Comparative tests of differentiated fertilizer application for wheat using task cards and nitrogen scanner

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Abstract. In the training and experimental farm of the Kuban State Agrarian University Krasnodarskoe from February 19 to July 6, 2020, an experiment was conducted on the comparative analysis of differentiated fertilizer application in on-line and off-line modes. The aim of the experiment was to compare the modes of differentiated application of nitrogen fertilizers (first and second top dressing) for winter wheat using task maps and GreenSeeker sensors. The calculation of economic efficiency showed that when using nitrogen scanners, fertilizers are saved on average 16 kg / ha, compared to the mode of creating task maps based on the NDVI index based on satellite data without losing grain yield and quality (gluten content increased by 2.3 %; protein content-0.6 %).

From February 19 to July 6, 2020, comparative tests of differentiated fertilizer application in on-line and off-line modes were conducted in the training and experimental farm of the Kuban State Agrarian University "Krasnodarskoe".

The aim of the experiment was to compare the modes of differentiated application of nitrogen fertilizers (first and second top dressing) for wheat using task cards and nitrogen scanner.

In 2020 we conducted a questionnaire survey on issues related to the exact farming, which was attended by 81 expert (56 % of the respondents belong to the category "science ", 26 % – business, 11 % administrative staff; 7 % other) (figure 1) [1].

The following questions were related to the efficiency of using precision farming elements:

- unmanned aerial vehicles: 70 % – yes (effective); 19 % - no (not effective), 11 % - not sure;

- NDVI satellite images: 64 % - yes; 21 % - no, 15 % - undecided;

- purchase of an agrochemical laboratory: 66 % - yes, 25 % - no, 9 % - difficult;

- using nitrogen scanners when applying fertilizers on-line: 65 % - yes, 17 % - no, 18 % - difficult;

- start with the yield mapping system: yes-65 %, no-24 %, 11 % - difficult.

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Fig. 1. Expert survey questionnaire.

Based on the above, it can be summarized that comparative testing of differentiated fertilizer application for winter wheat using task cards and nitrogen scanners is a relevant area for research [2, 3, 4].

The conditions of the experiment were as follows. Ammonium nitrate was used as fertilizer. The first top dressing was carried out on February 19, 2020 during the resumption of spring vegetation (tillering phase), the second top dressing – on March 23, 2020. (start of getting on the phone). A Claas Axion 850 tractor with an Amazone ZA TS 4200 fertilizer spreader was used (Figure 2). The working speed of movement was 19 km / h with the width of the spreader capture 28 m. In the cab of the tractor, an on-board computer Amatron 3 was used. Two GreenSeeker optical sensors were placed in front of the tractor at a height of 130 cm from the ground and a distance of 565 cm. The Farm Works Mobile software (LLC Agro-Soft) was used to create mission.

a   *b*

Fig. 2. Differential fertilizer application unit (Claas Axion 850 tractor + Amazone ZA TS 4200 spreader): a-for applying fertilizers using task cards; b - for applying fertilizers using a nitrogen scanner.

Before conducting comparative tests, a selection of fields was made for conducting the experiment: field 2.2 (a task map was created for differentiated fertilizer application) and 2.3 (a nitrogen scanner was used), with an area of 74.73 hectares and 82.78 hectares, respectively, on which wheat of the Bezostaya 100 variety was sown on October 16, 2019. The precursor in both cases was corn for silage (Figure 3).

Fertilizer application doses were determined for zones with different vegetation periods in field 2.2 (Figure 4):

– the first dressing: the low area of vegetation (the value of the NDVI – 0...0,59) – dose of fertilizer 125 kg/ha, the average (NDVI – ...0,59 0,74) – 75...125 kg/ha, high (NDVI – 0,74 1,00...) -75 kg/ha; total weight of fertilizer application on the field – 8676 kg; average dose of fertilizer – 105 kg/ha;

– the second feeding: low area of vegetation (NDVI – 0...0,63) – dose of fertilizer 180 kg/ha, the average (NDVI – 0,65) – 140 kg/ha, high (NDVI – 0,66 1,00...) – 100 kg/ha; total weight of fertilizer application on the field – 9670 kg; average dose of fertilizer – 117 kg/ha.
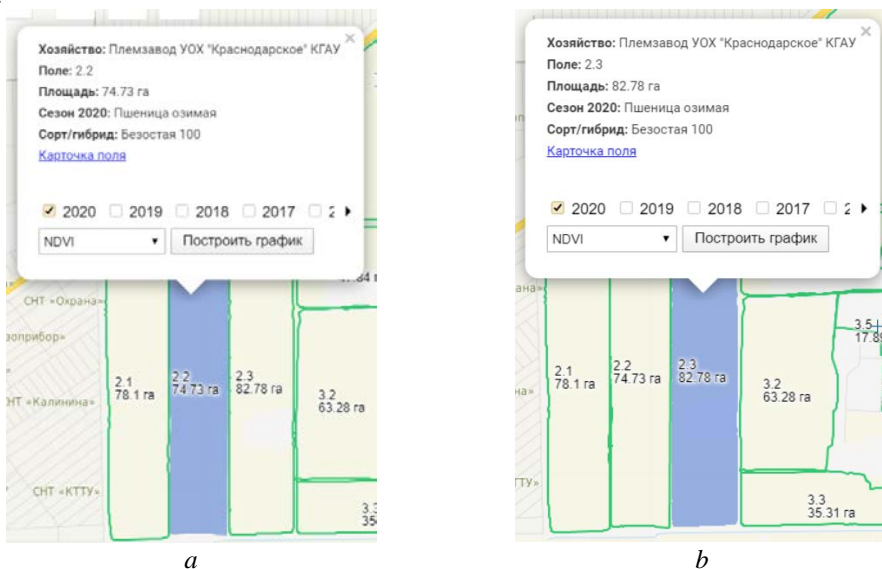

Fig. 3. Experimental fields (2.2-left, 2.3-right).

– the first feeding: low (index NDVI – 0...0,65) – dose of fertilizer 125 kg/ha, the average (NDVI – 0,65 0,76...) – 100 kg/ha, high (NDVI – 0,76 1,00...) – 75 kg/ha; total weight of fertilizer application on the field – 7250 kg; average dose of fertilizer – 97 kg/ha;
    - second top dressing: low-180 kg / ha, medium-140 kg/ha, high-100 kg/ha; total weight of fertilizer applied in the field-10500 kg; average fertilizer application dose-141 kg/ha.
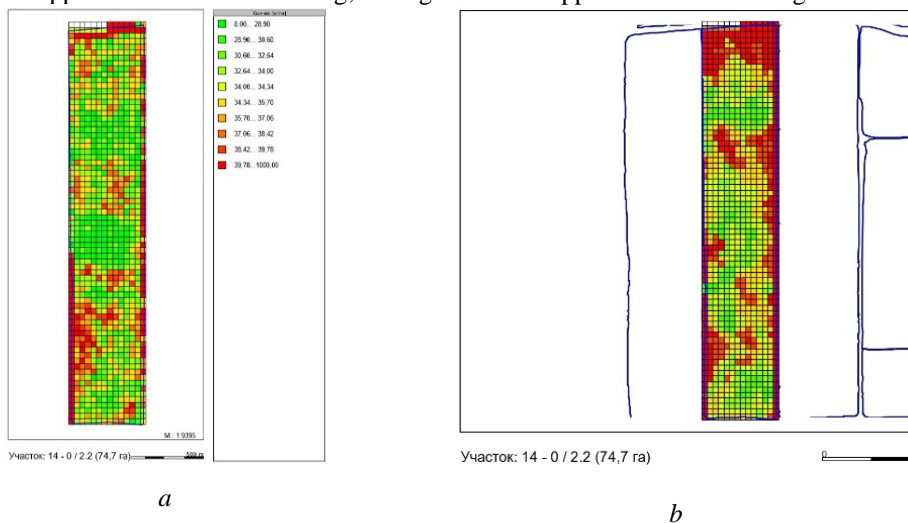

Fig. 4. Maps-feeding tasks for field 2.2: a – first; b – second.

The analysis of plant developmentwas performed using satellite images in the KosmosAgro system for plant vegetation (NDVI index) based on the basic, analytical and NDVI distribution scales.

Comparing the fields, we can see that after 17.03.2020, the best development of plants in field 2.3 occurs-Figure 5.
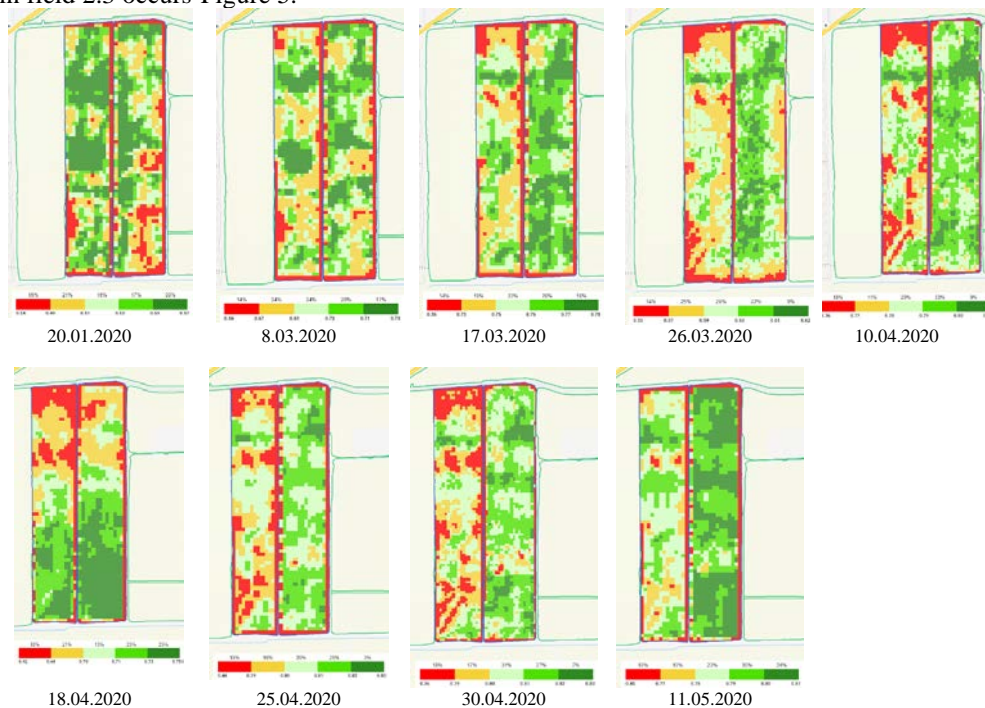

| 20.01.2020 | 8.03.2020 | 17.03.2020 | 26.03.2020 | 10.04.2020 |

| 18.04.2020 | 25.04.2020 | 30.04.2020 | 11.05.2020 |

Fig. 5. Analysis of plant development from satellite images (NDVI distribution): left – field 2.2, right-field 2.3

Before the first top dressing in field 2.2, the area of the field with the index NDVI = 0.53 was

37 %, in field 2.3 with the index NDVI = 0.52-32 % (Table 1).

After 18 days after the first feeding, the situation has not changed – the highest percentage is higher in field 2.2. After 27 days, the situation changes and field 2.3 takes the lead (7 % higher).

This trend continues even after the second feeding in 3 (26.03.2020) and 15 (10.04.2020) days.

Wheat harvesting was carried out on July 5-6, 2020 by Tucano 450, 480, 580 combines with Telematics system (Figure 6).

Fig. 6. Harvesting.

Table 1. Comparative analysis of fields by the highest value of the NDVI index.

Field	20.01.2020		8.03.2020		17.03.2020		26.03.2020		10.04.2020		18.04.2020		25.04.2020		30.04.2020		11.05.2020	
	NDVI	%	8.05.2020 NDVI %	%	NDVI	%	NDVI	%	NDVI	%	NDVI	%	NDVI	%	NDVI	%	NDVI	%
2.2	0,53	37	0,72	30	0,76	27	0,60	33	0,79	32	0,7	24	0,81	36	0,81	31	0,79	43
2.3	0,52	32	0,70	23	0,77	34	0,61	33	0,80	46	0,74	30	0,82	43	0,82	42	0,81	41

The average yield values obtained in the Telematics system (Figure 7) for field 2.2 were 7.03 t/ha (actual 6.44 t/ha), for field 2.3 – 6.81 t/ha (actual 6.59 t/ha). Averaging the values for preliminary, actual and mapping yields, we get the same values for the compared fields of 7 t / ha.
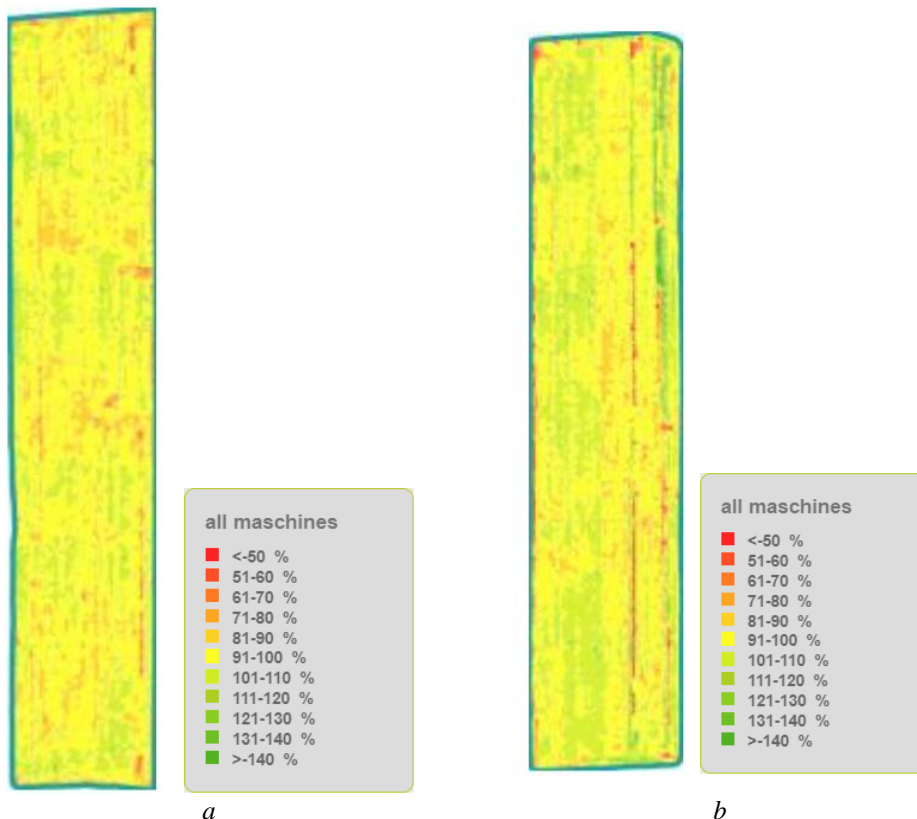

a   *b*

Fig. 7. Field yield maps: a-2.2; b-2.3.

A program developed by AIS LLC was used to highlight pixels corresponding to green biomass in the obtained images, including those taken from an unmanned aerial vehicle (UAV). This program, based on preliminary training based on marked-up images of various green leaves, generates a certain indicator, hereinafter referred to as the bioindex (BIO). This indicator is a measure of the amount of chlorophyll corresponding to an image pixel. The higher the BIO value, the higher the chlorophyll content.

To study the relationship between the bioindex values and winter wheat yield, we used images of winter wheat fields at the time of applying the first and second top dressing, as well as the results of yield measurements during harvesting. Field 2.2 has more than 1,200 measurements, and Field 2.3 has more than 2,200 measurements.

The values of the bioindex variation obtained when processing field photographs taken with UAVs and the resulting map of actual yield are shown in Figure 8 (Field 2.2).
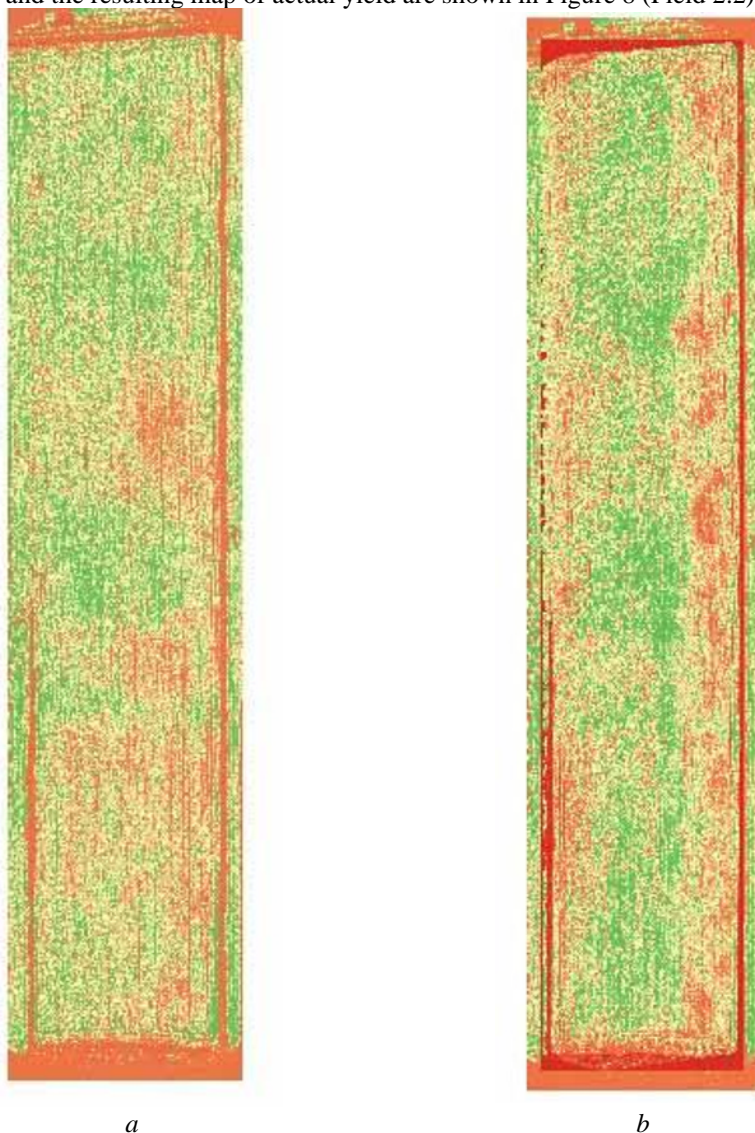

a   *b*

Fig. 8. Maps of the field 2.2 bioindex during feeding: a – first; b – second.

During harvesting, the geographical coordinates of the harvesting machine were measured and the yield was recorded. Based on the initial photos of the field during the second top dressing, the bioindex value was calculated and averaged over a 3x3 m plot centered at the coordinate point for which the harvest yield value was recorded. The values of the biondex-yield pairs obtained in this way were divided into classes. Each class included those pairs for which the yield value lies in a certain interval. For each of these classes, the average value of the bioindex for all pairs of this class was calculated.

The correlation coefficient "yield-bioindex" for field 2.3 was 0.863. The correlation coefficient "yield-smoothed bioindex" was 0.974. Averaging was carried out by taking the average value of the bioindex for neighboring three points.

If the bioindex values are low, there are few plants per unit field area and the yield is low. As the bioindex value increases, the number of plants (biomass) per unit field area increases and the yield increases. If weeds grow in the field, then the corresponding place will have a high bioindex and biomass value, but low yield (weeds contribute to the amount of chlorophyll, but do not contribute to the yield). If pests appear in the field (for example, mouse colonies) the bioindex at the time of shooting may be high due to the good development of plant biomass, and the yield in the affected area may be low due to pest destruction before harvesting. This introduces an additional spread in the bioindex values for field sections with the same yield.

The bioindex calculated from field photos taken with a UAV standard color camera without using multispectral equipment strongly correlates with wheat yield. This allows to predict crop yields based on field photos, plan the distribution of the rate of application of top dressing and fertilizers over the field area, depending on the biomass, in order to reduce costs and optimize available resources.

As a result of the comparative tests of differentiated fertilizer application for wheat using task maps and nitrogen scanners, the calculation of economic efficiency was performed taking into account the actual area of fields participating in the experiment without scaling to the total area for fertilizer application on the farm.

The calculation of economic efficiency showed that when using nitrogen scanners, fertilizers are saved on average 16 kg / ha, compared to the mode of creating task maps based on the NDVI index based on satellite data without losing grain yield and quality (gluten content increased by 2.3 %; protein content-0.6 %).

Calculation of the cost-effectiveness of using the bioindex obtained by processing images from UAVs showed that additional savings are possible compared to using task maps for differentiated fertilization, created on the basis of the NDVI index obtained from satellite data. The average fertilizer savings will be 10 kg / ha.

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