Remote monitoring of chlorophyll content in soybean crops in the conditions of the Ryazan region

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Abstract. The article considers research on the supervision of soybean crops, conducted in 2021 on the fields of the Institute of Seed Production and Agrotechnologies (a branch of the Federal State Budget Scientific Institution "Federal Scientific Agroengineering Center VIM"). The purpose of the research is to analyze and collect data on the photosynthetic state (PSS) of soybean plants (using the chlorophyll content as an example) and their impact on yield and quality indicators. The object of research is the early ripe varieties Kasatka, Mageva, Georgiy and Svetlaya. The study used a DJI Phantom 4 pro quadcopter, ground-based scanning - an N-tester express diagnostic device. Monitoring was carried out in three stages: 1st stage - phase R5 (beginning of seed formation); 2nd stage - phase R6 (seed filling); 3rd stage - phase R7 (beginning of ripeness). It has been established that with the use of UAV aerial photography, a reproducible picture of the spatial distribution of the ClGreen chlorophyll index is achieved, which is highly consistent with the results of ground-based scanning. It was revealed that varieties Kasatka, Mageva and Georgiya gradually reduce the chlorophyll content, starting from the R6 phase (with an average chlorophyll content of 511-588 units of the device) to the R7 phase, the chlorophyll content decreases by 44.8-56.1% (comprising 258 - 282 units of the device). A close positive relationship (r=+0.893) with the state of chlorophyll in the R6 phase with yield was established, an average (r=+0.597) - with oil content; significant negative relationship (r=-0.728) with protein content. Thus, when monitoring the UAV and the obtained ground information on the content of chlorophyll in the soybean seed filling phase (R6), it is possible to obtain predictable data on the yield and quality indicators of the future crop in advance.

1 Introduction

Over the past few years, a significant increase in soybean (Glycine max (L.) Merr.) sown areas has been noted in Russia, in particular, in the Ryazan region [1]. This was facilitated by a number of factors, the leading of which are the favorable price environment in the

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world markets and high purchase prices in the domestic market, a significant need for complete and high-quality feed from the rapidly developing poultry and livestock industries.

Given the ever-growing demand for soybeans as a high-protein and oil-bearing product, the priority is to develop methods that allow monitoring the photosynthetic state (PSS) of this crop, in particular, the content of chlorophyll, as a factor that plays a leading role in the process of photosynthesis and metabolism of a plant organism in in general.

Remote monitoring using unmanned aerial vehicles (UAVs) allows you to quickly, without unnecessary costs, receive information about the state of crops in real time, and the information accumulated over a certain period allows you to analyze the production process in dynamics [2-5].

Images obtained with digital cameras mounted on UAVs are increasingly being used in scientific research and practical purposes. When assessing the content of chlorophyll in leaves, vegetation indices are used based on the spectral channels NIR (near infrared) and Green (green) [6]. Thus, the data obtained from the UAV allow for the assessment of the FSS of crops.

The main component in FSS is chlorophyll, the green pigment of plants [7]. Chlorophyll are the main photosynthetic pigments. Chlorophyll a (Chl a) is a universal pigment that converts light energy into charge separation energy, i.e. the first stage of energy conversion during oxygenic photosynthesis. Chlorophyll b (Chl b) is a special chlorophyll of light-harvesting antenna complexes that promotes an increase in light collection in low light and dissipation of excess absorbed energy in high light [8-9]. The amount of chlorophyll is a factor that determines the intensity of photosynthesis and the biological productivity of plants [10-11].

The purpose of the research is to analyze and collect data on the photosynthetic state (PSS) of soybean plants (using the chlorophyll content as an example) and their impact on yield and quality indicators.

2 Materials and methods

Research on the supervision of the FSS of soybean crops was carried out in 2021 on the fields of the Institute of Seed Production and Agrotechnologies (a branch of the Federal State Budget Scientific Institution "Federal Scientific Agroengineering Center VIM"). Approbation of these studies began in 2018. The soil of the plot is dark gray forest, heavy loamy in granulometric composition, of medium fertility (humus content - 5.3% (according to Tyurin)).

The object of research is the early ripe soybean varieties of the northern ecotype of its own selection (FGBNU FNATS VIM) Kasatka, Mageva, Georgiy and Svetlaya. Studies were carried out in accordance with standard procedures [12]. Agrotechnics - generally accepted for the growing area. Biochemical analysis of soybean grains was carried out on an infrared analyzer Infratec 1241 (FOSS, Denmark). Chlorophyll content in soybean leaves was determined using an N-tester. Leaf express diagnostics was carried out directly in the field on vegetative plants and in various phases of development. The measurements were carried out in the middle part of the upper leaves. Correlation analysis was carried out using the Excel program.

Observations were carried out in three stages: 1st - phase R5 (beginning of seed formation); 2nd - phase R6 (filling seeds); 3rd - phase R7 (beginning of ripeness).

The study used a DJI Phantom 4 pro quadcopter (Dajiang Innovation Technology Co., China), which takes pictures in 4 channels. Appropriate software was used for photogrammetric processing [13]. Based on this processing, a highly detailed orthophotomap, reflection maps, and maps of the vegetation index of chlorophyll ClGreen

(Green chlorophyll index) were created [14]. The chlorophyll index is used to identify seasonal changes in the FSS of plants, since green and near-infrared reflection intensity linearly correlates with total chlorophyll content.

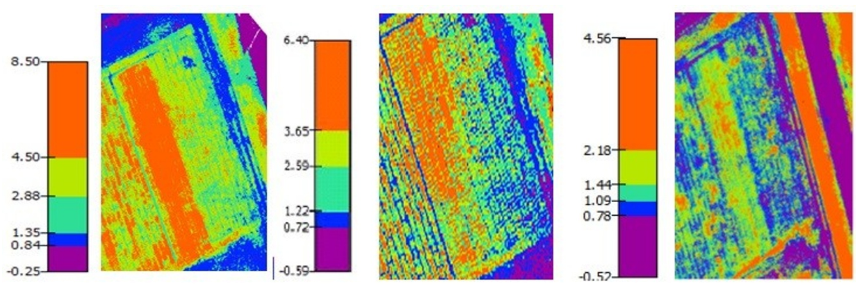
The years of research differed in weather conditions (Table 1).

Table 1. The sum of active temperatures, HTC and the duration of the growing season of the studied varieties.

Variety name	Vegetation period, days	The sum of temperatures, °C	HTC
Kasatka	91	1948	0.58
Mageva	96	2220	0.65
Georgiya	96	2220	0.65
Svetlaya	93	1996	0.59

3 Results

Based on the results of photography and ground scanning of the studied soybean varieties, vegetation maps of the distribution of the ClGreen index were built at each survey period (Figure 1).



R5 R6 R7

Fig. 1. The range of values of the ClGreen index in soybean development phases.

Based on the results of monitoring soybean crops in different phases of development, it can be concluded that using UAV aerial photography, a reproducible picture of the spatial distribution of the ClGreen chlorophyll index is achieved, which is highly consistent with the results of ground-based scanning using express diagnostic devices (N-tester).

There is a relationship between the absorption coefficient in the red region and the content of chlorophyll, and, as a result, with the concentration of nitrogen in plants. In our studies, it can be traced, and it is clearly expressed with the indicators of the N-tester (Figure 2).

Comparison of the data obtained using the UAV and the analysis of the N-tester revealed that the more chlorophyll in plants, as well as nitrogen, the greater the absorption capacity of sowing in the red region of the spectrum.

The readings of the N-tester device and vegetation maps demonstrate that the soybean varieties Kasatka, Mageva and Georgiya gradually reduce the chlorophyll content during the passage of their phenological phases towards the beginning of ripening, which is a natural physiological process for all crops. Starting from the R6 phase (seed filling), with an average chlorophyll content of 511-588 c.u. units device and the range of values of the ClGreen index from 3.65 to 6.40, partial drying of the vegetative organs begins due to the attraction of plastic substances into soybean seeds and by the R7 phase (the beginning of ripeness), the chlorophyll content decreases by 44.8-56.1%, amounting to 258-282 c.u. units instrument, the range of values of the ClGreen index is 2.18-4.56.

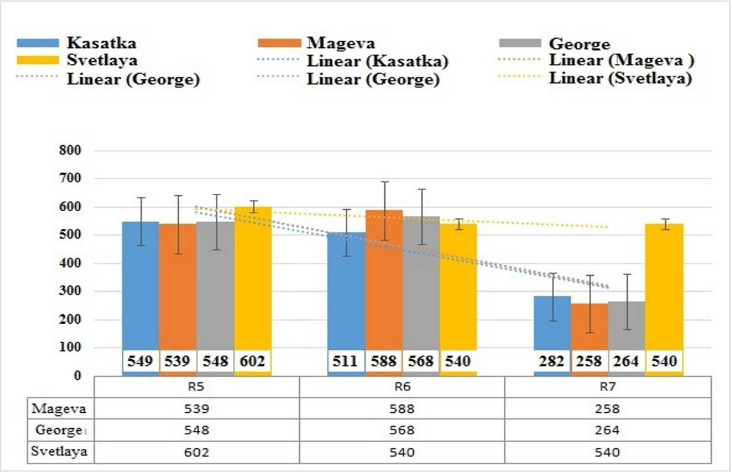


Fig. 2. Indications of the N-tester device depending on the variety and phase of soybean development, c.u. units prior.

In the soybean variety Svetlaya, unlike other studied varieties, there is a very slow decrease in the content of chlorophyll, which is due to the genetic aspect of the variety - the preservation of the pigment stability of the photosynthetic apparatus in chloroplasts until the ripeness of the variety.

The correlation analysis carried out revealed significant direct and inverse relationships with the state of chlorophyll during the second stage of monitoring soybean crops in the R 6 phase (seed filling), the most important stage of soybean development (Table 2).

Table 2. Yield and quality indicators of seeds of the studied varieties.

Variety	Protein, % (per dry matter)	Oil content, % (per dry matter)	Productivity, t/ha
Svetlaya	40.9	20.0	1.17
Georgiy	39.8	20.6	1.24
Mageva	40.6	20.2	1.21
Kasatka	41.4	20.0	1.07
HCP_{05}	0.4	0.2	0.12
Correlation with the state of chlorophyll R5	+0.234	-0.451	-0.090
Correlation with the state of chlorophyll R6	-0.728*	+0.597*	+0.893*
Correlation with the state of chlorophyll R7	+0.275	-0.508	-0.091

* - Confidence probability $P \geq 0.95$

A significant negative relationship (r=-0.728) can be traced between the state of chlorophyll and the protein content of the studied varieties, that is, with a decrease in chlorophyll indicators, the protein content in soybean grain increases, i.e. the attraction of plastic substances goes to the formation of qualitative indicators.

A close positive relationship (r=+0.893) with the state of chlorophyll in the R6 phase was found with yield, an average (r=+0.597) with oil content. Thus, when monitoring the UAV and the information obtained during it on the content of chlorophyll in the soybean seed filling phase (R6), it is possible to obtain in advance approximate data on the yield and quality indicators of the future crop.

As you know, there is an inverse relationship between the content of protein and fat in soybean grain, which was also confirmed by our studies (r=-0.949). According to the data of the correlation analysis, it was found that the fat content in the grain and its collection is in a positive correlation with the yield (r=+0.763), and the protein content in the grain is negative (r=-0.917).

4 Discussion

Research has revealed the relationship between the map of the ClGreen chlorophyll vegetation index, created using UAVs, and the content of chlorophyll in soybean leaves with the N-tester indicators in different phases of crop monitoring. The readings of the N-tester device and vegetation maps demonstrate that soybean varieties Kasatka, Mageva and Georgiya gradually reduce the chlorophyll content during the passage of their phenological phases towards the beginning of maturation, starting from the R6 phase (seed filling). A close positive relationship (r=+0.893) with the state of chlorophyll in the R6 phase was found with yield, an average (r=+0.597) with oil content.

5 Conclusion

Based on the results of monitoring soybean crops in different phases of development, it can be concluded that using UAV aerial photography, a reproducible picture of the spatial distribution of the ClGreen chlorophyll index is achieved, which is highly consistent with the results of ground-based scanning using express diagnostic devices (N-tester). This allows the use of unmanned surveys as an alternative to surveys with optical ground sensors. The main indicator for remote determination for agronomists is the green phytomass of agricultural crops. The collection of information in the soybean seed filling phase (R6) can be used to determine the possible predicted yield and quality indicators of the future crop. The revealed pattern of distribution and content of chlorophyll in soybean leaves with the help of UAVs can be used by agricultural producers, especially when using intensive cultivation technologies in growing these varieties, to predict the possible use of chemicals (desiccants) that affect the acceleration of maturation of this crop. The advantages of surveying crops using unmanned aerial photography are high efficiency and productivity, the reliability of the information received and the ability to evaluate even in conditions where it is difficult to travel to the field.

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