

Barley Productivity and Protein Content: Fertilization Effect

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Abstract — The results of study of yield and protein content in grains of chaffy and naked barley in the experiment with the increasing rates of mineral fertilizers were described. The relationship between the nitrogen content in the leaves of barley plants and protein content in grains were calculated. For the Acha variety the optimal fertilizer rate was based on the yield of 3.0 t/ha. Higher fertilizer rates were needed to realize yield potential of the Philadelphia and Nudum 95 varieties based on the yield of 5.0 t/ha.

The highest protein content in the barley grain was formed in the options with the calculated rate of fertilizers for the yield of 5 t/ha: Acha - 15%; Philadelphia - 13.5%; Nudum 95 - 18%. A positive relationship was established between the nitrogen content in the leaves and the amount of protein in the grain: $r = 0.934; 0.880; 0.877$ for the Acha, Philadelphia, Nudum 95 varieties, respectively. In collecting protein from the area unit, the Acha variety has shown the best results, the advantage of which was 131 kg/ha compared to the Philadelphia variety, and 95 - 127 kg/ha compared to Nudum 95.

Keywords— *barley, varieties, yield, protein, protein collection.*

I. INTRODUCTION

Barley in Siberia occupies significant areas. Its grains are used primarily as a concentrated component of animal feed. High nutritional value of barley grain is due to a set of essential amino acids. As for the contents of lysine and tryptophan, barley is superior to wheat and maize [1,2]. The yield potential of barley varieties cultivated in the Tyumen Region was studied by many researchers [3,4,5,6,7]. When assessing the quality indicators, in particular, the protein content in the grain, its lack was identified regarding the requirements of current state standard for feed grain barley [8, 9].

The formation of grain with a high content of protein in it contributes to sufficient concentration of nitrogen in soil, which is a very important element found in proteins, nucleic acids, chlorophyll and other compounds of the cell. The

biological characteristics of barley indicate that barley is a demanding crop regarding the level of mineral nutrition. Most intensively it consumes nutritious elements in the tillering period and stem elongation. The researchers argue that high availability of nutrients to crops contributes to the fullest realization of yield potential and quality of cultivated varieties [10].

To obtain high-quality grain, there should be a sufficient concentration of nitrogen for the plants during the entire growing season. The introduction of nitrogen before planting in normal rates has little effect on the grain quality. This is explained by the fact that plants intensively use fertilizers in the initial periods of growth, and in the late development phases it may not be enough [11]. In this regard, an important element of barley cultivation technology can be considered nitrogen subcortex during the growing season of plants.

In terms of protein content and nutritional value, the grain of naked barley has an advantage over the chaffy one [12-14]. Its use is particularly effective in feed mixtures when feeding pigs [15,16].

The purpose of research is to study the yield and protein content in grain of chaffy and naked barley regarding the influence of increasing norms of mineral fertilizers in the conditions of northern forest-steppe zone of the Tyumen region.

II. SUBJECTS AND METHODS

The studies were conducted in the period of 2011-2013 in OOO Vozrozhdenie of Zavodoukovsk District in the northern forest-steppe zone of the Tyumen region. The soil of the experimental field was leached chernozem. Annual grass was used as an ancestor to experience. The study included varieties of chaffy barley such as Acha and Philadelphia and naked barley - Nudum 95. The experimental options provided for the application of mineral fertilizers based on the grain yield were as follows: 3 t/ha; 4 t/ha; 5 t/ha. Besides, an option with a

fractional introduction of nitrogen was studied at a general rate based on the yield of 5 t/ha (N20 is foliar dressing in tank mixture with herbicide). The total area of the plot was 700 m²; the accounting area amounted to 200 m².

Observations and records during the field experiment were carried out according to the method of the State test of agricultural crops. The protein content was determined by the Kjeldahl method.

III. RESULTS

The temperature and moisture conditions were the most favorable for the growth and development of barley plants in 2011. This contributed to a significant effect of fertilizers on the yield of the studied varieties. This year the Acha variety had the highest yield, i.e. 5.31 t/ha (+1.37 t/ha as of control) with the calculated rate of fertilizers for the yield of 5 t/ha (Fig. 1).

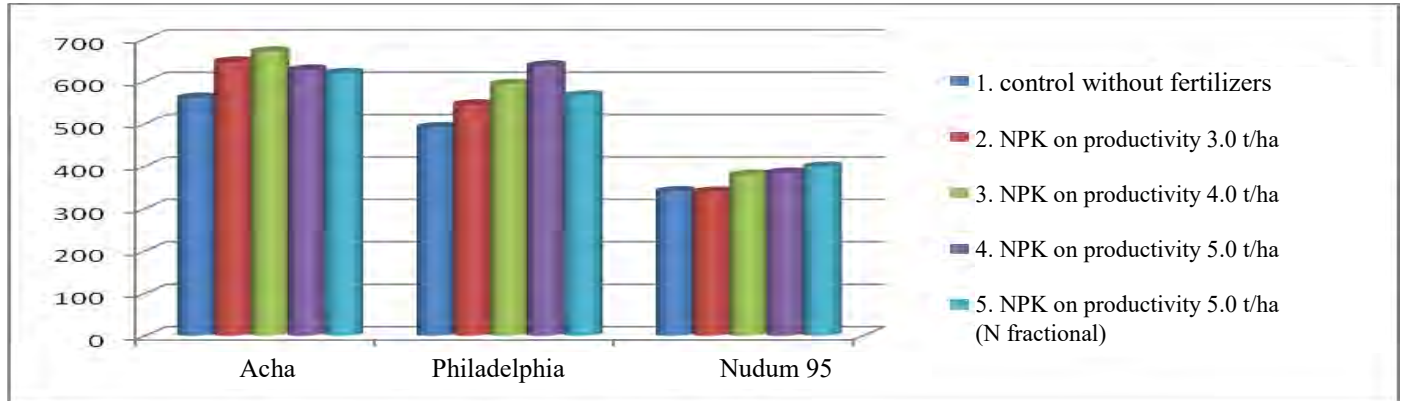


Fig. 1. Yield of chaffy and naked barley varieties effected by fertilizers, t/ha (2011-2013)

The highest yield of Philadelphia variety was observed during the fractional nitrogen addition - 4.91 t/ha (+1.66 t/ha). The responsiveness of Nudum 95 to fertilizers was low; the highest yield was obtained with the estimated fertilizer rate of 5 t/ha and with the nitrogen applied to the main fertilizer - 3.30 t/ha (+0.21 t/ha as of control). On average, over the years of research the most optimal rate of fertilizers for the Acha variety was identified for the yield of 3.0 t/ha, where 4.24 t/ha was obtained, which was 20% higher compared to the control option (Fig. 1).

20-24% was the case of higher rates of fertilizers with the corresponding increase in fertilizer cost and profitability decrease of production. The Philadelphia variety required higher rates of fertilizers compared to the Acha variety, i.e. the highest yield (4.11 and 3.92 t/ha) was obtained in the cases/options with the calculated yield rate of 5 t/ha. The Nudum 95 variety yielded in terms of productivity to chaffy varieties: Acha variety - by 35%, Philadelphia variety - by 25%. The best yields for Nudum 95 were obtained with the following rates of fertilizers: 4.0 and 5.0 t/ha (2.80; 2.85; 2.81 t/ha.).

The number of fertile stems was more responsive to fertilizers out of the elements of the yield structure. In the Acha variety,

the highest indicator (713 pcs/m²) was obtained in 2013 with the estimated rate of fertilizers for the yield of 4 t/ha. The Philadelphia variety has formed the largest number of fertile stems in 2012 with the calculated rate of fertilizers for the yield of 4 t/ha (649 pcs/m²) and with the norm of fertilizers for the yield of 5 t/ha (648 pcs/m²). The highest indicator for the Nudum 95 variety (470 pcs/m²) was obtained in 2012 with the estimated rate of fertilizers for the yield of 5 t/ha. On average, over the years of research for the Acha variety, the maximum value was noted in option 3 (estimated yield rate of 4 t/ha) - 671 pcs/m², which is 109 pcs/m² higher as of control (Fig. 2). For the Philadelphia variety the best option was the one with the fertilizer norm for the yield of 5 t/ha - 638 pcs/m² (+146 pcs/m² as of control). For the Nudum 95 variety the best indicator in the option with the fractional introduction of nitrogen was 399 pcs/m² (+58 pcs/m² as of control).

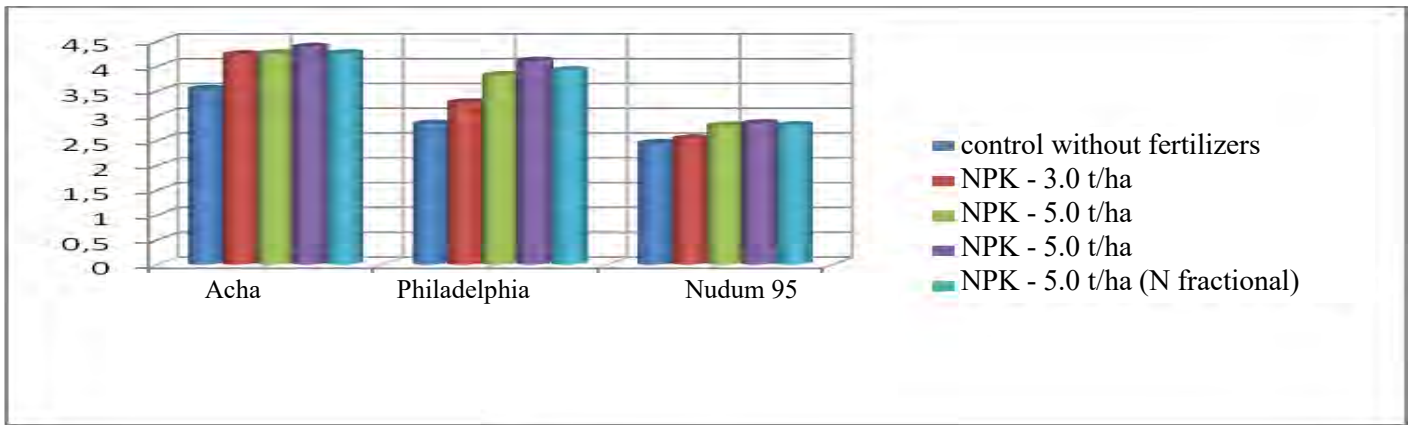


Fig. 2. The number of fertile stems in barley varieties, pcs (2011-2013)

In 2011, all the varieties formed an increased number of grains in the ear compared with the following years. The Acha variety had the largest number of grains (21 pcs) with the calculated rate of fertilizers for the yield of 3 t/ha. For the Philadelphia variety the best indicator (20 pcs) was in the option with fractional nitrogen addition. The Nudum 95 variety was characterized by an increased number of grains in the ear (21 pcs) with the calculated rate of fertilizers for the yield of 3 t/ha (21 pcs). On average, over the years of research for the Acha variety this indicator was 15.2–16.7 pcs, reaching its maximum in the option with fractional nitrogen addition (Table 1). The highest rate of the Philadelphia variety amounting to 15.9 pcs was observed in the same option (+ 2.2 pcs as of control). The Nudum 95 variety had the best indicator in option 3 (16.0 pcs) with the minimum rate of fertilizers. In the subsequent options of this variety, a slight decrease was observed (15.1-15.3 pcs).

2. NPK per yield 3.0 t/ha	16.3±2.8	14.5±2.1	16.0±2.8
3. NPK per yield 4.0 t/ha	15.5±1.8	14.6±2.0	15.1±1.6
4. NPK per yield 5.0 t/ha	16.0±1.8	14.7±2.1	15.3±1.9
5. NPK per yield 5.0 t/ha (N split)	16.7±1.8	15.9±2.2	15.3±2.2

In 2011, the highest grain mass per ear was observed. For the Acha variety the highest rate (0.85 g) was recorded in the option with the fertilizer rate calculated for the yield of 3 t/ha and in the option with fractional nitrogen addition. The highest rate for the Philadelphia variety (0.87 g) was also observed in the option with fractional nitrogen addition. In the Nudum 95 variety, a high grain mass per ear (0.96 g) was noted in three options: NPK per 3 t/ha, 4 t/ha, 5 t/ha. On average, over the years of research the naked barley Nudum 95 was identified as the best on the weight of grain from one ear, ranging from 0.74 to 0.78 g (Fig. 3). In the Acha variety, this indicator was 0.66-0.72 g, and in the Philadelphia variety it was a little lower, comprising 0.58-0.69 g. The tendency of positive influence of the options with fertilizers on the value of grain weight per ear was noted.

TABLE I. NUMBER OF GRAINS REGARDING BARLEY VARIETY, PCS (2011-2013)

Variety	Acha	Philadelphi a	Nudum 95
1. Control without fertilizers	15.2±1.4	13.7±1.4	15.8±2.7

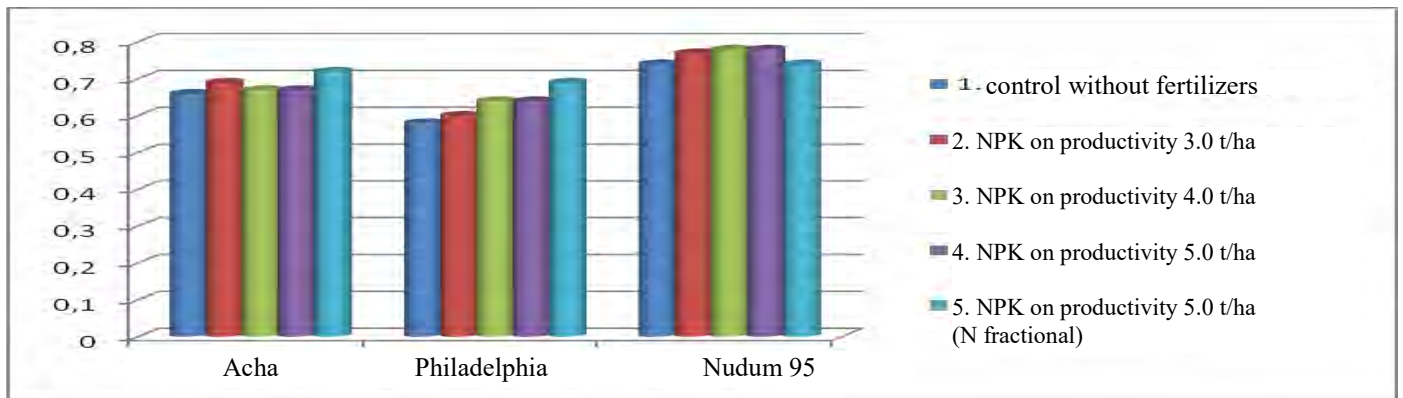


Fig. 3. Grain weight from one ear of different barley varieties, g (2011-2013)

On average, over the years of research the Nudum 95 variety was distinguished by mass of 1000 grains - 44.1-45.9 g; the Acha and Philadelphia varieties had almost the same level of 38.7-40.4 g and 38.8-39.4 g, respectively. The Acha variety also had a tendency to reduce the weight of 1000 grains in the options with fertilizers as of control.

According to the protein content in the grain, the naked grain of Nudum 95 variety was distinguished (Table 2). A high amount of protein (17.86-17.93%) was formed in the grain of this variety in the options with the calculated rate of fertilizers for the yield of 5 t/ha. In the same options, the best performance was observed in chaffy varieties: Acha - 14.67-14.97%, and Philadelphia - 13.37-13.50%. The advantage of naked Nudum 95 variety in comparison with the chaffy varieties on the protein content was on average in terms of experiment: Acha - 2.87% and Philadelphia - 4.46%. As the results showed, fractional application of nitrogen fertilizers (option 5) did not have any significant advantage compared to the case where fertilizers were applied as a general rule before sowing (option 4). The tendency of protein increase in barley grains in this option can be noted.

TABLE II. CONTENTS OF PROTEIN IN BARLEY GRAIN VARIETIES,% (2011-2013)

Variety	Acha	Philadelphi a	Nudum 95
1. Control without fertilizers	12.90±0.21	11.17±0.09	15.77±0.07
2. NPK per yield 3.0 t/ha	13.61±0.15	11.86±0.18	16.20±0.12
3. NPK per yield 4.0 t/ha	14.13±0.23	12.47±0.18	16.87±0.24
4. NPK per yield 5.0 t/ha	14.67±0.14	13.37±0.09	17.86±0.29
5. NPK per yield 5.0 t/ha (N split)	14.97±0.12	13.50±0.12	17.93±0.27

A composite indicator for assessing the variety in terms of productivity and quality can be considered as protein collection per unit area. For the Acha variety, the options with fertilizers contributed to an increase in protein collection by 120; 144; 188; 182 kg/ha; for the Philadelphia variety - by 71; 160; 233; 211 kg/ha; for the Nudum 95 variety - by 24; 86; 123; 116 kg/ha (Fig. 4).

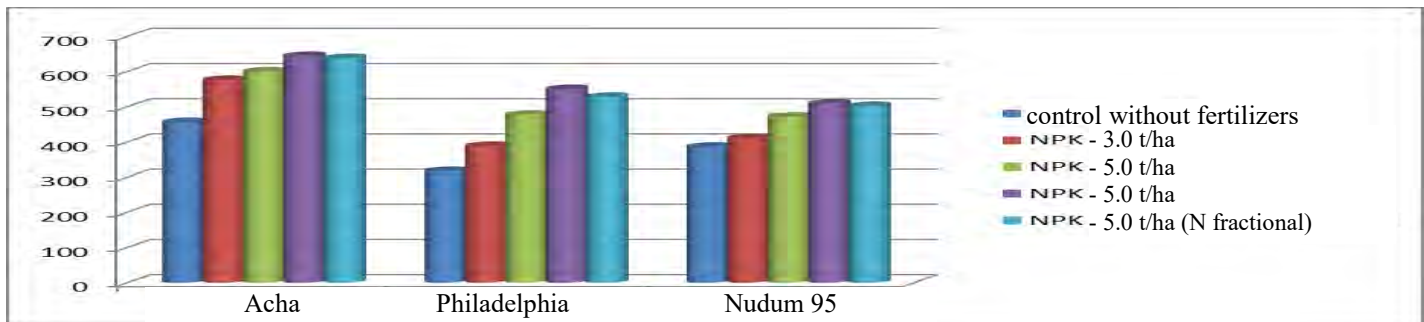


Fig. 4. Collecting protein from chaffy and naked barley, kg/ha (2011-2013)

The highest protein yield per unit area was obtained from all varieties in the option with the calculated rate of fertilizers for the yield of 5 t/ha. For the Acha variety, this indicator was 645 kg/ha, for Philadelphia - 551 kg/ha, for Nudum 95 - 510 kg/ha. As far as the collection of protein from one hectare is concerned, the Acha variety exceeded Philadelphia by 131 kg/ha (on average throughout all options) and Nudum 95 - by 127 kg/ha.

During the ear stage the nitrogen content in the leaves of plants is determined in order to identify the relationship of this indicator with the protein content in the grain. In the course of the study it was established that most of the nitrogen is contained in the plant leaves and enters the grain during its development. Consequently, the content of nitrogenous substances in leaves is largely dependent on mineral fertilizers and other elements of technology, as well as weather conditions during the growing season.

During the filling and ripening of grain, complex physiological and biochemical processes take place ensuring the accumulation of spare nutrients. The course and result of these processes largely depend on the conditions of mineral

nutrition. The dynamics of accumulation of nutrients in plants occurs simultaneously with the growth of dry matter; however, the maximum rate is observed not at the end of the growing season, like in dry matter, but at the earlier stages.

The intensity of nutrients entering the plants begins to decrease by the time of the development of reproductive organs. During this period the redistribution of previously absorbed nutrients from the vegetative organs to the reproductive organs takes place. The amount of nitrogen substances from vegetative organs entering the grain varies considerably depending on the plant availability of nitrogen during this period [17].

For the Acha variety the nitrogen content in leaves varied from 2.10 to 3.23% according to the experiments (Table 3). The highest indicator was observed in the option with top dressing or fertilizing (an increase by 1.3% as of control). The amount of nitrogen in the leaves of plants of the Philadelphia variety was slightly lower than that of the Acha variety (on average by 0.19%). The largest percentage of nitrogen content in leaves of this variety was also in the option with top dressing or fertilizing (2.97). The variety of naked barley

Nudum 95 was far superior to the chaffy varieties in terms of nitrogen content in leaves. On average, the indicator was 4.28% which was higher than the Acha variety by 1.67% and higher than the Philadelphia variety by 1.86%. The highest nitrogen content in the leaves of the Nudum 95 variety was observed in the option with top dressing or fertilizing (4.90%).

TABLE III. NITROGEN CONTENT IN LEAVES OF BARLEY VARIETIES, % (2011-2013)

Variety	Acha	Philadelphi a	Nudum 95
1. Control without fertilizers	2.10±0.0 2	1.97±0.20	3.13±0.1 4
2. NPK per yield 3.0 t/ha	2.30±0.1 5	2.17±0.23	4.26±0.1 8
3. NPK per yield 4.0 t/ha	2.47±0.1 8	2.30±0.21	4.40±0.3 5
4. NPK per yield 5.0 t/ha	2.97±0.1 4	2.70±0.15	4.73±0.2 3
5. NPK per yield 5.0 t/ha (N split)	3.23±0.0 9	2.97±0.14	4.90±0.2 1

As a result of calculating the correlation coefficients between the nitrogen content in the leaves of barley plants and protein in the grain, a high positive relationship was established between these characteristics (for the Acha variety - $r = 0.934$; for the Philadelphia variety - $r = 0.880$; for the Nudum 95 variety - $r = 0.877$). Consequently, at a level of high positive relationship between the nitrogen content in leaves and the protein content in grains the studied varieties differed in correlation coefficient; its highest value was observed in the Acha variety (0.934).

IV. CONCLUSION

1. In the conditions of the northern forest-steppe zone of the Tyumen region, the optimum rate of fertilizer for barley of the Acha variety was established for the yield of 3 t/ha. For this option an average yield of 4.24 t/ha was obtained over the years of research, which was 20% higher as of control. To realize the yield potential of the Philadelphia and Nudum 95 varieties, higher rates of fertilizers were required based on the yield of 5 t/ha.

2. The highest content of protein in the barley grain was formed in the options with the calculated rate of fertilizers for the yield of 5 t/ha: Acha - 15%; Philadelphia - 13.5%; Nudum 95 - 18%.

3. As far as the protein collection from the area unit is concerned, the Acha variety amounted to 131 kg/ha in comparison with the Philadelphia variety, and 95 - 127 kg/ha in comparison with the Nudum variety.

4. The highest amount of nitrogen in the leaves of barley plants was observed in the option with the fractional

introduction of nitrogen (before sowing and feeding in the tank mixture with the herbicide): the Acha variety - 3.23%, Philadelphia - 2.97%, Nudum 95 - 4.90 %.

5. A high positive relationship was established between the nitrogen content in the leaves and the amount of protein in the grain: $r = 0.934$; 0.880; 0.877 for the Acha, Philadelphia, Nudum 95 varieties, respectively.

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