Effects of application rates of urea mineral fertilizer suspension on winter wheat yield

Shavkat Djabborov[1*], *Saodat* Asatova[1], *Bekzod* Xalimov[1], *Aliya* Maxkamova[1] and *Mukambar* Musurmonova[1]

[1]Tashkent State Agrarian University, 100140 Tashkent, Uzbekistan

Abstract. One of the key challenges today is ensuring food security for the growing global population. To achieve this, the efficient and environmentally sustainable use of mineral fertilizers in agricultural crops is essential for obtaining high-quality yields. This study examines the effects of urea application at different growth stages — 4.0 kg/ha during tillering, 8.0 kg/ha during tuber formation, 12.0 kg/ha during spiking, and 16.0 kg/ha during milk-wax ripening — on crop productivity. The results demonstrate that the use of diluted urea suspensions significantly improves grain yield by enhancing leaf surface area and overall plant growth.

1 Introduction

Since wheat grain is a primary source of food in the diets of people worldwide, increasing the area of cultivation, as well as improving its yield and quality, has become a growing focus. Currently, more than 200 million hectares of land are used for wheat cultivation globally, producing 729.0 million tons of grain. As wheat grain remains a key element in global food consumption, attention to expanding its cultivation area, increasing productivity, and enhancing the quality of the harvest continues to grow [1].

In our country, the cultivation of wheat on irrigated lands has enabled grain self-sufficiency, with the surplus being exported to foreign markets. The next objective is to intensify agriculture on irrigated lands, improve the efficiency of mineral fertilizers through resource-saving technologies, and further develop sustainable farming practices [3].

In this regard, creating early-maturing and high-yielding wheat varieties while considering the soil and climatic conditions of each region, as well as the biogenetic characteristics of wheat, has become a modern necessity. Developing specific agrotechnical practices for each variety, particularly determining optimal norms and timing for wheat fertilization, is also a current demand [1-3]. Therefore, scientifically developing measures aimed at improving the agrochemical properties of the irrigated typical gray soils of the Tashkent region and enhancing the efficiency of mineral fertilizers in foliar feeding of winter wheat is considered a pressing task.

Fertilizers are applied to winter wheat at rates of N-250, P2O5-175, and K2O-125 kg/ha, the highest nutrient absorption is observed. However, this does not significantly

[*] Corresponding author: djabborov@gmail.com

affect crop productivity. Therefore, applying fertilizers at N-200, P2O5-140, and K2O-100 kg/ha is found to be more effective and appropriate [7-8].

B.M. Azizov notes that foliar feeding not only increases the protein content but also improves its quality. The reaction of urea solution is neutral and does not have any negative impact on plants. When winter wheat is fed with a 7–10% urea solution during the heading stage, grain yield increases by 2–2.5 c/ha, the protein content in the grain rises by 1.5–2%, and gluten content improves by 3–4% [4-5].

According to scientists after spraying the suspension, dew droplets appear on wheat leaves in the evening as air humidity rises. The dissolved nutrients are effectively absorbed through the stems and leaves of the plants. As a result, plant tissues thicken, take on a lush green color, and the biochemical composition of the cell sap changes, enhancing the crop's resistance to diseases and pests [9,11].

Currently, it is essential to implement urgent agrotechnical measures in wheat cultivation. To address water scarcity, it is necessary to develop comprehensive measures for wheat care, organize nitrogen fertilizer feeding, and conduct 4–5 foliar feedings using suspensions. This includes creating reserves of UAN (urea-ammonium nitrate) and urea-based fungicides in advance, accumulating 5 tons of local organic fertilizers per hectare, and organizing activities such as nitrogen fertilization, irrigation, weed and disease control, and suspension application. Implementing these measures in a timely and high-quality manner, based on the recommendations above, ensures abundant yields from existing wheat fields [10].

Foliar feeding of winter wheat increases the amount of chlorophyll granules in the leaves, which, in turn, accelerates the photosynthesis process. This compensates for rapid plant growth during the tillering and heading stages as well as for insufficient rainfall or irrigation water shortages. Moreover, appropriately timed and dosed suspensions positively affect the height of the main stem [6].

Experiments to determine the effectiveness of urea-based suspensions at optimal rates and times for winter wheat were conducted on the typical gray soils at the Tashkent State Agrarian University's experimental field. The “Grom” variety of winter wheat was selected for the trials. The experiments were carried out in three repetitions in a single tier, with plot sizes of 50x4.8=240 m² and accounting plots measuring 120 m² [5].

2 Materials and Methods

It should be noted that the optimal rates of suspensions for winter wheat during its developmental stages were determined in the experiment. The experimental system is presented in the table.

The following types of mineral fertilizers were used in the experiments: ammonium nitrate (33–34%), urea (46%), simple superphosphate (P2O5 -16%), and potassium chloride (K2O - 60%).

Mineral fertilizers (phosphorus and potassium) were applied based on the annual norms outlined in the PSUEAITI methodological guidelines during autumn plowing, while nitrogen fertilizers were applied according to the experimental system. Soil moisture prior to irrigation was maintained at 75-75-65% of the field capacity.

Table 1. Experimental system (2019–2021)

Number of option	Rates and timing of suspension application				
	At the Branching	Number of option	At the Tillering	Number of option	At the Heading stage
1	Control (water)	6	Control (water)	11	Control (water)
2	4,0 kg/ha	7	4,0 kg/ha	12	4,0 kg/ha
3	8,0 kg/ha	8	8,0 kg/ha	13	8,0 kg/ha
4	12,0 kg/ha	9	12,0 kg/ha	14	12,0 kg/ha
5	16,0 kg/ha	10	16,0 kg/ha	15	16,0 kg/ha

3 Results and Discussion

It should be noted that the experiments were conducted over time and space, i.e., on new fields each year, as winter wheat was rotated under a short crop rotation system (1:1). Therefore, the agrochemical properties of the soil in each experimental field were determined separately. In the plow layer (0–30 cm) of the soil, the humus content during the study years (2018–2019–2020) was 1.20%, 1.232%, and 1.119%, respectively, while in the subsurface layer, it was 0.900%, 0.679%, and 0.780%. The total nitrogen content in 2019 was 0.108–0.058%, phosphorus was 0.185–0.175%, and potassium was 1.550–0.480%. A downward trend in the levels of humus and total nutrient elements was observed in the deeper soil layers.

In the 0–30 cm and 30–50 cm layers of the soil (in the experiments), the following nutrient levels were identified:

N-NO3: 20.7–22.1 and 8.9–14.1 mg/kg,

N-NH4: 12.5–15.8 and 11.0–12.1 mg/kg,

P2O5: 20.2–21.8 and 14.5–16.8 mg/kg,

K2O: 240–280 and 210–220 mg/kg.

Thus, it was determined that the fields were poorly supplied with nutrients. Despite the experiments being conducted on new fields each year, the initial agrochemical properties of the soil in these fields were observed to be relatively similar.

When suspensions were applied at optimal rates and timings on a background of N-180, P2O5-125, K2O-90 kg/ha, the total NPK content in the plants during the tillering stage was found to be 3.100%, 0.740%, and 1.320%, respectively, and in the grain, it was 2.320%, 0.860%, and 0.520%. These values were higher by 0.010%, 0.060%, and 0.040% in the plants, and 0.040%, 0.060%, and 0.030% in the grain, compared to the control.

Relatively high grain yield (62.3 c/ha) and straw yield (71.8 c/ha) were achieved when suspensions of urea at rates of 8.0 kg/ha during the tillering stage and 12.0 kg/ha during the heading stage were applied on a background of N-180, P2O5-125, K2O-90 kg/ha.

Data on grain and straw yields depending on the rates of urea-based suspensions indicate that there were no significant differences between replications and options, owing to favorable climatic conditions during the research years. It should also be noted that nearly identical results were obtained in the control options, regardless of the timing of suspension applications.

In the control option, where urea-based suspensions were applied to winter wheat during the tillering stage, the grain yield across the years was 49.7, 53.1, and 50.8 c/ha, with an average of 51.2 c/ha over three years. The average straw yield was 61.6 c/ha. In the second option, where urea suspensions were applied at a single rate of 4.0 kg/ha, the average grain and straw yields were 55.8 and 67.8 c/ha, respectively, yielding an additional 4.6 c/ha of grain and 6.2 c/ha of straw compared to the control.

It should be emphasized that in all options, nitrogen (N180), phosphorus (P2O5-125), and potassium (K2O-90 kg/ha) were applied during foliar feeding of winter wheat. Thus, the additional grain and straw yields obtained depended solely on the rates and timings of suspension applications. It was determined that suspensions prepared with 4.0 kg/ha of urea were sufficient for early-stage foliar feeding (during tillering). When suspension rates during this stage were increased to 8.0–12.0 kg/ha, additional grain yields of approximately 4.5–4.8 c/ha were observed.

In the control options where suspensions were applied during the stem elongation stage, the average grain and straw yields over three years were 51.5 c/ha and 61.8 c/ha, respectively, differing only slightly from the control of the tillering stage (0.3 and 0.2 c/ha, respectively). However, during this stage (stem elongation), the optimal effect of suspensions slightly increased, resulting in additional grain and straw yields of 3.6 c/ha and 5.6 c/ha, respectively, at a rate of 4.0 kg/ha. In contrast, during tillering, the effect of this rate (4.0 kg/ha) produced additional yields of 4.6 and 6.2 c/ha, respectively. This indicates that as the leaf area of winter wheat increases, the optimal suspension rates should also increase.

By the stem elongation stage, relatively higher yields were observed at a suspension rate of 8.0 kg/ha, with grain yields reaching 57.2 c/ha and straw yields 70.4 c/ha. These resulted in additional yields of 5.7 and 8.6 c/ha, respectively, which were 1.1 and 1.5 c/ha higher than those of the optimal option of the first stage (tillering).

By the heading stage, the grain and straw yields in the control option remained unchanged (51.4–62.0 c/ha). However, the highest grain (59.2 c/ha) and straw (71.0 c/ha) yields were observed when suspensions with 12.0 kg/ha of urea were applied, resulting in additional yields of 7.8–9.0 c/ha.

Thus, it was determined that the optimal rates of urea-based suspensions depend primarily on the growth stages of winter wheat, specifically on changes in leaf area.

4 Conclusion

In the experiment, it was observed that increasing the rates of mineral fertilizers from N-150, P2O5–105, K2O–75 kg/ha to N-180, P2O5–125, K2O–90 kg/ha and N-210, P2O5–145, K2O–105 kg/ha led to an increase in nitrate nitrogen levels in the soil during the ripening period of winter wheat. In the control options (0-30 cm layer of the plowed layer), nitrate nitrogen increased by 2.7–1.4 mg/kg, mobile phosphorus by 0.7–2.4 mg/kg, and exchangeable potassium by 20–28 mg/kg compared to the initial state.

At the optimal fertilizer rates (N-180, P2O5–125, K2O–90 kg/ha), when 8.0 kg/ha of urea-based suspension was applied during stem elongation and 12.0 kg/ha during heading, nitrate nitrogen (N-NO3) content reached 16.6 mg/kg, mobile phosphorus (P2O5) reached 23.7 mg/kg, and exchangeable potassium (K2O) reached 300 mg/kg. These values were 2.1, 2.9, and 30.0 mg/kg higher than the initial state, respectively.

It was determined that the relatively favorable conditions for the growth and development of winter wheat were created when suspensions were applied at 8.0 kg/ha of urea during stem elongation and 12.0 kg/ha during heading, against a background of N-180, P2O5–125, K2O–90 kg/ha. These conditions resulted in a stem height that was 9.2 cm higher than the control, 22 more total stems, 21 more productive stems, a spike length increase of 0.8 cm, 1.7 more grains per spike, a grain mass increase of 2.1 g, and a 1000-grain weight that was 2.8 g higher.

Although good results were also obtained at the fertilizer rates of N-210, P2O5–145, K2O–105 kg/ha with suspensions applied during the same growth stages, the values were slightly lower than the second treatment (optimal rates): stem height was 2.2 cm lower, productive stems were 8 fewer, spike length was 0.2 cm shorter, grains per spike were 1.0 fewer, and the 1000-grain weight was 1.0 g less.

Reference

1. O.S. Amirqulov, Changes in Chlorophyll in Wheat Leaves During Suspension Feeding. /Proceedings of the Republican Scientific-Practical Conference "Resource-Saving Technologies in Agriculture and Transport." Karshi (2015).
2. Z. Abdiev, U. Khurramov, J. Karimov, K. Zokirov, M. Omonov, L. Jumanov, G. Ruzmetov, E3S Web of Conferences **452**, 01012 (2023). https://doi.org/10.1051/e3sconf/202345201012
3. A. Avliyokulov, A. Turgunboev, Uzbekistan Agriculture, **9.** 19 (2006).
4. B.J. Azimov, B.B. Azimov, Methodology of conducting experiments in vegetable, vegetable and potato growing (National Encyclopedia of Uzbekistan, 2002)
5. B.M. Azizov, Effect of Late Nitrogen Fertilization on Grain Yield and Quality of Winter Wheat. Agrarian Science Bulletin Journal. **34,** 7-10 (2008).
6. B.A. Dospexov, Field experiment methodology (Kolos, Moscow, 1980)
7. N.M. Ibragimov, L.A. Mirzaev, D.U. Gofurov, Effect of Different Rates of Nitrogen Fertilizers on Nitrate Nitrogen in Soil and Grain Yield of Winter Wheat. Proceedings of the Republican Scientific-Practical Conference. Tashkent, 75-77 (2011)
8. I. Igamov, A Critical Period in Grain Cultivation. Uzbekistan Agriculture. **4**, 2-3 (2008).
9. D. Jo'raev, O.J. Amanov, AGRO Hydro NEWS Journal **21** (2020).
10. K. Sobirov, B. Akramov, Serious Attention to Grain Cultivation. Uzbekistan Agriculture **4**, 4 (2010).
11. I.V. Yakushkin, M.M. Edelstein, Foliar Feeding of Agricultural Crops. ("Znanie" Publishing House, Moscow, 1955).