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The effect of planting pattern and fertilizer rates on the accumulation of biological dry mass of rice

Muminova Mukhabat Gofurzhanovna
Doctoral student of Rice Research Institute
ORCID:0009-0005-8505-8061
Tel: (+99888 255-85-30)
Kalandarov Bakhtiyor Iskandarovich
Ph.D., Senior Researcher, Rice Research Institute
ORCID: 0000-0002-2482-3437
tel:.(+99890-960-14-54)

Abstract. This study investigated the effect of different planting schemes and mineral fertilizer (NPK) rates on the accumulation of dry matter and total biomass of rice plants under the soil-climatic conditions of the Tashkent region. The rice varieties Billur and Gulistan were used as research objects. The experiment included three fertilizer treatments ($N_{60}P_{60}K_{90}$, $N_{90}P_{60}K_{90}$, and $N_{120}P_{60}K_{90}$) combined with different seedling densities (planting schemes). The results showed that increasing the nitrogen rate significantly enhanced both the dry mass of a single plant and the total dry biomass per unit area. The highest individual plant dry mass values were recorded under the 25×25 cm planting scheme combined with the $N_{120}P_{60}K_{90}$ fertilizer rate. Wider spacing provided better access to light, nutrients, and moisture, which promoted greater biomass accumulation per plant. During the ripening phase, the total dry biomass of the Billur variety reached 24.4–29.6 t/ha depending on the treatment. It was observed that when plant density per unit area was low (wider spacing), the dry mass of an individual plant was higher. Conversely, when seedling density was high (narrower spacing), total biomass accumulation per hectare increased due to the greater number of plants, despite the lower dry mass per individual plant. Overall, the findings indicate that both planting pattern and nitrogen fertilizer rate play a decisive role in dry matter accumulation and biomass formation in rice. Optimizing the balance between plant density and mineral nutrition is essential for achieving maximum biological productivity under the given agro-ecological conditions.

Keywords: rice, seedling cultivation, NPK fertilizers, planting pattern, seedling density, dry mass, total biomass, tillering phase, stem elongation phase, ripening phase, yield.

Introduction. The continuous increase in global food prices, along with the decline in quality indicators in some cases, necessitates further improvement of agricultural production, particularly in the rice sector. In this regard, enhancing breeding programs, developing high-yielding and competitive varieties, strengthening seed production systems, and introducing advanced agrotechnical practices into production have become essential priorities. These measures are crucial for increasing the volume and diversity of food production in the republic and for more fully satisfying the growing demand of the population.

Rice (Oryza sativa L.) is one of the oldest cultivated crops in the world and currently serves as a staple food for nearly one-third of the global population. Although it originated in tropical regions, rice is now widely cultivated under temperate climatic conditions as well. Approximately 60% of the world's population lives in Asia, and more than 90% of global rice production is concentrated in this region. For a large proportion of the Asian population, rice remains the primary staple food and has strategic importance for food security.

In recent years, large-scale reforms aimed at modernizing agriculture, diversifying the sector, and ensuring food security have been implemented in the Republic of Uzbekistan. In particular, the Presidential Decree No. PQ-4973 dated February 2, 2021, "On Measures for Further Development of Rice Cultivation," outlines specific tasks such as the rational use of land and water resources, the introduction of scientifically based agrotechnologies, and the increase of yield and gross production.

In line with these objectives, determining the optimal rates of mineral fertilizers (NPK) for rice cultivation using the seedling method under the soil and climatic conditions of the Tashkent region has been identified as an urgent scientific task. The study aims to optimize the fertilization system, improve plant nutrition conditions, enhance biological dry matter accumulation, and increase overall productivity through the development of scientifically grounded recommendations.

Research methods: The dry mass of rice plants was determined by taking and drying plant samples from three points with an area of 0.25 m 2 during the harvesting, tillering, and ripening phases.

Results and discussion. In rice cultivation, normal plant growth and development are primarily reflected in the accumulation of dry matter and biological yield indicators. In cereal crops, including rice, there is a positive correlation between dry matter accumulation and grain yield. Numerous studies have reported that an increase in plant dry mass leads to a corresponding increase in grain productivity.

The dry mass of rice depends on several factors, including seedling density, tillering capacity, plant height, and the degree of root system development. Conventionally, dry matter is divided into vegetative organ dry mass (stems, leaves, roots) and reproductive organ dry mass (grain). Its formation is closely associated with physiological processes occurring within the plant, particularly the intensity of photosynthesis. The better the development of leaf area and the greater the number of leaves, the more active the photosynthesis process, resulting in higher dry matter accumulation.

Therefore, in our experiments, the effects of different planting schemes and mineral fertilizer (NPK) rates on rice dry matter accumulation were studied. The total dry biomass per unit area was calculated based on the dry mass of a single plant and the number of seedlings per unit area.

During the tillering stage, in the Gulistan variety under the N60P60K90 rate, the dry mass of one plant was 6.27 g at 15×15 cm spacing, 6.50 g at 20×20 cm, and 6.63 g at 25×25 cm. Under the N90P60K90 rate, these values were higher, and under the N120P60K90 treatment, they reached approximately 7.20–7.90 g. In the Billur variety during the tillering phase, the dry mass per plant under N60P60K90 ranged from 7.17 to 7.73 g; under N90P60K90 from 7.33 to 7.80 g; and under N120P60K90 from 8.07 to 8.70 g.

During the stem elongation stage, in the Billur variety under N60P60K90 (at seedling densities of 1333, 750, and 480 thousand plants per hectare), the dry mass per plant ranged from 9.70 to 10.33 g. Under N90P60K90, it ranged from 9.80 to 10.77 g, while under N120P60K90 it was approximately 8.07–8.70 g. In the Gulistan variety at this stage, the dry mass per plant under N60P60K90 was 9.33–9.87 g, under N90P60K90 it was 9.47–10.07 g, and under N120P60K90 it reached 10.47–10.97 g.

At the ripening stage, in the Billur variety under N60P60K90, the dry mass per plant ranged from 12.87 to 18.97 g, and total dry biomass from 17.16 to 25.29 t/ha. Under N90P60K90, these values increased to 16.17–20.30 g per plant and 21.56–27.07 t/ha, respectively. The highest indicators were recorded under N120P60K90, where dry mass per plant reached 18.33–22.20 g and total dry biomass reached 24.44–29.60 t/ha.

It was observed that with an increase in plant density per unit area, the total dry biomass of the crop stand increased proportionally.

Table 1

Effect of planting pattern and fertilizer rates on dry mass accumulation of rice variety Billur (g/plant) (2023-2025 yy)

	Variants	Planting scheme	Phases of development					
			Tillering		Stem elongation		Ripening	
			Dry mass of one plant, g/plant	Total dry biomass, t/ha	Dry mass per plant, g/plant	Total dry biomass, t/ha	Dry mass per plant, g/plant	Total dry biomass, t/ha
	St. Gulistan							
1	$N_{60}P_{60}K_{90}$	15x15	6.27	8.36	9.33	12.44	12.27	16.36
2		20x20	6.50	8.67	9.53	12.71	15.13	20.18
3		25x25	6.63	8.84	9.87	13.16	16.40	21.87
4	$N_{90}P_{60}K_{90}$	15x15	6.47	8.62	9.47	12.62	15.37	20.49
5		20x20	6.80	9.07	9.77	13.02	16.27	21.69
6		25x25	7.07	9.42	10.07	13.42	18.07	24.09
7	$N_{120}P_{60}K_{90}$	15x15	7.20	9.60	10.47	13.96	18.63	24.84
8		20x20	7.70	10.7	10.73	14.31	20.10	26.80
9		25x25	7.90	10.53	10.97	14.62	21.03	28.04
Billur								
0	$N_{60}P_{60}K_{90}$	15x15	7.17	9.56	9.70	12.93	12.87	17.16
1		20x20	7.33	9.78	10.07	13.42	15.77	21.06
2		25x25	7.73	10.1	10.33	13.78	18.97	25.29
3	$N_{90}P_{60}K_{90}$	15x15	7.33	97.8	9.80	13.07	16.17	21.56

4		20x20	7.53	10.04	10.23	13.64	18.63	24.84
5		25x25	7.80	10.40	10.77	14.36	20.30	27.07
6	$N_{120}P_{60}K_{90}$	15x15	8.07	10.76	16.23	21.64	18.33	24.44
7		20x20	8.37	11.16	16.50	22.00	20.77	27.69
8		25x25	8.70	11.60	17.07	22.76	22.20	29.60

An increase in nitrogen fertilizer rates was associated with a proportional rise in both individual plant dry mass and total crop biomass.

Tillering phase: In the Guliston variety, total dry biomass at the $N_{60}P_{60}K_{90}$ level was 8.36 t/ha under a 15×15 cm planting scheme, 8.67 t/ha at 20×20 cm, and 8.84 t/ha at 25×25 cm. When the $N_{90}P_{60}K_{90}$ rate was applied, biomass increased to 9.47–10.70 t/ha, and under N120P60K90, it reached 9.60–10.53 t/ha. In the Billur variety, total dry biomass at this stage was 9.56–10.31 t/ha at $N_{60}P_{60}K_{90}$, 9.78–10.40 t/ha at N90P60K90, and 10.76–11.60 t/ha at $N_{120}P_{60}K_{90}$.

Stem elongation phase: In Billur, total dry biomass increased to 129.3–13,78 t/ha at $N_{60}P_{60}K_{90}$, 13.07–14.36 t/ha at $N_{90}P_{60}K_{90}$, and 21.64–22.76 t/ha at $N_{120}P_{6}0K_{90}$. In Guliston, total biomass at this stage was 12.44–13.16 t/ha, 12.62–13.42 t/ha, and 13.96–14.62 t/ha at $N_{60}P_{60}K_{90}$, $N_{90}P_{6}0K_{90}$, and $N_{120}P_{60}K_{90}$, respectively, across plant densities of 1,333, 750, and 480 seedlings per hectare.

Ripening phase: In the Billur variety, total dry biomass reached 171.6–25.29 t/ha at N_{60}, 21.56–27..7 t/ha at N_{90}, and 24.44–29.60 t/ha at N_{120}.

The experiment demonstrated that the 25×25 cm planting scheme combined with $N_{120}P_{60}K_{90}$ fertilization promoted the most rapid plant growth and the highest dry mass accumulation. Under this treatment, individual plant dry mass was 8.70 g at tillering, 17.07 g at stem elongation, and 22.20 g at ripening.

Analysis further indicated that at lower plant densities, individual plants spread more extensively, with well-developed tillers, resulting in higher leaf area and dry mass per plant; however, total crop biomass per unit area was relatively lower. Conversely, increasing seedling density slightly reduced individual plant performance, but total dry biomass per unit area increased.

Conclusion:

Therefore, in rice seedling cultivation, scientifically optimizing the planting scheme and nitrogen fertilizer rate is a crucial agronomic strategy for enhancing dry mass accumulation and improving overall yield.

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