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Original article

# Influence of Systematic Mineral Fertilization on the Yield and Quality of Malting Barley Variety "Ahat"

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**Abstract**

The study was carried out during the period of 2019-2021 in the experimental field of the IASS "Obraztsov chiflik" - Ruse in a long-term stationary fertilizer trial with a 4-pole crop rotation, including interchange of corn, barley, beans and wheat, according to the scheme of Georges Ville in three replications located according Rümker. Fertilization options are the individual and combined application of the three macroelements – nitrogen, phosphorus, potassium and the non-fertilized control is used for comparison. The yields of the wintering malting barley variety "Ahat" grown in the conditions of permanent fertilizer experiment are affected by the weather conditions, and during the research period 2020 appears to be the most favorable for the development of the crop, due to the sufficient amount of evenly distributed precipitation and its combination with optimal average monthly temperatures during the growing season. In all years of testing, the variants with individual and combined application of nitrogen showed proven higher yields compared to the control. The long-term accumulation of phosphorus and potassium in the variants with their individual and combined applications has a depressing effect on the plants, and hence a negative impact on the yield. The quantitative and qualitative indicators of the grain are changed under the influence of fertilization, analogously to yields. The parameters mass per 1000 grains, germination and crude protein content were higher in the variants with nitrogen fertilization and decreased or close to the control in the other variants. Differences in hectoliter weight and grain uniformity are not statistically proven.

**Keywords:** Malting Barley, Mineral Fertilization, Yield, Yield Parameters.

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## INTRODUCTION

Barley is a valuable feed for animal husbandry and raw material for the brewery (Melnikova & Torikov, 2011; Mazurov et al., 2013). The two directions have different requirements for the protein content of the grain. According to Bulgarian State Standard (BSS 207-84), the brewer's barley should have a limited protein content of up to 12.5%. One of the guidelines in the selection work with barley is the creation of brewing varieties combining high productive potential and low protein content in the grain (Pasynkov, 2002; Kalmykova et al., 2014). In addition to the variety, the highest influence on the yield formation and the quality of the production have the moisture level during the growing season and the level of fertilization (Fedotov et al., 2004; Novikov et al., 2009; Kapranov et al., 2012).

Fertilizers affect the properties of the soil and improve the yields of crops (Černy et al., 2010; Shafran, 2014; Kiryushin, 2019). The nutrient balance deficiency leads to unrealizing the potential of soil and climate for agricultural production and reduces the potential of the variety, plant protection products, etc. (Kudeyarov, 2019). Proper application of fertilizers contributes to increasing yields and improving the quality of the product obtained, and incorrect often leads to a decrease in yields and quality.

Many studies have shown that the use of nitrogen fertilizers leads to an increase in yield, protein content (over 12% in grain) and the grain uniformity of brewer's barley, and phosphorus and potassium - improve the accumulation of photosynthesis products, which contribute to reducing the proteins in the barley grain (Pasynkov, 2002; Abeledo et al., 2003; Melnikova & Torikov, 2011; Hawkesford et al., 2012; Zörb et al., 2014; Novikov & Solovyeva, 2020). On the other hand, with a lack of affordable potassium and phosphorus, plants form low yield, but very often with increased protein content (Abeledo et al., 2003; Kirillova & Zhukov, 2003).

The long-term use of organic and mineral fertilizers at suitable doses does not pose a risk of pollution of barley grain with risk elements when crops are grown on mineral-rich and non-west metal agricultural soils (Morell et al., 2011; Hejcman et al., 2013). In the production of barley in water deficiency, grain quality can be improved by integrated fertilizer application (Maleki et al., 2011; Moreno-Jiménez et al., 2016).

The purpose of this study is to determine the influence of systemic mineral fertilization and weather conditions on the yield and quality of the grain of brewerous barley variety "Ahat" grown in the conditions of the soil type strongly leached chernozem.

## MATERIALS and METHODS

The study was carried out during the period of 2019-2021 in the experimental field of the IASS "Obraztsov chiflik" - Ruse in a long-term stationary fertilizer trial with a 4-pole crop rotation, including interchange of corn, barley, beans and wheat. The experiment was started in 1912 according to the

scheme of Georges Ville in three replications located according Rümker, with the size of the experimental plot being 100 $m^2$, and the harvest plot - 60 $m^2$.

Fertilization variants are 1 – individual application of nitrogen fertilizer ($N_{10}$) - 10 kg active substance per da; 2 - individual application of phosphorus fertilizer ($P_2O_5$) - 12 kg a.s. $da^{-1}$; 3 - individual application of potassium fertilizer ($K_2O$) - 7 kg a.s. $da^{-1}$; 4 – combined application $N_{10}P_{12}$; 5 – combined application $N_{10}K_7$; 6 – combined application $P_{12}K_7$; 7 – triple combination $N_{10}P_{12}K_7$. For comparison, the control O non-fertilizing - $N_0P_0K_0$ is maintained.

The soil type on which the experiment is carried out is strongly leached chernozem, which is characterized by a low content of humus - 1.75%, poorly stocked with mineral nitrogen (19.75 mg/1000g soil) and mobile phosphorus (5.31 mg/100g soil), but well stocked with potassium (22.75 mg/100g soil) in the 0-40 cm layer. The mechanical composition is heavy sandy loam, and the soil reaction is moderately acidic (pH – 5.0).

The barley variety "Ahat" is a high-yielding wintering two-row malting barley selected in the DAI "Gen. Toshevo" in 2012. It is characterized by a rapid rate of vegetation recovery in the spring months, increased cold and winter resistance. It exhibits high resistance to powdery mildew, net spot and fusarium (Mihova et al., 2014).

The sowing of the crop was carried out in the optimal technological term for the area. All agrotechnical measures were carried out according to the adopted technology.

Data on precipitation and average monthly air temperatures were obtained from an automated weather station on the territory of the Institute.

In the trial, the grain productivity and some indicators related to the brewing properties of barley were recorded. Yield is weighted. The main quantitative and qualitative indicators of the grain, as well as the crude protein content, were determined in the laboratory according to the adopted methods (BSS ISO 7971-3 (2009); Methodology for sampling and analyzes for purity, germination and mass of 1000 grains, 2009; nitrogen according to modified Kjeldahl method (Sandev, 1979).

The statistical evaluation of the obtained results was performed using the dispersion method in the Statgraph v.2.1 program.

## RESULTS and DISCUSSION

Barley is the earliest maturing cereal crop, in which the stages of organogenesis pass quickly and the response to weather conditions deviating from the optimum is sensitive. Critical phases of crop development with respect to humidity are stalk shooting and ripening. During the stalk shooting period, barley consumes more than 50% of the total water requirement during the growing season (Fedotov et al., 2004; Filatov et al., 2021). The lack of moisture during ripening leads to a lower realization of the

already established productive possibilities. The accumulation of moisture reserves in the phases of stalk shooting - earing (third ten days of April - beginning of May) depends on the rainfall. Precipitation in amounts of 50-90 mm during the earing - ripening period (June) is favorable for the conditions of Bulgaria (Yankov et al., 2002).

Meteorological conditions during the study period differed in terms of temperatures and precipitation (Figure 1), but all three could be generally defined as favorable for barley growth and development. The first economic year is characterized as less favorable than the other two. Moisture storage during the autumn-winter period of 2018-2019 is very good. The meteorological conditions in the fall favour the timely and even sprouting of barley. The initial phases of development take place with good soil moisture and average daily temperatures around the norm. During the winter period, there are no frost conditions. Precipitation in April, May and the first half of June was higher than normal for the area (Figure 1). The greater amount of precipitation predisposes to the development of fungal diseases such as powdery mildew, brown and yellow rust, septoria, etc. The lack of rainfall in the second half of June and July allowed for a timely harvest.

The most favorable in terms of yield and quality of barley is the economic year 2019-2020. Moisture storage during the autumn-winter period is very good. The meteorological conditions in the fall favour the timely and even sprouting of barley. In January, the average minimum temperature reaches - 7.5°C. Despite the prolonged low temperatures, there are no frost conditions due to the presence of snow cover. Precipitation in April and May is above normal for the area, and the temperature total is around normal (Figure 1). Again, the higher amount of rainfall predisposed the development of fungal diseases. Despite the higher amount of rain in the first half of July, the barley harvest was done on time.

In terms of climate, the economic year 2020-2021 is characterized by significant precipitation in the months of October, February, June and July, and in general, for the entire economic year, the precipitation exceeds the climatic norm for the 109-year period by 8.05%. The rainfall in October and November provide moisture for the normal progress of the initial phases of the barley vegetation. Agrometeorological conditions in January and February are characterized by frosty weather, with negative temperatures below -11ºC (January) and -13ºC (February) recorded. The formed permanent snow cover provides protection from the effects of low negative temperatures. The rainfall in June maintains a good level of soil moisture reserves but causes the lodging of barley and creates conditions for the development of fungal diseases.

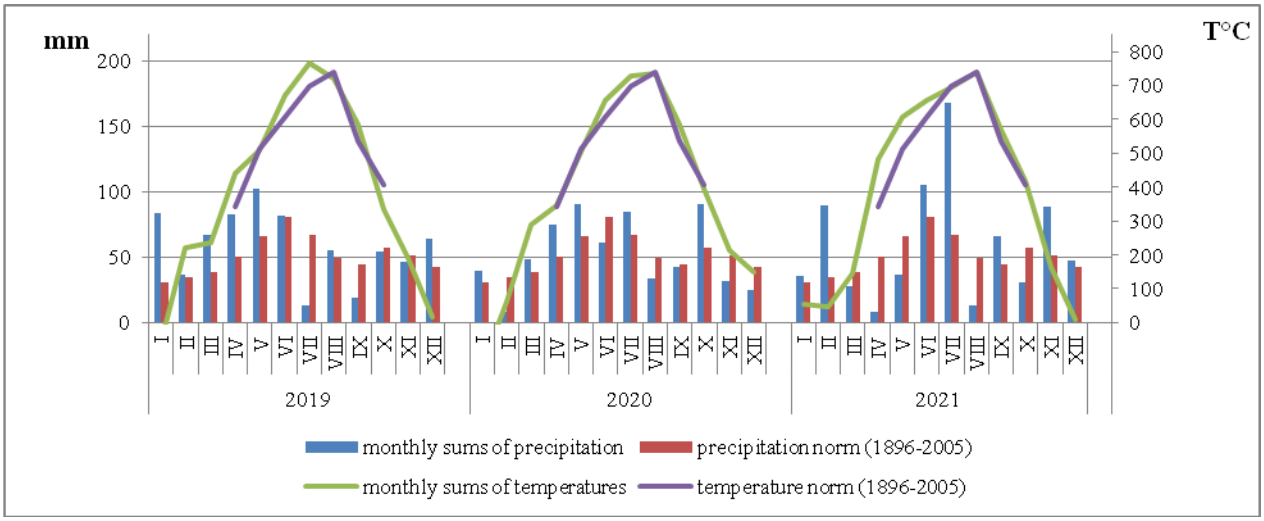


**Figure 1**. Climatogram for the period 2019–2020.

In 2019, the highest yield was recorded in the variant with full mineral fertilization ($N_{10}P_{12}K_7$) - 468 kg da$^{-1}$, followed by the combined $N_{10}P_0K_7$ - 452 kg da$^{-1}$, with the increase compared to the control being respectively 243 kg da$^{-1}$ and 227 kg da$^{-1}$ or by 208% and 201%. The higher yields were proven for all variants with the participation of nitrogen fertilization, and for the rest, the differences were not statistically proven (Table 1).

**Table 14.** Yield and grain qualities of brewing barley variety Ahat, 2019.

| Variant | Yield, kg da$^{-1}$ | Mass per 1000 grains, g | Hectoliter mass, kg hl$^{-1}$ | Grain uniformity >2,5 % | Germination, % | Crude protein, % |
|---|---|---|---|---|---|---|
| $N_{10}P_0K_0$ | 418$^{b}$ | 44.32 | 63.15 | 85.90 | 97 | 10.92 |
| $N_0P_{12}K_0$ | 223$^{a}$ | 41.12 | 64.85 | 81.70 | 95 | 8.95 |
| $N_0P_0K_7$ | 224$^{a}$ | 42.08 | 64.00 | 83.00 | 95 | 8.55 |
| $N_{10}P_{12}K_0$ | 429$^{bc}$ | 44.27 | 61.70 | 86.20 | 98 | 10.74 |
| $N_{10}P_0K_7$ | 452$^{cd}$ | 43.94 | 61.70 | 85.80 | 97 | 10.66 |
| $N_0P_{12}K_7$ | 215$^{a}$ | 40.89 | 63.20 | 85.20 | 94 | 8.87 |
| $N_{10}P_{12}K_7$ | 468$^{d}$ | 44.36 | 61.60 | 85.45 | 97 | 10.77 |
| $N_0P_0K_0$ | 225$^{a}$ | 42.21 | 61.95 | 80.05 | 95 | 8.47 |
| **BSS 207-84** | | | **>67** | **>85** | **>92** | **<12.5** |

$^{a,b,c,d}$ – the differences proved at P<0.05

The mass of 1000 grains is in the range from 40.89 g for the combined $N_0P_{12}K_7$ fertilization to 44.36 g for the complete mineral fertilization, at 42.21 g in the control variant. The reported hectoliter mass for all variants is lower than the requirements of BSS. All fertilization options with the participation of nitrogen fertilizer and the $N_0P_{12}K_7$ combination meet the requirements of BSS in terms

of levelling. All variants meet the requirements of the germination standard. The crude protein content of the grain has very good values compared to the standard requirements for malting barley.

The yields in 2020 show (Table 2) that the highest result was obtained with complete mineral fertilization - 626 kg da$^{-1}$, followed by the options $N_{10}P_{12}K_0$ - 545 kg da$^{-1}$, $N_{10}P_0K_7$ - 515 kg da$^{-1}$ and individual nitrogen fertilization ($N_{10}P_0K_0$) – 512 kg da$^{-1}$. The increase over control was 361 kg da$^{-1}$, 280 kg da$^{-1}$, 250 kg da$^{-1}$ and 247 kg da$^{-1}$ (236%, 206%, 194% and 193%), respectively. The variant with combined application of phosphorus and potassium ($N_0P_{12}K_7$) also exceeds the control variant in yield. This year, the yields from the variants with independent phosphorus and potassium fertilization show proven lower results compared to the control.

**Table 2.** Yield and grain qualities of brewing barley variety Ahat, 2020.

| Variant | Yield, kg da$^{-1}$ | Mass per 1000 grains, g | Hectoliter mass, kg hl$^{-1}$ | Grain uniformity >2,5 % | Germination, % | Crude protein, % |
|---|---|---|---|---|---|---|
| $N_{10}P_0K_0$ | 512$^{d}$ | 43.92 | 61.00 | 88.50 | 96 | 11.09 |
| $N_0P_{12}K_0$ | 235$^{a}$ | 41.81 | 61.80 | 88.70 | 95 | 8.85 |
| $N_0P_0K_7$ | 239$^{a}$ | 42.01 | 61.80 | 88.30 | 95 | 8.53 |
| $N_{10}P_{12}K_0$ | 545$^{e}$ | 44.07 | 63.50 | 92.20 | 97 | 11.87 |
| $N_{10}P_0K_7$ | 515$^{d}$ | 44.09 | 63.00 | 94.40 | 97 | 11.66 |
| $N_0P_{12}K_7$ | 300$^{c}$ | 40.93 | 62.80 | 87.50 | 94 | 8.89 |
| $N_{10}P_{12}K_7$ | 626$^{f}$ | 44.14 | 63.60 | 92.60 | 97 | 11.97 |
| $N_0P_0K_0$ | 265$^{b}$ | 42.79 | 64.00 | 91.5 | 96 | 8.47 |
| **BSS 207-84** | | | **>67** | **>85** | **>92** | **<12.5** |

$^{a,b,c,d,e,f}$ – the differences proved at P<0.05

The mass of 1000 grains varies from 40.93 g for the $N_0P_{12}K_7$ combination to 44.14 g with complete mineral fertilization, with the non-fertilized control showing intermediate results - 42.79 g. The hectoliter mass does not meet the requirements of the standard, but the highest value was registered in the unfertilized control. According to the other indicators (uniformity of the grain, germination and crude protein content), all fertilization options cover the technological requirements for malting barley.

The results obtained in 2021 (Table 3) show that the yield is highest with the combination $N_{10}P_{12}K_0$– 698 kg da$^{-1}$, followed by the variants $N_{10}P_0K_7$ – 666 kg da$^{-1}$ and the complete mineral fertilization ($N_{10}P_{12}K_7$) – 652 kg da$^{-1}$, as the increase compared to the control, was 526 kg da$^{-1}$, 494 kg da$^{-1}$ and 480 kg da$^{-1}$ (406%, 387% and 379%), respectively. The difference of 14 kg da$^{-1}$ between the two variants $N_{10}P_0K_7$ and $N_{10}P_{12}K_7$ is not statistically proven. All variants with the participation of nitrogen fertilization proved to exceed the control, and the variant with individual phosphorus fertilization gave the lowest yield.

**Table 3.** Yield and grain qualities of brewing barley variety Ahat, 2021.

| Variant | Yield, kg da$^{-1}$ | Mass per 1000 grains, g | Hectoliter mass, kg hl$^{-1}$ | Grain uniformity >2,5 % | Germination, % | Crude protein, % |
|---|---|---|---|---|---|---|
| $N_{10}P_0K_0$ | 581$^c$ | 43.88 | 64.40 | 85.80 | 98 | 11. 69 |
| $N_0P_{12}K_0$ | 92$^a$ | 41.73 | 65.60 | 82.80 | 95 | 8.85 |
| $N_0P_0K_7$ | 158$^b$ | 42.88 | 66.50 | 83.00 | 95 | 8.93 |
| $N_{10}P_{12}K_0$ | 698$^e$ | 43.97 | 63.70 | 86.20 | 98 | 11.88 |
| $N_{10}P_0K_7$ | 666$^d$ | 43.94 | 64.20 | 85.80 | 96 | 11.67 |
| $N_0P_{12}K_7$ | 179$^b$ | 41.09 | 64.60 | 84.60 | 94 | 8.87 |
| $N_{10}P_{12}K_7$ | 652$^d$ | 44.36 | 63.80 | 85.00 | 98 | 12.07 |
| $N_0P_0K_0$ | 172$^b$ | 42.21 | 64.00 | 82.75 | 96 | 9.27 |
| BSS 207-84 | | | >67 | >85 | >92 | <12.5 |

$^{a,b,c,d,e}$ – the differences proved at P<0.05

The mass of 1000 grains varies from 41.09 g in the $N_0P_{12}K_7$ combination to 44.36 in the complete mineral fertilization, with the unfertilized control showing intermediate results - 42.21 g. The highest value of the hectoliter mass, approaching the minimum required by the standard, was recorded in the individual potassium fertilization. The uniformity of the grain in all variants with the participation of nitrogen fertilization meets the requirements of the standard. Germination and crude protein content meet the requirements of the standard in all tested variants.

The summarized results of the three-year study support the opinion that 2020 appears to be the most favorable climate in terms of productivity, providing stable yields from all fertilization options (Table 4).

**Table 4.** Barley grain yield, 2019-2021.

| Years | Variant, kg da$^{-1}$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $N_{10}P_0K_0$ | $N_0P_{12}K_0$ | $N_0P_0K_7$ | $N_{10}P_{12}K_0$ | $N_{10}P_0K_7$ | $N_0P_{12}K_7$ | $N_{10}P_{12}K_7$ | $N_0P_0K_0$ |
| 2019 | 418$^a$ | 223$^b$ | 224$^b$ | 429$^a$ | 453$^a$ | 215$^b$ | 468$^a$ | 225$^b$ |
| 2020 | 512$^b$ | 235$^b$ | 239$^b$ | 545$^b$ | 515$^b$ | 300$^c$ | 626$^b$ | 265$^c$ |
| 2021 | 581$^c$ | 92$^a$ | 158$^a$ | 698$^c$ | 666$^c$ | 179$^a$ | 652$^c$ | 172$^a$ |

$^{a,b,c}$ – the differences proved at P<0.05

The summarized average results for the period of the study show the influence of independent fertilization with nitrogen, phosphorus and potassium, as well as the combinations between them, on some parameters of the seeds (Table 5).

**Table 5.** Parameters of barley grain, 2019-2021.

| Variant | Mass per 1000 grains, g | Hectoliter mass, kg hl$^{-1}$ | Grain uniformity >2,5 % | Germination, % | Crude protein, % |
|---|---|---|---|---|---|
| $N_{10}P_0K_0$ | 44.04$^{d}$ | 62.85$^{a}$ | 86.73$^{a}$ | 97$^{cd}$ | 11.32$^{b}$ |
| $N_0P_{12}K_0$ | 41.55$^{b}$ | 64.08$^{a}$ | 84.40$^{a}$ | 95$^{b}$ | 8.88$^{a}$ |
| $N_0P_0K_7$ | 42.32$^{c}$ | 64.10$^{a}$ | 84.77$^{a}$ | 95$^{b}$ | 8.67$^{a}$ |
| $N_{10}P_{12}K_0$ | 44.10$^{d}$ | 62.97$^{a}$ | 88.20$^{a}$ | 98$^{d}$ | 11.49$^{b}$ |
| $N_{10}P_0K_7$ | 43.99$^{d}$ | 62.97$^{a}$ | 88.67$^{a}$ | 97$^{c}$ | 11.33$^{b}$ |
| $N_0P_{12}K_7$ | 40.97$^{a}$ | 63.53$^{a}$ | 85.77$^{a}$ | 94$^{a}$ | 8.88$^{a}$ |
| $N_{10}P_{12}K_7$ | 44.29$^{d}$ | 63.00$^{a}$ | 87.68$^{a}$ | 97$^{cd}$ | 11.30$^{b}$ |
| $N_0P_0K_0$ | 42.40$^{c}$ | 63.32$^{a}$ | 84.77$^{a}$ | 96$^{b}$ | 8.74$^{a}$ |

$^{a,b,c,d}$ – the differences proved at $P<0.05$

The application of the triple combination of the main macronutrients ($N_{10}P_{12}K_7$) leads to an increase in the grain yield of malting barley increasing the mass of 1000 grains, germination and the content of crude protein in the grain. For the indicator mass per 1000 grains, proven higher values are reported for all variants with nitrogen fertilization, while for the individual phosphorus and potassium fertilization, as well as for the combination between them, the data do not exceed the control variant. Similar results were reported for the of germination and crude protein content.

During the study, the influence of individual fertilization and the combination of the main macroelements on the hectoliter mass and grain uniformity was not proven.

These results are consistent with the findings of Novikov & Solovyeva (2019) regarding the effect of nitrogen fertilization leading to an increase in the grain yield of barley plants and the total protein content of the grains. Also, under conditions of sufficient nitrogen supply, phosphorus and potassium fertilization increases grain yield and seed germination. A similar conclusion was reached by Zavyalova & Shishkov (2020) and Filatov et al. (2021). At the same time, individual and combined applications of phosphorus and potassium do not affect yield (Laconde et al., 1993) and protein content in wheat (Ershov, 1990), which is confirmed in malting barley by the results obtained.

**Conclusion**

The yields of the wintering malting barley variety "Ahat" grown in the conditions of permanent fertilizer experiment are affected by the weather conditions, and during the research period 2020 appears to be the most favorable for the development of the crop, due to the sufficient amount of evenly distributed precipitation and its combination with optimal average monthly temperatures during the growing season.

In all years of testing, the variants with individual and combined applications of nitrogen showed proven higher yields compared to the control. The long-term accumulation of phosphorus and potassium in the variants with their individual and combined application has a depressing effect on the plants, and hence a negative impact on the yield.

The quantitative and qualitative indicators of the grain are changed under the influence of fertilization, analogously to yields. The parameters mass per 1000 grains, germination and crude protein content were higher in the variants with nitrogen fertilization and decreased or close to the control in the other variants. Differences in hectoliter weight and grain uniformity are not statistically proven.

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## REFERENCES

Abeledo, L., Calderini, D., & Slafer, G. (2003). Genetic improvement of yield responsiveness to nitrogen fertilization and its physiological determinants in barley. *Euphytica*, 133, 291-298.

Černý, J., Balík, J., Kulhánek, M., Čásová, K., & Nedvěd V. (2010). Mineral and organic fertilization efficiency in long-term stationary experiments. *Plant, Soil and Environment*, 56, 28-36.

Ershov, V. (1990). Productivity and grain quality of durum wheat when using chemical agents. *Konferentsiya Omsk*, 61-62.

Fedotov, V., Goncharov, S., & Rubtsov, A. (2004). *Malting barley in the Central Black Earth Region*. Moskva, Russia: Mezhdunarodnogo selskokhazyaystvennogo zhurnala, 120.

Filatov, A., Mazurov, V., Khramoy, V., & Arlantseva, E. (2021). Effect of tillage methods and levels of mineral nutrition on yield and grain quality of the "Vladimir" spring barley variety in the Central Region of the Non-Chernozem Zone. *Izvestiya TSKHA*, 1, 18-28.

Hawkesford, M., Horst, W., Kichey, T., Lambers, H., Schjoerring, J., Moller, I., & White, P. (2012). Functions of macronutrients. *Marschner's mineral nutrition of higher plants*. Academic Press, 2012. 135-189.

Hejcman, M., Berková, M., & Kunzová E. (2013). Effect of long-term fertilizer application on yield and concentrations of elements (N, P, K, Ca, Mg, As, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Zn) in grain of spring barley. *Plant, Soil and Environment*, 59, 329-334.

Kalmykova, Y., Efremova, Y., & Khossain, A. (2014). Influence of malting barley varieties on the quality of beer. *Vestnik APK Stavropolya*, 4(16), 52-55.

Kapranov, V., Ratnikov, A., Sviridenko, D., Khramoy, V., & Filatov, A. (2012). Effectiveness of new complex organo-mineral fertilizers in the cultivation of spring barley on the soggy forest soil. *Problemy agrokhimii i ekologii*, 3, 19-22.

Kirilova, G., & Zhukov, Y. (2003). Barley quality and the application of fertilizers at various rates on sod-podzolic soil. *Agrokhimiya*, 12, 33-37.

Kiryushin, V. (2019). Management of soil fertility and productivity of agrocenoses in adaptive landscape farming. *Pochvovedenie*, 9, 1130-1139.

Kudeyarov, V. (2019). Soil and biogeochemical aspects of arable farming in the Russian Federation. *Pochvovedenie*, 1, 109-121.

Lanconde, Y., Cochet, J., & Castillon, P. (1993). Apported l'azote en pensant a la qualite de recolte. *Perspectives Agricola*, 184, 62-69.

Maleki-Farahani, S., Chaichi, M., Mazaheri, D., Tavakkol-Afshari, R., & Savaghebi, G. (2011). Barley grain mineral analysis as affected by different fertilizing systems and by drought stress. *J.Agr.Sci.Tech.*, 13, 315-326.

Mazurov, I., Lukashov, V., & Isakov, A. (2013). Use of grain crops and legume-cereal grain mixtures for feeding livestock in the Kaluga region. *Zernobobovye i krupyanye kultury*, 2(6), 123-125.

Melnikova, O., & Torikov, V. (2011). Brewing qualities of grain and malt of spring barley at different levels of mineral nutrition. *Problemy agrokhimii i ekologii*, 2, 54-57.

Mihova, G., Ivanova, A., Doneva, S., & Petrova, T. (2014). Economic characteristics of new varieties of winter two-row barley created at the Dobrudja Agricultural Institute. *Sbornik Zemedelie*, 2, 125-134.

Morell, F., Lampurlanes, J., Alvaro-Fuentes, J., & Cantero-Marthinez, C. (2011). Yield and water use efficiency of barley in a semiarid Mediterranean agroecosystem: Long-term effects of tillage and N fertilization. *Soil and Tillage Research*, 117, 76-84.

Moreno-Jiménez, E., Fernandez, J.M., Puschenreiter, M., Williams, P., & Plaza, C. (2016). Availability and transfer to grain of As, Cd, Cu, Ni, Pb and Zn in a barley agri-system: Impact of biochar, organic and mineral fertilizers. *Agriculture, Ecosystems & Environment*, 219, 171-178.

Novikov, N., & Solovyeva, N. (2019). Influence of nutrition mode and phytoregulators (Novosil, Epin) on grain quality and proteins composition of brewing barley grown on sod-podzolic soil. *Izvestiya TSKHA*, 3, 5-18.

Novikov, N., & Solovyeva, N. (2020). Formation of the brewing properties of barley grain depending on the diet and the use of phytoregulators when growing on the sod-podzolic soil. *Izvestiya TSKHA*, 2, 5-19.

Novikov, N., Myakinkov, A., & Sychev, R. (2009). Formation of brewing properties of the Mikhailovskiy barley variety depending on the level of nitrogen nutrition when grown on sod-podzolic medium-loamy soil. *Izvestiya TSKHA*, 3, 65-73.

Pasynkov, A. (2002). Yield and brewing quality of different varieties of barley depending on the application rate and the ratio of nitrogen and potash fertilizers. *Agrokhimiya*, 7, 25-31.

Sandev, S. (1979). *Chemical methods for the analysis of fodders*. Sofia, Bulgaria: Zemizdat

Shafran, S. (2014). Further study on the diagnosis of mineral nutrition of plants. *Agrokhimya*, 3, 3-11.

Yankov, B., Terziev, Zh., Moskov, G., & Yancheva, H. (2002). *Crop production*. Plovdiv, Bulgaria: Academic press of AU.

Zavyalova, N., & Shishkov, D. (2020). Effect of mineral fertilizerson crop quality and yield in long-term stationary experiment in the climatic conditions of the Cis-Urals. *Izvestiya TSKHA*, 5, 5-17.

Zörb, C., Senbayram, M., & Peiter, E. (2014). Potassium in agriculture – status and perspectives. *Journal of Plant Physiology*, 171, 656-669.