**DOI:** https://doi.org/10.31073/mivg202302-362
Available at (PDF): https://mivg.iwpim.com.ua/index.php/mivg/article/view/362

UDK 633.11:631.8

# NORMALIZED DIFFERENTIAL VEGETATION INDEX OF WINTER WHEAT DEPENDING ON THE RATES OF NITROGEN FERTILIZER AND NITRIFICATION INHIBITOR

**S.V. Muntyan[1], Ph.D. in Agricultural Sciences, A.P. Shatkovskyi[2], Doctor of Agricultural Sciences, L.O. Semenko[3], Ph.D. in Agricultural Sciences**

[1] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, Ukraine;
https://orcid.org/0000-0002-8933-9283; e-mail: ais_888@ukr.net;
[2] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, Ukraine;
https://orcid.org/0000-0002-4366-0397; e-mail: andriy-1804@ukr.net;
[3] The National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine;
https://orcid.org/0000-0002-4586-3681; e-mail: larisa-s@ukr.net

***Abstract.*** *The article presents the results of experimental studies of the relationship between the normalized differential vegetation index and the yield of winter wheat at different rates of nitrogen fertilizers and the nitrification inhibitor 3.4-dimethylpyrazole phosphate with carbamide-ammonia mixture (CAM-32). Field research was carried out in 2018–2021 in the research department of the Limited Liability Agricultural Company (LLAC) "Druzhba Nova" of the Varvyn district of the Chernihiv region (department of the "Kernel" agricultural holding). Analytical and mathematical and statistical methods were used to process experimental data. The normalized differential vegetation index (NDWI) was determined from the satellite images of WorldView-2, WorldView-3, Geoeye-1 (Maxar USA). The scheme of the one-factor field experiment was the use of options with different rates of nitrogen fertilizers ($N_{100}$ and $N_{120}$), as well as the use of the nitrification inhibitor 3.4-dimethylpyrazole phosphate in mixture to CAM-32. The control (backgroung) option was the application of fertilizers at the rate of $N_{10}P_{30}K_{40}$. The results of experimental studies proved that NDWI is directly correlated with the yield of winter wheat for all 4 years of research. It was established that the NDWI, on average over three summer months, was higher in 2018 in the range of 0.56–0.67 and in 2020 – 0.53–0.66. The yield of winter wheat was also higher in 2018 and 2020, namely: in 2018 from 3.72 t/ha to 8.14 t/ha and in 2020 – from 3.77 t/ha to 7.25 t/ha. The NDWI, in 2019 and 2021, averaged over three summer months according to the experiment options was lower and amounted to 0.33–0.38 in 2019, and 0.30–0.33 in 2021. This trend correlates with winter wheat yields, which were also low during this period. So, in 2019 it was 3.63 t/ha – 5.10 t/ha and in 2021 – 3.83–4.81 t/ha. The correlation coefficient between NDWI and the yield of winter wheat was high: in July and August, it was from 0.93 to 0.97 on the options with nitrogen fertilizer rates $N_{100}$ and $N_{120}$.*
***Key words:*** *nitrification inhibitor, 3.4 dimethylpyrazole phosphate, carbamide-ammonia mixture, normalized differential vegetation index, yield, winter wheat*

**The relevance of research.** Growing crops, as a rule, is carried out over fairly large areas, which makes crop monitoring more difficult and expensive. In addition, each culture has its own different phases of growth and development, phenological rhythms are inherent in it, etc. Therefore, at the present stage of agronomic practice, remote sensing of fields is optimal as a more advanced and accessible technology for monitoring such crops [1–4].

Over the past 40 years, many vegetation indices have been developed and implemented, but the normalized differential vegetation index (NDWI) [5] has become the most widely used. NDWI shows the coverage of the vegetative mass with the difference between the visible and infrared spectrum of radiation. It is essentially a measure of plant health based on the reflectivity at specific frequencies of the various wavelengths being absorbed. This index is most used for monitoring the dynamics of crop vegetation at the regional and global levels [6, 7]. NDWI is also widely used in determining the density of crops, which shows the amount of active photosynthetic biomass [6, 8, 9]. In practice, the processing of digital data and images from satellites provides tools for data analysis through mathematical indices and algorithms [10]. Remote satellite sensors provide digital and graphical data for monitoring of cultivation areas use and changes in the vegetation cover of these areas in approximately real-time at different scales [11, 12]. Crop monitoring by standard methods, such as visual crop diagnosis or sampling, usually requires human resources, time-consuming, lengthy procedures, and is inaccurate for evaluating changes in plant development over large areas [13, 14]. Therefore, we can conclude that the use of crop monitoring using the NDWI index is quite relevant.

**Analysis of recent research and publications.** An important component in the direction of crops' sensing, despite its shortcomings, is understanding the potential, interpreting the data obtained, fixing errors and the relationship with the final result and sensing goals [5, 15]. Such experiments were carried out in the USA, in the state of Kansas. They concerned the measurement of NDWI and the mapping of crops that were grown in relatively large areas. The accuracy of the measurements was high and amounted to more than 84 % [16]. In addition, field experiments were conducted in Denmark to measure the NDWI index on winter wheat during different growing seasons on the background of different nitrogen's rates application. The use of the NDWI index has been found to be a useful tool, but is dependent on the choice of spectral length [17]. In 2000–2013 Ukrainian scientist I.G. Semenova studied NDWI and established quantitative relationships between the index and the productivity and yield of individual crops for seasonal forecasting for all 25 regions of Ukraine. [18]. Also, the obtained results of experiments on the use of materials taken from the MSU-E space sensor or similar systems proved the possibility of their use for early prediction of the winter wheat productivity with a high level of correlation [19].

Therefore, the **study aimed** to establish the actual correlation between the level of the normalized differential vegetation index NDWI and the grain yield of winter wheat with the use of different rates of nitrogen fertilizers and nitrification inhibitors (NI) in combination with the application of CAM-32.

**Research materials and methods.** Experimental studies were carried out in the production conditions of the Limited Liability Agricultural Company (LLAC) "Druzhba Nova" of the Varvyn district, Chernihiv region (department of the "Kernel" agricultural holding). The soil of the experimental plot is typical chernozem with low humus, the arable layer is characterized by the following main indicators: humus content – 3.4 %, pH neutral and close to neutral – 5.7–7.0, the content of mobile forms of phosphorus – from high to very high – 15.4–26.3 mg/100 g of soil, exchangeable potassium – from medium to high – 7.1–16.2 mg/100 g of soil, lightly hydrolyzed nitrogen – from high to high – 5.7–7.9 mg/100 g of soil. The studies were carried out according to a single-factor experiment design. The sown area of the experimental plot is 0.6 hectares, and the alternation of options is sequential. Field experiments were laid out and carried out according to the generally accepted methodology for field experiments (Dospehov B.A., 1985). The harvest was taken into account by the method of continuous harvesting and weighing of the bunker mass from each plot, followed by recalculation to standard humidity and weed content according to DSTU 2240-93 in triplicate. Mathematical and statistical calculation of the data was carried out using the Agrostat software and information complex. The normalized differential vegetation index (NDWI) was determined based on the results of images from satellites WorldView-2, WorldView-3, Geoeye-1 (Maxar USA). The images were taken by a separate satellite, depending on its location and cloudiness level, three times during the growing season: in June, July, and August. According to the decision of the regulatory commission of the European Union No. 1257/2014, which corrects the regulation of EC No. 2003/2003 of the European Parliament and the Council regarding fertilizers and changes to supplements I and IV of November 24, 2014, the norm for the use of the ***nitrification inhibitor (NI) 3.4-dimethylpyrazole phosphate has been established (DMPP)*** (EU No. 424-640-9), which ranges from 0.8 % to 1.6 % [20]. Per the regulation, the minimum rate of IN DMPF of 0.8 % was used on amide $NH_2^-$ and ammonium $NH_4^+$ forms of nitrogen.

According to this minimum calculated rate of 0.8 %, the rate of use of NI DMPP on CAM-32 is 7.02 l per 1000 kg of CAM-32. Accordingly, the calculated rate of IN DMPF for CAM-32with a rate of 250 kg/ha was 1.76 l/ha according to CAM-32 norms, and 300 kg/ha – 2.11 l/ha, respectively.

The following options for applying mineral fertilizer rates were used in the experiment:

1. Background – $N_{10}P_{30}K_{40}$, NPK 7-20-28 granular fertilizers were applied at the rate of 150 kg/ha per sowing.
2. Background+$N_{100}$+ NI (granulated ammonium sulfate at a rate of 100 kg/ha on frozen soil and CAM-32 at a rate of 250 kg/ha with the application of NI in the spring after the resumption of the vegetation).
3. Background+$N_{120}$+ NI (granulated ammonium sulfate at a rate of 100 kg/ha on

frozen soil and CAM-32 at a rate of 300 kg/ha with the application of NI in the spring after the resumption of the vegetation).

4. Background+$N_{120}$ (granulated ammonium sulfate at a rate of 100 kg/ha on frozen soil and CAM-32 at a rate of 300 kg/ha without an application of NI in the spring after the resumption of the vegetation).

**Research results and discussion.** NDWI is a numerical indicator of the condition and number of plants in a certain area of the field. It is calculated by satellite imagery and depends on how plants reflect and absorb light waves of different lengths. According to the study results, winter wheat NDWI for 2018–2021 varied throughout the growing season and was highest in June and decreased in July and August (Table 1). Thus, the NDWI level in June was the highest in the years of research and was at the level of 0.74–0.82 in 2018, 0.69–0.77 in 2019, 0.71–0.80 in 2020 and 0.42–0.48 in 2021. During July and August, NDWI was lower than in June. So, in July, according to the years of research, it was in the range of 0.49–0.60 in 2018, 0.16–0.20 in 2019, 0.47–0.61 in 2020, and 0.23–0.26 in 2021 In August, NDWI was respectively in the range of 0.44–0.58 in 2018, 0.13–0.17 in 2019, 0.42–0.57 in 2020 and 0.24–0.26 in 2021.

If we consider the level of NDWI in the context of field experiment options, then there is a clear tendency to correlate the level of NDWI depending on different rates of nitrogen fertilizers and the application of the nitrification inhibitor (NI) 3.4-dimethylpyrazole phosphate (DMPP) both separately by month and on average over three months. Thus, in 2018, in the control variant $N_{10}P_{30}K_{40}$ (background), the NDWI level was the lowest in June, July and August, 0.74; 0.49 and 0.44, respectively, which averaged 0.56 over three months. With an increase in the nitrogen rate and the addition of NI DMPP, the NDWI increased: in the background+$N_{100}$+ NI experiment in June, July, and August, the NDWI was 0.79; 0.57 and 0.55, which averaged 0.64 over three months.

NDWI slightly increased in the variant of the experiment with an increased nitrogen rate – background+$N_{120}$+ NI – and was 0.80 in June, July and August; 0.59 and 0.57, which averaged 0.65 over three months. The highest level of NDWI was in the variant of the experiment with an increased nitrogen rate, but without the use of NI – background+$N_{120}$ – and was 0.82 in June, 0.60 in July and 0.58 in August, and on average over three months – 0.67. A similar trend was observed during other years of research. The lowest NDWI level was observed on the control variant $N_{10}P_{30}K_{40}$ (background) in June, July and August and on average for three months in 2019, namely: 0.69; 0.16; 0.13 and 0.33, in 2020 – 0.71; 0.47; 0.42 and 0.53 and in 2021 – 0.42; 0.23; 0.24 and 0.30. The level of NDWI increased with an increase in the nitrogen rate and the addition of NI DMPP. Thus, in the experimental option – background + N100 + NI – the NDWI level in 2019 in June, July and August was 0.74; 0.19; 0.16 and on average for three months 0.36;

1. Normalized differential vegetation index of winter wheat depending on the application of different rates of nitrogen fertilizers with the addition of a nitrification inhibitor (2018–2021)

| **Experiment options** | **Month** | **Years of research** | | | | **Correlation coeficient** |
|---|---|---|---|---|---|---|
| | | **2018** | **2019** | **2020** | **2021** | |
| $N_{10}P_{30}K_{40}$ (background) | June | 0.74 | 0.69 | 0.71 | 0.42 | –0.67 |
| | July | 0.49 | 0.16 | 0.47 | 0.23 | 0.25 |
| | August | 0.44 | 0.13 | 0.42 | 0.24 | 0.38 |
| | Average | 0.56 | 0.33 | 0.53 | 0.30 | – |
| Background+$N_{100}$+ NI | June | 0.79 | 0.74 | 0.77 | 0.46 | 0.71 |
| | July | 0.57 | 0.19 | 0.55 | 0.25 | 0.97 |
| | August | 0.55 | 0.16 | 0.54 | 0.28 | 0.93 |
| | Average | 0.64 | 0.36 | 0.62 | 0.33 | – |
| Background +$N_{120}$+NI | June | 0.80 | 0.74 | 0.78 | 0.47 | 0.75 |
| | July | 0.59 | 0.18 | 0.61 | 0.25 | 0.94 |
| | August | 0.57 | 0.15 | 0.55 | 0.27 | 0.93 |
| | Average | 0.65 | 0.36 | 0.65 | 0.33 | – |
| Background +$N_{120}$ | June | 0.82 | 0.77 | 0.80 | 0.48 | 0.70 |
| | July | 0.60 | 0.20 | 0.61 | 0.26 | 0.97 |
| | August | 0.58 | 0.17 | 0.57 | 0.26 | 0.97 |
| | Average | 0.67 | 0.38 | 0.66 | 0.33 | – |

in 2020, respectively – 0.77; 0.55; 0.54 and 0.62 and in 2021 – 0.42; 0.23; 0.24 and 0.30. In the experiment variant – background + $N_{120}$ + NI – the NDWI level in 2019 in June, July, and August was 0.74; 0.18; 0.15, and on average for three months 0.36; in 2020, respectively, 0.78; 0.61; 0.55 and 0.65 and in 2021 – 0.47; 0.25; 0.27 and 0.33.

The highest level of NDWI was observed in the variant with an increased nitrogen rate – background + $N_{120}$, but without the application of NI DMPP. Thus, the NDWI level in 2019 in June, July and August was 0.77; 0.20; 0.13 and on average for three months 0.38; in 2020 0.80; 0.61; 0.57 and 0.66, respectively, and in 2021 – 0.48; 0.26; 0.26 and 0.33. The correlation coefficient was high: in July and August in the variants of the experiment – background+$N_{100}$+ NI at the level of 0.93–0.97, in the variant – background+$N_{120}$+ NI at the level of 0.93–0.94 and in the variant – background+$N_{120}$ – 0.97.

As for NDWI indicators of winter wheat in terms of years of research, the trend of dependence of NDWI on meteorological parameters can be traced. Thus, on average over three months in the section of all variants of the experiment, NDWI was higher in 2018 (0.56–0.64) and in 2020 (0.53–0.66), which is associated with the optimal water regime of the soils. On the other hand, in 2019 and 2021, the NDWI values on average for three months across all variants of the experiment were lower and ranged from 0.33 to 0.38 and 0.30–0.33, respectively. In a mixture with CAM-32 NI DMPP makes it possible to preserve the main supply of mineral nitrogen for a longer period until the moment when it is most needed by wheat plants. It is NI DMPP in a mixture with CAM-32 that is able not only to prolong the use of available nitrogen in the soil but also to significantly optimize its assimilation by plants. Table 2 shows data on the yield of winter wheat depending on different rates of nitrogen fertilizers and the use of NI DMPP as an addition to CAM-32 and their combined use.

According to the results of the research, the yield of winter wheat varied by year. Thus, the highest yield was obtained in 2018, when it ranged from 3.72 t/ha to 8.14 t/ha ($LSD_{05}$ in 2018 was 1.33 t/ha) and in 2020 – from 3.77 t/ha to 7.25 t/ha ($LSD_{05}$ in 2020 was 2.03 t/ha). A relatively lower level of winter wheat grain yield was observed in 2019: from 3.63 t/ha to 5.10 t/ha with $LSD_{05}$ 1.86 t/ha and in 2021 – from 3.83 t/ha to 4.81 t/ha with $LSD_{05}$ 2.49 t/ha. The average grain yield of winter wheat according to the experimental options during 2018–2021 ranged from 3.74 t/ha to 6.30 t/ha.

A clear trend towards an increase in the yield of winter wheat has been established, both individually by year and on average over 4 years of research with an increase in the application rate of nitrogen fertilizers and the use of NI DMPP.

Thus, the lowest yield of winter wheat was obtained in the control option with the application of $N_{10}P_{30}K_{40}$ (background), where it was 3.72 t/ha in 2018, 3.63 t/ha in 2019, 3.77 t/ha in 2020 and 3.83 t/ha in 2021, which averaged 3.74 t/ha over 4 years. With an increase in the rate of nitrogen fertilizers and the use of NI DMPP, the yield of winter wheat increased. So, on the variant – background+$N_{100}$+NI, the yield of winter wheat was 8.00 t/ha in 2018, 5.05 t/ha in 20219, 7.20 t/ha in 2020, and 4.81 t/ha in 2021, which averaged 6.27 t/ha over the 4 years of research. With a further increase in the rate of nitrogen fertilizers and the application of NI DMPP, the yield of winter wheat also increased. The only exception was 2021, when in the background+$N_{120}$+NI option, the yield of winter wheat was 8.14 t/ha in 2018, 5.10 t/ha in 2019, and 7.25 t/ha in 2020 and 4.72 t/ha in 2021, which averaged 6.30 t/ha over 4 years of research. With the application of the maximum rate of nitrogen fertilizers, but without the use of NI DMPP (background+$N_{120}$), the yield was higher than the control option ($N_{10}P_{30}K_{40}$ (background), but lower than the options with the same rate of nitrogen fertilizers and the use of NI DMPP (background+$N_{120}$+ NI) and the option with a reduced rate of nitrogen fertilizers

2. Grain yield of winter wheat depending on the application of various rates of nitrogen fertilizers with the addition of a nitrification inhibitor (2018–2021), t/ha

| **Experiment option** | **Yield, t/ha** | | | | **Average productivity 2018–2021, t/ha** |
|---|---|---|---|---|---|
| | **2018** | **2019** | **2020** | **2021** | |
| $N_{10}P_{30}K_{40}$ (background) | 37.2 | 36.3 | 37.7 | 38.3 | 37.4 |
| Background+$N_{100}$+NI | 80.0 | 50.5 | 72.0 | 48.1 | 62.7 |
| Background +$N_{120}$+NI | 81.4 | 51.0 | 72.5 | 47.2 | 63.0 |
| Background +$N_{120}$ | 74.0 | 46.4 | 68.5 | 45.0 | 58.5 |
| $LSD_{05}$ | 1.33 | 1.86 | 2.03 | 2.49 | – |

and using DMPP NI (background+$N_{100}$+NI). So, in the option – background+$N_{120}$ – the yield was 7.40 t/ha in 2018, 4.64 t/ha in 2019 year, 6.85 t/ha in 2020 and 4.50 t/ha in 2021, which averaged 58.5 t/ha over the 4 years of research.

**Conclusions.** According to the results of experimental studies, it has been proven that NDWI correlates with the yield of winter wheat grain. It was found that NDWI during the summer growing season of winter wheat plants in the context of experimental variants was higher in 2018 and 2020 and amounted to 0.56–0.67 and 0.53–0.66, respectively. The grain yield of winter wheat was also higher in these years of research: in 2018 – from 3.72 t/ha to 8.14 t/ha and in 2020 – from 3.77 t/ha to 7.25 t/ha. During 2019 and 2021, NDWI indicators on average for three summer months in the context of experience options were lower and amounted to 0.33–0.38 in 2019 and 0.30–0.33 in 2021. Winter wheat grain yield was also at its lowest level in these years of study: in 2019 ranging from 3.63 t/ha to 5.10 t/ha and in 2021 – from 3.83 t/ha to 4.81 t /ha. The correlation coefficient between NDWI and winter wheat yield was the highest in July and August in the variants: background+$N_{100}$+NI; background+$N_{120}$+NI and background+$N_{12}$0 and ranged from 0.93 to 0.97. So, the possibility and feasibility of using of this indicator for remote monitoring of the condition of winter wheat crops have been confirmed.

## References

1. Chen, Z., Li, S., Ren, J., Gongi, P., Zhang, M., Wang, L., Xiao, S., & Jiang, D. (2008). Monitoring and management of agriculture with remote sensing. In: Liang, S. (Ed.), Advances in Remote Sensing. Springer Science+Business Media B.V., 397–421.

2. Gitelson, A.A., Kaufman, Y.J., & Merzlyak, M.N. (1996). Use of a green channel in remote sensing of global vegetation from EOS-MODIS. *Remote Sensing of Environment*, 58 (3), 289–298.

3. Pettorelli, N., Vik, J.O., Mysterud, A., Gaillard, J.M., Tucker, C.J., & Stenseth, N.C. (2005). Using the satellite-derived NDVI to assess ecological responses to environmental change. *Trends in Ecology & Evolution*, 20 (9), 503–510.

4. Jiang, Z., & Huete, A.R. (2006). Global intercomparison of three NDVI datasets for 1981–2001. *Remote Sensing of Environment*, 101 (2), 366–379.

5. Hatfield, J.L., Gitelson, A.A., Schepers, J.S., & Walthall, C.L. (2008). Application of spectral remote sensing for agronomic decisions. *Agronomy Journal*, 100 (1), 121–127.

6. Tucker, C.J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. Rem. *Sens. Environ*, 8 (2), 127–150. https://doi.org/10.1016/0034- 4257 (79)90013-0

7. Myneni, R.B., Hall, F.G., Sellers, P.J., & Marshak, A.L. (1995). The interpretation of spectral vegetation indexes. *IEEE Transactions on Geoscience and Remote Sensing*, 33 (2), 481–486.

8. Vrieling, A., De Leeuw, J., & Said, M.Y. (2013). Length of growing period over Africa: variability and trends from 30 years of NDVI time series. *Rem. Sens*., 5 (2), 982–1000. https://doi.org/10.3390/rs5020982

9. Zhu, Z., Bi, J., Pan, Y., Ganguly, S., Anav, A., Xu, L., Samanta, A., Piao, S., Nemani, R.R., & Myneni, R.B. (2013). Global data sets of vegetation leaf area index (LAI) 3g and fraction of photosynthetically active radiation (FPAR) 3g derived from global inventory modeling and mapping studies (GIMMS) normalized difference vegetation index (NDVI3g) for the period 1981 to 2011. *Rem. Sens.,* 5 (2), 927–948. https://doi. org/10.3390/rs5020927

10. Eid, A.N.M., Olatubara, C.O., Ewemoje, T.A., Farouk, H., & El-Hennawy, M.T. (2020). Coastal wetland vegetation feature and digital change detection mapping based on remotely sensed imagery: El-Burullus Lake Egypt. *Int. Soil Water Conserv. Res,*. 8 (1), 66–79. https://doi.org/10.1016/j.iswcr.2020.01.004

11. Darby, F.A., & Turner, R.E. (2008). Below- and aboveground Spartina alterniflora production in a Louisiana salt marsh. *Estuar. Coast*, 31, 223–231. https://doi.org/ 10.1007/s12237-007-9014-7.

12. Justice, C.O., Townshend, J.R., Holben, B.N., & Tucker, C.J. (1985). Analysis of the phenology of global vegetation using meteorological satellite data. *International Journal of Remote Sensing*, 6 (8), 1271–1318.

13. Ozesmi, S.L., & Bauer, M.E. (2002). Satellite remote sensing of wetlands. *Wetl. Ecol. Manag*., 10 (5), 381–402. https://doi.org/10.1023/a:1020908432489

14. Ghosh, S., Mishra, D.R., & Gitelson, A.A. (2016). Long-term monitoring of biophysical characteristics of tidal wetlands in the northern Gulf of Mexico – a methodological approach using MODIS. Rem. *Sens. Environ*., 173, 39–58. https://doi.org/10.1016/j. rse.2015.11.015

15. Greben', A.S., & Krasovskaya, I.G. (2012). Analiz osnovnykh metodik prognozirovaniya urozhajnosti s pomoshch'yu dannykh kosmicheskogo monitoringa, primenitel'no k zernovym kul'turam stepnoj zony Ukrainy [Analysis of the main methods of yield forecasting with the help of space monitoring data, as applied to cereal crops of the steppe zone of Ukraine]. *Radioelektronni i kompiuterni systemy*, 2 (54), 170–180 [In Russian].

16. Wardlow, B.D., & Egbert, S.L. (2008). Large-area crop mapping using time-series MODIS 250 m NDVI data: An assessment for the U.S. Central Great Plains. *Remote Sensing of Environment*, 112 (3), 1096–1116.

17. Hansen, P.M., & Schjoerring, J.K. (2003). Reflectance measurement of canopy biomass and nitrogen status in wheat crops using normalized difference vegetation indices and partial least squares regression. *Remote Sensing of Environment*, 86 (4), 542–553.

18. Semenova, I.H. (2014). Vykorystannia vehetatsiinykh indeksiv dlia monitorynhu posukh v Ukraini. [The use of vegetation indices for drought monitoring in Ukraine]. *Ukrainskyi hidrometeorolohichnyi zhurnal*, 14, 43–52. [In Ukrainian].

19. Tarariko, O.H., Syrotenko, O.V., Ilienko, T.V., & Kuchma, T.L. (2019). Ahroekolohichnyi suputnykovyi monitorynh [Agroecological satellite monitoring]. Kyiv, 135–158. [In Ukrainian].

20. European Parliament and of the Council. (2014). Commission regulation (EU) № 1257/2014 amending Regulation (EC) No. 2003/2003 of the European Parliament and of the Council relating to fertilizers for the purposes of adapting Annexes I and IV., 12.

УДК 633.11:631.8

# НОРМАЛІЗОВАНИЙ ДИФЕРЕНЦІЙНИЙ ВЕГЕТАЦІЙНИЙ ІНДЕКС ПШЕНИЦІ ОЗИМОЇ ЗАЛЕЖНО ВІД НОРМ АЗОТНИХ ДОБРИВ ТА ІНГІБІТОРА НІТРИФІКАЦІЇ

**С.В. Мунтян[1], канд. с.-г. наук, А.П. Шатковський[2], докт. с.-г. наук, Л.О. Семенко[3], канд. с.-г. наук**

[1] Інститут водних проблем і меліорації НААН, Київ, Україна;
https://orcid.org/0000-0002-8933-9283; e-mail: ais_888@ukr.net;
[2] Інститут водних проблем і меліорації НААН, Київ, Україна;
https://orcid.org/0000-0002-4366-0397; e-mail: andriy-1804@ukr.net;
[3] Національний університет біоресурсів та природокористування України, Київ, Україна;
https://orcid.org/0000-0002-4586-3681; e-mail: larisa-s@ukr.net

***Анотація.*** *У статті наведено результати експериментальних досліджень із вивчення взаємозв'язку між нормалізованим диференційним вегетаційним індексом та врожайністю пшениці озимої за використання різних норм азотних добрив та інгібітора нітрифікації 3,4-диметилпіразолфосфат з КАС-32. Польові дослідження проведено протягом 2018–2021 рр. у науково-дослідному відділі СТОВ «Дружба Нова» Варвинського району Чернігівської області (відділення агрохолдингу «Кернел»). Для обробки експериментальних даних використано аналітичні та математично-статистичні методи. Нормалізований диференційний вегетаційний індекс (NDWI) визначали за результатами знімків із супутників WorldView-2, WorldView-3, Geoeye-1 (Maxar USA). Схемою однофакторного польового досліду було використання варіантів із різними нормами азотних добрив ($N_{100}$ та $N_{120}$), а також використання інгібітора нітрифікації 3,4-диметилпіразолфосфат при додаванні в КАС-32. Контрольним був варіант із внесенням добрив у нормі $N_{10}P_{30}K_{40}$. Результатами експериментальних досліджень доведено, що NDWI прямо корелює з урожайністю пшениці озимої за всі 4 роки досліджень. Встановлено, що NDWI в середньому за три місяці за варіантами досліду був вищим у 2018 р. у межах 0,56–0,67 та в 2020 р. – 0,53–0,66 Врожайність пшениці озимої також була більшою в 2018 та 2020 роках, а саме: у 2018 р. від 3,72 т/га до 8,14 т/га та у 2020 р. – від 3,77 т/га до 7,25 т/га. В 2019 р. та у 2021 р. NDWI в середньому за три літні місяці за варіантами досліду був нижчим та складав: у 2019 р. 0,33–0,38, у 2021 р. – 0,30–0,33. Ця тенденція корелюється з урожайністю пшениці озимої, яка також була на нижчому рівні в цей період. Так, у 2019 р. вона становила від 3,63 т/га до 5,10 т/га та у 2021 р. – 3,83–4,81 т/га. Коефіцієнт кореляції між NDWI та врожайністю пшениці озимої був високим: у липні та серпні на варіантах із нормами азотних добрив $N_{100}$ і $N_{120}$ становив від 0,93 до 0,97.*

***Ключові слова:*** *інгібітор нітрифікації, 3,4 диметилпіразолфосфат, карбамідно-аміачна суміш, нормалізований диференційний вегетаційний індекс, урожайність, пшениця озима*