Use of Digital Technologies to Improve Efficiency of Potato Production on Private Plots

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Abstract. In Russia, potato is the second economically important crop, which is widely cultivated not only on commercial fields, but also on numerous private plots, which produce a doubled potato yield comparing to agricultural companies. Nevertheless, during the last 30 years, the total potato production in Russia reduced by 40%. In the case of private plots, potato production reduced by even more then 50%. One of the possible reasons is that potato is difficult in cultivation and is susceptible for a number of diseases able to significantly reduce the yield quantity and quality. This paper describes a new approach to the crop protection based on the use of digital technologies to control the early and late blight of potato and to reduce the negative influence of excess fungicides on the human health and environment.

1. Introduction

Potato is one of the strategic crops in Russia important for the food safety of the country. The crop is widely used in the food and forage industry, as well as for the alcohol and starch production. As a forage crop, potato has a benefit of a high-yield crop, which exceeds in this aspect all other forage crop excepting sugar beet and has a high nutritional value. Potato and waste potato from the food and technical industry are widely used for feeding of pigs, cattle, and sheep. Due to a high content of easily digestible protein (75–92%), use of potato for feeding of pigs provides better lactation and good weight gain rate [1,2].

The crop capacity of potato and the quality of harvested is significantly influenced by various potato pathogens. The most important and devastating diseases of a potato foliage are the late blight caused by the oomycete Phytophthora infestans and the early blight caused by fungi Alternaria solani and A. alternata. In Russia, as well as in the whole world, both diseases are controlled mainly by fungicide applications. Since these pathogens are very dangerous and aggressive, potato growers often use multiple fungicide treatments. For example, schemes of potato protection against the late blight used in the Western Europe include 12–18 fungicide applications per a year (Table 1).

Table 1. Number of fungicide applications on potato fields in some Western Europe countries [3]

| Country      | Number of applications in Western Europe |
|--------------|------------------------------------------|
|              | 2004 | 2005 | 2006 | 2007 | 2008 | 2015 | 2016 |
| Belgium      | 15   | 16   | 12–16| 18   | 15   | 13   | 16   |
| Germany      | 2–10 | 1–10 | 4–7  | 4–18 | 7    | 9    | 13   |
| Netherlands  | 10–15| 8–14 | 7–20 | 15   | 15   | 14   | 16   |
| Great Britain| 4–14 | 5–14 | 8–12 | 9–10 | 10–11| 12   | 9    |
The negative influence of fungicides on human health and environment and their high cost resulted in the need to search for new technologies which would provide a significant optimization of the number of fungicide applications while maintaining acceptable levels of potato production and quality.

2. Use of Decision Support Systems and its advantages

One of the popular and widely applied solutions is the use of digital decision support systems (DSS). In Russia, as well as in other countries, many agricultural companies and farmers already use DSS to control potato diseases. These information systems make it possible to predict disease outbreaks, i.e., to protect plants only prior these periods, and to choose fungicides, which met to the anti-resistance strategy and sanitary limitations [4,5]. For example, the Agrodozor DSS service (https://agropatrol.com/) developed at the All-Russian Research Institute of Phytopathology on the basis of the previous DSS VNIIFBlight provides a 1.5–2-fold reduction of the number of protective treatments while keep a low risk of the late blight re-infection (Table 2) [6,7].

Table 2. Efficiency of the Agrodozor DSS use to reduce crop losses and spraying costs [3]

| Parameter                              | Routine treatment (every 7–10 days) | DSS use in seasons favorable/unfavorable for the late blight outbreaks |
|----------------------------------------|-------------------------------------|---------------------------------------------------------------------|
|                                        | unfavorable                         | middle                  | favorable               |
| Reducing of the crops losses (compared to the control fields) | > 90%                              | > 90%                   | > 90%                   |
| Spraying number                        | 6                                  | 3                      | 3.5                     | 4.2                     |
| Spraying costs (rub/ha)                | 20-25                              | 10-12                  | 13-14                   | 16-17                   |
| Toxic index                            | 928                                | 246                    | 504                     | 699                     |

However, today the use of state-of-the-art technologies for improved potato protection is limited by large agricultural producers. Owners of small private plots, who grow 2/3 of the total potato yield in Russia, do not use such technologies applying instead the approaches developed 20–30 years ago. As a result, the crop capacity of potato grown on private plots is 1.5–2-fold lower than in large companies. Note that 30 years ago the situation was quite opposite, and the crop capacity on private plots exceeded that in large companies in the same 1.5–2 times.

To correct this situation and to provide a significant increase of potato yield in a private owner sector, the following measures should be taken:
1. Adaptation of commercial DSS for non-professional users and their availability to a wide range of countrymen.
2. Development of new Internet services assisting countrymen to improve the efficiency of potato growing and including an interactive geoinformation system and cartographic services.
3. Conducting of active educational work among private plot owners intended to popularize the use of modern potato-growing technologies including digital services.

The accomplishment of these tasks became the aim of the researchers from the All-Russian Research Institute of Phytopathology.

3. Adaptation of commercial DSS to the needs of the private plot owners

To make the latest digital DSS technologies (including VNIIFBLIGHT DSS) to be extremely simple and user-friendly, an online DSS (www.agropatrol.com) was developed at the All-Russian Research Institute of Phytopathology.

To provide users with the most suitable and convenient solution, this online interactive service collects different data, such as the weather forecast, information about fungicides and potato cultivars, data obtained from potato growers, etc. After entry into the system, potato growers can find all
necessary recommendations updated at a daily basis. An interactive dialogue system provides a possibility to specify local recommendations for each potato field.

In spite of a user-friendly interface, this service could not be used by unprofessional potato growers, since mathematical models used for the risk calculation and formation of recommendations were based on agrotechnologies used by commercial agricultural companies. To adapt the service to technologies used by unprofessional potato growers, some new models were added to the system:

1. Recommendations of the service include commercial names of fungicides approved for use on private plots instead of the names of active substances of fungicides;
2. Analyzing the phytopathogenic situation, the system makes some corrections in relation to the expected higher density of plants typical for private plots and higher risks for the spreading of infection from near-located potato fields;
3. The resulted recommendations of the system do not take into account agrotechnical approaches, which are not used for small plots (for example, sprinkling irrigation).

Thus, the scenario for the user's work was simplified to make commercial DSS more understandable and intuitively comprehensible for unprofessional users.

4. New geoinformation services

Along with the adapted DSS version, our task included the development of additional services, which could be used by unprofessional potato growers to improve potato protection efficiency.

Today researchers from the All-Russian Research Institute of Phytopathology prepare to develop VNIIFBlight-based online cartographic services providing a user with a real-time possibility to assess the current risk of occurrence and development of the most harmful potato diseases at an arbitrary geographical point, as well as to get a forecast of changes in the phytosanitary situation (Fig. 1). Using such maps, unprofessional potato growers will be able to quickly assess the risk of the leaf blight development and, in the case of a heightened risk, to form a good-substantiated program of protective measures using the above-described adapted DSS.

5. Educational programs

Though the modern technologies significantly simplified the solving of complex agronomical tasks, they will never be able to replace an agronomist. Even in the case of the most advanced and automated services, their user should have at least basic knowledge in the field of agronomy and plant protection. Due to this reason, along with the development of modern digital-based agronomy services, All-Russian Research Institute of Phytopathology pays a lot of attention to the educational activity and
popularization of agronomic knowledge among unprofessional potato growers. In 2020, we developed a career-guidance program for the senior school called “School of young agronomists “Agrodozor” (http://school.agropatrol.com/). Since that time, more than 200 pupils from >30 schools from different regions of Russia have been trained within the framework of this program. Students took theoretical courses, learned how to work with modern digital agronomical services, and also applied the obtained knowledge on practical studies.

6. Conclusion
The mass use of digital technologies in plant growing allow potato growers to significantly increase the yield of the crop and to reduce costs of protective activities due to the application of scientifically substantiated adaptive programs of crop protection. Simple and user-friendly digital technologies can be successfully used not only in the commercial agricultural sector, but also for potato growing on private plots.

7. References
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