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Phenological And Growth Analysis of 45 Winter Wheat Varieties in Khorezm Region: Insights from Crop Growth Parameters

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Abstract

Winter wheat is a staple crop in the Khorezm region of Uzbekistan, playing a critical role in ensuring regional food security and economic stability. The region's agricultural productivity is heavily dependent on efficient management of natural resources and the selection of optimal cultivars suitable for its unique agroecological conditions. Despite its importance, variability in yield outcomes often arises due to differences in cultivar performance, climatic conditions, and management practices. Addressing these challenges requires a thorough understanding of the growth dynamics and phenological characteristics of winter wheat varieties.

Keywords:

Introduction

The phenological and growth traits of winter wheat are influenced by factors such as genetic potential, environmental interactions, and management practices. In this context, analyzing crop growth parameters such as the leaf area index (LAID), grain weight (GWAD), and biomass components (e.g., stem weight and canopy weight) provides insights into physiological processes and yield potential. Understanding these dynamics enables farmers and researchers to optimize practices for better resource use efficiency and higher productivity.

This study focuses on 45 winter wheat varieties cultivated under the specific agroclimatic conditions of the Khorezm region. By examining key growth parameters and their interrelationships, this research aims to:

1. Identify high-yielding cultivars: Determine which varieties exhibit superior yield potential under the environmental conditions of Khorezm.
2. Understand growth dynamics: Characterize the growth trajectories of various varieties and pinpoint critical growth stages affecting yield formation.

3. Investigate inter-parameter relationships: Explore the correlations between parameters such as LAID, SWAD (stem weight), and CWAD (canopy weight) to uncover physiological mechanisms driving yield variation.
4. Provide actionable insights for crop management: Use the findings to guide cultivar selection, refine planting schedules, and develop targeted management strategies for improving winter wheat production.

By leveraging time-series data, advanced statistical tools, and crop growth modeling through the Decision Support System for Agrotechnology Transfer (DSSAT), this study offers a comprehensive analysis of phenological and growth characteristics. The results are expected to support informed decision-making for enhancing agricultural practices, promoting sustainable production, and improving food security in the region.

1.1.1.1 References

- [Include studies on wheat phenology and growth parameters, such as references to research using LAID, GWAD, and DSSAT modeling in similar agroecological contexts.]
- [Cite studies specific to Uzbekistan or the Khorezm region if available, focusing on wheat production and cultivar performance.]
- [References on global best practices for optimizing wheat yield through cultivar and management strategies.]

2 Materials and Methods

2.1 Study Site and Experimental Design

This study was conducted in the Khorezm region of Uzbekistan, a semi-arid area characterized by hot summers, cold winters, and predominantly loamy soils. The experimental setup followed a randomized complete block design (RCBD) with three replications to ensure reliable and unbiased results. Each experimental plot measured 4 meters by 10 meters, providing adequate space for plant growth and accurate data collection.

2.2Plant Material

Forty-five winter wheat varieties, representing a diverse genetic pool, were selected for the experiment. These varieties exhibited significant variability in genetic, ecological, and agronomic traits. Genetic traits included disease resistance and vernalization requirements, while ecological preferences such as drought and salinity tolerance were also assessed. Agronomic characteristics, including maturity date and plant height, further highlighted the diversity of the dataset. This broad range of traits facilitated a detailed evaluation of growth patterns and yield potential, emphasizing the importance of cultivar-specific management and breeding approaches.

2.3Data Collection

Data collection involved field and laboratory measurements to assess plant growth and yield parameters. The process included multiple field visits and laboratory analyses, ensuring a comprehensive dataset suitable for descriptive statistics and crop modeling.

Pre-Winter Assessments. The winter wheat crop was sown on October 7, and plant emergence and density were assessed by the end of October. The number of plants per square meter was counted in all plots to establish baseline population metrics before winter dormancy.

Post-Winter Population Assessment. In mid-March of the following year, the plant population was reassessed using similar methods to account for winter survival and evaluate the number of viable plants per square meter.

Sequential Growth Parameter Measurements. Field sampling began in late March and continued until mid-June, with six key sampling dates: March 27, April 8, April 23, May 7, May 29, and June 17, 2024. At each visit, plant samples were collected from three replicates per cultivar. Five to six plants, including their root systems, were carefully extracted, stored in cooling boxes, and transported to the laboratory for detailed analysis.

In the laboratory, 10 representative plant shoots (stems) per sample were selected for measurements. The analysis included:

• Biomass components: Leaf, stem, and head weights.
• Morphological parameters: Plant height and leaf area index (LAI).
• Phenological growth parameters: "LAID" (Leaf Area Index Duration), "PAD" (Plant Area Duration), "SWAD" (Stem Weight), "GWAD" (Grain Weight), "LWAD" (Leaf Weight), "CWAD" (Canopy Weight), "PWAD" (Pod Weight), and "SHAD" (Shell Weight).

These measurements, recorded at the specified six time points, constitute time-series data utilized for subsequent analysis and DSSAT model simulation.

At harvest maturity on June 17, 2024, final yield and biomass-related parameters were recorded. Measurements included:

• Yield components: Harvest Weight at Maturity (HWAM), Harvest Weight per Unit Area (HWUM), Harvest Unit Mass (HUM), and Harvest Area Mass (HAM).

- Biomass components: Canopy Weight at Maturity (CWAM) and Byproduct Weight at Harvest (BWAH).
- Leaf Area Index: Maximum LAI (LAIX).

The collected dataset serves dual purposes: descriptive analysis of phenological and growth parameters and input data for DSSAT crop modeling simulations. This comprehensive data collection strategy enables a detailed evaluation of growth dynamics and yield performance across the 45 winter wheat cultivars studied.

2.4Analysis of Growth Parameters and Correlations

The script provides a detailed examination of crop growth and yield parameters for 45 winter wheat cultivars. The analysis integrates field-measured time-series data and final harvest data, employing descriptive statistics, visualizations, and correlation analysis to uncover patterns and relationships between parameters.

Visualization of LAI Dynamics. Leaf Area Index (LAI) data, an important growth parameter, was analyzed for temporal trends across all cultivars. The dataset was divided into two groups of cultivars to enhance visualization clarity. Temporal Dynamics described by bBoxplots illustrate LAI distributions at different dates, while a smooth LOESS regression curve captures growth trends. Cultivar-Level Variation faceted plots highlight variability in LAI between cultivars, emphasizing differences in growth trajectories.

Crop Growth Parameter Distribution. The distribution of key growth parameters (e.g., LAID, PAD, GWAD, PWAD, SHAD) was visualized using boxplots. Faceted Representation each parameter is plotted on its own scale, allowing for direct comparison of variability across cultivars. Inter-Cultivar Differences the results demonstrate significant variability in growth characteristics, reflecting cultivar-specific growth patterns.

Harvest Yield Analysis. At harvest, yield-related parameters were summarized and visualized. Key metrics included HWAM (Harvest Weight at Maturity), CWAM (Canopy Weight at Maturity), BWAH (Byproduct Weight at Harvest), and LAIX (Maximum Leaf Area Index). Yield Variability, a bar plot revealed differences in yield performance across cultivars, with cultivars ranked by HWAM. Average Yield Parameters, cultivar-level means were computed for all yield metrics, offering a benchmark for performance evaluation.

Correlation Analysis. Correlation matrices were derived for both growth and yield parameters. Growth Parameters include variables such as LAID, PAD, and GWAD showed significant relationships, indicating interconnected growth dynamics. Yield Parameters correlations among HWAM, HWUM, HUM, HAM, CWAM, BWAH,

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and LAIX provided insights into yield determinants and their interplay with growth traits.

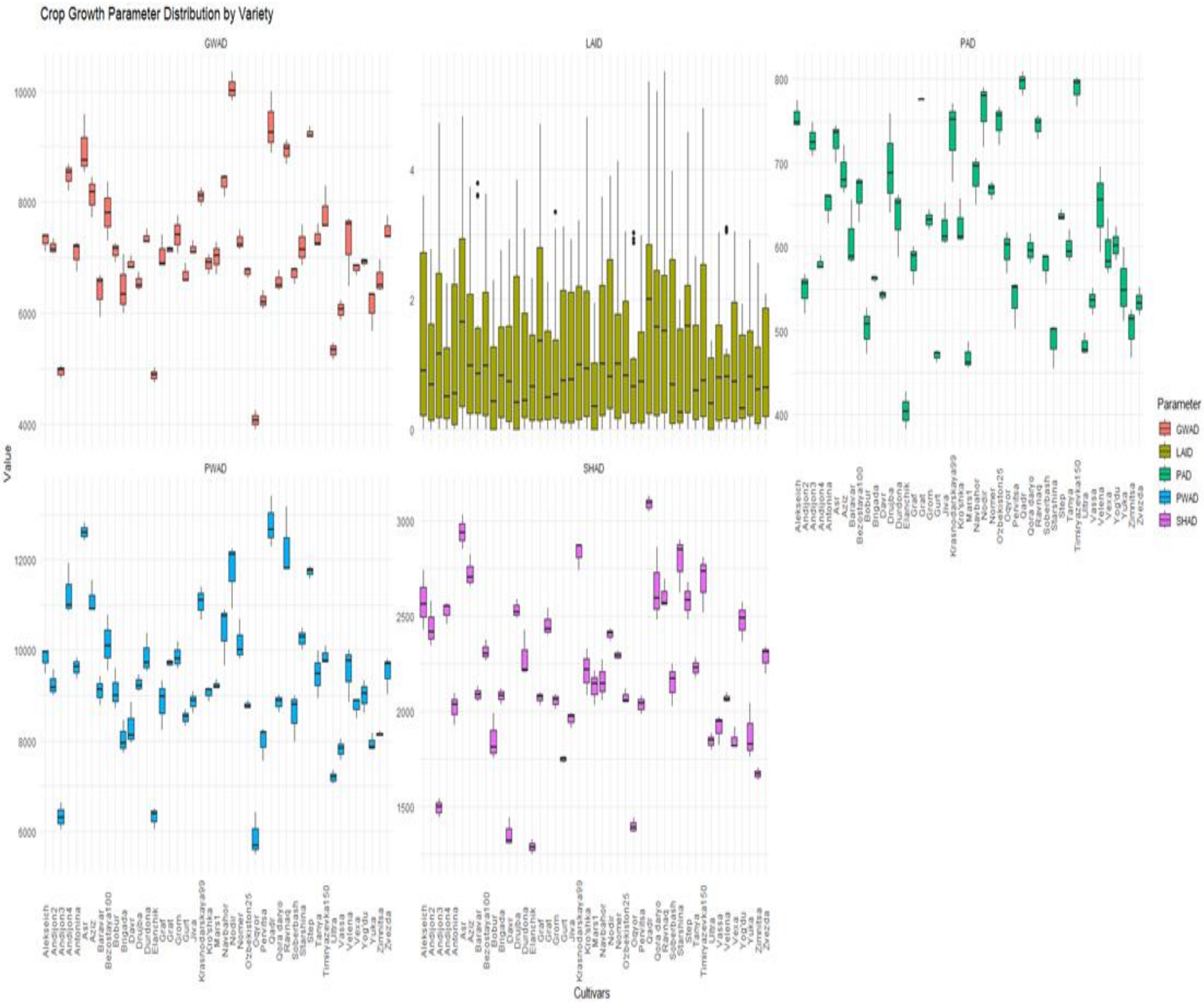
3 Results

3.1 Phenological Variations:

• Significant variability was observed in phenological stages among the 45 winter wheat varieties. Tillering commenced in early March, with anthesis occurring in early May. Harvest dates varied across varieties, with the majority reaching maturity in mid-June.

3.2 Growth Dynamics and LAI:

• Time-series analysis revealed distinct growth patterns among varieties. LAI increased rapidly during the vegetative stage, peaking in late April, and subsequently declined as the crop matured. LAIX varied significantly among varieties, with some cultivars exhibiting higher maximum LAI.



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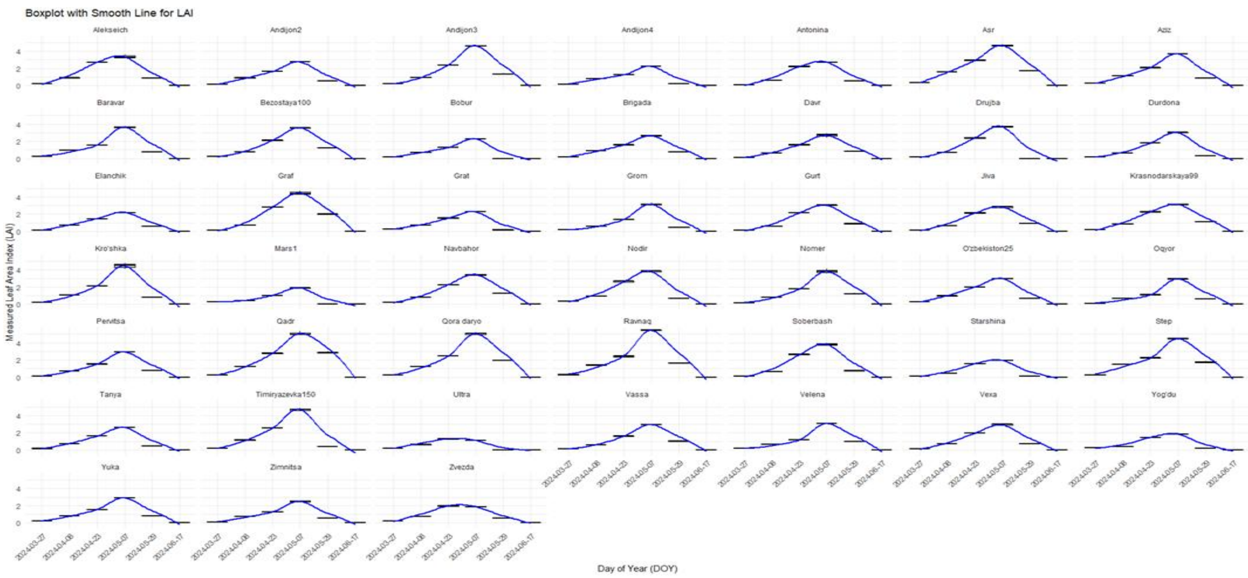

3.3 Yield Performance:

- Mean yield (HWAM) across all varieties was 5,230 kg/ha, with values ranging from 4,500 to 6,000 kg/ha. High-yielding varieties consistently demonstrated optimal LAIX, early ADAT, and favorable biomass accumulation.

3.4 Correlation Analysis:

The correlation analysis provides valuable insights into the relationships between key harvested parameters in winter wheat, highlighting the factors that contribute to yield.

A strong positive correlation of 0.83 was observed between HWAM (Harvest Weight at Maturity) and HAM (Number of Heads per Square Meter). This relationship indicates that as the density of heads per square meter increases, the overall harvest weight also rises. This is logical since more heads typically result in higher grain production.

Similarly, HWAM and CWAM (Tops Weight at Maturity) showed a very strong positive correlation of 0.90. This suggests that larger total plant biomass, which includes leaves and stems, is strongly associated with greater harvest weight. This finding emphasizes the critical role of vegetative growth in contributing to overall yield.

Moderate positive correlations were observed for several parameters. HWAM and BWAH (Byproduct Weight at Harvest) exhibited a correlation of 0.68, indicating that higher byproduct weight, such as straw, is associated with increased harvest weight. This relationship might be explained by larger plant sizes or more vigorous growth leading to both higher grain and byproduct production. A moderate correlation of 0.45 was found between HWAM and HUM (Number of Grains per Unit), suggesting that an increase in the number of grains per spike or head contributes to yield, albeit to a lesser extent than biomass-related factors. Additionally, HWAM and LAIX (Maximum Leaf Area Index) showed a correlation of 0.42, pointing to a relationship between greater photosynthetic capacity and higher harvest weight.

A weaker positive correlation of 0.12 was found between HWAM and HWUM (Weight per Grain). While heavier grains contribute slightly to overall harvest weight, the number of grains (as indicated by HAM) appears to have a more significant impact on yield.

Overall, this analysis underscores the multifaceted factors influencing yield in winter wheat. Higher harvest weight is primarily driven by the density of heads per square meter, larger plant biomass, and greater photosynthetic capacity. The contribution of grain count and individual grain weight, while present, is relatively moderate.

The observed relationships are likely influenced by environmental factors such as water and nutrient availability, as well as climatic conditions during the growing season. Genetic variability among the 45 winter wheat cultivars studied may also affect these correlations, highlighting the importance of breeding efforts to optimize traits for specific environments.

In conclusion, this analysis provides a clear understanding of how various crop growth parameters interact to determine yield. Further investigations using regression modeling and incorporating environmental variables could deepen this understanding, while studies on genetic diversity could inform the selection of cultivars best suited for targeted yield optimization.

Correlation Matrix of Crop Growth Parameters

	HWAM	HWUM	HUM	HAM	CWAM	BWAH	LAIX
HWAM	1.0000000	0.1175892	0.4478386	0.8300975	0.9030039	0.6820103	0.4233513
HWUM	0.1175892	1.0000000	-0.1330120	-0.4255282	0.0605819	0.0025717	-0.1864923
HUM	0.4478386	-0.1330120	1.0000000	0.4931573	0.2937494	0.1170754	-0.1163314
HAM	0.8300975	-0.4255282	0.4931573	1.0000000	0.7894312	0.6339697	0.4807877
CWAM	0.9030039	0.0605819	0.2937494	0.7894312	1.0000000	0.9300664	0.5749019
BWAH	0.6820103	0.0025717	0.1170754	0.6339697	0.9300664	1.0000000	0.6166076
LAIX	0.4233513	-0.1864923	-0.1163314	0.4807877	0.5749019	0.6166076	1.0000000

4. Conclusion

This study investigated the phenology and growth characteristics of 45 winter wheat varieties cultivated in the Khorezm region, Uzbekistan. Time-series data on key growth parameters, including LAID, GWAD, and biomass components, were collected and analyzed to understand growth dynamics, inter-parameter relationships, and yield performance.

Results revealed significant variability among cultivars in growth rates, phenological stages, and yield potential. High-yielding varieties consistently demonstrated optimal LAIX, early anthesis, and favorable biomass accumulation. Correlation analysis highlighted strong positive relationships between LAID and biomass components, emphasizing the importance of canopy development for yield.

The findings of this study have several implications for winter wheat production in the Khorezm region:

• Cultivar Selection: Identifying high-yielding and well-adapted cultivars is crucial for optimizing wheat production in the region. The results of this study can guide cultivar selection based on specific traits such as LAIX, ADAT, and biomass accumulation.

• Crop Management: Understanding the growth dynamics and inter-parameter relationships can inform the development of targeted management strategies. For example, optimizing planting dates to maximize LAI during the critical growth stages could enhance yield potential.

• Future Research: Further research is needed to investigate the impact of environmental factors such as temperature, water availability, and nutrient availability on growth and yield. Integrating these findings with crop models will enable more accurate predictions of crop performance and facilitate the development of climate-resilient cropping systems.

Overall, this study provides valuable insights into the phenology and growth dynamics of winter wheat varieties in the Khorezm region. The findings can contribute to improved cultivar selection, optimized crop management practices, and enhanced winter wheat production in the region.

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