straw processing by the harvester during its movement from the crusher to the surface of the field with straw treated by nitrogen and other basic fertilizers, micro-fertilizers and other chemicals that help to accelerate the restoration of soil fertility.
The technical result is achieved by the fact that the device has pneumatic slot sprayers that create an air-drop jet that processes crushed straw, which moves from the crusher to the harvester and is scattered across the field after being treated with chemicals and biological remedies for disposal [1].

The device has a hydraulic pipe through which the working fluid for straw processing comes from a tank mounted on the roof of the harvester through an equalizing tank for regulating static pressure to the sprayers [1] or a jet-forming device [2].

To create an air-drop jet, an air stream is supplied to the sprayers from the compressor of the harvester through a receiver and a pressure regulator by a pneumatic pipe, through which the working fluid is injected and dispersed.

![Diagram of a harvester with a device for spraying crushed straw.](image)

**Figure 1.** Diagram of a harvester with a device for spraying crushed straw.
1-cabin, 2-chopper, 3 – tank, 4-equalizing tank, 5-pneumatic and hydraulic drives, 6-sprayer, 7-collector, 8-compressor, 9-receiver, 10-pressure regulator

The formed air-drop jet processes the crushed straw mass.

In this way, the non-grain part of the crop is prepared for utilization in the soil to increase its fertility.

For processing crushed straw with working fluids with subsequent sealing, various preparations are recommended, in particular, "Sternya 12"; KAS-32, which in its composition has nitrogen, potassium, various bacteria and microorganisms. The rate of consumption of the chemical is 1.5 l/ha with a rate of flow of the working fluid of 200 l/ha.

To adjust the device to the specified rate, it is necessary to regulate the flow of working fluid from the tank to the sprayers. The working fluid flows out of replaceable feeding tubes with diameters of 2, 3, 4, 5 mm. To change the pressure of the working fluid may change the working fluid may change the position in height of the surge capacity relative to the air nozzle of a stream converter. The flow rate of the working fluid is also affected by the air pressure from the slot nozzle, the parameters of which are set by the pressure regulator in the range of 1.5; 2.0; 2.5; 3 bars [3].

To analyze the quantitative parameters of straw spraying process with working liquid, namely, determining the flow rate (l/min), the study was conducted of the dependence of the sprayer liquid flow on the pressure and the position of the equalizing tank Fig 2.

The necessary parameters of the working fluid flow by the spraying device were determined by planning a two-factor experiment.
For setting up a two-factor experiment, a symmetrical composite plan of the type $B_k$ was chosen. Factors, intervals, and levels of variation are shown in Table 1.

**Table 1.** Factors, intervals and levels of variation.

| Variable factors          | Coded symbols, $x_i$ | The range of variation in $\Delta_i$ | Variation levels |
|---------------------------|----------------------|--------------------------------------|------------------|
| Position of the equalizing tank, $h$, mm | $x_1$ | 1 | +10 | 0 | -10 |
| The pressure, $P_i$, bar  | $x_2$ | 0.5 | 1.5 | 2 | 2.5 |

The factor levels were selected so that their optimal values, taking into account existing restrictions, entered the center of the range of variation.

Factor encoding was completed:

$$x_i = \frac{X_i + X_{i0}}{\Delta_i},$$  

where $x_i$ – encoding value of the $i$ factor;

$X_i$ – natural value of the $i$ factor;

$X_{i0}$ – natural value of the $i$ factor in the center of the experiment’s plan;

$\Delta_i$ – interval of the factor’s variation.

The experiment planning matrix and experiment results are presented in Table 2.

**Table 2.** Matrix of experiment planning and the results of experiments.

| №  | Natural values of factors | Encoding of values of factors | Response, ml / min |
|----|--------------------------|-------------------------------|-------------------|
|    | $d_i$, mm                | $P_i$, bar                    | $x_i$  | $x_2$ |               |
| 1  | -10                      | 2.5                           | +1     | +1    | 598             |
| 2  | +10                      | 2.5                           | +1     | +1    | 538             |
| 3  | -10                      | 1.5                           | +1     | -1    | 620             |
| 4  | +10                      | 1.5                           | +1     | -1    | 532.5           |
| 5  | -10                      | 2                             | +1     | 0     | 620             |
| 6  | +10                      | 2                             | -1     | 0     | 548             |
| 7  | 0                        | 2.5                           | 0      | +1    | 927             |
| 8  | 0                        | 1.5                           | 0      | -1    | 536             |
| 9  | 0                        | 2                             | 0      | 0     | 945             |

The experiment was performed at the position of the sprayer relative to the equalizing tank at +10; 0; -10 cm (Fig. 3). Air came to the sprayer from the compressor through the pressure regulator, its value was taken in 1.5; 2; 2.5 bars. After setting the necessary parameters, the liquid was fed through the equalizing tank and air by a compressor through the pressure collector directly to the sprayer.
After mathematical processing, we get a regression equation for the performance of the sprayer.

\[ y = 943,78 + 90,17x_1 + 4,33x_2 + 6,75x_1x_2 + 360,2x_1^2 - 11,66x_2^2, \]  

(2)

where \( y \) – liquid flow, ml/min;
\( x_1 \) – position of the equalizing tank, mm;
\( x_2 \) – air pressure, bar.

We tested the hypothesis about the statistical significance of the obtained regression coefficients according to the Student’s \( t \)-criterion. We tested the hypothesis of adequacy of the obtained equation (2) by the Fisher’s criterion.

Substituting the values \( x_1 \) and \( x_2 \) in the original regression equation, we found the values of the optimization parameter at the extremum of the response surface at the value of the free term of the canonical equation \( Y_s = 949.34 \) ml/min [4].

The response surface has the form of a hyperbolic paraboloid, and the smallest value of the response function is located at the point with coordinates: \( x_1 = -0,12376; \ x_2 = -0,14994 \).

We considered the response surface (Fig. 3) near the optimal values of factors using two-dimensional sections (Fig. 4).
Figure 4. Two-dimensional cross-section of the surface of the dependence of liquid flow on the position of the equalizing tank (h) and air pressure (P1)

The regression equation describing the process of influence of factors on the flow rate of the working fluid and displaying in an oxanometric (volumetric) image, does not allow you to perform tuning operations of the sprayer.

Accordingly, according to the results of the study, the graphs Fig. 5 and Fig. 6 are constructed.

Figure 5. Chart of the working fluid flow depending on the position of the equalizing tank G = f (h)

The graph (Fig. 5) shows a parabola within h (the position of the equalizing tank) from -10 to +10 cm, which shows that the maximum flow rate G is 949 ml/min at the position of the equalizing tank, respectively is 0.

The minimum flow rate G = 590 ml / min can be obtained at a minimum pressure of 0.15 MPa and the position of the equalizing tank +10 Fig. 6.
Figure 6. Chart of the working fluid flow depending on the pressure.

The graph in figure 6 shows an almost linear relationship with a slight change in fluid flow from pressure, but with an effect from 470 to 940 depending on the pressure, which varies from 1.5 to 2.5 bars.

Conclusions
The optimal parameters of a pneumatic slot sprayer were determined experimentally by setting a two-factor experiment on a symmetrical composite orthogonal plan. When the parameters of the air nozzle are 5 mm wide and 1 mm thick and the diameter of the feed tube is 5 mm. The optimal operating parameters of the sprayer were found: air pressure 0.2 MPa and the position of the equalizing tank - 0.

To set up the device for a harvester for fertilization and straw utilization, it is necessary to use 3 sprayers with a flow rate of 943.4 mm per sprayer at a speed of 6 km/h and a working fluid flow rate of 200 l/ha.

Modernization of the harvester by installing a device for crushed straw processing with fertilizers in order to dispose of it in the soil will reduce the energy intensity of combined harvesting of grain crops in comparison with a separate cleaning process and reduce the unit labor costs and operating costs.

References
[1] Patent Rus 2552081 Device for harvesting grain crops and utilization of non-grain part of the crop / G. G. Maslov, E. I. Trubilin, S. M. Borisova - 2006, Bul. #16.
[2] Patent Rus 2709982C1 Device for harvesting grain crops and utilization of non-grain part of the crop / S.M. Borisova, S.K. Papusha, A.S. Serguntsov, V.K. Papusha / - 2019, Bul. # 36
[3] Patent Rus 2058740 Sprayer / G. G. Maslov, S. M. Borisova, G. V. Tarasenko. - 1996, Bul. # 26.
[4] Patent Rus 2227455 Ultra small volume sprayer / G. G. Maslov, S. M. Borisova, A.K. Mechkalo. - 2006. Bul. # 14.