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Influence of three agricultural systems on physiological, biometric parameters, and aphid infestation in common wheat (*Triticum aestivum* L.)

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Abstract: This study evaluates the physiological and biometric parameters, as well as aphid infestation levels, in winter wheat grown under conventional, organic, and biodynamic farming systems during 2020 – 2022, at the Institute of Agriculture – Karnobat. The wheat variety Miryana was used. Key physiological traits such as photosynthetic activity and water use efficiency were measured alongside biometric parameters and yield components. The study revealed that organic farming enhances water use efficiency but compromises yield and photosynthetic activity. Biodynamic farming performed comparably to the conventional system in physiological terms, while achieving the highest yield in the second year and exhibiting the lowest aphid infestation. These findings highlight biodynamic agriculture as a sustainable and resilient option for wheat production.

Keywords: wheat; physiology; yield, aphids; sustainable farming; water use efficiency

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important agricultural crops, playing a critical role in global food security (FAO, 2021). Throughout its vegetation period, wheat is subjected to various biotic and abiotic stress factors that can affect its growth, development, and yield. Among the major biotic threats to wheat are pests, with aphids (*Sitobion avenae*) being among the most harmful. Aphids not only cause direct damage by extracting plant sap, but also transmit viral diseases (Zhang et al., 2018). Furthermore, aphid infestation negatively affects the physiological processes of plants, leading to a decrease in photosynthetic activity and water status, which ultimately results in stunted growth and reduced yields (Niu et al., 2020; Johnson et al., 2014).

The physiological and biometric parameters of wheat are closely related to its resistance to pests. For instance, plants with high photosynthetic activity and optimal water status generally exhibit greater resistance to aphid infestation (Zhang et al., 2020). Conversely, aphid attacks can significantly reduce photosynthetic capacity and alter plant growth, leading to lower biometric values and diminished yields (Zhang et al., 2020). Plants infested by pests often show reduced chlorophyll concentration, a direct indicator of decreased photosynthetic efficiency (Gupta et al., 2012).

Different farming systems play a crucial role in these interactions. Variations in agricultural practices can influence both the physiological and biometric parameters of plants, as well as the extent of aphid infestation. Conventional, organic, and biodynamic farming are three major approaches used in wheat production, each exerting distinct impacts on plants and pests.

Conventional farming relies on chemical fertilizers and pesticides for crop and pest management. Although this approach can lead to higher yields, it also creates conditions conducive to the development of resistant pest populations, including aphids (Bàrberi, 2002; Zander et al., 2021). Studies have shown that chemical treatments in conventional farming can adversely affect the physiological parameters of wheat by reducing chlorophyll content and photosynthetic activity, thereby increasing plant vulnerability to pests (Tilman et al., 2002; Johnson et al., 2014).

Organic farming, on the other hand, relies on organic fertilizers and biological pest control methods. Research indicates that plants grown under organic conditions exhibit better water status and higher chlorophyll levels, compared to those cultivated in conventional systems, which may enhance their resistance to aphid attacks (Pimentel et al., 2005; Gurr et al., 2016; Tsatsakis et al., 2020). Organic practices often involve the use of biological predators to regulate pest populations while maintaining healthy physiological parameters in plants.

Biodynamic farming incorporates the principles of organic agriculture along with astronomical and spiritual practices. Although research in this area is limited, preliminary studies suggest that biodynamic practices may enhance plant resistance to pests by stimulating biological processes in the soil and improving overall plant resilience (Holmgren, 2001; Garzón et al., 2020). While further investigation is necessary, early findings indicate that biodynamic methods could contribute to increased resistance to pests such as aphids.

The aim of the present study is to examine the relationships between physiological and biometric parameters of wheat and aphid infestation levels under three different farming systems. Understanding these interactions will provide valuable insights for optimizing agricultural practices and improving wheat resilience to pests.

MATERIALS AND METHODS

The experiment was conducted in the experimental fields of the Institute of Agriculture – Karnobat, during the 2020 - 2022 period. Experimental plots of 500 m² were established under conventional, organic, and biodynamic farming systems, each with four replications, using the wheat variety Miryana.

In the conventional field, wheat was grown with the application of synthetic nitrogen fertilizers (N_{10}) and pesticides Florasulam + Tritosulfuron and Fenoxaprop-P-etil; Epoziconazole + Pyraclostrobin and Cypermethrin (at recommended doses).

In the organic field, cow manure (50–60 t/ha) was applied without the use of pesticides.

In the biodynamic field, biodynamic compost made from cow manure supplemented with standard biodynamic preparations (BD 502, 503, 504, 505, 506, 507) was applied at a rate of 5–6 t/ha, with no chemical fertilizers or pesticides used.

After wheat maturity, plant samples were collected using meter-long sections, and biometric measurements were performed to assess biometric parameters. Wheat yields under the three farming systems were also recorded. A one-way analysis of variance (One -Way ANOVA) was used to analyze the biometric data and yield results.

Observations for aphid infestations were conducted directly on plants at 10 randomly selected sites, with 10 wheat stems assessed per site in each replication and treatment. The average values from the four replications were used in the analysis.

Physiological measurements:

Leaf gas exchange parameters were measured using a portable intelligent photosynthesis system (LCpro+ Ti) over two consecutive vegetation periods. Intact flag leaves from each crop were selected to determine the photosynthetic assimilation rate (A), transpiration rate (E), intercellular (sub-stomatal) CO_2 concentration (Ci), and stomatal conductance (Gs). Instantaneous water use efficiency (iWUE) was subsequently calculated as the ratio A/E.

Measurements were performed at the medium milk development stage of the grains (Zadoks scale №75), using the middle section of each leaf. Data were collected between 09:00 AM and 11:00 AM.

The ambient conditions within the measurement chamber were as follows: air temperature ranged from 25.4 - 26.4°C and 26.5 - 28.3°C; air relative humidity (RH) ranged from 16.8 - 17.8 mbar and 13.7 - 15.0 mbar; photosynthetically active radiation (PAR) ranged from 699 - 1100 µmol m^{-2} s^{-1} and 1300 - 1700 µmol m^{-2} s^{-1}; and ambient CO_2 concentration ranged from 385 - 395 ppm and 405 - 418 ppm.

Agrometeorological overview for the study period

The 2020/2021 growing season was characterized by higher-than-average monthly temperatures, with an overall increase of 1.8°C compared to the multiannual average. The first frost in the Karnobat region occurred on November 1, 2020, and the last was recorded on May 12, 2021. The cooler and wetter conditions during March and April delayed crop development, ultimately exerting a beneficial effect on the growth of cereal crops and positively influencing yields. This delay was subsequently offset by elevated temperatures commencing in the final ten days of April and continuing through May.

Total precipitation for the 2020/2021 agricultural year reached 691.8 mm, representing a 21% increase compared to the multiannual norm. From the perspective of rainfall, the year was favorable, as the surplus precipitation compensated for previously depleted soil moisture reserves. Nevertheless, the uneven spatial and temporal distribution of rainfall, often of torrential intensity, resulted in excessive soil moisture, hampering timely soil cultivation and sowing operations. Moreover, the substantial precipitation recorded during December and January created unfavorable conditions for the normal overwintering of crops. Rainfall during April, however, provided sufficient soil moisture, enabling crops to successfully transition through critical developmental stages such as stem elongation, heading, and the milk ripeness phase without experiencing drought stress. Conversely, abundant rainfall from the second ten-day period of June through the first ten days of July complicated harvesting operations.

In the 2021/2022 agricultural year, rainfall emerged as the main limiting factor, with total precipitation during both the autumn-winter and spring-summer periods falling below the multiannual average. Overall, precipitation levels were 13% lower than historical norms and were unevenly distributed throughout the season. In terms of thermal conditions, the year was distinguished by anomalously high temperatures, with an average increase of 2.1°C compared to the long-term average for the Karnobat region.

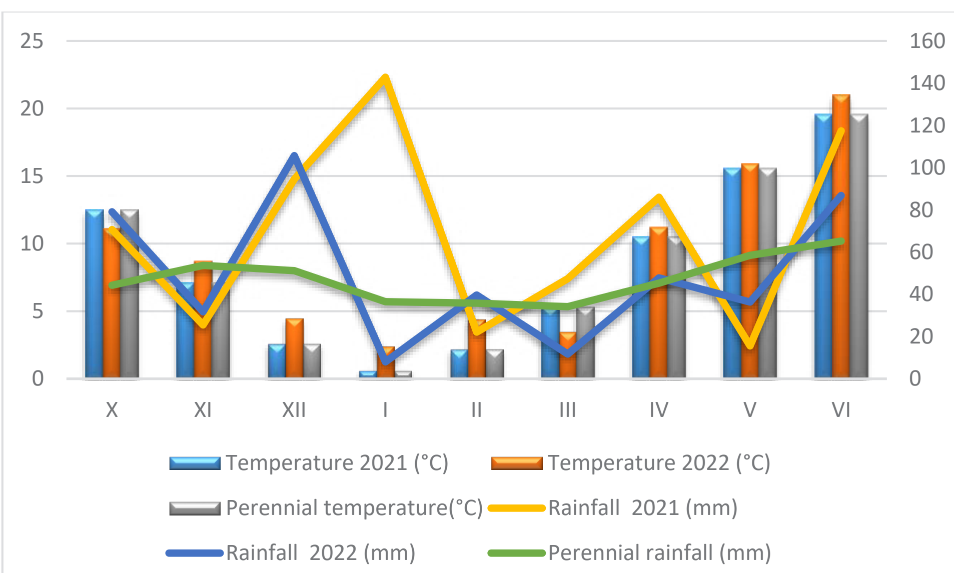

Figure 1. Agrometeorological conditions during the study period

The accumulated thermal sum (October - June) was 193.6°C higher than the multiannual mean. Air humidity was also reduced, with nine out of twelve months exhibiting values 7.4% lower than the long-term average, further exacerbating the challenges to crop development.

Autumn and spring-summer droughts can thus be identified as key risk factors affecting field crops in the Karnobat region (Fig. 1).

RESULTS AND DISCUSSION

Results

Analysis of physiological measurements in wheat variety Miryana

A two-year comparative study was conducted to evaluate photosynthetic activity, transpiration rate, stomatal conductance, and instantaneous water use efficiency in wheat cultivar Miryana, grown under three different farming systems - conventional, organic, and biodynamic (Tables 1 and 2).

In 2021, plants from the conventional and biodynamic plots exhibited similar levels of net photosynthetic rate (A), while significantly lower activity was observed in the organic system ($p < 0.05$). Significant differences were also found in transpiration (E) and stomatal conductance (Gs) across the different farming systems, with values in the organic and biodynamic systems being 30% to 100% lower compared to the control group (conventional system). This reduction corresponded with a recorded increase in instantaneous water use efficiency (A/E).

Table 1. Physiological measurements in wheat – 2021

Measurements	Ci	E	Gs	A	iWUE
Conventional farming					
Average values	**284,5**±5,65	**2,43**±0,12	**0,30**±0,027	**11,64**±0,72	**4,84**±0.28
Organic farming					
Average values	**241,9±12,98**	**0,94±0,06**	**0,09±0,009**	**5,98±0,58**	**6,47**±0.32
t-test	**0.0149**	**0.0001**	**0.0001**	**0.0001**	**0,021**
Biodynamic farming					
Average values	**247,8±11,80**	**1,69±0,07**	**0,16±0,009**	**10,51±1,10**	**6,16**±0.41
t-test	**0.0302**	**0.0002**	**0.0005**	0.3437	**0,044**

A – CO_2 Photosynthetic Assimilation Rate; E – H_2O Transpiration Rate (E); Intercellular (Sub-stomatal) CO_2 Concentration (Ci); Stomatal Conductance (Gs); and Instantaneous Water Use Efficiency (iWUE)

Table 2. Physiological measurements in wheat – 2022

Measurements	Ci	E	Gs	A	iWUE
Conventional farming					
Average values	**125,0**±9,98	**1,47**±0,14	**0,043**±0,004	**6,52**±0,54	**4,54**±0.27
Organic farming					
Average values	**127,3±10,97**	**0,64±0,06**	**0,033±0,002**	**5,47±0,30**	**8,50±0.51**
t-test	0,204	**0,002**	0,053	0,237	**0,0003**
Biodynamic farming					
Average values	**179,9**±16,47	**0,86**±0,10	**0,056**±0,009	**6,52**±0,15	**7,99**±0.45
t-test	**0,014**	**0,002**	0,215	1,000	**0,001**

A – CO_2 Photosynthetic Assimilation Rate; E – H_2O Transpiration Rate (E); Intercellular (Sub-stomatal) CO_2 Concentration (Ci); Stomatal Conductance (Gs); and Instantaneous Water Use Efficiency (iWUE)

In 2022, although the overall photosynthetic activity was lower than in the previous year, the same trend persisted. Biodynamic and conventional systems maintained higher levels of photosynthetic activity and transpiration, whereas plants grown under the organic farming system once again demonstrated the highest water use efficiency.

These data confirm that the farming system exerts a significant influence on the physiological status of the plants. In particular, organic farming appears to optimize the water balance more effectively, albeit at the expense of photosynthetic productivity.

Analysis of variance of yield components under different farming systems

The biometric parameters of wheat over the two-year period are presented in Figure 2.

An analysis of variance (ANOVA) was conducted to assess the number of fertile tillers in 2021 across the three farming systems. The results revealed statistically significant differences between the groups ($p < 0.001$). The lowest aver-

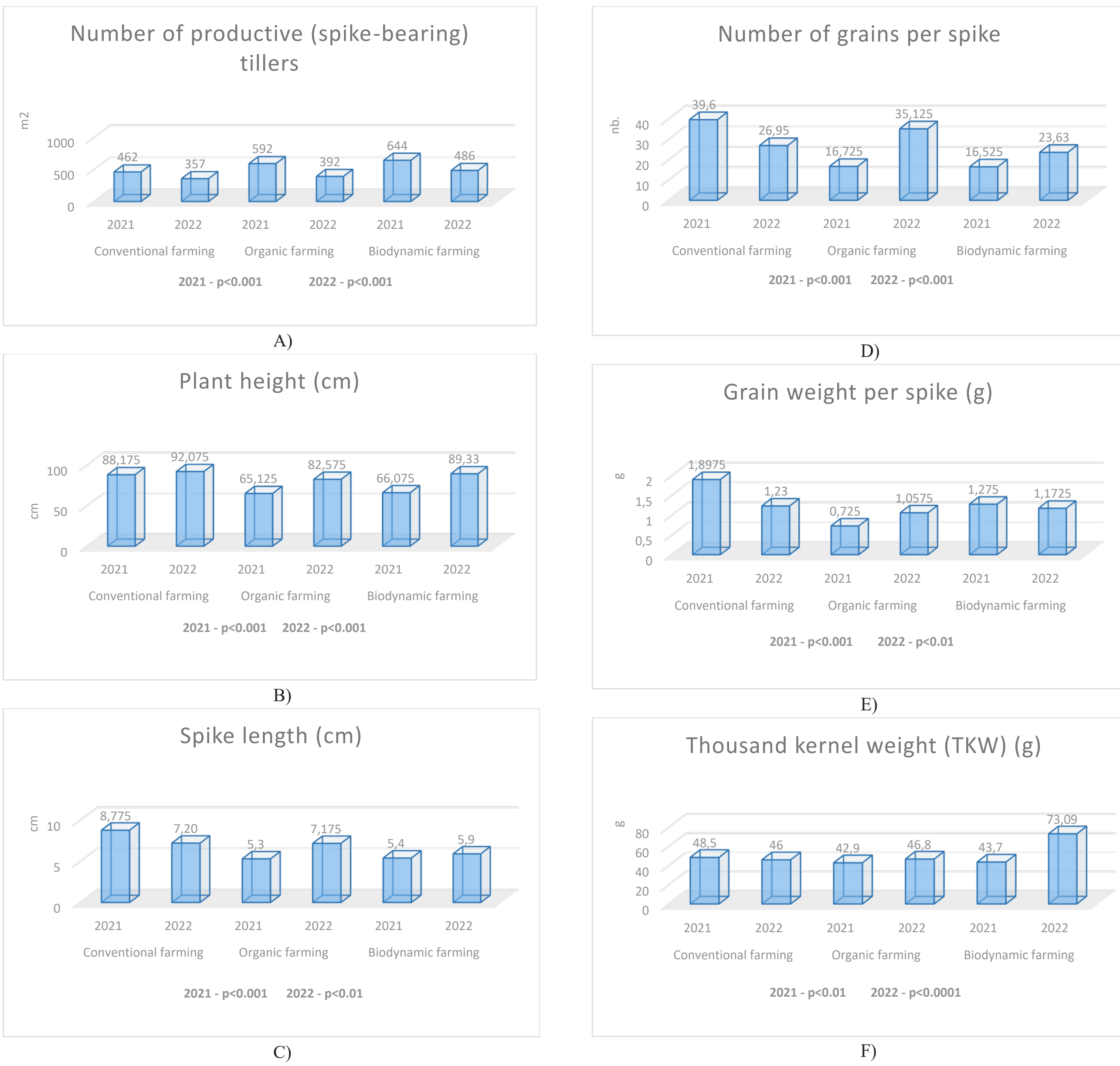

Figure 2. Biometric parameters of wheat plants (A-F)

age number of fertile tillers was recorded under conventional farming (462), followed by organic farming (592), with the highest values observed under biodynamic farming (644). The superior performance in the biodynamic system highlights its positive influence on the yield potential of winter wheat. In 2022, ANOVA results similarly indicated statistically significant differences among the farming systems ($p < 0.001$), with the lowest value again recorded under the conventional system (357), followed by the organic (392), and the highest under the biodynamic system (486). These findings demonstrate the potential of biodynamic agriculture to support a greater number of productive tillers, which directly contributes to higher yield potential (Fig. 2A).

An ANOVA was also performed to assess plant height under different farming systems in 2021. The average plant height was significantly greater under conventional farming (88.2 cm) compared to organic (65.1 cm) and biodynamic (66.1 cm) systems ($p < 0.001$). In 2022, the differences in plant height remained statistically significant ($p < 0.001$). Plants under the conventional system were the tallest (92.1 cm), followed by those in the biodynamic (89.3 cm) and organic systems (82.6 cm). These results reflect the strong influence of agronomic practices on the morphological development of the crop (Fig. 2B).

A one-way ANOVA was conducted on spike length in 2021, revealing statistically significant differences between the three farming systems ($p < 0.001$). The average spike length was highest in the conventional system (8.78 cm), and significantly longer than those in the organic (5.3 cm) and biodynamic (5.4 cm) systems, which were similar to each other. This highlights the considerable impact of the farming system on the morphological characteristics of the spike. In 2022, ANOVA again revealed statistically significant differences in spike length among systems ($p < 0.01$). The conventional and organic systems showed similar values (7.2 cm), while the biodynamic system was significantly shorter (5.9 cm). This likely reflects physiological differences in spike development under varying agricultural practices (Fig.2C).

An ANOVA of the number of grains per spike in 2021 showed clearly significant differences among the three farming systems ($p < 0.001$). Conventional farming resulted in a significantly higher number of grains per spike (mean 39.6) compared to both the organic (16.7) and biodynamic (16.5) systems, which were similar. This underscores the high yield potential of the conventional system. In 2022, the number of grains per spike again differed significantly among systems ($p < 0.001$). The organic system recorded the highest value (35.1), exceeding both the conventional (26.95) and biodynamic (23.6) systems. This result suggests that organic farming may stimulate grain formation, although this does not necessarily guarantee increased grain mass or final yield (Fig. 2D).

The analysis of grain mass per spike in 2021 also revealed statistically significant differences between the farming systems ($p < 0.001$). The conventional system showed the highest average grain mass (1.90 g), followed by the biodynamic (1.28 g), while the organic system had the lowest value (0.73 g). This confirms the greater yield capacity of the conventional system and the intermediate performance of the biodynamic system. In 2022, the grain mass per spike again differed significantly between systems ($p < 0.01$). The highest value was observed under conventional farming (1.23 g), followed by biodynamic (1.17 g), and the lowest under organic farming (1.06 g) (Fig. 2E).These findings indicate more effective grain filling in the intensive systems, particularly under optimal nutrient and water conditions.

The analysis of thousand grain weight (TGW) in 2021 showed statistically significant differences between the three farming systems ($p < 0.01$). The conventional system achieved the highest mean TGW (48.5 g), followed by the biodynamic (43.7 g), and the lowest was observed in the organic system (42.9 g). These differences confirm the yield advantage of the conventional system, while also highlighting the potential of biodynamic farming as a sustainable alternative. In 2022, the analysis of TGW showed highly significant differences among systems ($p < 0.0001$). The biodynamic system achieved the highest

TGW (73.1 g), considerably exceeding the values recorded under conventional (46.0 g) and organic (46.8 g) farming (Fig. 2F). This result emphasizes the ability of the biodynamic system to produce heavier and more fully developed grains, possibly as a result of enhanced soil microbiome and biological activity (Maneva and Atanasova, 2018).

Based on the two-year results, it can be concluded that organic farming leads to reduced photosynthetic activity and lower plant height, spike length, number of grains per spike, grain weight per spike, and thousand kernel weight in winter wheat compared to conventional and biodynamic systems. However, it ensures higher water use efficiency. Biodynamic farming exhibited photosynthetic parameters comparable to those of conventional farming, while simultaneously providing a significantly higher number of productive tillers, as well as comparable plant height, spike length, grain number, and grain weight. Notably, it achieved the highest yield in the second year of the study. These findings suggest the potential to reduce dependency on intensive agricultural practices through the adoption of biodynamic approaches that combine high productivity with sustainable use water resource.

Analysis of variance of grain yield under different farming systems

The analysis of variance (ANOVA) for grain yield in 2021 revealed highly statistically significant differences among the three farming systems ($p < 0.0001$). The highest yield was recorded under conventional farming (8.77 t/ha), followed by the biodynamic system (8.21 t/ha), while the organic system registered significantly lower values (4.29 t/ha) (Fig. 3).

In 2022, yields again differed significantly between the systems ($p < 0.001$). This time, biodynamic farming exhibited the highest yield (5.70 t/ha), surpassing both the conventional (4.39 t/ha) and organic (4.15 t/ha) systems. These results demonstrate the stability and high potential of the biodynamic system under varying climatic conditions (Fig. 3).

The results of the analyses indicate that the farming system has a substantial impact on wheat yield. Conventional farming generally results in higher yields compared to organic systems, which may be attributed to the use of synthetic fertilizers, pesticides, and other inputs that support plant growth and protection. Biodynamic farming, which also showed high yields, likely benefits from the integration of organic and ecological practices that enhance soil health and plant resilience.

At the same time, organic farming, which excludes the use of chemical fertilizers and pesticides, produced considerably lower yields than the other two systems. These findings highlight the need for further research, aimed at optimizing agricultural practices within organic systems to improve yield outcomes without compromising the sustainability of the agroecosystem.

This study demonstrates that differences among farming systems have a significant impact on wheat yields. The variation in agricultural practices between conventional, organic, and biodynamic farming results in statistically significant differences in productivity. These outcomes emphasize the importance of selecting an appropriate farming system to achieve optimal yields, while maintaining ecosystem sustainability and reducing negative environmental impacts.

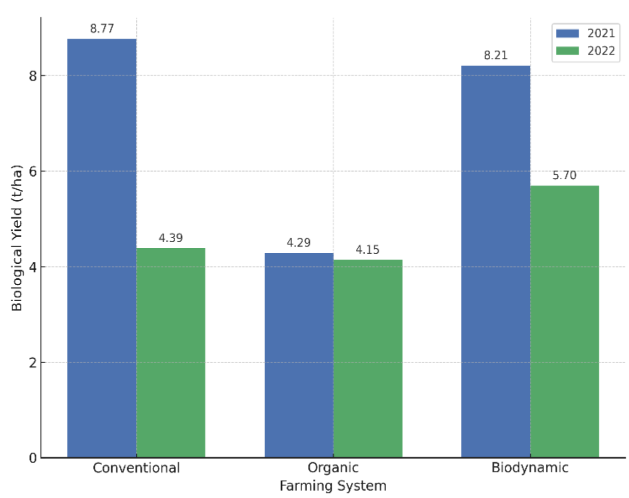

Figure 3. Biological yield of winter wheat under different farming systems

Analysis of aphid infestation dynamics on winter soft wheat under three farming systems

Figures 4 and 5 illustrate the development of aphid populations on winter wheat cultivated under conventional, organic, and biodynamic farming systems during the 2021 and 2022 growing seasons, respectively.

In 2021 (Figure 4), the highest aphid density was recorded in the conventional farming system, followed by the organic system, while the lowest infestation level was observed in wheat plots managed under biodynamic practices. The population peak in the conventional system occurred earlier and was more pronounced, suggesting favorable conditions for pest development, likely due to a simplified agroecosystem structure and reduced presence of natural biological regulators. In contrast, the biodynamic system maintained consistently low aphid densities throughout the season, which may be attributed to enhanced bio-

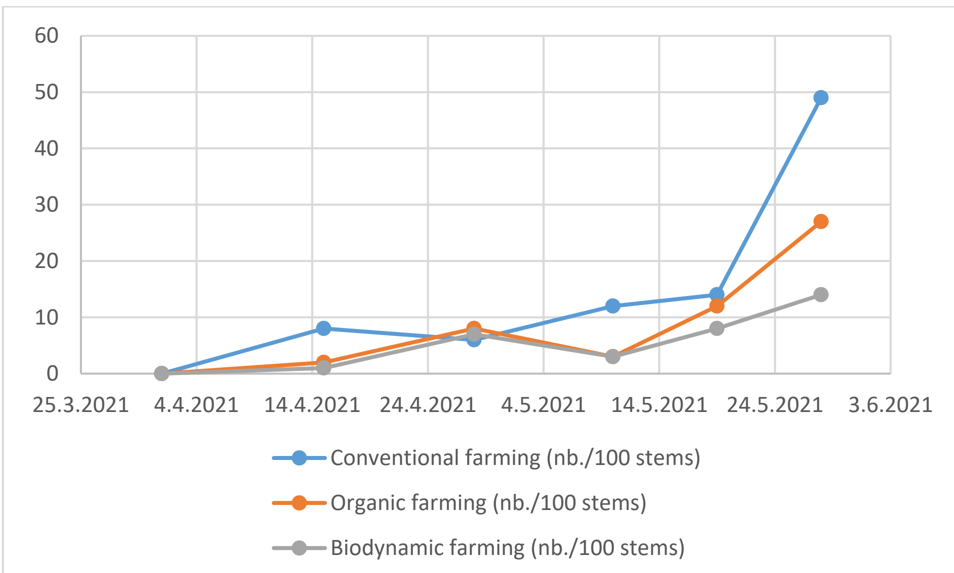

Figure 4. Numerical dynamics of aphids in three farming systems on wheat – 2021

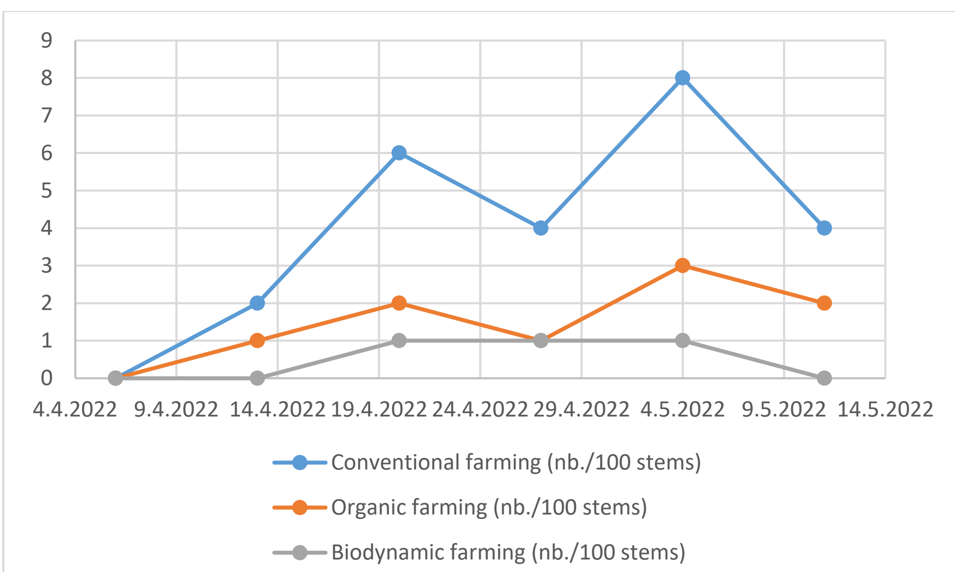

Figure 5. Numerical dynamics of aphids in three farming systems on wheat – 2022

diversity, biologically active soil, and the presence of natural enemies or repellent compounds induced by biodynamic preparations.

In 2022 (Figure 5), a similar trend was observed, although with a slightly delayed population buildup and lower overall pest pressure. Once again, the conventional system exhibited the highest level of aphid infestation, whereas both the organic and biodynamic systems demonstrated more limited and delayed pest population development. These findings confirm the greater resilience of ecologically oriented agricultural systems.

A comparison with biometric and physiological data reveals a notable pattern: although the conventional system achieved higher yields, this occurred at the cost of reduced ecological stability, especially in terms of pest management. The biodynamic system, despite slightly lower yields in some years, showed greater resistance to aphid infestation, suggesting healthier plants and improved agroecosystem balance.

The organic farming system, while associated with lower yields, maintained intermediate aphid levels and demonstrated high water-use efficiency, according to physiological measurements. This confirms its ecological potential, although further improvements are needed to enhance its productivity.

The two-year results clearly demonstrate that biodynamic farming offers the highest potential for pest suppression without the use of synthetic plant protection products. Its effectiveness supports the hypothesis that enhanced biological interactions, increased activity of soil microbiota, and agroecosystem diversification play a key role in the natural regulation of pest populations.

The integrated analysis of yield, morphological, physiological, and entomological data suggests that biodynamic farming is a promising model for sustainable wheat production, particularly under conditions of climatic stress and biotic pressure.

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DISCUSSION

The physiological and yield responses of wheat under the three farming systems demonstrate the trade-offs between productivity and sustainability.

Higher iWUE in organic farming aligns with previous findings (Pimentel et al., 2005; Tsatsakis et al., 2020), which indicate improved water balance under low-input systems. However, the reduced photosynthetic activity and yield in our organic plots correspond with similar limitations reported by Gurr et al. (2016), emphasizing the need for enhanced nutrient management in organic systems.

The comparable physiological performance of biodynamic and conventional systems mirrors observations by Garzón et al. (2020), who noted improved crop vigor under biodynamic practices. The superior TKW and yield stability of biodynamic wheat, especially in 2022, suggest long-term benefits of enhanced soil microbiota, as supported by Maneva & Atanasova (2018).

The lower aphid densities in biodynamic systems support the ecological pest regulation framework proposed by Holmgren (2001) and reaffirm the value of system diversification in reducing pest outbreaks (Zander et al., 2021).

These comparisons highlight that while conventional farming maximizes yield short term; biodynamic systems provide a balance between productivity, pest resilience, and resource efficiency, confirming its viability as a sustainable alternative in varied agroclimatic conditions.

CONCLUSIONS

Organic farming, while ensuring higher water-use efficiency, leads to reduced photosynthetic activity and lower values across key morphological and yield-related traits (plant height, spike length, grain number and weight, and thousand kernel weight) in winter wheat (cv. Miryana) compared to conventional and biodynamic systems.

Biodynamic farming achieves performance comparable to conventional practices in terms of photosynthetic efficiency, while providing a higher number of productive tillers and achieving the highest yield in the second year. It thus demonstrates the potential to combine high productivity with sustainable resource use.

The observed statistically significant differences in yield between farming systems highlight the critical role of agronomic practices in shaping wheat productivity. These findings reinforce the need for system-specific strategies that balance yield performance with ecological sustainability.

Biodynamic farming shows the greatest potential for pest suppression without synthetic pesticides, supporting the hypothesis that biological complexity, active soil microbiota, and system diversification are fundamental to natural pest regulation.

The integrated evaluation of agro-morphological, physiological, and entomological indicators positions biodynamic farming as a viable model for sustainable wheat production, especially under conditions of climatic stress and biotic pressure.

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