Mongolian Journal of Agricultural Sciences, *Vol.17, No.40 (2024)*
https://doi.org/10.5564/mjas.v17i40.3802

Effect of fertilizer type on wheat yield and soil fertility content

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Received: 30.11.2023 Revised: 21.06.2024 Accepted: 28.06.2024

Abstract
According to the researchers, soil erosion in the cultivation center area is 61.1-81.3%. That the yield of moderately and severely eroded areas has decreased by 50-80%, the grain ripens late, and the quality and standards of the product have not been met. Soil erosion and fertility degradation are causing disaster and destruction in agricultural areas. Therefore, there is an urgent need to use fertilizers in the agricultural areas of our country. Fertilizers, minerals, nutrients, bacteria, and mineral-nutrient fertilizers used in our study were studied by soil layers at the same time, which is unique to the work of other researchers. According to the results of our research, wheat yield is 9.0-16.4 t/ha higher in all fertilized scenarios than in the unfertilized (control) scenario. The highest yield was obtained with Wacom fertilizer (42.6 t/ha). Fertilizer types increased by 0.18-0.95% in soil humus content compared to the control version. The highest increase was 1% in the version with mineral-nutrient type (BR-481) series fertilizers.

Keywords: Humus, Nutrient, Grain, Texture of wheat

Introduction

One of the biggest challenges facing humanity is to provide food for 9-10 billion people by 2050, prevent dangerous climate change, and find opportunities to produce more agricultural products per unit of input [1]. It is estimated that between 713 and 757 million people, corresponding to 8.9 and 9.4 percent of the global population, respectively, may have faced hunger in 2023. Considering the mid-range (733 million), this is about 152 million more people than in 2019. Trends at the regional level differ considerably. While hunger is still on the rise in Africa, it has remained relatively unchanged in Asia, and there is notable progress in Latin America. From 2022 to 2023, hunger increased in Western Asia, the Caribbean and in most subregions of Africa [2]. The main factors driving and aggravating food insecurity is the degradation of one third of the world's agricultural soils (FAO, 2017). Considering that soils produce more than 95 percent of the food we eat, the conservation of soil health and fertility should be one of the guiding principles in food insecurity eradication plans (FAO and ITPS, 2023). According to the International Fertilizer Association (IFA), 85% of the world's soil is deficient in nitrogen, 73% in phosphorus, and 55% in potassium [3]. FAO of the United Nations, 1/4 of the world's population, or 1.75 billion people, feed on crops enriched with fertilizers, and the countries of the world produce and use a total of 200.2 million tons (calculated as active substances) of various fertilizers (UN.FAO information 2020). The use of fertilizers allows the world's crop yields to be nearly doubled compared to those without fertilizers. Crops deplete soil nutrients in a variety of ways [4]. According to our country's research on fertilizer use, the average fertilizer consumption in Mongolia between 1993 and 2018 is 8.7 kg/ha, with the lowest being 0.4 kg/ha in 1994 and the highest being 32 kg/ha in 2018 [5]. As of 2018, the average fertilizer use per hectare in agriculture across 162 countries worldwide is 199.6 kg. In comparison, our country's fertilizer use is 167.8 kg/ha lower than the world average [6]. Compost can be used as a source of humus in the soil and is gradually used by plants year after year. If the soil is fertile and has a high content of humus, there is a large number of microorganisms and insects that live in the soil and create humus from the decomposition of the compost.

All organic fertilizers are processed by plant residues, microorganisms, insects, bacteria and fungi into soil humus and mobile compounds that can be used by plants. It is important to determine the biological activity of the soil and the effect of fertilizers on the soil in order to increase soil fertility [7]. Various fertilizers such as minerals, nutrients, and bacteria are used in agriculture, but there are no studies or results of a single experiment on the effect of those fertilizers on soil fertility. Therefore, scientific determination of the effect of fertilizer types on the fertility of the soil in wheat-planted areas is the basis of this research work.

Materials and methods

Methodology for determination of soil humus

Laboratory analyses were conducted to evaluate various parameters. The humus content was measured using Turin's method, which involves the oxidation of humus with a 0.4 N solution of potassium dichromate in distilled water and sulfuric acid [8].

Methodology of plant analysis

Wheat protein content was determined by the Kjeldahl method, where wheat seeds 0.5 g were burned in sulfuric acid with selenium as a catalyst at 338°C. The N in the sample is converted to ammonium (NH_4^+) by digestion with concentrated H50, in the presence of salicylic acid and a catalyst mixture.

NH is determined after steam distillation and capture in an excess boric acid.

Procedure Exactly 0.5 g oven-dry plant material are treated in a 200 ml Kjeldahl digestion flask with 10 ml sulfuric acid - salicylic acid mixture. After 30 minutes, add 5 g Na25203 and shake. After another. 15 minutes, add 1.0 g K,504 and 0.1 g Se as catalysts. Heat the flask on the digestion rack for about 3 hours. After cooling, add 30 ml of a 30 % NaOH solution and start the steam distillation immediately, taking care that the glass receiver tube is immersed into the collecting solution. Collect the distillate into a 250 ml Erlenmeyer flask containing 10 ml boric acid-indicator mixture. After distillation of all NH. titrate the boric acid solution with 0.01 n HCl. At the endpoint the indicator turns from green to red. Quote as g A per kg dry matter [9].

The gluten content was assessed by grinding the wheat seeds and washing them to separate and quantify the gluten. After washing and completely removing the starch film from the gluten, pinch the mountain gluten to compact it and pinch it between 2 palms. In this way, absorb the gluten water in your palm, wipe your palms until they are dry, and press them together again. Gluten

Pinch it with your finger until it changes from the outside to the inside, and when it's dry again, absorb the water and repeat many times to make the gluten easily stick to your hands. After that, the gluten is weighed on a technical scale. Then again with water for 3 minutes.

After washing, squeeze and weigh again. If the weight difference between these 2 weights is not more than 0.1g, washing is considered complete. So, this weight is wet consider the percentage of the 25 g sample taken as the weight of gluten and find the percentage of wet gluten [10].

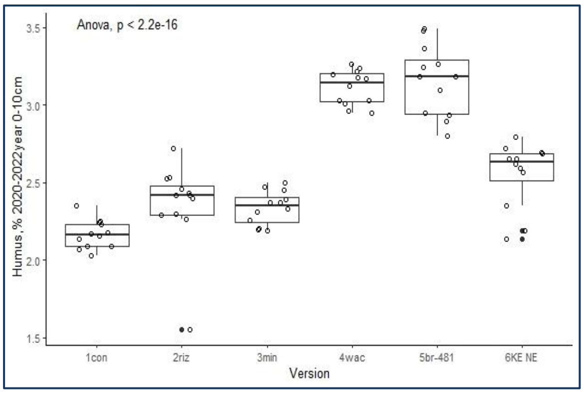
Data analysis

The statistical processing of the research work was analyzed a novo with R software, and regression analysis was done with Excel software

Results

Humus is an organic compound with a complex structure and composition, high molecular weight, and unique properties, and it has a decisive effect on the creation of a suitable and stable environment for the growth of plants and crops in the soil.

We investigated how the types of fertilizers applied affected the nutrient content of the soil, as shown in the figure below (figure1a-Humus, % 0-10cm depth, figure1b- Humus, % 10-20cm depth, figure1c- Humus, % 20-30cm depth,)



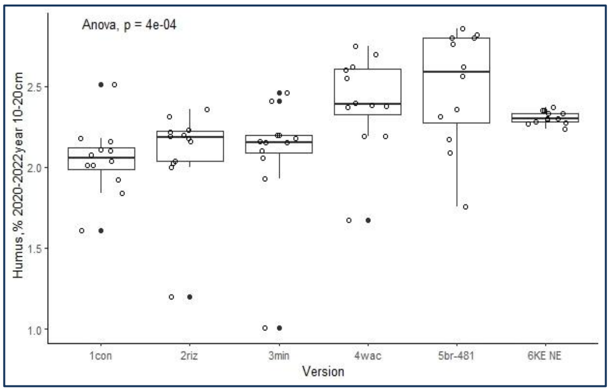


Figure 1a. Humus, % 0-10cm depth

Figure 2b. Humus, % 10-20cm depth

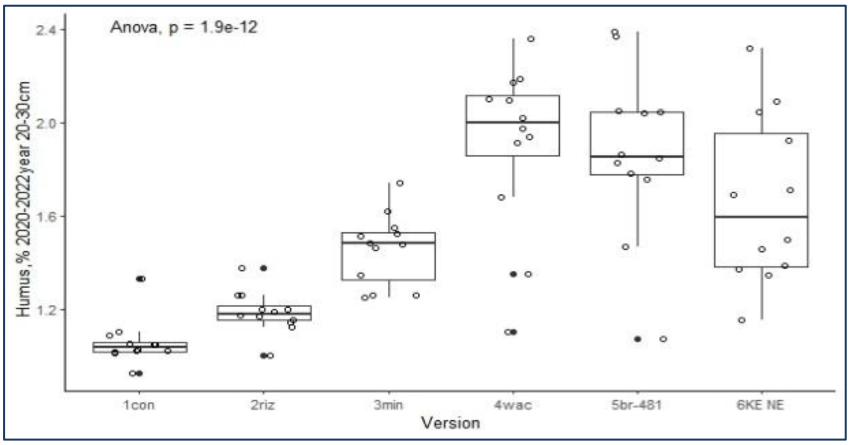


Figure 1c. Humus, % 20-30cm depth

Figure 1. Effect of fertilizer types on soil humus content

The results of the soil humus content analysis, calculated in the R program, showed a significant difference between the types of fertilizers with a P<0.00. The humus content at a depth of 0-10 cm in the control variant was 2.16%. The humus content in the other fertilized variants was different compared to the control variant: the humus content in the variant fertilized with rhizobacteria was 2.36%, which was 0.20% higher than the control/unfertilized variant. The humus content in the mineral fertilized variant was 2.34%, which was 0.18% higher than the control. The humus content in the Wacom fertilized variant was 3.11%, which was 0.95% higher than the control. The content of BR-481 fertilizer was 3.16%, which was 1.0% higher than the control. Finally, the humus content in the KE NE fertilizer variant was 2.55%, which was 0.39% higher than the control.

Effects of fertilizers on growth and development stages of wheat

The growth period of wheat is determined by the number of days from germination to seed ripening, and its duration and changes depend greatly on the conditions and factors of the growing environment in addition to the genetic variability of the variety and sample.

The main factor that limits the growing season of crops in Mongolia is the late spring and early autumn cold temperatures. It is important to establish the length of the growing period because the yielding process of different varieties of pods varies in regions with extreme climates and geographically different regions [11].

In order to calculate the effectiveness of various fertilizers, we compared the stages of wheat growth in unfertilized and fertilized versions and made phenomenological observations at the wheats' various stages of seeding, germination, crushing, main pricking, early flowering, and full fruiting [12].

Table 1.

Effects of fertilizers on growth and development stages of wheat

Variations	Planting time	Germination	Tillering	Stem elongation	Heading	Flowering	Milk develonment	Dough development	Ripening	Total days
Control	22\V	16	19	16	13	12	7	9	10	103
Rhizobacteria	22\V	14	17	16	11	13	6	8	10	95
Mineral	22\V	13	17	14	12	13	7	11	8	95
Organic	22\V	14	16	15	10	12	6	10	8	91
BR-481	22\V	12	18	15	12	12	8	10	9	95
NEKE	22\V	14	17	16	12	12	9	10	9	99

In terms of growth stages, the organic fertilizer application took the shortest time to reach maturity at 91 days, which was 11 days less than the unfertilized control. Meanwhile, the NEKE fertilizer application took nearly 4 days less than the control to reach maturity. However, the other versions expired 8 days before full maturation.

Table 2.

Effect of fertilization on biometric parameters of wheat

Variations	Plant height (cm)	Number of plants)	Total number of stems	Number of stems per product	Crushing in products (s)	Seed weight (g)
Control	91.7	125	396	205	1.6	24.0
Rhizobacteria	98.7	128	437	255	2	31.1
Mineral	94.7	135	382	251	1.9	25.8
Organic	104	136	452	273	2	37.1
BR-481	101	124	389	261	2.1	28.2
NEKE	99.7	146	396	240	1.6	26.5

In our study, the highest plant height was 104 cm for the Wacom fertilized version, which was 12.3 cm higher than the control. The BR-481 applied version was 9.3 cm higher than the control, and the other versions were 3-8 cm higher than the control.

Considering the number of plants per 1 m^2, which is an important indicator of yield, the NEKE variant had the highest number of plants at 146.5 plants, which is 20.6 plants more than the control, while the fewest plants were produced in the BR-481 version. The BR-481 version produced 123.8 plants, which is 2.1 plants less than the control. Similarly, the other variants had 2.3-10.1 plants less than the control.

Regarding the number of stems per product, all variants had 34.6 to 68.0 more stems than the control, with the highest number of stems produced by the Wacom version with 68 stems.

Table 3

Effect of fertilizers on wheat yield

Variations	Length of stem (cm)	Number of seeds	weight of seeds per head (g)	1000- seed weight of (g)	Yield (quintals/ha)
Control	7.9	31.1	1.27	40.6	26.2
Rhizobacteria	8.2	32.1	1.41	45	37.6
mineral	8.9	33.5	1.35	43.9	37.1
Organic	9.2	34.1	1.39	45.7	42.6
BR-481	9	33.0	1.32	46.3	39.5
NEKE	8.5	32.8	1.3	44.7	35.2

The length of the stems from all versions were 0.3-1.3 cm longer than the control, with the Wacom version being the longest at 1.3 cm. The number of seeds in the variant fertilizers was 1-3 more seeds than the control, and the highest yield was 34.1 in the Wacom version, which produced 3 more seeds than the control.

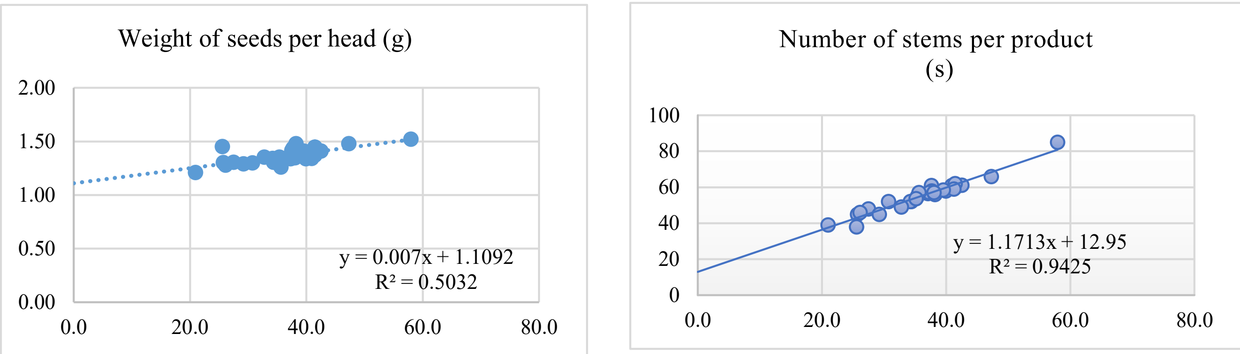


Figure 2. Relationship between yield and yield structure

The wheat yield is positively correlated with the number of stalks in the product according to the regression analysis of excel program (r=0.68) [13]. When comparing the number of stems in the product with the yield, there is a strong positive correlation (r=0.96), which is equivalent to the results of the above study.

According to the results of our study, all the scenarios using fertilizers had a yield of 8.9-16.3 t/ha compared to the control, which indicates a real difference in yield from the control.

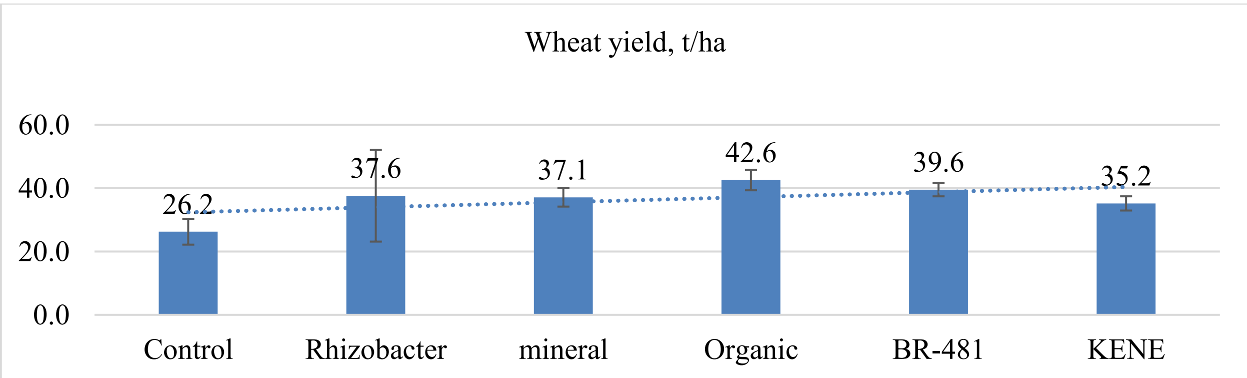


Figure 3. Effect of fertilizer types on wheat yield

According to the results of our research, wheat yield is 9.0-16.4 t/ha higher in all fertilized scenarios than in the unfertilized (control) scenario. The highest yield was obtained with Wacom fertilizer (42.6 t/ha). Fertilizer types increased by 0.18-0.95% in soil humus content compared to the control version. The highest increase was 1% in the version with bio-organic type (BR-481) series fertilizers.

There is a significant yield difference between the fertilized variants SRD(95%)=8.65 t/ha.

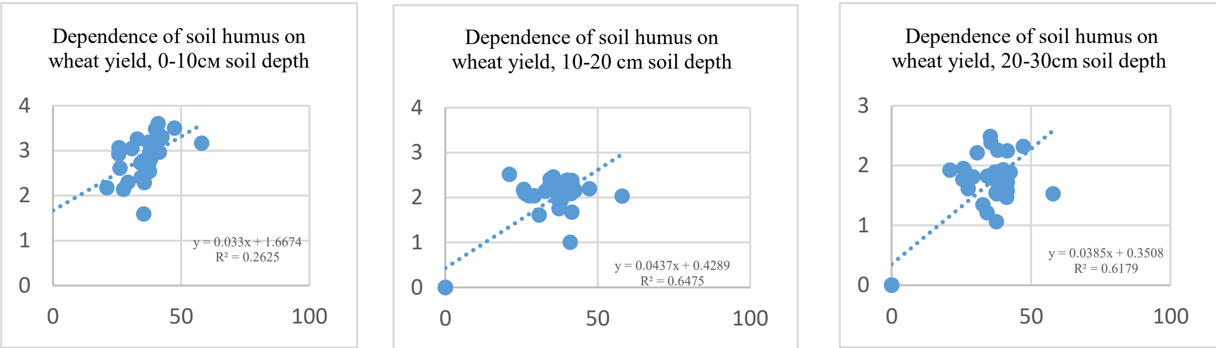


Figure 4. Relationship of soil humus layers to wheat yield

As can be seen from the figure above, the relationship between wheat yield and humus in the regression analysis of the Excel program shows a weak relationship at depths of 0-10 cm and 10-20 cm. However, the relationship between wheat yield and humus is strongly related at depths of 20-30 cm. It is observed that the yield increases when there is humus around the roots of wheat.

Effect of fertilizers on technological quality of wheat

Many scientists and researchers have determined that wheat quality parameters change significantly depending on the country's soil, climate, agrotechnical methods, and varieties. The technological quality of wheat depends on the physical quality and chemical composition of the seeds, which change depending on the biological characteristics of the variety, soil and climatic conditions.

The seed yield and quality depend greatly on the quality of the seed. Seed quality is a complex composition of genetic, physical, physiological and biochemical characteristics.

Protein: According to our research, wheat protein content ranged from 13.7 to 14.9%, with mineral (14.9%), WACOM (14.8%), BR-481 (14.7%), and NEKE (14.5%) tending to be higher in protein than alternative fertilizers. B. Jambaajamts and Ts. Bundoohu, found that the protein content in wheat seeds was 13.1%, granted that geographical influence from the Mongolian landscape is taken into account.

Table 4.

Effect of fertilizers on biochemical properties of wheat

Variations	Moisture, (%)	Gluten, (%)	Protein, (%)	Classes, (%)
Control	9.6	26.5	13.7	55.4
Rhizobacteria	9.5	27.5	14.3	57.4
Mineral	9.3	27.5	14.9	57.8
Organic	9.5	28	14.8	57.1
BR-481	8.8	27	14.7	57.8
NEKE	8.6	27.3	14.5	56.9

Wheat seeds gluten content is classified as the following: high if they have a wet gluten content of more than 30%; moderate if they have 25-29.9%; and low if they have a gluten content of 24.9% or less. Among the quality indicators of cereal products, the most important is gluten and its quality. Gluten consists of two proteins, gliadin and glutamine.

These two proteins are endosperm storage proteins that account for more than 80% of all proteins in wheat germ. The quality of wheat bread depends on the protein and gluten quality of the endosperm. Results showed that organic (28.0%), Rhizobacteria (27.5%), Minerals (27.5%), NEKE (27.3%), and BR-481 (27.0%) fertilizers were all 0.5-1.5% higher than the control version. In 2022, the gluten content was 26.5-28.0%, which is directly related to the climate of that year. In this research year, the amount of precipitation that fell in the stage of development of wheat seeds in August (73 mm) was more than OJD, which was the main reason for the washout and reduction of seed gluten.

Russian scientist Laskowski first proved in 1865 that the amount of protein in wheat grain increases from the North-West to the South-East. Depending on the variety and technological conditions, soft wheat seeds contain 9.8-25.8% protein, with an average of 17% protein, which accounts for 12-14% of the seed weight. The gluten content of wheat seeds varies from 7 to 50% and usually wheat with at least 28% gluten is considered high in gluten. The content of wheat gluten depends largely on climatic conditions, as well as on the characteristics of the variety and the agro-technique of cultivation.

Discussion

In our study, three with compost humus content and plants in the alternative the content of mobile elements of feed compared to the unfertilized control is increasing [14]. The process of wheat crop formation takes place under the influence of many ecological, genetic and agrotechnical factors. In wheat is mainly influenced by the number of stalks and early seeds per unit area [13]. Biomass, kernel weight, and grain weight per spike were positively correlated with grain yield while days to heading and maturity were negatively correlated with grain yield [15]. The amount of current assimilates and stem reserves contributed to grain yield was reduced, respectively, by 54 and 11% under drought. Genotypic differences in percent contribution of stem reserves to grain yield were significant in well-watered (ranging from 19.1 to 53.6%) and in droughted-field (ranging from 36.6 to 65.4%) conditions. The wheat genotypes responded differently to drought. Main spike grain yield was reduced by 43% under drought due to 26 and 11% reduction in grain weight and number of grains, respectively. Grain yield was correlated with linear grain growth under well-watered ($r = 0.96$) and droughted ($r = 0.83$) conditions [16].

The possible contribution of stored carbon in the stem to final grain yield was estimated to be 22, 18 and 14% in the rat, Rht1 and Rht2 lines. In these estimates, the loss of mass was adjusted by 33% to allow for respiration. It was concluded that the larger stem reserves in rat wheats are of no real advantage under favorable environmental conditions, and may in fact be a disadvantage if the accumulation of that extra dry matter results in a reduction of sink size [17].

In addition, the precipitation ratio value tended to be significantly higher (23.2% in 0 − 5 cm, 24.6% in 5 − 10 cm, and 16.5% in 10 − 20 cm, $P < 0.05$) in mineral fertilizer with cattle manure additions than mineral fertilizer alone. Our results showed that combined application of mineral fertilizer with cattle manure was the most effective management practice to increase humus carbon pool, which could be regarded as a useful indicator of the carbon sequestration process in paddy soil [18]. It was determined that the humus content could be increased by 17.1 - 28.9% after 30 years by applying a combination of mineral and biofertilizers to the brown soil of the central agricultural zone [19]. The use of organic fertilizers contributes to a positive balance of humus. The amount of the increase varies from 0.06% to 0.14% [20]. It was found that the systematic use of mineral and organic fertilizers can compensate for the decrease in humus content by increasing the humus content in the soil at a depth of 0-20 cm by an average of 6.10% or 2.4 t per hectare due to the action of mineral fertilizer ($N_{60}P_{40}K_{40}$), by 17.7% or 6.9 t due to manure (10 t/ha), and by 15.2% and 6.0 t due to the interaction of manure and complete mineral fertilizer [21].

Conclusion

The study found that different types of fertilizers have a positive effect on soil humus, and bio-organic fertilizer BR-481 has the highest increase. The types of fertilizers increased the soil humus content by 0.18-0.95% compared to the control variant. Yield analysis revealed a strong correlation between the number of stems per unit area and the weight of the plant seeds, and wheat yield was 9.0-16.4 c/ha higher in all fertilized variants than in the unfertilized (control) variant.

Among the fertilizers, Wacom fertilizer (42.6 t/ha) showed the highest yield, and Wacom also had the highest wheat glut en. These types of organic and bio-mineral fertilizers have a positive effect on soil fertility and wheat yield.

Conflict of interests
The authors declare no conflict of interests.

Authors' Contribution
B. G. Performed laboratory and field experiments, data analysis, and prepared the original draft, B. A. contributed to writing, review and editing. All authors have read and approved the final manuscript.

Acknowledgment
We would like to thank the staff of the Department of Agriculture and Soil Science, the School of Agroecology, the Nart Center of the National Institute of Agriculture, and the supervising professor A.Buyanbaatar for their support in carrying out this research work.

Reference
[1] P. Smith *et al.*, "How much land-based greenhouse gas mitigation can be achieved without compromising food security and environmental goals," *Glob. Change Biol.*, vol. 19, no. 8, pp. 2285–2302, Aug. 2013. https://doi.org/10.1111/gcb.12160
[2] FAO, IFAD, UNICEF, WFP, and WHO, *The State of Food Security and Nutrition in the World 2024*. 2024. https://doi.org/10.4060/cd1254en
[3] T. W. Bruulsema, P. Heffer, R. M. Welch, I. Cakmak, and K. Moran, "Fertilizing Crops to Improve Human Health: A Scientific Review," May 2012.
[4] Z. X. Tan, R. Lal, and K. D. Wiebe, "Global Soil Nutrient Depletion and Yield Reduction," *J. Sustain. Agric.*, vol. 26, no. 1, pp. 123–146, Jun. 2005. https://doi.org/10.1300/J064v26n01_10
[5] World Bank, *Development Indicators News*, 2018.
[6] FAO, *World Food and Agriculture – Statistical Yearbook 2020*. 2020. https://doi.org/10.4060/cb1329en
[7] D. Azzaya, B. Gantsetseg, and D. Munkhzul, *The Heat Resource and Its Change in the Agriculture Regions of Mongolia*, 2005.
[8] Global Soil Laboratory Network and GLOSOLAN, *Soil Organic Carbon Walkley-Black Method: Titration and Colorimetric Method*, 2021.
[9] Global Soil Laboratory Network and GLOSOLAN, *Soil Nitrogen Kjeldahl Method*, 2021.
[10] MNS0254-7:1989, "Methods for Determining Quantity and Quality of Gluten in Wheat".
[11] D. Azzaya, *Plant Growth in the Central Agricultural Zone of Mongolia: Agro-Climatic Assessment of Conditions* (PhD thesis), 1997.
[12] J. Wang *et al.*, "Wheat and Rice Growth Stages and Fertilization Regimes Alter Soil Bacterial Community Structure, But Not Diversity," *Front. Microbiol.*, vol. 7, Aug. 2016. https://doi.org/10.3389/fmicb.2016.01207
[13] B. Love *et al.*, "Associations between endogenous spike cytokinins and grain-number traits in spring wheat genotypes," *Eur. J. Agron.*, vol. 152, p. 127011, Jan. 2024. https://doi.org/10.1016/j.eja.2023.127011
[14] D. E., D. T., and T. M., "Effects of mineral and organic fertilizers on soil organic carbon fractions in agricultural chestnut soil," *Mong. J. Agric. Sci.*, vol. 22, no. 3, pp. 103–108, May 2018. https://doi.org/10.5564/mjas.v22i03.958
[15] "Transferability of Marker Trait Associations in Wheat Is Disturbed Mainly by Genotype × Year Interaction," *Crop Breed. Genet. Genomics*, 2020. https://doi.org/10.20900/cbgg20200013
[16] A. Borrell, "The Influence of the Rht1 and Rht2 Alleles on the Deposition and Use of Stem Reserves in Wheat," *Ann. Bot.*, vol. 71, no. 4, pp. 317–326, Apr. 1993. https://doi.org/10.1006/anbo.1993.1041
[17] H. Bai *et al.*, "Influences of irrigation amount on the rhizospheric microorganism composition and carbon dioxide flux of maize crops," *Geoderma*, vol. 343, pp. 1–9, Jun. 2019. https://doi.org/10.1016/j.geoderma.2019.02.022
[18] W. Mi, Y. Sun, Q. Gao, M. Liu, and L. Wu, "Changes in humus carbon fractions in paddy soil given different organic amendments and mineral fertilizers," *Soil Tillage Res.*, vol. 195, p. 104421, Dec. 2019. https://doi.org/10.1016/j.still.2019.104421

[19] D. Zandraagombo and D. Tuul, “Study on the changes of brown soil humus,” p. 16, 2016.
[20] N. Kloster, V. Azarov, and V. Lotkova, “The content of soil humus when using organic and mineral fertilizers,” *E3S Web Conf.*, vol. 548, p. 01010, 2024. https://doi.org/10.1051/e3sconf/202454801010
[21] D. Tuul, *Study of the Humus Content and Composition of Brown Soil in the Central Region*, p. 86, 2008.