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Thousand kernel weight of durum wheat (*Triticum durum* Desf.) over a 30-year period as affected by mineral fertilization and weather conditions

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Abstract

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The aim of the study was to determine the influence of mineral fertilization and weather conditions on thousand kernel weight over a 30-year period. The experiment was carried out at the Field Crops Institute-Chirpan, Bulgaria and represents 30 consecutive years (1990–2019). Nitrogen and phosphorus fertilizers were studied in rates of 0, 40, 80, 120 and 160 kg ha^{-1}. Fertilizers were applied alone and in different combinations. A variant without fertilization (N_0P_0) was taken as control. The results showed the strong dependence of the thousand kernel weight on the conditions of the year and nitrogen fertilization. The most suitable conditions for growing durum wheat were moderately dry years with normal temperatures for the region. We also found that long-term single application of N above 80 kg ha^{-1} resulted in a decrease in values. A single application of phosphorus has no effect. The highest thousand kernel weight, averaged over a 30-year period, was recorded when fertilized with $N_{80}P_{120}$, the excess over the control being 4.70%.

Keywords: durum wheat; meteorological conditions; nitrogen; phosphorus; tthousand kernel weight

Introduction

Durum wheat (*Triticum durum* Desf.), is a crop of global importance. Among the grains, wheat is widely used as a staple food for various preparations by the majority of the world population and it is a major source of protein vegetarian population (Dhanavath & Rao, 2017). In addition, durum wheat is an indispensable part of the traditional dishes of many crops, such as pasta, bulgur and couscous. Durum wheat is the second most economically important wheat species after common wheat, and it accounts for 10% of the wheat grown in the world (Bienkowska et al., 2020). Durum wheat is grown annually on over 17 million hectares worldwide (Zaim et al., 2020).

The grain yield of wheat is the results of two basic elements of the yield structure, i.e., the number of grains per unit area (grain density) and the weight of grains, expressed as 1000 grain weight (TKW) (Grzebisz & Potarzycki, 2022). According to Xin et al. (2020) TKW is one of the important component yield components in wheat. Kruszona et al. (2020) even define it as one of the most important components of cereal yield. TKW contributes about 20% of the genetic variation in grain yield (Schierenbeck et al., 2021). Improving TKW is a prior to enhance wheat yield and quality (Qu et al., 2021). TKW can be regulated by fertilization (Lu et al., 2021). Optimizing N fertilizer management may improve grain filling and increase grain weight and yield, for example, by improving soil N availability (Zhang et al., 2022). TKW is strongly influenced by the variation in the dose of nitrogen supply (Batista et al., 2020). Although increased nitrogen application rates can promote grain yield, they can indirectly lead to undesirable grain quality traits (Stupar et al., 2020).

N and P are most important nutrients limiting wheat growth and yield (Abera et al., 2021). Nitrogen limitation is the key factor for wheat production worldwide (Zhang et al., 2021). Nitrogen is a primary nutrient absorbed by wheat crop from soil in large proportions (Sadineni et al., 2021). In developing countries, more than 55% of the increase in food production comes from application of fertilizers, particularly nitrogen fertilizer (Lai et al., 2022). Nitrogen fertilization has become one of the main criticisms of modern agriculture in society (Neuweiler et al., 2021), as ample nitrogen fertilizer input is the predominant way to guarantee crop yields and maintain soil fertility (Mitova & Dinev, 2021). A result of the better accessibility of mineral fertilizers was the massive overuse and mismanagement of those chemicals (Yu et al., 2020). The excessive and inefficient use of fertilizer N is a global issue that requires not only high production costs, but results in environmental population and the increase in GHG emissions (Mălinaş et al., 2022). Something more, intensive inorganic fertilizer usage in agriculture causes so many health problems and unrecoverable environmental pollution (Al-Naggar et al., 2021), that the way fertilizers are applied to a durum wheat crop may have a significant impact on environmental footprints (Li et al., 2018). To impart sustainability to modern intensive farming system, environmental pollution caused by nitrogen fertilizers in needs to be reduced by optimizing their doses (Kizilgeci et al., 2021).

Phosphorus (P) is the second major fertilizer comes after nitrogen (Elgala & Abd-Elrahman, 2021). Phosphorus (P) is a critical element required for normal plant development (Meier et al., 2022). After nitrogen stress, phosphorus is the second most widely occurring nutrient deficiency in cereal system around the world (Awulachew, 2019). Although fertilizing soil with P increases its phytoavailability, only a small fraction (< 20%) of all P added remains available for plants (Sanchez-Rodriguez et al., 2021). It is not only wasteful but also affected the environmental adversely (Fang et al., 2022). Intensive use of phosphorus in agriculture has raised concerns about its sustainability due to potential resource scarcity and its nonudicious use, which has led to serious environmental pollution (Bhattacharya, 2019). For this reason, improvement in phosphorus management is of high priority (Kominko et al., 2019).

The used of balanced fertilizers have a promising role in growth and development of crop plants which resulted in improved quality and quantity of the agricultural produce (Desta & Almayehu, 2020). Abera et al. (2020) emphasize that some of the factors contributing to lower yield and quality of durum yield are poor fertilizer application practices. However, regional and temporal variations in magnitudes of the recent fertilizer use reduction are still unclear (Yu et al., 2020). Over the years, numerous studies have been conducted to determine the impact of mineral fertilizers on the productivity and quality of durum wheat. Many varieties, different types of fertilizers in different rates and combinations, the action of environmental conditions and the interaction of factors have been studied. However, scientists still did not determine a balanced fertilizer rate that is environmentally friendly and human health. For these reasons, our study aimed to determine the impact of mineral fertilization and environmental conditions on a thousand kernel weight over a 30-year period.

Material and Methods

In 1965, at the Field Crops Institute, Chirpan, Bulgaria (42°11′58″N, 25°19′27″E), a stationary fertilizer experiment was established in a two-pole cotton-durum wheat crop rotation. The field experiment was a complete randomized block design, with 4 replications and each plot size of 10 m^2. The data presented is for a period of 30 consecutive years (1990–2019). Nitrogen (N) and phosphorus (P) fertilizers were tested in rates of 0, 40, 80, 120 and 160 kg ha^{-1}. Fertilizers are applied alone and in combinations: $N_{40}P_{40}$, $N_{80}P_{40}$, $N_{120}P_{40}$, $N_{160}P_{40}$, $N_{40}P_{80}$, $N_{80}P_{80}$, $N_{120}P_{80}$, $N_{160}P_{80}$, $N_{40}P_{120}$, $N_{80}P_{120}$, $N_{120}P_{120}$, $N_{160}P_{120}$, $N_{40}P_{160}$, $N_{80}P_{160}$, $N_{120}P_{160}$, $N_{160}P_{160}$, respectively. A variant without fertilization (N_0P_0) was taken as control. Ammonium nitrate was applied as a nitrogen fertilizer and triple superphosphate was applied as a phosphorus fertilizer. The full dose of phosphorus fertilizer and ⅓ of the nitrogen rate were applied before wheat sowing before the last tillage. The remaining ⅔ of the nitrogen was applied in the spring in the tillering phase.

A one-way ANOVA was performed to analyze differences in TKW across observed years. For this purpose, each of the studied years was entered as a repetition. Comparisons between differences were performed using (LSD) ($P \leq 0.01$).

Pellic Vertisols was the soil type. The humus content for the 0–20 cm layer is very high – 3.85% (Table 1). Its content was relatively uniform, decreasing in depth from 2.80% to 1.9% in the 80–100 cm layer. The salt content is low. This shows that the soils have good drainage and there was no danger of salinization. Total carbonates did not exceed 5% in the deep layers and there was no manifestation of chlorosis.

Table 1

The total stock of digestible nitrogen in the 0-30 cm layer is characterized by a low to medium content (Table 2). Total N in the plow layer was 0.095%, and in the 30–60 cm depth it was 0.085%. Profile depth has a stronger effect on total N content than fertilization. The content of total phosphorus is very low – 0.05–0.10%. Phosphorus in the soil is in the form of inorganic and organic phosphates in different proportions. In the upper soil layer, organically bound phosphorus varied from 20 to 70 mg P_2O_5/100 g soil, which was 25–55% of

Table 1. Humus content, assessment of humus stock, total nitrogen

Depth, cm	Humus, %	Humus stock in the layer 0–100 cm, kg ha^{-1}	Assessment of the humus stock in degree	Total N, %	$CaCO_3$, %
0–20	3.85	1386	high	0.20	0.00
20–40	2.80	1008	high	0.13	0.25
40–60	2.20	648	middle	0.10	2.25
60–80	1.95	450	low	0.07	4.56
80–100	1.90	324	low	0.04	4.56

Table 2. Content of mobile forms of macro- and microelements

Depth, cm	N, %	P_2O_5, %	Mn, mg/kg	Cu, mg/kg	Fe, mg/kg	Zn, mg/kg	B, mg/kg
0–30	0.095	0.085	12.2	1.68	4.6	0.90	1.25
30–60	0.085	0.063	11.0	1.29	3.2	1.63	1.32

the total stock in the soil. The total phosphorus content of soils cannot serve as an indicator of the supply of plants with phosphorus food. The total P_2O_5 content in the topsoil was 0.085% and decreased to 0.063% at 60 cm depth. The soil was poorly stocked in zinc, low to moderately stocked in copper, manganese and boron, and well stocked in iron.

Results and Discussion

Figure 1 shows the variation of temperature sums during the growing season of durum wheat for the studied period. Five of the observed years (2007, 2009, 2013, 2016 and 2019) were very warm. The temperature sum of these years exceeded the temperature sum of the multy-year period (2359 °C) by 432–578 °C. Four of the studied years (1994, 2001, 2011 and 2014) were warm and with a higher temperature sum by 275–367°C compared to the multi-year period. Eight of the studied years were characterized as moderately warm – 1992, 1995, 1997, 1998, 1999, 2000, 2010 and 2018. Seven of the studied years were defined as normal – 1990, 1991, 2002, 2003, 2004, 2005 and 2015. Three of the studied years were moderately cool – 2008, 2012 and 2017. Three of the studied years (1993, 1996 and 2006) were cold, with a sum of temperatures below 99–209 °C lower than the multi-year period.

Rainfall during the growing season of durum wheat was also different (Figure 2). 2004 and 2015 were very humid, 587.3 mm and 772.3 mm, respectively. These values exceeded the sum of the long-term period by 146.9 mm and 331.9 mm, respectively. 2008, 2014 and 2018 were observed as wet fit – by 90.3–107.1 mm above the multi-year values. The years 1995, 1998 and 2019 were moderately humid. Average precipitation values were reported in 1991, 1999, 2010, 2012, 2017 and 2013. The years 1997, 2000, 2002, 2005, 2006 and 2016 were moderately dry. The years 1992, 1993, 1994, 1996, 2001 and 2003 were characterized as dry. 1990, 2007, 2009 and 2011 were very dry. The amount of precipitation during these years varied between 231.8 mm–329.7 mm, while the amount of precipitation for the multi-year period was 440.4 mm.

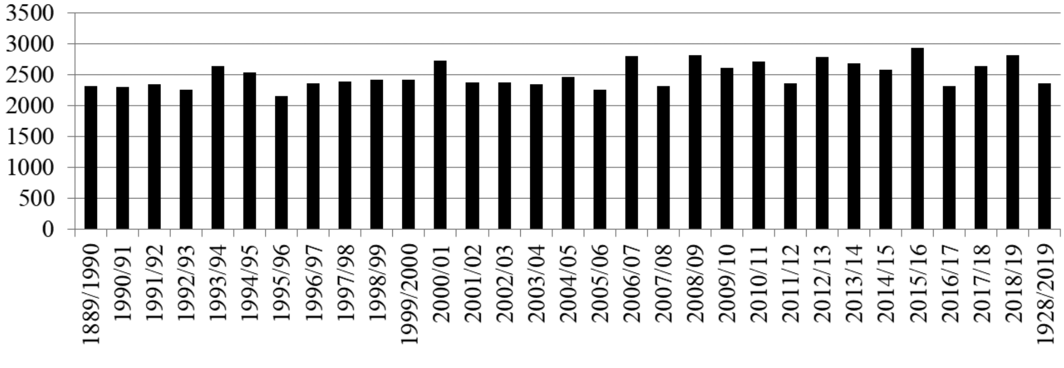

Fig. 1. Temperature sum (°C) during the vegetation period (X–VI) of durum wheat (1990–2019) and multy-year period (1928–2019)

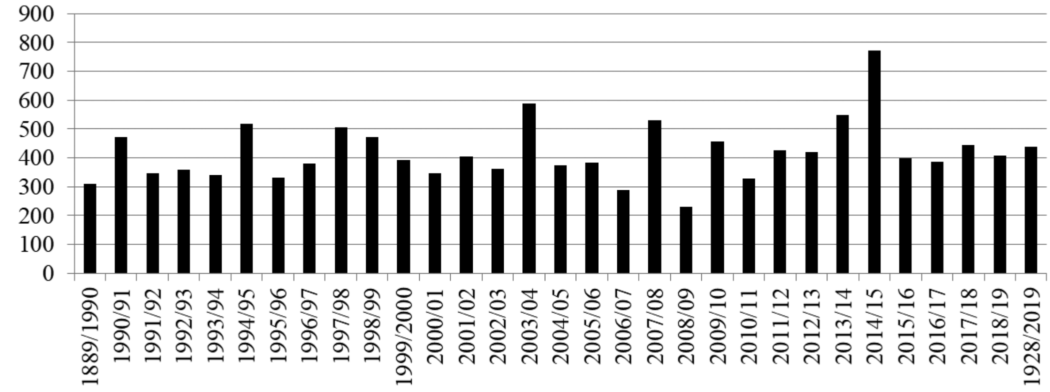

Fig. 2. Precipitation (mm) during the vegetation period (XVI) of durum wheat (1990–2019) and multy-year period (1928–2019)

The analysis of total variance revealed that the conditions of the year had the strongest impact ($P \leq 0.001$) on the formation of thousand kernel weight (TKW) (Table 3). The influence of mineral fertilization had also had a significant effect. Hu et al. (2021) confirmed the statistically significant effect of nitrogen fertilization on the values of the trait. On the variation of TKW, the deciding factor was weather conditions, with 94.29% of the total variation. This result coincided with the results of the same experiment, where Stefanova-Dobreva & Muhova (2022) reported that environmental conditions had a major influence on TKW with 61.28% of the total factor variance. A number of other studies, such as those by Desiderio et al. (2019) and Mangini et al. (2021), confirm the influence of environment on TKW.

Average over a 30-year period TKW without fertilization was 50.85 g (Figure 3). Nitrogen fertilization was shown to increase values up to 52.33 (4.01%), with the greatest impact being fertilization with 80 kg N ha^{-1}. Increasing the nitrogen rate above 80 kg N ha^{-1} led to a decrease in the values. Moreover, the values at the high N_{160} rate were lower than those of the no-fertilization variant. A similar trend in durum wheat fertilization was found by a number of studies, such as Panayotova et al. (2015), Hocaoğlu et al. (2020), Liu et al. (2021), even Abera et al. (2021) reported the highest TKW values of the non-fertilized variant in bread wheat. From a previous comparison of low fertilization rates from the same experiment, Stefanova-Dobreva & Muhova (2020) reported that N_{40} increased TKW to a greater extent than N_{80}, 5.76% and 3.24% over the control, respectively. However, from the same experiment, a different trend was reported for the effect of nitrogen fertilization during different growing seasons. Kirchev et al. (2017) reported that in 2014 TKW was highest under the low nitrogen rate (N_{40}) and in 2015 the highest values were recorded under N_{80} fertilization, with 11.0% and 14.9% above the control, respectively.

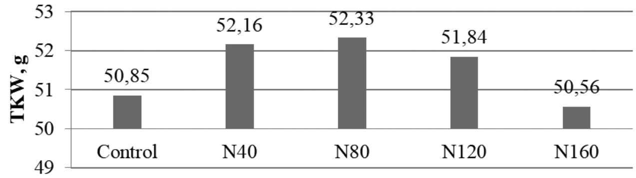

Fig. 3. Thousand kernel weight of durum wheat grain (g) at nitrogen fertilization (1990–2019)

No significant differences were observed under the effect of phosphorus fertilizer (Figure 4). The difference between the lowest and highest value was only 0.34 g, at P_{40} and P_{120}, respectively. The lower TKW values under the influence of P_{160} were consistent with Panayotova et al. (2017). Chen et

Table 3. Analysis of variance for thousand kernel weight of durum wheat at nitrogen and phosphorus fertilization (1990–2019)

Source of variation	Degrees of freedom	Sum of squares	Sum of squares, %	Mean squares	F
Total	749	49033.88	100		
Year	29	46233.5	94.29***	1594.26	455.11
Mineral fertilization	24	362.25	0.74***	15.09	4.31
Error	696	2438.13	4.97	3.50	

, * – significant at $p \leq 0.01$ and $p \leq 0.001$ level of probability, respectively

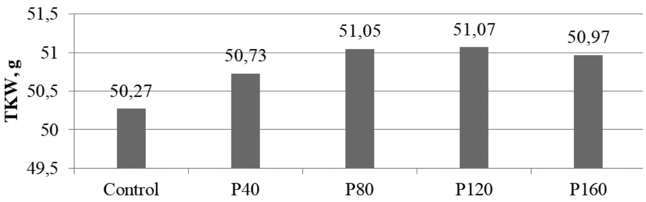

Fig. 4. Thousand kernel weight of durum wheat grain (g) at phosphorus fertilization (1990–2019)

al. (2019) reported the same influence of phosphorus fertilizers on TKW. On the other hand, Sial et al. (2018) found that increasing P rate increased TKW values. Soumay et al. (2021) also observed an increase in TKW values with increasing P rate, in both bread wheat and triticale. The results of the 30-year study differed from a shorter period. Two-year data from the same study showed that the introduction of P_{160} had a reliable impact, increasing values by 7.7% compared to the control (Stefanova-Dobreva et al., 2022).

The data from the combined fertilization showed that with the strongest effect on the values, averaged over a 30-year period, was fertilization with $N_{80}P_{120}$ – 52.63 g (Table 4). Moreover, the high nitrogen dose (N_{160}) did not show a statistically significant effect in combination with any phosphorus dose. However, the results of a study by Rajičić et al. (2020) were in conflict with ours. The authors reported that as the fertilizer rate increased in triticale, the values also increased. Postovalov (2021) also reported an increase in TKW in spring barley when the fertilizer rate was increased. The results averaged over a 30-year period differed from the reported 2-year average data from the same experiment. Stefanova-Dobreva & Muhova (2022) reported that $N_{120}P_{40}$ had the strongest effect on TKW, with an excess over control of 16.2%.

Bulgarian varieties of durum wheat are characterized by a high thousand kernel weight. Due to the large volume of data (25 variants x 30 years), the values of each variant in the respective year were not shown. However, must be note that, the values of the TKW were under 50 g in twelve of the studied years, between 50 and 60 in 11 of the studied years and above 60 g in 7 of the studied years. The most favorable was 2005. This year was moderate in meteorological terms, with TKW values ranging from 63.40 g to 68.6 g and an average of 66.49 g of all variants. This year was moderately dry in terms of rainfall and with normal vegetation temperatures. Such conditions favor the movement of nutrients from the stem and leaves to the spike. This helps to nourish the grains properly. Large grains were also formed in the favorable 2000, 2012, 2016, 2017 and 2019, with the average TKW exceeding 60 g. These years were moderately dry to moderately humid, and temperatures ranged from moderately warm to moderately cool. These conditions were also a prerequisite for high TKW formation.

Table 4. Thousand kernel weight of durum wheat grain (g) at NP fertilization (1990–2019)

Fertilizer rate	N_{40}	N_{80}	N_{120}	N_{160}
P_{40}	51.81^{NS}	52.57***	52.02***	50.97^{NS}
P_{80}	51.71**	52.17***	51.90***	50.94^{NS}
P_{120}	52.24***	52.63***	51.72**	50.76^{NS}
P_{160}	52.05***	52.51***	51.71**	51.71^{NS}
LSD 1%, 0.1% = 1.23; 1.60				

NS – no significant; **, *** – significant at $p \leq 0.01$ and $p \leq 0.001$ level of probability, respectively

Conclusions

The study presents summary data for the evaluation of the thousand kernel weight of durum wheat under the influence of nitrogen and phosphorus fertilization with increasing rates for the conditions of Central Southern Bulgaria. The results showed the strong dependence of the thousand kernel weight in durum wheat on the conditions of the year and nitrogen fertilization. The thousand kernel weight averaged over 30 years was found to be 51.61 g, varying from 50.27 g to 52.63 g. Twelve of the years studied had values below 50 g, 11 of the years studied had values between 50–60 g, and 7 of the years studied had values above 60 g. The most suitable conditions for growing durum wheat are moderately dry years with normal temperatures for the region. We also found that a long-term single application of N above 80 kg ha^{-1} resulted in a decrease in values. A single application of phosphorus had no effect. The highest thousand kernel weight, averaged over a 30-year period, was recorded when fertilized with $N_{80}P_{120}$, the excess over the control being 4.70%.

References

Abera, D., Tana, T. & Dessalegn, T. (2020). Effect of blended NPSB fertilizer rates on yield and grain quality of durum wheat (*Triticum turgidum* L.) varieties in Minijar Shenkora District, Central Ethiopia. *Ethio. J. Agric. Sci., 30*(3), 57-76.

Abera, T., Lemma, A., Hundesa, Ch., Husen, A. & Firomsa, T. (2021). Response of yield components of bread wheat (*Triticum aestivum* L.) to blended NPS and N fertilizer levels at Liban Chukala district, East Shewa Zone, Oromia, Ethiopia. *International Journal of Research and Innovations in Earth Science, 8*(1), 2394-1375.

Al-Naggar, A. M. M., Atta, M. M., El-Moneim, M. L. A. & Al-Metwally, M. S. (2021). Effects of organic and inorganic fertilizer with reduce nitrogen level on growth, nitrogen use efficiency, seed yield and quality traits of *Chenopodium quinoa*. *Plant Cell Biotechnology and Molecular Biology, 22 (71 and 72),* 438-453.

Awulachew, M. T. (2019). Effects of blended fertilizer (nitrogen, phosphorus, sulfur and boron) rates on yield, yield components and grain quality of crop, (Durum Wheat). *Acta Scientific Agriculture, 3*(11), 91-99.

Batista, V. V., Salapata, M. C., Oligini, K. F., Camana, D. F., Fonseca, A. C. & Adami, P. F. (2020). Performance and yield components of wheat cultivars submitted to nitrogen management. *Ciência Agricola, Rio Largo, 18*(3), 1-7. https://doi.org/10.28998/rca.v18i3.9024.

Bienkowska, T., Suchowilska, E. & Wiwart, M. (2020). *Triticum polonicum* L. as promising source material for breeding new wheat cultivars. *Journal of Elementology, 25*(1), 237-248. doi:10.5601/jelem.2019.24.2.1873.

Bhattacharya, A. (2019). Chapter 5 – Changig environmental condition and phosphorus use efficiency in plants. *Climate and Resource Use Efficiency in Plants*, 241-305. https://doi.org/10.1016/B978-0-12-816209-5.00005-2.

Chen, X., Zhang, W., Liang, X., Liu, Y., Xu, Sh., Zhao, Q., Du, Y., Zhang, L., Chen, X. & Zou, Ch. (2019). Physiological and developmental traits associated with the grain yield of winter wheat as affected by phosphorus fertilizer management. *Sci. Rep., 9*, 16580. https://doi.org/10.1038/s41598-019-53000-z.

Desta, B. T. & Almayehu, Y. (2020). Optimizing blended (NPSB) and N fertilizer rates for the productivity of Durum wheat (*Triticum turgidum* L. var. *durum*) in Central Highlands of *Ethiopia. Cogent Food and Agriculture, 6*(1). https://doi.org/10.1080/23311932.2020.1766733.

Desiderio, F., Zarei, L., Licciardello, S., Cheghamirza, K., Farshadfar, E., Virzi, N., Sciacca, F., Bagnaresi, P., Battaglia, R., Guerra, D., Palumbo, M., Cattivelli, L. & Mazzucotteli, El. (2019). Genomic regions from an Iranian landrace increase kernel size in durum wheat. *Front. Plant Sci.,* https://doi.org/10.3389/fpls.2019.00448.

Dhanavath, S. & Rao, U. J. S. P. (2017). Nutritional and nutraceutical properties of *Triticum dicoccum* wheat and its health benefits: An overview. *Journal of Food Science,* https://doi.org/10.1111/1750-3841.13844.

Elgala, A. M. & Abd-Elrahman, Sh. H. (2021). The possible use of scarce soluble materials as a source of phosphorus in *Vicia faba* L. grown in a calcareous soil. *Acta Agriculturae Slovenica, 113*(3), 1-14. doi:10.14720/aas.2021.117.3.1874.

Fang, H., Li, Y., Gu, X., Chen, P. & Li, Y. (2022). Root characteristics, utilization of water and nitrogen, and yield of maize under biodegradable film mulching and nitrogen application. *Agricultural Water Management, 262,* 107392. https://doi.org/10.1016/j.agwat.2021.107392.

Grzebisz, W. & Potarzycki, J. (2022). Effect of magnesium fertilization systems of grain yield formation by winter wheat (*Triticum aestivum* L.) during the grain-filling period. *Agronomy, 12*(12). https://doi.org/10.3390/agronomy12010012.

Hocaoğlu, O., Akçura, M. & Kaplan, M. (2020). Change in the grain element contents in durum wheat varieties of Turkey registered between 1967-2010. *Communications in Soil Science and Plant Analysis, 5*(4). https://doi.org/10.1080/00103624.2019.1709487.

Hu, T., Geng, Ch., Cui, X., Fan, J. & Zhang, F. (2021). Response of yield, yield components and water-nitrogen use efficiency of winter wheat to different drip fertigation regimes in Northwest China. *Agricultural Water Management, 255,* 107034. https://doi.org/10.1016/j.agwat.2021.107034.

Kirchev, H., Dobreva, St. & Muhova, A. (2017). Productivity and quality of durum wheat (*Triticum durum* Dest.) at increasing rates of nitrogen fertilization under long-term accumulation of nutrient in Pellic Vertisols. *Zbornik radova, Knjiga 1*, 165-171.

Kizilgeci, F., Yildirim, M., Islam, M. S., Ratnasekera, D., Iqbal, M. A. & Sabagh, A. E. (2021). Normalized difference vegetation index and chlorophyll content for precision nitrogen management in durum wheat cultivars under semi-arid conditions. *Sustainability, 13*(7), 3725. https://doi.org/10.3390/su13073725.

Kominko, H., Gorazda, K. & Wzorek, Z. (2019). Potentiality of sewage sludge-based organo-mineral fertilizer production in Poland considering nutrient value, heavy metal content and phitotoxicity for rapeseed crops. *Journal of Environmental Management, 248*. https://doi.ogr/10.1016/j.jenvman.2019.109283.

Kruszona, P., Bienias, A. & Milczarski, P. (2020). A complex network of QTL for thousand-kernel weight in the rye genome. *Journal of Applied Genetics, 61,* 337-348. https://doi.org/10.1007/s13353-020-00559-3.

Lai, Zh., Fan, J., Yang, R., Xu, X., Liu, L., Li, S., Zhang, F. & Li, Zh. (2022). Interactive effects of plant density and nitrogen rate on grain yield, economic benefit, water productivity and nitrogen use efficiency of drip-fertigated maize in northwest China. *Agricultural Water Management, 263*. https://doi.org/10.1016/j.agwat.2021.107453.

Li, L., Niu, Y., Ruan, Y., DePauw, R. M., Singh, A. K. & Gan, Y. (2018). Agronomy advancement in tillage, crop rotation, soil health, and genetic grain durum wheat cultivation: A 17-year Canadian story. *Agronomy, 8*(9), 193. https://doi.org/10.3390/agronomy8090193.

Liu, Y., Liao, Y. & Lin, W. (2021). High nitrogen application rate and planting density reduce wheat grain yield by reducing filling rate of inferior grain in middle spiklets. *Crop. J., 9*(2), 412-426. https://doi.org/10.1016/j.cj.2020.06.013.

Lu, J., Hu, T., Geng, Ch., Cui, X., Fan, J. & Zhang, F. (2021). Response of yield, yield components and water-nitrogen use efficiency of winter wheat to different drip fertigation regimes in Northwest China. *Agricultural Water Management, 255,* 107034. https://doi.org/10.1016/j.agwat.2021.107034.

Malinas, A., Vidican, R., Rotar, I., Malinas, C., Moldovan, C. M. & Proorocu, M. (2022). Current status and future prospective for nitrogen use efficiency in wheat (*Triticum aestivum* L.). *Plants, 11,* 217. https://doi.org/10.3390/plants11020217.

Mangini, G., Blanco, A., Nigro, D., Signorile, M. A. & Simeone, R. (2021). Candidate genes and quantitative trait loci for grain yield and seed size in durum wheat. *Plants, 10,* 312. https://doi.org/10.3390/plants10020312.

Meier, S., Morales, A., Lopéz-Olivari, R., Matus, I., Aponte, H., Campos, P. S., Khan, N., Cartes, P., Meriño-Gergichevich, C., Castillo, D. & Seguel, A. (2022). Synergistic role between phosphorus and water use efficiency in spring wheat genotypes.

Agricultural Water Management, 263, 107481. https://doi.org/10.1016/j.agwat.2022.107481.

Mitova, I. G. & Dinev, N. S. (2021). Growth indicators and structure of headed cabbage production depending on the fertilization applied. *Bulg. J. Agric. Sci., 27*(1), 161-166.

Neuweiler, J. E., Trini, J., Maurer, H. P. & Wurschum, T. (2021). Do lower fertilization levels require breeding of different types of cultivars in triticale? *Teor. Appl. Genet.,* https://doi.org/10.1007/s00122-021-04012-9.

Panayotova, G., Kostadinova, Sv. & Valkova, N. (2015). Durum wheat quality as affected by genotype and nitrogen. *Scientific Papers. Series A. Agronomy, LVIII,* 277-283.

Panayotova, G., Kostadinova, Sv. & Valkova, N. (2017). Grain quality of durum wheat as affected by phosphorus and combined nitrogen-phosphorus fertilization. *Scientific Papers. Series A. Agronomy, LX,* 356-363.

Postovalov, A. A. (2021). The role of mineral fertilizers for controlling spring barley root rot development. *IOP Conf. Se.: Earth Environ. Sci., 624,* 012089.

Qu, X., Lin, J., Xie, X., Xu, Q., Tang, H., Mu, Y., Pu, Z., Li, Y., Ma, J., Gao, Y., Jiang, Q., Liu, Y., Chen, G., Wang, J., Qi, P., Habib, A., Wei, Y., Zheng, Y., Lan, X. & Ma, J. (2021). Genetic mapping and validation of loci for kernel-related traits in wheat (*Triticum aestivum* L.). *Front. Plant Sci., 12,* 667493. doi:10.3389/fpls.2021.667493.

Rajicic, V., Popovic, V., Perisic, V., Biberdzic, M., Jovovic, Z., Gudzic, N., Mihailovic, V., Colic, V., Duric, N. & Terzic, D. (2020). Impact of nitrogen and phosphorus on grain yield in winter triticale grown on Degraded Vertisol. *Agronomy, 10,* 757. doi:10.3390/agronomy10060757.

Sanchez-Rodriguez, A. R., Rey, M. D., Nechate-Drif, H., Castillejo, M. A., Jorrin-Novo, J. V., Torrent, J., Campillo, M. C. & Sacristan, D. (2021). Combining P and Zn fertilization to enhance yield and grain quality in maize grown on Mediterranean soils. *Sci. Rep., 11,* 7427. https://doi.org/10.1038/s41598-021-86766-2.

Sadineni, T., David, A. A., Thomas, T., Swaroop, N., Hasan, A. & Kondappali, A. S. T. (2021). Assessment of inorganic fertilizer and organic manure on growth, yield and economics of wheat (*Triticum aestivum* L.). *The Pharma Innovation 10*(10), 680-683.

Schierenbeck, M., Alqudah, A. M., Lohwasser, U., Tarawneh, R. A., Simon, M. R. & Borner, A. (2021). Genetic dissection of grain architecture-related in a winter wheat population. *BMC Plant Biology, 21,* 417. https://doi.org/10.1186/s12870-021-03183-3.

Sial, N. A., Abro, S. A., Abbas, M., Irfan, M. & Depar, N. (2018). Growth and yield of wheat as affected by phosphate solubilizing bacteria and phosphate fertilizer. *Pak. J. Biotechnol., 15*(2), 475-479.

Soumay, P. R., Singh, D., Sharma, S., Singh, A. M. & Pandey, R. (2021). Evolution of diverse wheat (*Triticum aestivum*) and triticale (x *Triticosecale*) genotypes for low phosphorus stress tolerance in soil hydroponic conditions. *Journal of Soil Science and Plant Nutrition*. doi: 10.1007/s42729-021-00436-w.

Stefanova-Dobreva, St. & Muhova, A. (2020). Effect of low rates of mineral fertilizers on the productivity of durum wheat (*Triticum durum* Dest.). *Scientific Papers. Series A. Agronomy, LXIII*(1), 134-141.

Stefanova-Dobreva, St. & Muhova, A. (2022). Durum wheat grain yield and quality depending on mineral fertilization under field conditions. *Journal of Mountain Agriculture on the Balkans, 25*(5), 191-206.

Stefanova-Dobreva, St., Muhova, A. & Bonchev, B. *(2022).* Nitrogen and phosphorus fertilizers affecting the quality and quantity of the durum wheat. *Scientific Papers. Series A. Agronomy, LXV*(1), 533-539.

Stupar, V., Paunovic, A., Madic, M., Kneževic, D. & Durovic, D. (2020). Influence of genotype, nitrogen fertilization and weather conditions on yield variability and grain quality in spring malting barley. *Journal of Central European Agriculture, 22*(1), 86-95. doi:10.5513/JCEA01/22.1.2858.

Xin, F., Zhu, T., Wei, Sh., Han, Y., Zhao, Y., Zhang, D., Ma, L. & Ding, Q. (2020). QTL mapping of kernel traits and validation of a major QTL for kernel length-width ratio using SNS and bulked segregant analysis in wheat. *Sci. Rep., 10*(25). https://doi.org/10.1038/s41598-019-56979-7.

Yu, X., Li, H. & Doluschitz, R. (2020*)*. Toward sustainable management of mineral fertilizers in China: An integrative analysis and review. *Sustainability, 12,* 7028. doi:10.3390/su12177028.

Zhang, G., Liu, Sh., Dong, Y., Liao, Y. & Han, J. (2022). A nitrogen fertilizer strategy for simultaneously increasing wheat grain yield and protein content: Mixed application of controlled-release urea and normal urea. *Field Crops Research, 277,* 108405. https://doi.org/10.002/csc.2.20491.

Zhang, X., Ma, Q., Li, F., Ding, Y., Yi, Y., Zhu, M., Ding, J., Li, Ch., Guo, W. & Zhu, X. *(2021)*. Transcriptome analysis reveals different responsive patterns to nitrogen deficiency in two wheat near-isogenetic lines contrasting for nitrogen efficiency. *Biology, 10*(11), 1126. https://doi.org/10.3390/biology10111126.

Zaim, M., Kabbaj, H., Kehel, Z., Gorjanc, G., Filali-Maltouf, A., Belkadi, B., Nacjit, M. & Bassi, F. M. (2020). Combining QTL analysis and genomic predictions for four durum wheat populations under drought conditions. *Front. Genet*., https://doi.org/10.3389/fgene.2020.00316.

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