Research on the measurement of spraying time with seed treatment agent using an innovative valve

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Abstract. The demand for agricultural products increases with limited access to agricultural land. As a result, there is an increase in yield owing to new techniques applied to agriculture, i.e. precise seed potatoes treatment. For this purpose, the dressing of seed potatoes was tested using the author’s method of checking the quality of spraying with dressing agent and improving seed coverage. In the hereby work, the method of image analysis was used to detect the movement of particles of working liquid. The article presents a test stand for measuring spraying time after exiting an innovative pressure-pneumatic valve using image analysis. The analysis was made using a fast Cronos 1.4 camera. The subject of the research was the construction of the station and evaluation of the work of the innovative pressure-pneumatic valve in two configurations: without the addition of compressed air and using additional compressed air.

1. Introduction

The areas that served as the basis for the production of agricultural produce are increasingly being replaced by the development of roads, rail, and air infrastructure. This is due to the continuous increase in population and the desire to develop [1, 2]. The dynamic development of agriculture, including precision agriculture, puts economic and ecological factors on the pedestal and affects the development of more accurate technologies. In Poland, the area of potato cultivation decreases year by year [3], so the production potential should be used to the best. Crop standards for the amount of plant protection products used also have a large impact on the cultivation of agricultural produce. Currently, the protection of potatoes against viral, fungal, and pest diseases is reduced to the use of fungicides, zoocides, herbicides in the form of spraying on the above-ground part of the plant. Very often, these treatments are repeated many times due to adverse weather conditions, which means that the standards for the amount of plant protection products are exceeded. Along with the development of agricultural machinery and plant protection products, more and more often preventive measures are more ecological. One such action is the use of seed treatment (chemicals) for seed potato tubers. Properly constructed devices, in particular for applying these agents by the intermittent method, can significantly reduce the use of chemicals without losing the effectiveness in disease and pest control. In order to increase production capacity, modern technologies may be implemented; for instance, a modern pneumatic-pressure valve to improve the coverage of the potato with seed treatment at the time of planting. For this process to take place efficiently, the process of spraying droplets should be examined at the time of potato treatment. The main goal is to develop the concept and build a station for comparing the time of cone development during spraying on potato tubers for a standard valve and using an innovative valve.
with an auxiliary air stream. The research will involve the use of a fast camera, which has already been used in similar tests concerning the potato dressing process [4], or the potato size assessment itself [5], followed by an analysis of the obtained image. Image analysis can be used in a very wide range, for example, for identification, dimensional measurements and quality assessment of kernels, tubers, vegetables and fruit [6-13], pest identification [14], and also to assess the quality of muscles and joints [15, 16], to evaluate the effects of drying processes [17, 18], as well as for the assessment of cavitation erosion. This research method should not be considered as limited to the subject of potatoes, it can also be used to analyse other products such as powders [19, 20]

2. Material and research methods

The stand reflects the process of spraying potatoes during planting using a standard valve and using an innovative valve with an auxiliary air stream.

To determine the optimal cone development time during spraying, measurements were planned and carried out at operating pressure settings of 0.2 and 0.3 MPa as well as compressed air 0.15, 0.175, 0.25, 0.275 MPa. Water was used as the test liquid because it has similar properties to the seed treatment agents, i.e. water and chemical agent. An innovative pressure-pneumatic valve was used for testing to reduce the time required to obtain a full water spray cone. Tests without compressed air have also been carried out. To capture the start moment, spraying water from the valve and determining the moment when the cone that develops during spraying fully developed, a fast Cronos 1.4 camera with a resolution of 1280x1024 at 1057fps was used. A photographic screen on a stand was not used during the research.

The scheme of the test stand, which was constructed for measuring the time of cone development during spraying the agents (water) is shown in Figure 1, and the actual picture of the stand, in Figure 2. The stand consisted of: a water tank (1), a circulating pump (2), innovative pneumatic-pressure valves (3), Cronos 1.4 high-speed camera (4), compressed air tank (5), pressure regulator for water (6), pressure regulator for compressed air (7) and two LED lighting lamps with a stabilising system (8). The whole station was powered by 12V voltage. The voltage value has been selected so that the pressure-pneumatic valve (4) as well as its controller and circulation pump (2) with the tank (1) can be mounted on the agricultural tractor. Besides, there were pressure regulators (6) and (7) at both the pump outlet (2) and the compressed air tank outlet (5).

Preliminary tests were carried out for various settings of water pressure and compressed air values, which allowed indicating in the case of working fluid (water) the working pressure in two pressure values, 0.2 MPa and 0.3 MPa. For compressed air, the range was set for 5 pressure values. The range of these values was 0 – 0.275 MPa. Detailed settings of working fluid (water) pressure and compressed air pressure are shown in Table 1.

![Figure 1. Scheme of the test stand: 1 – water tank; 2 – pomp; 3 – pressure-pneumatic valve; 4 – high-speed camera; 5 – compressed air tank; 6 – water control valve; 7 – air regulating valve; 8 – lamp.](image-url)
During the tests on the stand presented above, a film was recorded with a speed of 58 frames per second, data transfer rate 4.82 Mb/s, frame size 496x240 set by the camera software to frame the object in detail. When framing the resolution and frame rate decreased concerning the maximum capability of the camera. The Cronos 1.4 camera was equipped with a lens with ISO 740, 6-60 mm f/1.7 parameters. During the tests, the lens was located at a distance of 70 cm from the innovative pressure and pneumatic valve, which is protected by patent law PL 219 769 B1. The focus was set by the standard lens setting. The acquired images extracted from the recorded film were analysed in the Video Editor. The method consisted in selecting a picture frame on which the moment of the start of atomisation of the liquid from the valve was captured, and then selecting a frame in which the atomisation obtained the largest possible cone. The reading of individual frames of the recorded film, which showed the formation of a cone of the analysed liquid, was carried out manually. There was no need to use image analysis algorithms here. By analysing the number of frames, the time to develop a full cone of working liquid (water) was obtained. Figure 3 shows selected film frames for a water working pressure of 0.3 MPa but without the use of compressed air (air pressure 0 MPa). In Figure 3a the initial stage of cone development is presented, while in Figure 3b its maximum size when sprayed from an innovative pressure-pneumatic valve.

Figure 4 shows the selected film frames for water working pressure of 0.3 MPa and compressed air pressure of 0.275 MPa. In Figure 3a, there is the initial stage of cone development, and in Figure 4b its maximum size when spraying from an innovative pressure-pneumatic valve.

| Table 1. Pressure settings used in research. | Water pressure, MPa | Air pressure, MPa |
|---------------------------------------------|---------------------|------------------|
| Series no.                                  |                     |                  |
| Series 1                                    | 0.2                 | 0                |
|                                              | 0.3                 | 0                |
| Series 2                                    | 0.2                 | 0.15             |
|                                              | 0.3                 | 0.25             |
| Series 3                                    | 0.2                 | 0.175            |
|                                              | 0.3                 | 0.275            |
Figure 3. Image for analysis at 0.3 MPa water working pressure without compressed air: a) start of spraying; (b) expanded spraying.

Figure 4. Image for the analysis of water at an operating pressure of 0.3 MPa, 0.275 MPa compressed air: (a) start of spraying; (b) expanded spraying.

3. Results
As a result of image analysis of individual frames, the time after which the maximum spray liquid cone developed during spraying from the valve for individual test series was determined, which was 1.9 s for the first series, 0.41 s for the second series, and 0.34 s for the third series. Results for water working pressure at the level of 0.2 MPa are shown in Figure 5. Standing in contrast, Figure 6 shows the development time of the maximum cone for a working pressure of 0.3 MPa, which was 1.8 s for the first series, 0.49 s for the second series, and 0.34 s for the third series.

The first series of tests was generated during the operation of the valve without compressed air for a working pressure of 0.2 MPa and 0.3 MPa. Series 2 is the results of tests using additional compressed air at a level less than the water pressure by 0.05 MPa. Series 3 are tests also carried out with compressed air, but its value has been reduced by only 0.025 MPa.
4. Conclusions

Measurement of the time to obtain the maximum cone when spraying water from the innovative pressure-pneumatic valve showed that by using the innovative valve with compressed air, the time to obtain the maximum cone can be reduced three times. The time of formation of the maximum cone decreased by about 1.5 seconds in comparison with the first series of tests concerning the second and third series of tests. Thanks to this solution, the use of an electronically intermittent stream of outflow of the working liquid can be used and finds the application.

The developed method and test stand are suitable for determining the time of development of a full spray cone of liquid from pressure, pressure-pneumatic valves, as well as can be used in many other fields of science and industry, e.g. for analysis of propagation time, disturbance of flow or analysis of two-phase liquid flow – solid.

Tests in which no additional compressed air was used show how and at what time the spraying of working liquid will be carried out using a standard valve. It can be seen that the use of a normal valve (without compressed air) requires more time to reach the maximum taper and therefore has greater inertia.

The use of an innovative pressure-pneumatic valve which has lower inertia, which causes faster development of the maximum cone during spraying, causes more precise coverage of anything with working liquid. An example of this is the seed potato dressing process (water and chemicals). The planting process is continuous, and the valve operation is interrupted to reduce the number of chemical agents used. Therefore, this has an advantage for the environment as fewer chemicals go directly to the soil and for the farmer as fewer chemicals are to buy for seed potato treatment.

Figure 5. Comparison of the average time to reach the maximum spray cone from an innovative pressure-pneumatic valve at a working water pressure of 0.2 MPa. Series 1 – compressed air pressure 0 MPa, series 2 – compressed air pressure 0.15 MPa, series 3 – compressed air pressure 0.175 MPa. The standard deviation for these studies was 0.87.

Figure 6. Comparison of the average time to reach the maximum spray cone from an innovative pressure-pneumatic valve at a working water pressure of 0.3 MPa. Series 1 – compressed air pressure 0 MPa, series 2 – compressed air pressure 0.25 MPa, series 3 – compressed air pressure 0.275 MPa. The standard deviation for these studies was 0.80.
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