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Application of photometry for diagnostics of nitrogen nutrition in spring barley

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Abstract. The article discusses a method for diagnosing nitrogen nutrition of spring barley (*Hordeum vulgare* L.) in different phases of the growing season using a photometric device (N-tester) Yara. The studies were carried out in the conditions of the Moscow region (Russia) on the Mikhailovsky spring barley variety on sod-podzolic medium loamy soils with a high and medium content of phosphorus and potassium and a low content of humus (1.9). The agrometeorological conditions of the growing season of spring barley were characterized by sharp fluctuations in air temperature and the amount of precipitation over decades of the month and in comparison with average long-term observations. Abundant and prolonged precipitation during the grain ripening phase led to lodging in most of the experiments, which affected the yield. To diagnose crops, a model experiment was laid with the introduction of increasing doses of nitrogen fertilizers into pre-sowing cultivation with a step of 30, at which the dose of nitrogen ranged from 30 to 150 kg/ha. Diagnostics was carried out in three phases of vegetation: tube emergence ((Z42), earing (Z55), milk ripeness of grain (Z73) with the Yara N-tester and with the help of stem diagnostics according to the modified method of V. Zerling. The results of photometric diagnostics in the stemming phase (Z42) have a strong correlation with the yield of spring barley grain and with the results of stem diagnostics (R = 0.85). Wherein, the N-tester readings in the earing phase (Z55) and milk ripeness of grain (Z73) with yield R = 0.23 and R = 0.17, respectively, have a weak correlation. This is possibly due to lodging of crops and a change in yield, not as a result of poor plant nutrition, but with difficult mechanized harvesting.

1 Introduction

Modern agriculture, like many other industries, is moving along the path of automation. Devices that carry information about the relationship between the environment and the state of plants at a certain moment play an important role in this process. The most popular in recent years have received devices that allow quickly, without violating the integrity of agricultural plants to assess its physiological state by optical properties [1]. The measurement principle is associated with the photosynthetic activity of the plant, which correlates with provision of crops with nitrogen [2-3].

Plant chemical diagnostics makes it possible to determine the supply of plants with micro- or macroelements in the process of crop formation at one stage or another of development. It is tissue, in which fresh plant samples are analyzed without ashing in the laboratory, and leaf, according to which the total content of elements in the sample after ashing of leaves or other plant parts is determined [4, 5]. For leaf diagnostics, specialized laboratories are required, skills in working in them, and most importantly, a significant amount of time for analysis and decision-making. Rapid methods of tissue diagnostics have become widespread in the Soviet Union since the 30s of the last century [4]. However, application of plant diagnostics is complicated by the need for laboratory equipment or skills in working with acids in laboratory or field experiments.

The purpose of the study is to substantiate the efficiency of using the Yara photometric device for operational diagnostics of nitrogen nutrition in spring barley in the conditions of the Moscow region.

2 Materials and Methods

The studies were carried out in the field experiment of the Federal State-Owned Publicly-Funded Institution of Higher Education RGAU-Moscow Agricultural Academy named after K.A. Timiryazev (Moscow) in 2012-2015. The soils of the experimental site are well supplied with phosphorus (P_2O_5) - 361-483 mg/kg and potassium (K_2O) - 126-133 mg/kg (GOST 26207-91), an increased content of easily hydrolyzable nitrogen - 64-69 mg/kg (MU, 1985), the average humus content is 1.7-1.9 % (GOST 26213-91). A variety of spring barley *(Hordeum vulgare* L.) - Mikhailovsky was chosen as the object of study. The measurements were carried out with a portable optical instrument Yara (Konica Minolta, Japan). It measures the concentration of chlorophyll in leaves at two wavelengths using artificial light that is absorbed by chlorophyll at different intensities. The light not absorbed by chlorophyll is captured by the photodiode and converted into a measured value, which are conventionally referred to as “cu”. To obtain a representative sample of one section of the field, it is necessary to take 30 measurements. For this, typical plants are taken, on which, respectively, measurements are taken on the youngest, well-developed leaves. In this case, sometimes individual values appear, which deviate significantly from the average. In this case, they are rejected by the device and are not taken into account in the calculation of the average. A defect in a single measurement may be due to incorrect positioning of the device on the sheet, damage to the sheet, or its strong contamination. N-tester readings are not affected by: time of day, measurements, pesticide treatment, moisture on the leaves. The Timiryazevskaya 42 variety is characterized by a small flag leaf, the area of which, however, is sufficient for taking readings with a Yara optical device. The first measurement was carried out in the phase of entering the tube (Z41-Z43), and the subsequent ones after reaching the next full phase of development (Z55, Z65, Z73). Simultaneously with photometric diagnostics, plant (stem, tissue) diagnostics were carried out according to the modified method of V.V. Zerling [4]. Evaluation takes place on a 3-point scale directly in the field. To detect the amount of NO_2, NO_3 ions in the juice of living plants, on a piece of which 0.5 g of diphenylamine dissolved in 100 ml of concentrated H_2SO_4 is applied.

The experiment scheme was developed to study the readings of photometric devices at different levels of fertilizing with nitrogen fertilizers. It included control – without the introduction of root fertilizing and the introduction of increasing doses of nitrogen fertilizers (NH_4 NO_3) from N_{30} to N_{150} kg r.a./ha for seedlings. Fertilizers were applied manually with an even distribution over the plot. The accounting area of the plots is 10 m^2, the replication is fourfold, the placement of options in all the years of the study is randomized, the agricultural technology adopted for the zone. Statistical processing of the results of the field experiment was carried out by methods of variance and correlation analysis [6].

Agroclimatic conditions in the year of study according to the V.A. Michelson (Moscow) were characterized by heterogeneity. Significant variation in the mean ten-day air temperature and precipitation was noted during the growing season of spring barley. In general, the air temperature was 1-2 °C higher than the average long-term data. Precipitation in the first ten days of May and June exceeded the mean annual values by more than two times. Abundant rainfall in the second and third ten days of August led to lodging of barley in most options of the experiment, which negatively affected the grain yield.

3 Results and Discussion

When carrying out stem diagnostics in the tube exit phase (Z42), fairly high results were obtained in options of the experiment with fertilizing in doses of 90 kg/ha nitrogen, which amounted to 2.5-2.6 points. These indicators indicate that at the moment the plants are sufficiently supplied with nitrogen and do not need additional feeding. The maximum indicator is 3 points – the plant is supplied with nitrogen. [7]. In options with nitrogen doses of 30-60 kg/ha, results were obtained showing the need for plants in feeding (1.3-2 points). In the control, the indicators of stem diagnostics determined the acute need for additional fertilizing – 0 points. In the earing phase (Z55), the stem diagnostics indices changed insignificantly in comparison with the first measurement in the direction of decreasing. In the phase of milky grain ripeness (Z73), when green leaves remained on the plants only in the upper tier, the indicators of stem diagnostics significantly decreased and averaged 0.48 points (Table 1). When assessing the results of stem diagnostics in the late phases of the growing season, such indicators are normal, since the amount of nitrates in the juice of plants, as well as the content of juice itself, decreases [4].

Table 1. Results of stem diagnosis for spring barley, points.

Option	Productivity, t/ha	Stem diagnostics, point		
		Z43	Z65	Z73
Control	3.31	0.1	0	0
N_{30}	3.50	1.3	0.3	0.7
N_{60}	4.41	2.0	1.5	0.9
N_{90}	3.51	2.5	2.5	0.7
N_{120}	3.77	2.5	2.7	0.3
N_{150}	3.80	2.6	2.1	0.3
NSR_{05}	0.54	0.6	1.1	1.1

The results of photometric diagnostics with the Yara N-tester in three phases of spring barley development showed the highest results in the earing phase (Z65) – on average 483 (**Fig. 1.**). In the phase of milk ripeness, the readings of the device decreased relative to the readings obtained in the phase of entering the tube (Z42) in options with nitrogen doses of 30-60 kg/ha and slightly increased in options with nitrogen doses greater than 90 kg /ha, which suggests that the additional fertilizing was reflected in the length of the growing season, as a result of which the plants stayed green longer.

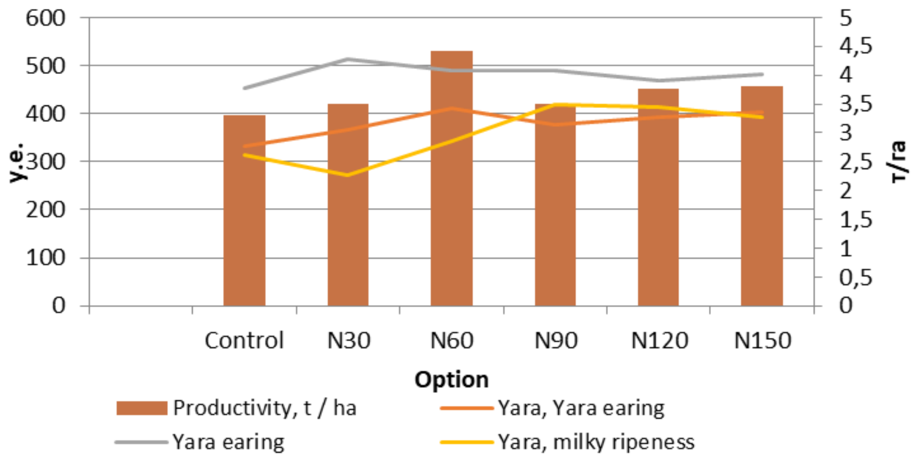

Fig. 1. Caption of the Figure 1. Below the figure.

Increasing doses of nitrogen fertilizers had a positive effect on the grain yield of spring barley. It ranged from 3.31 t/ha in the control, to 3.50-4.41 t/ha when applying top dressing. However, in spite of the actual increase in grain in all options of the experiment, only the increase in option N_{60} was statistically significant, which exceeded the grain yield in the control option by 33.2 %. The yield of barley grain was significantly affected by the lodging of crops.

4 Discussion

It is advisable to compare the indications of plant diagnostics during the growing season with the final yield [8, 9]. However, the value of the yield on the experimental plots was reduced due to lodging, which began during the period of abundant and prolonged precipitation in the phase of the beginning of milk ripeness of grain and in most options of the experiment amounted to 20 to 70 % of the crops. Lodging was not observed only on the plots of the first three options: control, N_{30} and N_{60}. When carrying out diagnostics in the stemming phase, the results of stem diagnostics had a weak correlation with the yield in the stemming phase (Z42) and in the earing phase (Z65) - R = 0.47 and 0.35, respectively. The average dependence in the phase of milk ripeness (Z73) - R = 0.57. The results of stem diagnostics during the exit into the tube (Z42) strongly correlated with the results of diagnostics by the Yara N-tester - R = 0.85. The same correlation coefficient was obtained between the Yara N-tester readings and the yield. Subsequently, the Yara N-tester readings had a very weak negative relationship with yield. This suggests that lodging in the crops did not affect the state of the plants, they continued to vegetate. However, it greatly affected the quality of mechanized harvesting.

5 Conclusion

Operational diagnostics using the Yara N-tester in a model experiment has shown its effectiveness at the early stages of plant development. The N-tester readings in the tube exit phase correlated with the readings carried out using the chemical method – stem diagnostics (R = 0.85). Lodging of crops makes its own adjustments to the level of yield, therefore, there was no correlation between the readings of the device and the yield in the later phases of the growing season. However, in the options of the experiment without fertilizers or with a low dose of nitrogen application (N_{30}), the N-tester shows the smallest indicators, which were 333 in the phase of entering the tube (Z42), in options N_{90} - N_{150} - 378-402; in the earing phase (Z65) - 453, in options N_{90} - N_{150} - 490-482; in the phase of milk ripeness (Z73) - 315, in options N_{90} - N_{150} - 418-394. To interpret the data of the photometric device, it is necessary to carry out test measurements in specific soil and climatic conditions.

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