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INFORMATION TECHNOLOGIES OF REMOTE ASSESSMENT OF HERBICIDE CONSEQUENCES ON WINTER RAPE CROPS

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Abstract. *A separate group of substances with potential phytotoxicity are herbicides. These chemicals contain potent biologically active substances designed to destroy certain types of vegetation. Residues of some of these substances can be stored in the soil for several years, showing interaction with other substances and, undesirably, a negative effect on cultivated plants. With increasing use and range of herbicides, the risk of aftereffects increases significantly. A clear description of the drugs, the mechanism of their action is indicated in the regulations of their use. However, in production, as a rule, there are subjective and objective factors, as well as a number of random factors that can lead to the manifestation of adverse effects or after-effects of drugs. In order to determine the possibility of using spectral monitoring from the platform of an unmanned aerial vehicle (UAV), research was carried out at the industrial fields and experimental experimental field of NUBiP of Ukraine, in the optical range, using the RGB camera and the Slantrange complex. The image processing was carried out using firmware (software), as well as the standard and stress indexes provided by the developer. Data obtained from the FC200 optical camera in RGB format was computed in the mathematical package MathCAD.*

It was found out that in winter crop rape, in the vegetative phase of 5-7 leaves, as a result of the action of the herbicide occurs anomalous coloring of the two lower leaves of the plant. To identify this feature in the optical range, the most informative are red and green channels. With the use of Slantrange 3 complex among the embedded stress indexes,

SlantView software is the most informative of Veg. Fraction and Yield potential. It is shown that in order to increase the reliability of the data obtained, it is advisable to carry out additional research on the parameters of debugging the given system.
Keywords: *remote monitoring, winter oilseed rape, digital camera, Slantrange, phytotoxic effect of herbicides*

Introduction. Diagnosis of the state of winter crop sowing in relation to the manifestation of the effects of chemical agents in field crop rotations and the presence of affected areas due to phytotoxic effects of herbicides introduced in previous crops in real time is extremely important for obtaining the planned harvest. Characteristically, modern crop rotation is due to compulsory technological measures and contractual obligations with the use of highly effective broad herbicides, which often causes damage to plants of subsequent crops by residues in the soil of metabolites of a complex of drugs. Thus, Diana Alberto et all (2016) [1] shows that the usual assessment of the seasonal dynamics of the effect of herbicides on a crop plant is generally not inaccurate, and toxicity is relatively difficult to determine. In the articles of E. Dumas et all (2017) [2] and Ehab Azab et all (2018) [3], on the effectiveness of the action of the newest herbicides is noted the possibility of unpredictable behavior of herbicides under different agroecological conditions, which is appropriate to consider both during the test and the use of modern drugs. Recognized herbicides, such as glyphosate, have not been sufficiently studied in terms of exposure to non-target objects and the environment. Thus, in the papers M. Milan et al (2018) [4] and E. Dumas et all (2017) [5] the toxic effect of micro-residues of certain groups of herbicides even on reproduction of marine microorganisms is shown. However, plants have a certain immunity to toxic effects, but, as noted by M. D'Alessio et all (2019) [6], they can be weakened by the action of a number of substances which get on the field with organic fertilizers.

It has been established that besides technological stresses, such as micro-residues of herbicides on crops of individual cultures, other factors also make influence, like temperature, humidity of air and soil, correlation and deficiency of nutrition elements, and others. Studies on the influence of climatic factors on the effectiveness of modern plant growing have become relevant in recent decades and reliably manifested climate change. Thus, the effect of temperature and humidity on the state of wheat crops, which is most often used in crop rotation along with rape, is given in the works of F. de Mol et all (2018) [7], Muhammad Arshad et all (2018) [8] and Xiangying Xu et all (2018) highlighted changes in the organogenesis of plants with intensive technologies [9]. Similar studies directly on rape were conducted by B. Sharif et al (2018) [10], E. Poisson et all (2018) [11].

The feature of the use of mineral nutrient maps for the diagnosis of stress states is reflected in M. Cherni et all (2019) [12] and Yufeng Li et all (2019) [13].

According to the results of observations described by J. Doltra et all (2019) [14] and Sara Minoli et all (2019) [15], certain stressful conditions of field crops can be leveled to some extent by the implementation of appropriate technological measures. The control of which is determined by the results of the remote monitoring of the reasons that caused the impression of plants. At the same time, major factors for successful resuscitation measures are a timely determination of the degree and intensity of the initial defeat of vegetative plants. Laboratory analysis for detecting micro-residues of the active substance of herbicides in soil or in a plant are relatively expensive and prolonged, which complicates the decision-making efficiency. The most promising field for monitoring industrial scale is the leaf diagnosis.

The purpose of the work is to test such hypotheses:

• the presence of characteristic phytotoxic signs especially for leaf diagnosis, which testifies to the effect of aftereffects of herbicides;

• suitability of leaflet diagnostic criteria for assessing the effects of herbicide aftereffects on winter rape crops for industrial remote monitoring using UAV.

Materials and methods of research. At this stage, leaf diagnosis based on the use of digital technologies, including machine vision devices, an overview of which is presented in the work of T. Würschum (2019) [16]. Leaf diagnosis has a certain universality and to determine the effect of chemicals on the growth and development of new crops in crop rotations. Thus, in the work of D. Bečka et all (2016) [17] is described an experience of leaf diagnostics to monitor certain infectious diseases of rape, which can be used on mobile equipment. Determination of the nitrogen nutrition state by spectral indices is given in the work of Lantao Li et all (2016) [18], where it is stated that infrared spectrum ranges are informative, besides the standard optical one. According to Yi Peng et all (2019) [19], an additional parameter for spectral analysis is the dimensions of plants determined by the index of the leaf surface of the LAI, but it's determination is usually carried out when recalculation of the spectral indices is made. Analysis of the leaves spectrum itself remove the effects of soil analysis possible for each pixel of the image that has been shown in the work of J.

Senthilnath et all (2017) [20], which were identified by filtering rows of plants. However, the identification of the dimensions for continuous cropping is complicated by more complex identification methods, such M. Han et all (2018) [21] has received positive results with regard to the use of neural networks, which requires significant computing power. It meant the proposed solutions, based on spectral monitoring, require further research, for their use in identifying stresses as a result of the aftereffect of micro-residues of herbicides.

In modern conditions, mobile work with appropriate spectral sensory equipment is used to monitor agrocenoses. Creation of robots, in particular for monitoring, is considered in the works of G. Ponomaryova et all (2018) [22] and I. Nevliudov et all (2018) [23]. When choosing the sensor equipment for the unification of equipment and cost savings, directly used as standard optical sensors, and specialized systems with filters, the method of calibration of which is presented in the works of I. Korobiichuk et all (2018) [24], V. Lysenko et all (2018) [25], D. Komarchuk et all (2019) [26]. However, along with the relatively low cost of spectrum equipment (action room) and low requirements for UAV to create an orthophoto map, it is appropriate to use cloud computing services, which requires a powerful internet channel and significant volumes of operating time. J. Enciso et all (2019) [27] shows the experience with the use of the specialized Slantrange sensor system, which is capable of creating stress-based maps directly in the field for several hours, which is essential for the evaluation of the effectiveness and effects of technological operations. However, the Slantrange complex, as compared to similar developments of the MicaSense RedEdge type, calibrated in the work of Sen Cao et all (2019) [28], does not have a measuring channel for the blue component of color. Accordingly, it is advisable to determine how the absence of such a channel will affect the reliability of the measurement results.

Experimental methodology.

Experimental area. Experimental researches were carried out on manufacturing fields in the Kyiv region (GPS coordinates: 50°15'32"N, 30°20'58"E) and on the experimental fields of the VN NUBiP of Ukraine "Agronomic research station" (GPS coordinates: 50º4'28"N, 30º13'20"E). According to production technological maps, in 2017 on individual crops was added a double dose of herbicide with the active substance methyl thifensulfuron. NUBiP in-patient station examined crops of winter rape in areas where herbicides have not been used for several years. To ensure an assessment of the stress condition due to lack of nutrients, fertilizers on the experimental site were not introduced. Before the start of the flight, crops in the experimental field were visually inspected for the absence of foreign plants (weeds) and contamination with plant residues from the previous culture. Separate areas of soil without plants were studied.

Sensory equipment and shooting modes. The following sensory equipment was used for monitoring:

• Standard RGB camera PHANTOM VISION FC200, which is the standard equipment for DGI Phantom 3+ UAV.

• Specialized equipment - complex Slantrange 3.

The research was carried out for uniform illumination and weather conditions. For PHANTOM VISION FC200, the camera was calibrated using the built-in exponometer according to the method described in in the work of S. Shvorov et all (2018) [29] (setup for PHANTOM VISION FC200 Light Source in manual mode - Fine Weather). Illumination changes for the Slantrange complex were taken into account using built-in algorithms for the development of equipment using a standard anti-aircraft sensor. The adjustment of the exposure duration was carried out by a measuring complex for each channel separately (Fig. 1), which was later used for calibration when creating stress indices.

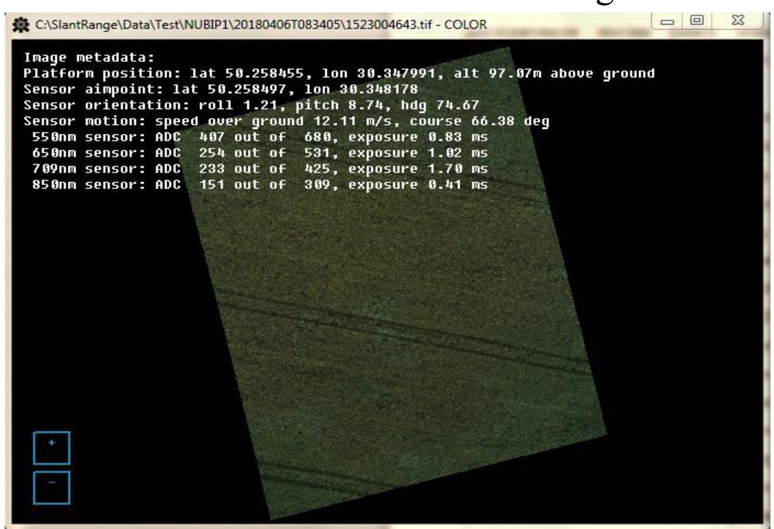

Fig. 1. SlantView image window with metadata

The UAV flight altitude during the monitoring of the experimental area in the experimental field and the field was 100 meters.

Processing of experimental data. For the processing of RGB graphic data obtained from the use of the FC200 camera, the MathCad software environment suitable for processing JPEG image data was used. The use of this mathematical software for the processing and interpretation of digital graphic data has been shown in the works of J. Agrisuelas et all (2017) [30] and in J. Agrisuelas et all (2018) [31]. The pixel analysis for the selected section of the photo, (calculating the number of pixels with the corresponding intensity of RGB for each color component) was performed using the developed algorithm and the software product created in the MathCAD environment.

Sensory system Slantrange saved the results of shooting in graphic data in the format tiff, which was used by the firmware software developer SlantView, which converted the data for correction for illumination and created maps for distributing changes in stress indices. Along with commonly accepted stress indices, such as various variants of NDVI, the company-developer also offers its own indexes of Stress, Yield potential, etc., whose calculation is based on dependencies that are their intellectual property. To facilitate the perception of area placement for the user, stress index cards are imposed as a separate layer on a satellite imagery from the Google Earth service.

On a map of stress indexes, user can get the index value for a particular field with geolocation, based on the results of the use of the graphical interface. If the values of the stress index are close to 0, there is no color of such area (Fig. 2).

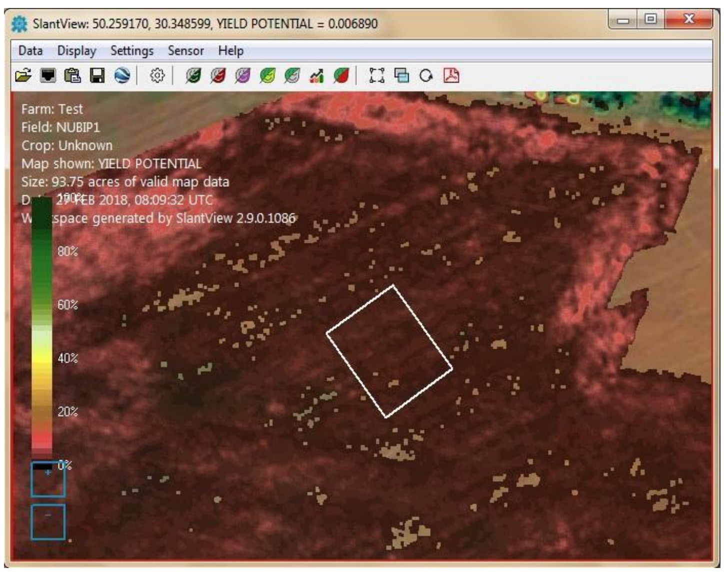

Fig. 2. SlantView map window (Yield potential)

Obtained results and discussion. The main examination of winter rape crops was made on April 20, 2018, because during this period the soil became suitable for use of ground equipment. At this time, farms should determine the feasibility of reanimation measures for damaged crops or the use of fields for sowing another culture. The fig. 3 shows photographs of rape crops in the optical range for areas with a recommended dose of herbicide and a doubling of the amount of reagent.

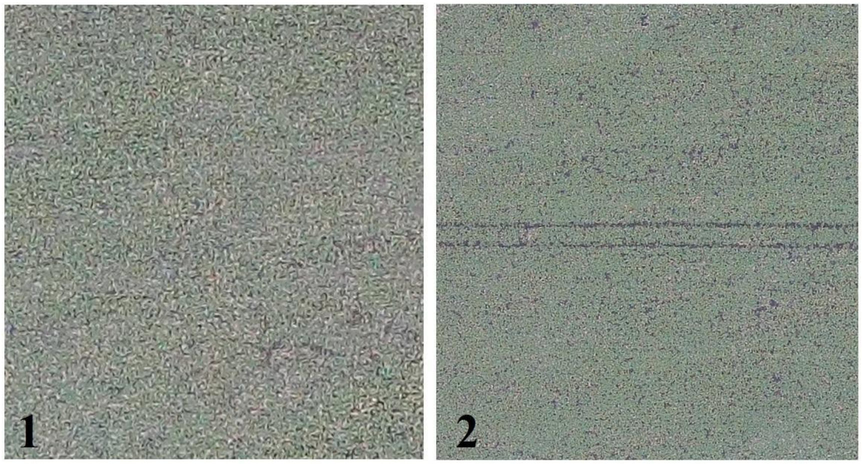

Fig. 3. Images of winter rape crops obtained by the RGB camera FC200, where: 1-double the dose of herbicides under the previous culture; 2-the recommended dosage of the drug. SlantView map window (Yield potential)

Similar images of areas from the Slantrange 3p complex are presented in Figure 4 in pseudo-colors, as there is no blue channel in the systems.

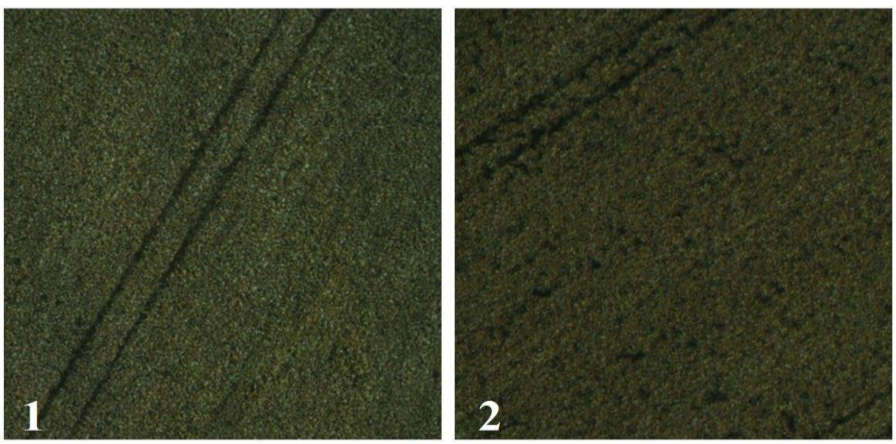

Fig. 4. Images of winter crop sown from SlantView software, where: 1-twice the dose of herbicides under the previous culture; 2.-the recommended dosage of the drug.

In the visual examination, it was found out that in the area of winter rape, where the double dose of the reagent was added, the state of plants in general is slightly worse than in areas with the recommended dose of herbicide. A special difference between the crops in these areas was the widespread change in the color of the two lower leaves of rape in plants that suffer from the effects of the herbicide. Unlike green leaves of healthy plants, in the affected areas, the two lower leaves had a milky white color. At the same time, the dimensions of these leaves were sufficient for their fixation by the presented cameras (Figs 3(1) and 4(1)).

The results of calculating the stress indexes by means of SlantView are presented in the table.

1. Stress indices of sites with different application of herbicides in the previous culture are calculated Slantview software.

№	Index	Range	Herbicide × 2	Herbicide × 1
1	Green NDVI	0 .. 1	0.61±0.03	0.64±0.03
2	Red NDVI	0 .. 1	0.60±0.02	0.64±0.03
3	Red edge NDVI	0 .. 1	0.42±0.05	0.42±0.04
4	Stress	0 .. 0,5	0.33±0.03	0.28±0.04
5	Veg. fraction	0 .. 100%	0.024±0.009	0.12±0.05
6	Yield potential	0 .. 100%	0.001±0.0008	0.09±0.02
7	Chlorophyll	0 .. 10	2.4±0.2	2.6±0.1

As can be seen from the information provided, the standard stress indices constructed on the NDVI algorithm did not provide sufficient selectivity for interpreting data on the determination of the nature of stress. The best results were obtained for the stress indices presented by the developers of the Slantrange complex (Veg. Fraction and Yield potential), where the results of the measurements for the areas had a difference several times. However, part of the plants in the area affected by the effects of herbicides, the SlantView software was identified as lost (Fig. 2), although in subsequent observations, the plants were not killed. The developers of the system provide the possibility of custom setup regarding data filtering and, accordingly, there is an opportunity to increase the selectivity and reliability of the monitoring results.

An additional way to improve the quality of the results is to take into account the dimensions of the plants, which can be recorded using laser radar and the technology described by J. Willers et all (2012) [32].

When analyzing the data obtained in the optical range, the results were compared with both the production areas and the experimental field. The results for the red channel are shown in Figure 5.

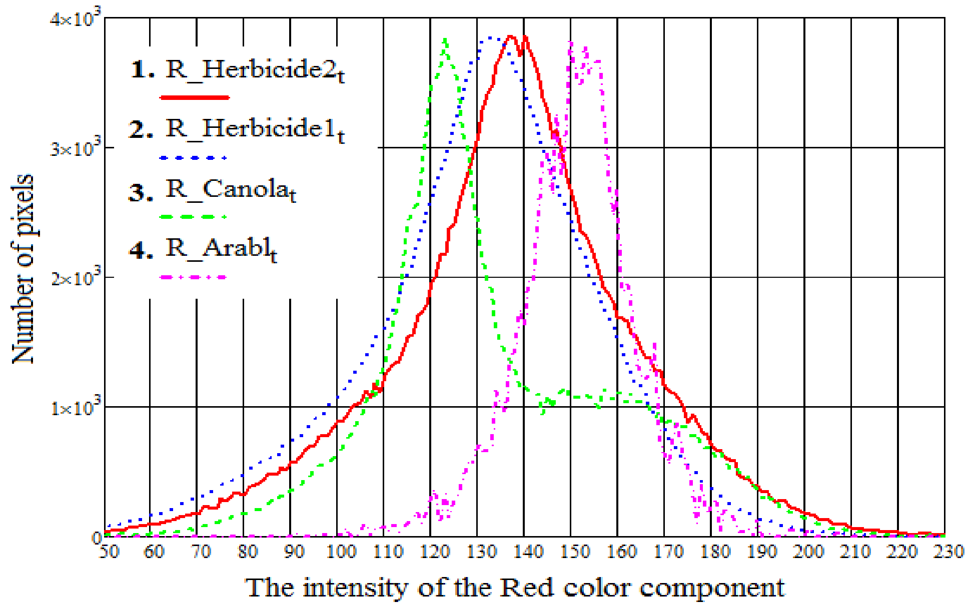

Fig. 5. Dependence of the number of pixels on the intensity of the red component of color for areas where: 1 - doubled dose of herbicides, 2 - recommended dose of herbicides, 3 - rape area with deficiency of nutrition elements, 4 - arable land

The dependence of the number of pixels on the intensity value of the color component for the experimental sites is described by the normal distribution. The difference, which is fixed for the area of crops with a lack of power, is due to the fixation of the ground in the frame due to the relatively small dimensions of the winter rape. The monitoring results for the green and blue components are presented in Figures 6 and 7, respectively. Numbers of sites are similar to Figure 5.

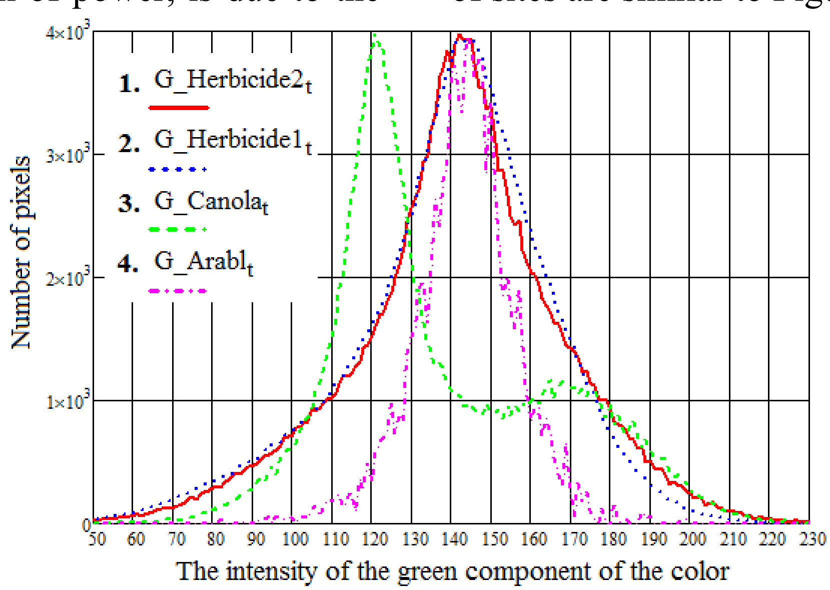

Fig. 6. Dependence of the number of pixels on the intensity of the green component of color

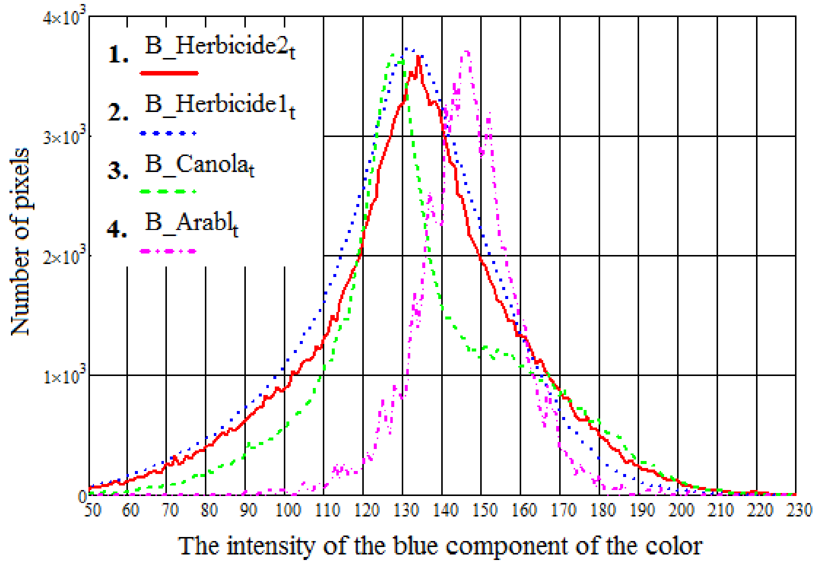

Fig. 7. Dependence of the number of pixels on the intensity of the blue component of color

Based on the data presented, the green channel of the optical range can be useful for monitoring rape crops, in particular for determining the state of mineral nutrition, but to recognize the abnormal color of a part of the leaves was ineffective.

The blue channel did not provide data selectivity and had the worst performance for soil recognition than red.

Direction of further research

The presence of a specific leaf color indicates the effect of the aftereffects of the herbicide, but for more confident fixation of this phenomenon it is necessary either to increase the resolution of the measuring equipment, or to reduce the flight height of the UAV. Such approaches will increase the amount of data and, accordingly, increase the duration of the research, which is undesirable. Since the herbicide was introduced by technical means with the observance of technological tracks, the possible identification of the stresses caused by the effects of herbicides is the analysis of the distribution of stress areas along the field with the determination of the connection with the routes of movement of ground equipment.

Conclusions

For the diagnosis of the effects of herbicides on winter crop rations, we can use the technology of leafy diagnostics: in the vegetative phase of 5-7 leaves an abnormal coloring of the two lower laminae of milk and white color appears.

In the optical range, the most informative are red and green channels, so the use of the Slantrange system where the blue channel is not used is justified.

The most informative of the embedded stress indexes of the SlantView software are the indexes of Veg Fraction and Yield potential, however, in order to increase the reliability of the data obtained, it is advisable to carry out additional research on the parameters of the adjustment of the specified system.

Confirmation and thanks.

Preliminary results of the study were presented in the form of abstracts "Information Technology for Remote Evaluation of after Effects of Residues of Herbicides on Winter Crop Rape" at International scientific conference "3rd International Conference on Advanced Information and Communications Technologies (AICT 2019)" DOI: 10.1109/AIACT.2019.8847850.

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ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ ДИСТАНЦІЙНОЇ ОЦІНКИ ПІСЛЯДІЇ ГЕРБІЦИДІВ НА ПОСІВАХ РІПАКУ ОЗИМОГО

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Анотація. *Окрему групу речовин із потенційною фітотоксичністю складають гербіциди. Ці хімічні речовини містять сильнодіючі біологічно активні речовини, призначені для знищення окремих видів рослинності. Залишки окремих із таких речовин можуть зберігатися в ґрунті протягом кількох років, проявляючи взаємодію з іншими речовинами і, що небажано, негативну дію на культурні рослини. Зі збільшенням обсягів застосування і асортименту гербіцидів ризик післядії значно зростає. Чітка характеристика препаратів, механізм їх дії зазначається у регламентах їх застосування. Проте у виробництві, як правило, накладаються суб'єктивні й об'єктивні чинники, а також низка випадкових факторів, що можуть призводити до прояву негативної дії чи післядії препаратів. Для того щоб визначити доцільність використання спектрального моніторингу з платформи БПЛА було ініційоване дослідження на виробничих полях та дослідному стаціонарі НУБіП України. Дослідження здійснювались в оптичному діапазоні з використанням RGB камери та спеціалізованого комплексу Slantrange 3. Для комплексу Slantrange 3 із використанням фірмового програмного забезпечення* *досліджувались стандартні та надані розробником стресові індекси. Дані отримані від оптичної камери FC200 в форматі RGB обчислювались в математичному пакеті MathCAD.*

Було встановлено, що на посівах ріпаку озимого в фазі вегетації 5-7 листків в наслідок дії гербіциду відбувається аномальне забарвлення двох нижніх листків рослини. Для ідентифікації цього в оптичному діапазоні найбільш інформативними є червоний та зелений канали. При використанні комплексу Slantrange 3 найбільш інформативними із вбудованих стресових індексів ПЗ SlantViewє є індекси Veg. Fraction та Yield potential. Показано, що для підвищення достовірності отриманих даних доцільно провести додаткові дослідження щодо параметрів налагодження вказаної системи.

Ключові слова: *дистанційний моніторинг, ріпак озимий, цифрова камера, Slantrange, фітотоксична дія гербіцидів*