Effective use of various forms of nitrogen fertilizers in barley cultivation

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Abstract. The paper aims to assess the use of various forms of nitrogen fertilizers (seedbed dressing and foliar dressing) in barley cultivation in the steppe and forest-steppe zones of the Omsk region. The research objects were barley, nitrogen fertilizers, ordinary steppe chernozem, forest-steppe meadow chernozem. Variety – Sasha. The most agronomic efficiency in the steppe zone, 5.52 kg of grain derived from 1 kg of fertilizer nitrogen, was yielded in response to the use of N_{30} in the form of ammonium nitrate and urea during sowing. N_{60} (seedbed dressing + foliar fertilizing) resulted in a reimbursement of 1 kg of fertilizer active agent in the maximum amount of 4.44 kg (ammonium nitrate + urea, ammonium nitrate + UAN). The greatest reimbursement in the forest-steppe zone, 11.11 kg of grain from 1 kg of fertilizer nitrogen, resulted from the use of N_{30} in the form of ammonium nitrate and UAN during sowing. N_{60} (seedbed dressing + foliar dressing) resulted in a reimbursement of 1 kg of active agent in the maximum amount of 11.11 kg of barley (ammonium nitrate + urea). The richest harvest of barley was taken in following seedbed dressing and supplementary fertilizing applied together during the growing season in a total dose of 60 kg/ha. In this case, the yield did not reliably depend on the forms of nitrogen fertilizers used; a greater effect resulted from nitrogen fertilizers in the forest-steppe zone.

1. Introduction

Barley is cultivated on 15-17% of the total sown area in the Omsk region. It is abundant in chernozem soils in the forest-steppe and steppe zones. The culture is responsive to fertilizers applied in the conditions of the region [1-3].

Nitrogen fertilizers play a leading role in the world industry, because they are produced in larger volumes than phosphorus-potash. Nitrogen fertilizers are classified based on the form (amide, nitrate or ammonium) nitrogen is used in fertilizers [4, 5]. The presence of different forms of nitrogen in fertilizers determines their agrochemical properties and conditions for effective use. Accordingly, a physiological response to nitrogen fertilizers is also different. As they grow and develop, plants selectively absorb ions, and even when chemically neutral salts are introduced into the soil, their physiological reaction can vary [6-8]. Since the effectiveness of agricultural practices depends on soil and climatic conditions, it is necessary to determine the agronomic feasibility of using various forms of nitrogen fertilizers in the region [9, 10].

The paper aims to assess the use of various forms of nitrogen fertilizers (seedbed dressing and supplementary fertilizing) in barley cultivation in the steppe and forest-steppe zones of the Omsk region.
2. Materials and methods
The use of urea, ammonium nitrate, urea-ammonium mixture (UAN) in various ways (seedbed dressing and foliar fertilization) in barley cultivation in the steppe (Poltava region, “Kobzar” farm) and forest-steppe zones (Kormilovsky district, “Sosnovskoe” farm) of the Omsk region was explored by the Department of Agrochemistry and Soil Science of the Omsk State Agrarian University in 2020. The research objects were barley, nitrogen fertilizers, ordinary steppe chernozem, forest-steppe meadow chernozem. Variety – Sasha. The plots were arranged on the experimental site in a systematic manner. The area of the plots was 16 m². The experiments were fourfold repeated, the arrangement of repetitions was in four tiers. The experiments were based on a two-factor scheme:

Factor A – seedbed dressing with nitrogen fertilizers:
1. No treatment, fertilizers omitted (control);
2. Ammonium nitrate (Nan) – 30 kg a.a./ha;
3. Urea (Nu) – 30 kg a.a./ha;
4. Urea-ammonia mixture (Nuan) – 30 kg a.a./ha.

Factor B – foliar fertilization:
1. No treatment, fertilizers omitted;
2. Urea (Nu) – 30 kg a.a./ha;
3. Urea-ammonia mixture (Nuan) – 30 kg a.a./ha.

Before sowing the content of nitrate nitrogen (according to Grandval-Lyazh) in the soil layer 0-40 cm of ordinary chernozem and meadow chernozem soil was low and medium, while mobile phosphorus and potassium (according to Chirikov) in the layer 0-20 cm – average and very high, respectively. Agricultural technique was generally accepted for the region [14]. Barley seeds were sown in due time concurrently with spring field activities. A seeding rate was recommended for the entire region.

The growing season was warm and dry, while the conditions for plants were characterized as quite abnormal due to a sharp deficit of wagi. During the target period of time, 112 and 151 mm of precipitation fell (in the steppe and forest-steppe, respectively), which amounted to only 63 and 74% of the average long-term value. The average temperature for 4 months was by 8.3 and 7.0 higher than average annual indicators.

3. Findings
All forms of nitrogen fertilizers applied in the experiment had a positive effect on the yield of barley grain in the steppe and forest-steppe zones. Thus, the fertilizers, used on ordinary chernozem of the steppe zone with a yield in the control option of 1.97, contributed to the grain yield of 2.03-2.23 t/ha (Fig. 1).

The seedbed dressing of 30 kg/ha nitrogen fertilizers resulted in a noticeable increase in the yield of barley, with the forms of fertilization being equivalent in terms of agronomic efficiency – the increase in yield amounted to 0.13-0.15 t/ha. The use of foliar nitrogen dressings, both against the background and in the seedbed dressing options of all forms of fertilizers, did not lead to a significant increase in yield. The low efficiency of foliar fertilization was most likely due to the fact that during the application period there was a lack of moisture caused by abnormally high temperature with a deficit of precipitation in the steppe zone.

The maximum yield of barley in the steppe zone resulted from a mixed application of seedbed dressing and foliar fertilization in a total dose of 60 kg/ha (30 + 30). Moreover, the yield did not depend on the forms of nitrogen fertilizers used.

Once applied differently on the meadow-chernozem soil of the forest-steppe zone of the Omsk region, all forms of nitrogen fertilizers were reported to have a positive effect on the yield of barley grain (Fig. 2). With a yield in the control option to make up 2.27, fertilization contributed to the yield of 2.43-2.93 t/ha.
Figure 1. Barley yield depending on nitrogen fertilizers applied on steppe ordinary chernozem in the Omsk region

Figure 2. Barley yield subject to nitrogen fertilizers applied on meadow-chernozem soil of the forest-steppe zone of the Omsk region
A significant increase in barley productivity resulted from seedbed dressing with 30 kg/ha nitrogen fertilizers, while the forms of fertilization were equivalent in terms of agronomic efficiency – a yield increase was 0.30-0.33 t/ha. Foliar top dressing without seedbed dressing led to a significantly increased yield (0.16-0.20), so did foliar top dressing used in addition to seedbed fertilization (0.06-0.23).

The highest barley yield in the forest-steppe zone was produced resulting from a combined use of seedbed dressing and foliar fertilization. Yet, the yield did not depend on the forms of nitrogen fertilizers applied, but more stable results were obtained following urea-based foliar fertilization.

The best agronomic efficiency in the steppe zone – 5.22 kg of grain from 1 kg of fertilizer nitrogen – resulted from the use of N\textsubscript{30} in the form of ammonium nitrate and urea during sowing. N\textsubscript{60} (seedbed dressing + foliar fertilization) made it possible to obtain a reimbursement of 1 kg a.a. fertilizers in the maximum amount of 4.44 kg (ammonium nitrate + urea, ammonium nitrate + UAN) (Table 1).

Maximum reimbursement of 1 kg of a.a. fertilizers in the forest-steppe zone (11.11 kg of grain from 1 kg of fertilizer nitrogen) resulted from the use of ammonium nitrate and UAN at a dose of N\textsubscript{30}. The combined application of seedbed dressing and foliar dressing provided the greatest reimbursement for 1 kg of a.a. in 11.11 kg as well (ammonium nitrate + urea).

**Table 1. Agronomic efficiency of the use of nitrogen fertilizers for barley in the Omsk region, kg/kg**

| Option                                      | Dose, kg | Steppe | Forest-steppe |
|---------------------------------------------|----------|--------|---------------|
| Nan (seedbed dressing)                      | 30       | 5.22   | 11.11         |
| Nu (seedbed dressing)                       | 30       | 5.22   | 10.00         |
| Nuan (seedbed dressing)                     | 30       | 4.44   | 11.11         |
| Nu (foliar fertilization)                   | 30       | 2.22   | 5.56          |
| Nuan (foliar fertilization)                 | 30       | 2.22   | 6.67          |
| Nan (seedbed dressing) + Nu (foliar fertilization) | 60       | 4.44   | 11.11         |
| Nan (seedbed dressing) + Nuan (foliar fertilization) | 60       | 4.44   | 9.44          |
| Nu (seedbed dressing) + Nu (foliar fertilization) | 60       | 3.33   | 8.89          |
| Nu (seedbed dressing) + Nuan (foliar fertilization) | 60       | 2.78   | 6.67          |
| Nuan (seedbed dressing) + Nu (foliar fertilization) | 60       | 3.33   | 7.22          |
| Nuan (seedbed dressing) + Nuan (foliar fertilization) | 60       | 3.33   | 6.67          |

A higher effect from the use of nitrogen fertilizers was observed in the forest-steppe zone. Thus, all forms of nitrogen fertilizers (urea, ammonium nitrate, urea-ammonium mixture) when applied under barley plants at a dose of 30 kg/ha simultaneously with sowing were similarly efficient. Foliar top dressing in the steppe zone proved to be ineffective as specified by the year; in the forest-steppe, it was effective, but less than the seedbed dressing. The highest reimbursement per unit of applied fertilizer (1 kg of nitrogen fertilizers) with seedbed dressing applied in a dose of N\textsubscript{30} in the form of ammonium nitrate and UAN was obtained in the forest-steppe zone and amounted to 11.11 kg of grain, in the steppe zone – 5.52 kg – resulting from N\textsubscript{30} applied in the form of ammonium nitrate and urea.

Consequently, nitrogen fertilizers should be considered the most reliable source for seedbed dressing to promote barley cultivation in the steppe and forest-steppe zones of the Omsk region.
The quality of the crop yield is directly related to the biochemical composition of plants, which is susceptible to many factors including climate, soil, background crop, variety, doses, forms and types of fertilizers, etc. One of the measures strengthening barley cultivation implies the use of fertilizers that has a significant effect on the protein content in the grain (Table 2).

Table 2. Grain quality indicators of spring wheat depending on nitrogen fertilizers in the Omsk region

| Seedbed dressing option (Factor A) | Foliar dressing (Factor B) | Steppe | Forest-steppe |
|-----------------------------------|---------------------------|--------|---------------|
|                                   |                           | hardness,% | gluten, % | hardness,% | protein, % |
| Non-dressing                     | N₃₀ (urea)                | 44      | 43          | 44          | 12.9       | 13.0       | 13.2       | 12.4       | 12.8       | 12.7       |
| N₃₀ (ammonium nitrate)            |                           | 44      | 45          | 46          | 13.0       | 13.2       | 13.2       | 46          | 48          | 47          | 12.4       | 12.8       | 13.0       |
| N₆₀ (urea)                       |                           | 48      | 46          | 44          | 13.2       | 13.4       | 13.0       | 46          | 46          | 46          | 12.6       | 12.8       | 12.6       |
| N₆₀ (UAN)                        |                           | 47      | 47          | 45          | 12.4       | 12.9       | 13.2       | 47          | 46          | 45          | 12.5       | 12.8       | 13.0       |

The protein content in the barley grain in the control option varied from 12.4 to 12.9%. The seedbed and supplementary fertilizing at a dose of 30 kg/ha provided a slight increase in the protein content of the grain by 0.1-0.8%.

Thus, the nutritional conditions of plants improved following nitrogen fertilizers to be applied have a positive effect on the protein content in barley grain.

4. Conclusion

Thus, various options for nitrogen fertilizers applied to advantage barley showed that seedbed dressing can be considered the best. The best agronomic efficiency in the steppe zone – 5.52 kg of grain from 1 kg of fertilizer nitrogen – was yielded in response to the use of N₃₀ in the form of ammonium nitrate and urea during sowing. N₆₀ (seedbed dressing + foliar fertilizing) resulted in a reimbursement of 1 kg of fertilizer active agent in the maximum amount of 4.44 kg (ammonium nitrate + urea, ammonium nitrate + UAN). The greatest reimbursement in the forest-steppe zone, 11.11 kg of grain from 1 kg of fertilizer nitrogen, resulted from the use of N₃₀ in the form of ammonium nitrate and UAN during sowing. N₆₀ (seedbed dressing + foliar dressing) resulted in a reimbursement of 1 kg of active agent in the maximum amount of 11.11 kg of barley (ammonium nitrate + urea). The richest harvest of barley was taken in following seedbed dressing and supplementary fertilizing applied together during the growing season in a total dose of 60 kg/ha. In this case, the yield did not reliably depend on the forms of nitrogen fertilizers used; a greater effect resulted from nitrogen fertilizers in the forest-steppe zone.

References

[1] Ermohin Yu I, Hajhan V V 1992 Diagnostics of the fertilizer requirements of spring barley based on the chemical analysis of the soil in the forest-steppe conditions of western Siberia Agrohimiya 9 72-78

[2] Voronkova N A, Bobrenko I A, Nevenchannaya N M, Popova V I 2020 Efficiency of biologization of agriculture in Western Siberia (on the example of the Omsk region) III International Scientific Conference: AGRITECH-III-2020: Agribusiness, Environmental Engineering and Biotechnologies. Krasnoyarsk Science and Technology City Hall of the
Russian Union of Scientific and Engineering Associations (Krasnoyarsk, Russia) p 22071

[3] Bobrenko I A, Goman N V, Kormin V P, Boldysheva E P, Popova V I 2020 The use of liquid nitrogen fertilizers in the cultivation of grain crops in the Omsk region: recommendations for production (Omsk: Publishing House IP Maksheeva E A) 44 p

[4] Gamzikov G P 2013 Agrochemistry of nitrogen in agrocenoses: monograph (Novosibirsk: Russian Academy of Agricultural Sciences, Siberian department) 790 p

[5] Zavalin A A, Sokolov O A 2016 Nitrogen fluxes in the agroecosystem: from the ideas of D.N. Pryanishnikov to the present day (Moscow: VNIIA) 596 p

[6] Shpedt A A, Aksenova Yu V, Shayakhmetov M R, Zhulanova V N, Rassypnov V A, Butyrin M V 2019 Soil and ecological evaluation of agrochernozems of Siberia International Transaction Journal of Engineering, Management, & Applied Sciences &Technologies 10(3) 309-318

[7] Aksenova Y, Nevenchannaya N, Boiko V 2019 Assessment of the agroecological state of long-term irrigated meadow-chernozem soil The Fifth Technological Order: Prospects for the Development and Modernization of the Russian Agro-Industrial Sector 393 50-54

[8] Bobrenko I A, Matveychik O A, Bobrenko E G, Popova V I 2020 Changes in humus content in forest-steppe soils of Western Siberia IOP Conference Series: Earth and environmental science 624 012219

[9] Bobrenko I A, Shumakova O V, Goman N V, Novikov Y I, Popova V I, Blinov O A 2017 Improving Competitiveness of the Wheat Production within the Siberian Region (in Terms of the Omsk region) Journal of Advanced Research in Law and Economics VIII 2(24) 426-436

[10] Ermohin Yu I, Trubina N K 2012 Soil fertility and environmental factors - the basis of crop programming: a tutorial (Omsk: OmSAU) 136 p