

Efficiency of root nitrogen supplementary feeding of winter wheat in conditions of autumn drought of Eastern Forest-steppe of Ukraine

Popov S.¹, Avramenko S.², Shevchenko T.³

^{1,2}V. Yuryev Institute of plant growing of NAAS, Moscovskii avenue, 142, Kharkiv, 61060, Ukraine, ³National academy of agrarian sciences of Ukraine, Mykhailo Omelianovych-Pavlenko Str., 9, Kyiv, 01010, Ukraine; e-mail: ¹sergivpopov@gmail.com, ²avsergiy1@gmail, ³toma.agrovet@gmail.com

The purpose. To probe effect of different doses of ammonium nitrate and carbamide on productivity and quality of grain of winter wheat depending on the predecessor, background of feed and weather environment during growing. **Methods.** General scientific: field experiments, laboratory (physicochemical parameters of quality of grain), calculation-relative and statistical. **Results.** On typical average humus chernozem of Left-bank Forest-steppe of Ukraine root nitrogen supplementary feeding in tillering stage in dose of N_{40} depending on the background of a feed after bare fallow promoted increase of yield in alternatives with importation of ammonium nitrate on 0,75 – 0,81 t/hectare, carbamide — on 0,71 – 0,92, and after pease for grain — accordingly on 0,71 – 0,72 and 0,69 – 0,80 t/hectare. At equal doses of supplementary feeding they did not fix essential variance in productivity and quality of grain between forms of nitrogen, and heightening rates of application from N_{40} up to N_{60} was economically ineffective. The most tall pay-back of 1 kg of nitrogen with grain was ensured by application of dose N_{20} after bare fallow on not fertilized background — 29,5 – 35,5 kg. In good weather environment root supplementary feeding in doses of N_{40} and N_{60} promoted deriving grain of 2nd and 3rd classes after bare fallow, and 3rd and 5th — after pease. **Conclusions.** Joint effect of base fertilizer ($N_{30}P_{30}K_{30}$ on the background of after-effect of dung) and root nitrogen supplementary feeding in tillering stage with ammonium nitrate or carbamide in dose of N_{40} is an efficient method of increase of yield and quality of grain of winter wheat. Optimization of importation of both kinds of nitrogen fertilizers by root method after bare fallow and pease equally raised their efficiency and pay-back by grain, especially in conditions of dry autumn.

Key words: winter wheat, ammonium nitrate, carbamide, root supplementary feeding, productivity, quality of grain.

DOI: <https://doi.org/10.31073/agrovisnyk201905-02>

Winter wheat is one of the most productive and valuable food crops. However, while the world's demand for food wheat is increasing, in Ukraine, class III-IV grain production, depending on the region, ranges from 12 to 25%, which holds back the build-up of its export potential. According to official data, the share of food wheat in the total amount of grain is 54%. Therefore, the challenge of improving the grain quality, along with stabilizing winter wheat yield, remains relevant [1-6], especially upon activation of climate warming processes, which has been clearly discernible in the last two decades [7, 8]. Thus, over the past 20 years on the territory of the Kharkiv region, the average daily temperature, depending on the month, has increased by 0.7-2.5 °C compared with the period of 1951-1993. The increase was the greatest in January and February (by 2.5-3.0 °C) and in the summer (by 1.5-2.5 °C) [8].

Winter wheat is only able to give high yields of good quality grain on fertile soils and with sufficient amounts of fertilizers [9 - 11]. According to the cumulative data of leading research institutions, the main reason for poor quality of grain is nitrogen deficit in wheat agrocenoses; therefore, in most cases it is impossible to obtain high-quality grain using modern resource-saving technologies without sufficient input of nitrogen [12, 13]. Nitrogen fertilization of crops is of particular importance; it should be moderate in autumn and sufficient in the periods of tillering and formation of yield structure elements. Nitrogen is the most intensely absorbed by plants during the active growth - from the spring tillering to the ear formation.

During the stem elongation phase nitrogen begins to be distributed over organs, and accumulation of nitrogen compounds in vegetative organs continues until the vegetation is over [14, 15]. Subsequently, they play a major role in grain formation, the protein of which is synthesized mainly by mobilizing nitrogen from leaves, stems and ears [16]. Solar illumination of all tiers of leaves is important, because nitrogen cycles are considered as the basis of production processes [17]. At the same time, upon water deficit, an increase in nitrogen fertilizers does not always guarantee positive results, even when winter wheat is grown after black fallow or pea. It is reported that the effects of both single and split application of nitrogen fertilizers on the yield are generally similar, and twice or thrice application of nitrogen is sometimes less effective than single application of the whole dose in autumn [2]. Review of foreign and domestic literature allowed us to elucidate that an increase in nitrogen doses to 120 - 180 kg/ha of active ingredient is not always effective even after non-fallow predecessors [17 - 19]. It is noted that solving the problem of increasing the protein content in grains depends both on nitrogen nutrition of plants and on weather conditions during certain stages of development, which are crucial to the grain quality [10, 20].

Despite multiple studies with nitrogen fertilizers, there is no consensus on the effectiveness of their different forms and effects on combination of high performance and grain quality. For root crop fertilization, ammonium nitrate (NH_4NO_3) is used, and carbamide $\text{CO}(\text{NH}_2)_2$ is used for foliar application, but its use for root fertilization requires further investigations, since it is no inferior to ammonium nitrate in terms of efficiency [21]. **Purpose.** The study purpose was to determine of the best doses of ammonium nitrate and carbamide for root fertilization and to evaluate their effects on the grain yield and quality of winter wheat sown after black fallow and grain pea, depending on nutrition background in the zone of interest. **Materials and Methods.** The study was carried out in a stationary 9-field crop rotation at the Department of Plant Production and Variety Investigations of the PPI nd. a. V.Ya. Yuriev of NAAS in 2015-2018. Soil was typical black medium-humus weakly-leached earth. In the crop rotation, the content of easily-hydrolyzed nitrogen in an arable layer was low or moderate (13.0-17.0 mg per 100 g of soil), and the contents mobile phosphorus and potassium forms were increased: 12.9-10.0 mg and 10.2- 11.4 mg, respectively. Upon manure aftereffect with application of $(\text{NPK})_{30}$, the nitrogen content was low or moderate, and the phosphorus (16.2-16.6 mg) and potassium (13.0-13.6 mg) contents were high. Highly-intensive variety Statna was used in the experiments. Root fertilization of plants in the spring tillering phase was conducted with ammonium nitrate or carbamide at doses of N_{20} , N_{40} and N_{60} on 2 nutrition backgrounds: crop rotation (no fertilizers, forms due to natural soil fertility and crop rotation) and organic/mineral (6.6 t/ha of the crop rotation area + $\text{N}_{30}\text{P}_{30}\text{K}_{30}$). The plots were arranged systematically; the total area was 34.0 m²; the accounting area was 25.0 m². The experiments were conducted in 3 replicas. Observations, records and analyses in the experiments were carried out in compliance with conventional techniques. Wheat was harvested by solid threshing of the plots with a harvester Samro-130. Quality parameters of the yield were determined in the Laboratory of Grain Quality. The experimental data were processed by analysis of variance [22].

The weather conditions during the study years were contrast both by the temperature regime and by water supply of plants. The hydrothermal conditions of the autumn period of 'emergence - cessation of vegetation' appear to be the most influential on the reproduction. Thus, the autumn of 2014 was dry, because of which post-black fallow plants entered the winter in the 2/3-shoot phase, and after pea they only formed 1-3 leaves. However, favorable for overwintering conditions as well as the warm and wet spring provided on the whole a sufficient plant stand. The summer months were dry; the temperatures in June and July were by 0.8 - 1.8°C higher than the norm. In June, the precipitation exceeded (by 44%) the norm, which contributed to grain filling and quality. The autumn of 2015 was warm and dry. The insufficient rainfall in September, October and the first 10 days of November (16%, 11% and 41%, respectively, related to the norm) delayed shooting. Even after properly maintained black fallow, as of October 10, 30-40% of shoots were just the first unfold leaves; 40-50% of seeds had little germinal roots; and the rest of seeds did not sprout. The temperature was close to the average multiyear value. Productive precipitation was only in the second and third 10 days of November: 38.2 mm and 30.1 mm, respectively. That is, in the autumn of 2015, neither of the predecessors provided robust shoots due to

soil drought. However, the abnormally warm and wet winter contributed to preservation of crops and formation of robust shoots in February with the average air temperature in the second - third 10 days of 5.6°C. The spring was early and wet: at increased temperature the rainfall amount in April-May was 2-2.5-fold compared with the norm. However, because of a thin plant stand, insufficient biomass of plants and shortening of interphase periods the performance and grain quality were not high.

In the autumn of 2016, there was soil drought, because of which shoots entered the winter in the 'the first unfold leaves' phase of and 1-2 leaves. However, the early spring of 2017 (March was by 5.4°C warmer than usually) contributed to intensive tillering of plants and, subsequently, to a sufficient density of productive plant stand. During the 'April - June' period, the total precipitation was 94.0 mm, which is by 48.5 mm less than the norm. The first half of July was characterized by elevated temperature associated with water deficit. Such conditions contributed to good setting and filling of grain having high quality parameters.

The autumn of 2017 were dry. It was hot in August and September, and the precipitation amount was only 18% and 48%, respectively, related to the norm, resulting in uneven shooting, some seeds remained ungerminated in soil or just started germinating. The October's precipitation and extremely hot weather during the 'October – December' period (the sum of effective temperatures $\geq 5^\circ\text{C}$ was 350-380°C) contributed to complete shooting and forming 2-3 shoots after black fallow and 2-3 leaves after pea. The winter was favorable for plant overwintering; the minimum temperature of soil at the tillering node depth was -7-8°C. The spring-summer period of 2018 was characterized by an increased temperature regime. In May - July, the average monthly air temperature was by 2.4 - 4.5°C higher than the norm. In March, the precipitation amount (109.3 mm) was 4-fold in comparison with the normal, but later during the May-July period the total precipitation (113.4 mm) was by 2.1 times less than the norm. Such conditions led to a shortening of interphase periods (ear formation - full maturation) and accelerated grain maturation.

Thus, the weather conditions during the study years were arid in the autumn and varied over the years during the spring and summer period, which enabled obtaining objective results and comprehensively evaluate them. Drastic fluctuations of the hydrothermal regime significantly affected production processes, and changes in biomass formation, especially in dry years, adequately impacted on the winter wheat grain yield and quality.

Results. Analyzing the effects of fertilizers on the yield, we noticed a significant increase in it was due to both basal fertilizing and nitrogen fertilization. On average, in 2015-2018, the post-black fallow grain yield was 7.06 t/ha on organic-mineral fertilization (manure aftereffect + $\text{N}_{60}\text{P}_{60}\text{K}_{60}$), which was by 1.17 t/ha higher than in the control (Table 1).

Root nitrogen fertilization in the tillering phase provided a considerable increase in performance in the both variants of nutrition, regardless of the dose of ammonium nitrate or carbamide. Thus, in the 'no basal fertilizing' experiments ammonium nitrate supplementation at doses of N_{20} , N_{40} and N_{60} resulted in a gain in the grain yield of 0.59, 0.81 and 0.87 t/ha, respectively, and carbamide supplementation – of 0.71, 0.92 and 1.05 t/ha, respectively, with the control yield of 5.89 t/ha.

1. Winter Wheat Yield Depending on Fertilization and Nitrogen Doses after Black Fallow, t/ha, 2015-2018.

Fertilizer (B)	Nitrogen dose (C)	Year				Average, t/ha	Payback, 1 kg of active ingredient by grain, kg
		2015	2016	2017	2018		
background – no basal fertilizing (A)							
Control	N_0	7.04	4.70	6.07	5.74	5.89	–
Ammonium nitrate	N_{20}	7.54	5.13	7.32	5.93	6.48	29.5
	N_{40}	7.50	5.40	7.78	6.10	6.70	20.3
	N_{60}	7.57	5.53	7.89	6.04	6.76	14.5

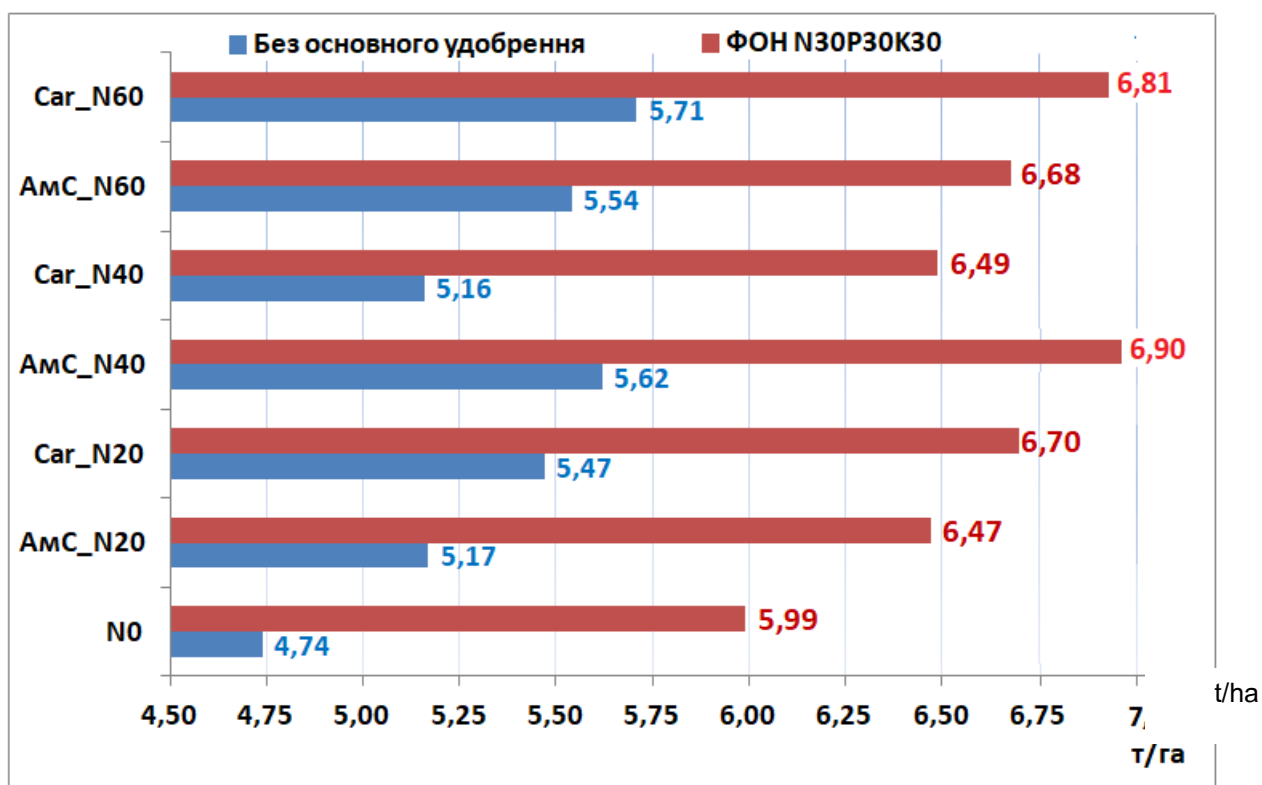
Carbamide	N ₂₀	7.60	5.30	7.66	5.85	6.60	35.5
	N ₄₀	7.69	5.45	8.17	5.92	6.81	23.0
	N ₆₀	7.30	6.31	8.20	5.95	6.94	17.5
background – manure aftereffect + N ₃₀ P ₃₀ K ₃₀ as basal fertilizing							
Control	N ₀	7.33	6.27	7.70	6.95	7.06	–
Ammonium nitrate	N ₂₀	7.63	6.44	8.57	7.23	7.47	20.5
	N ₄₀	7.82	6.99	8.95	7.47	7.81	18.8
	N ₆₀	7.94	7.05	8.98	7.46	7.86	13.3
Carbamide	N ₂₀	7.64	6.81	8.25	7.33	7.51	22.5
	N ₄₀	7.90	7.16	8.55	7.47	7.77	25.3
	N ₆₀	7.98	7.22	8.66	7.52	7.85	18.7
LSD ₀₅	A – 0.22; B – 0.19; C – 0.24; AB – 0.28; AC – 0.24; BC – 0.19; ABC – 0.26						

Thus, both ammonium nitrate and carbamide at a dose of N₆₀, compared with N₄₀, gave no significant increase in the yield, which was within 0.06-0.13 t/ha. There was no significant difference in the yield between the types of nitrogen fertilizers used at the equivalent doses (LSD₀₅ = 0.19 t/ha). Only in 2017, carbamide was more effective, regardless of the dose. In addition, in 2017, supplementation ensured the highest gain in the yield. When N₂₀, N₄₀ and N₆₀ were applied, a significant gain in the yield was 1.59, 2.10 and 2.13 t/ha, respectively, compared to the control, which was by 0.34, 0.39 and 0.31 t/ha higher than the values obtained with ammonium nitrate (LSD₀₅ = 0.24 t/ha). Without basal fertilizing, a lower, however significant, increase in the grain yield was recorded, which, on average throughout years, was the highest with N₄₀ and N₆₀: 0.75 and 0.80 t/ha, respectively, for ammonium nitrate and 0.71 and 0.79 t/ha for carbamide. The maximum rise in the grain yield was achieved in 2017, which was 1.16 and 1.52 t/ha, respectively, for the above-mentioned doses of ammonium nitrate and 1.05 and 1.24 t/ha, respectively, for carbamide. Thus, N₄₀ was the most effective after black fallow, since being applied as ammonium nitrate without basal fertilizing, it resulted in an increase in the yield of 0.81 t/ha, and being applied as carbamide without basal fertilizing, it gave a rise in the yield of 0.92 t/ha. With basal fertilizing, the gain was 0.75 and 0.71 t/ha, respectively.

After grain pea, on average for the four years without basal fertilizing, an increase in the nitrogen dose from N₂₀ to N₄₀ raised the yield in the experiments with ammonium nitrate from 0.43 to 0.72 t/ha and in the carbamide experiments from 0.44 to 0.80 t/ha, with the control yield of 4.74 t/ha (Fig. 1). The highest gain in the yield was obtained with N₆₀: 0.88 and 0.97 t/ha or 18.6 and 20.5%, respectively. At the same time, in 2015 and 2016, carbamide at the dose of N₆₀ provided the highest performance: 7.65 and 5.35 t/ha, respectively, which is by 0.36 and 0.39 t/ha higher in comparison with the equivalent dose of ammonium nitrate. It should be noted that basal fertilizing with N₃₀P₃₀K₃₀ (on manure aftereffect) increased the yield by 1.25 t/ha compared with the control, and additional root fertilization gave a gain in the grain yield that was similar to that obtained without basal fertilizing. We observed no dependence of performance on the type of nitrogen fertilizers. Thus, in the ammonium nitrate experiments, the rise in the grain yield was 0.48 - 0.91 t/ha, and in the carbamide experiments it was 0.50 - 0.82 t/ha (LSD₀₅ = 0.19 t/ha). The highest gain of 0.71 and 0.91 t/ha in the yield was achieved with N₄₀ and N₆₀, respectively, in the ammonium nitrate experiments and of 0.69 and 0.82 t/ha, respectively, — in the carbamide experiments. It is noteworthy that nitrogen fertilization at a dose of N₂₀ was more effective without basal fertilizing: the increase in the grain yield amounted to 10.0-12.1%, whereas with N₃₀P₃₀K₃₀ it was 5.8-6.3%.

Thus, it was economically feasible to use N₄₀ after the both predecessors.

No basal fertilizing



Note. AmC-ammonium nitrate; Car - carbamide.

Figure 1. Winter Wheat Yield Depending on Fertilization and Nitrogen Doses after Grain Pea, t/ha, 2015-2018.

After black fallow, depending fertilization, the yield increase with ammonium nitrate was 0.75-0.81 t/ha, and with carbamide - 0.71-0.92 t/ha; after grain pea - 0.71-0.72 t/ha and 0.69-0.80 t/ha, respectively. It should be noted that the increase in the dose of the both types of nitrogen fertilizers from N₄₀ to N₆₀ gave no significant rise in the yield, and the payback decreased. Greater grain yields in the experiments were produced due to a larger quantity of productive stems and larger number of grain per ear. At the same time, the 1000-grain weight did not change significantly.

In the experiments, a payback of high nitrogen fertilizers by grain was demonstrated; it largely depended on basal fertilizing and nitrogen supplementation doses. For example, after black fallow with application of N₃₀P₃₀K₃₀ and ammonium nitrate at doses of N₂₀, N₄₀, N₆₀ per kg of nitrogen, we produced 20.5, 18.8 and 13.3 kg of grain, respectively, and in the carbamide experiments - 22.5, 25.3 and 18.7 kg, respectively. Similar data were obtained after pea as a predecessor; the payback in the ammonium nitrate and carbamide experiments was 15.2-24.0 kg and 13.7-25.0 kg, respectively. Yet, a much higher payback of the both types of nitrogen fertilizers in grain was achieved in the experiments with their limited use. For example, after black fallow without basal fertilizing in the experiments with ammonium nitrate at doses of N₂₀, N₄₀, N₆₀, 29.5, 20.3 and 14.5 kg of grain was obtained per kg of active ingredient (nitrogen), respectively, and in the carbamide experiments - 35.5, 23.0 and 17.5 kg, respectively. Such a high return on nitrogen fertilizers is attributed to the rapid action of nitrogen compounds after additional fertilization of underdeveloped and thinned crops with the proviso that soil contains a sufficient amount of water.

The data of the laboratory analyses of grain quality parameters showed that they significantly differed from year to year and depended on the weather during the vegetative period, predecessor and doses of nitrogen fertilizers. The main parameters limiting the grain class were the protein content in grain as well as the gluten content and quality (Gluten Deformation Index [GDI]). In favorable 2015 characterized by humidification in the first half of the vegetation and lack of rainfall in June - July after black fallow, regardless of nutrition background, form and dose of nitrogen fertilizers, class III grain was harvested.

The exception was application of ammonium nitrate at the dose of N₆₀, which gave class II grain (Table 2). The highest protein (13.4-13.5%) and gluten (24.6-26.8%) contents in grain were recorded with application of carbamide at doses of N₄₀ and N₆₀. In 2016, depending on the nitrogen dose, the protein content in grain amounted to 13.4-14.8% without basal fertilizing and to 13.9-14.2% with basal fertilizing (NPK)₃₀, and the gluten content - to 18.4-22.8% and 21.2-23.6%, respectively. However, in all the experiments because of low vitreousness (19-35%) and falling numbers (62-65 sec), grain met to the requirements of class VI. In the most favorable 2017, even in the control variants, grain with high contents of protein (11.7-15.0%), gluten (19.6-22.8%) and high test weight (840-846 g/L) was harvested. Supplementation with ammonium nitrate and carbamide on basal fertilizing (N₃₀P₃₀K₃₀), depending on the nitrogen dose, increased the protein content in grain by 2.1-2.8% and the gluten content by 4.8-6.4%. At the same time, the grain corresponded to class II, and in the control - to class III (Table 2).

2. Winter Wheat Grain Quality Depending on Doses of Nitrogen Fertilizers after Black Fallow without Basal Fertilizing, 2015-2018.

Grain quality parameters according to State Standard 3768:2010	Nitrogen fertilizer and dose						
	Control	Carbamide			Ammonium nitrate		
		N ₂₀	N ₄₀	N ₆₀	N ₂₀	N ₄₀	N ₆₀
2015							
Test weight, g/L	784	780	760	776	780	776	768
Vitreousness, %	59	41	41	51	47	58	41
Protein content, %	13.2	12.9	13.5	13.4	13.0	13.4	13.5
Gluten content, %	21.6	22.8	24.6	26.8	20.4	21.6	23.6
Falling number, sec	242	264	215	238	264	236	261
GDI, units	30	20	35	35	45	50	30
Class of grain	III	III	III	III	3	III	II
2016							
Test weight, g/L	754	728	756	744	736	756	736
Vitreousness, %	27	23	32	29	19	34	33
Protein content, %	13.1	13.5	13.6	13.4	13.2	13.4	14.8
Gluten content, %	18.8	20.8	20.8	18.4	20.8	21.6	22.8
Falling number, sec	62	62	62	62	62	62	62
GDI, units	45	30	25	30	40	40	40
Class of grain	VI	VI	VI	VI	VI	VI	VI
2017							
Test weight, g/L	844	848	846	844	846	842	842
Vitreousness, %	68	67	73	70	71	71	71
Protein content, %	15.0	14.4	15.6	15.2	14.9	15.2	15.2
Gluten content, %	22.8	24.0	24.8	24.6	25.2	24.4	24.4
Falling number, sec	394	386	375	375	412	389	389
GDI, units	70	80	90	80	85	70	70
Class of grain	III	II	II	II	II	II	II

In 2015 after pea, class V grain was produced. Only application of ammonium nitrate at the dose of N₄₀ and carbamide at the dose of N₆₀ ensured class III grain. In unfavorable 2016, in all the experiments, grain met the requirements of class VI, and in favorable 2017 – class III. At the same time, on basal

fertilizing, supplementation with ammonium nitrate at doses of N_{40} and N_{60} improved the grain quality to class II. Hence, root fertilization with ammonium nitrate and carbamide at doses N_{40} - N_{60} equally contributed to a significant improvement in the grain quality, which in the favorable years after black fallow met the requirements class II/III, and after grain pea – class III-V. The main parameters limiting the grain rating were the protein content in grain as well as the gluten content and quality. Reduction in some parameters of the grain quality associated with increased performance indicates that there were not enough nitrogen compounds for plant biomass formation, which largely depended on the weather conditions during the vegetative period. Therefore, development of optimal nitrogen fertilization of plants is an infeasible and fast-response factor for the grain quality. Thus, the results allow us to conclude that after black fallow and grain pea nitrogen fertilization should be an integral part in winter wheat cultivation technologies. The efficiency of root fertilization with the both types of nitrogen fertilizers was to a great extent determined by moisture content in soil at the time of their application and during the main stages of plant development.

Conclusions

Combination of basal fertilization ($N_{30}P_{30}K_{30}$) and root nitrogen supplementation at a dose of N_{40} is an effective way to increase the winter wheat yield and grain quality. Nitrogen fertilization at a dose of N_{40} in the tillering phase, depending on nutrition background after black fallow, increased the yield by 0.75-0.81 t/ha in the ammonium nitrate experiments and by 0.71-0.92 t/ha in the carbamide experiments. After grain pea, the increase was 0.71 - 0.72 t/ha and 0.69 - 0.80 t/ha, respectively. An increase in the nitrogen dose from N_{40} to N_{60} , both with ammonium nitrate and with carbamide, was economically ineffective. There were no significant differences in the yield between nitrogen fertilizers used at equivalent doses. The both forms of nitrogen fertilizers at a dose of N_{20} provided the maximum payback of 1 kg of nitrogen in grain after black fallow without basal fertilizing on typical black medium-humus earth, which corresponded to 29.5-35.5 kg of grain. The best quality of grain was achieved in the N_{40} and N_{60} experiments; in these variants grain, under favorable weather conditions, met the requirements of class II-III after black fallow and class III-V after pea.

References

1. Larchenko K.A., Morhun B.V. (2010). Quality traits of wheat grain and methods for improving them. *Fiziolohiya i Biokhimiya Kult. Rasteniy*. Kiev. Vol. 42. No. 6. P. 26–31. [in Ukrainian]
2. Cherenkov A.V., Solodushko M.M., Zheliazkov O.I., Khorizko S.A. (2014). Modern technologies of winter wheat growing in the steppe zone. Dnipropetrovsk. 115 p. [in Ukrainian].
3. Desiatnyk L.M., Kotsiuban D.A. (2008). Influence of predecessors, fertilizer system and basic cultivation on winter wheat yields in the steppe of Ukraine. *Biul. In-tu Zern. Hosp-va UAAN*. Dnipropetrovsk. No. 33–34. P. 117–120. [in Ukrainian]
4. Chumak V.S., Yevtushenko V.V., Tsyliuryk O.I. (2007). Influence of weather conditions, predecessors and fertilizers on the winter wheat performance. *Biul. In-tu Zern. Hosp-va UAAN*. Dnipropetrovsk. Nos. 18-19. P. 78–81. [in Ukrainian].
5. Popov S.I., Fursova H.K., Avramenko S.V., Leonov O.Yu. (2014). Formation of winter wheat grain quality depending on fertilizer system under various weather conditions. *Visnyk TsNZ APV Kharkivskoi Oblasti*. Kharkiv: Mahda LTD, No. 17. P. 50-59. [in Ukrainian].
6. Cherenkov A.V., Shevchenko M.S., Khorishko S.A., Romanenko O.L. (2010). Performance of modern varieties of winter crops in the steppe of Ukraine. *Biul. In-tu Zern. Hosp-va UAAN*. Dnipropetrovsk. No 39. P. 3–7. [in Ukrainian]
7. Chaika V.M. Adamenko T.I. (2008). Climate change and phytosanitary status of agrocenoses in the forest-steppe. *Agronom*. No 2. P. 11–15. [in Ukrainian]
8. Popov S.I. Avramenko S.V., Bondarenko Ye.S. (2016). (Kyrychenko V.V. Ed.). Weather conditions and their influence on formation of winter crop yields in the eastern forest-steppe of Ukraine.

Fundamentals of the management of production processes in field crops: monograph. Kharkiv: Individual Entrepreneur Brovin O.V., P. 595–615. [in Ukrainian]

9. Zheliazkov O.I. (2011). Formation of winter wheat grain quality parameters of depending on predecessors, sowing dates and seeding rates in Prysvashshia. *Biul. In-tu Zern. Hosp-va UAAN*. Dnipropetrovsk. No. 40. P. 175–179. [in Ukrainian]

10. Zhemela H.P. Fertilizers, yield and grain quality. Kyiv: Urozhai, 1991. 136 p. [in Ukrainian]

11. Hasanova I.I., Bondarenko A.S., Porotska L.P., Hyrka A.D. (2006). Influence of agrotechnical techniques on the winter wheat grain quality in the northern steppe. *Biul. In-tu Zern. Hosp-va UAAN*. Dnipropetrovsk. Nos. 26-27. P. 95–98. [in Ukrainian]

12. Yankovskyi Yu., Bokoch I. (2006). Agrotechniques on winter wheat. *Propozytsiia*. No. 9. P. 60–63. [in Ukrainian]

13. Derhachov O.L. (2010). Influence of sowing dates and mineral nutrition on the bread-making quality of winter wheat grain. *Nauk.-Techn. Biul. Myronivskoho Instytutu imeni V.M. Remesla*. Issue 10. P. 247–253. [in Ukrainian]

14. Shevchenko A.I. (2010). Agrochemicals and technologies in modern agriculture: alternatives and perspectives. *Nauk.-Techn. Biul. Myronivskoho Instytutu imeni V.M. Remesla*. Issue 10. P. 222–229. [in Ukrainian]

15. Lykhchvor V.V., Petrychenko V.F., Ivashchuk P.V., Korniihuk O.V. (2010). Plant production. Cultivation technologies of agricultural crops. Lviv: Scientific-Production Firm "Ukr. Tekhnologii", 1088 p. [in Ukrainian]

16. Pasichnyk N.A. (2006). Nitrogen supplementation of winter wheat on meadow black earth of the northern forest-steppe. *Visnyk KhNAU im. V.V. Dokuchaeva. Series "Hruntoznavstvo, Ahrokhimiia, Zemlerobstvo, Lisove Hospodarstvo"*. Kharkiv. P. 141–149. [in Ukrainian]

17. Cherenkov A.V., Nesterets V.H., Solodushko M.M., Hasanova I.I. et al. (2015). Winter wheat in the steppe zone, climate changes and cultivation technologies. Ed. by A.V. Cherenkov Dnipropetrovsk: "Nova Ideolohiia", P. 342–343. [in Ukrainian]

18. Dogan R., Bilgili U. (2010). Effects of previous crop and N-fertilization on seed yield of winter wheat (*Triticum aestivum* L.) under rain-fed Mediterranean conditions. *Bulg J. Agr. Sc.* Vol.16, No 6. P. 733–739.

19. Dudkina O., Kaplun A. (2010). Nitrogen fertilization of wheat. *Propozytsiia*. No 7. P. 22–24. [in Ukrainian]

20. Nikolaev Ye.V. (1983). Reserves of increasing the production of strong and valuable wheat grain. M.: Kolos, 270 p. [in Russian]

21. Popov S.I., Bondarenko Ye.S., Kurilov A.C. (2018). Influence of nitrogen supplementation on the winter wheat grain yield and quality. *Visnyk TsNZ APV Kharkivskoi Oblasti*. Kharkiv: Private Enterprise "Styl-Izdat", No. 24. P. 68–78. [in Ukrainian]

22. Dospikhov B.A. (1985). Methodology of field experimentation (with basics of statistical processing of research data). M.: Agropromizdat, 351 p. [in Russian]