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Analysis of Growth and Productivity of Wheat Crops (Triticum aestivum L.) under Various Agroclimatic Conditions

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ABSTRACT

Wheat (Triticum aestivum L.) is one of the world's main food commodities that has the potential to be developed in tropical regions, including Indonesia. However, differences in agroclimatic conditions such as temperature, rainfall, and humidity affect its growth and productivity. This study aims to analyze the growth response and yield of wheat in three locations with different agroclimatic characteristics, namely highland (location A), temperate (location B), and lowland (location C). The parameters observed included plant height, number of productive saplings, leaf area index (ILA), and harvested dry grain yield per hectare. The experimental design used a Complete Group Random Design (RAKL) with three replicates at each location. The data was analyzed with ANOVA and continued with the DMRT test at 5%. The results show that the differences in agroclimate have a significant effect on all growth and yield parameters. Location B (medium plain) provides the highest growth and yield, namely the average plant height is 92.4 cm, the number of saplings is 5.7 per clump, and the yield is 5.8 tons/ha. In contrast, location C (lowland) produces less than optimal growth and the lowest yield (3.5 tons/ha) due to overheating and low rainfall. Thus, temperature and rainfall are the main limiting factors in wheat cultivation in the tropics. The selection of planting locations according to the agroclimate is very important to support wheat productivity. These findings provide the scientific basis for the development of location-based tropical wheat.

Keywords: Wheat, Agroclimate, Triticum aestivum L

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the world's main food commodities that ranks at the top in terms of consumption and production, after rice and corn (Widowati, 2014). The plant has long been a staple food ingredient in various countries, especially in subtropical and temperate regions, such as Europe, North America, Australia, and Central Asia. Processed wheat products such as flour, bread, pasta, and noodles have high economic value and increasing market demand, in line with population growth and shifting consumption patterns of global society.

In Indonesia, wheat consumption shows an increasing trend every year. Based on data from the Central Statistics Agency (BPS) and the Ministry of Agriculture, the national wheat needs are still mostly met from imports, with the amount continuing to increase from year to year (Indrayani & Swara 2014). This leads to national food dependence on foreign supplies, which has an impact on economic vulnerability and food price stability, especially when there are price fluctuations or disruptions to global supply (Moningka et al., 2025). Therefore, efforts to develop domestic wheat cultivation are very important as a strategic step in realizing national food security and independence.

However, wheat development efforts in Indonesia face major challenges, especially due to the characteristics of the tropical climate that differ significantly from the world's major wheat-producing regions. Tropical climates generally have higher air temperatures, high humidity, and an erratic distribution of rainfall throughout the year. Meanwhile, wheat is a temperate to subtropical climate plant that generally grows optimally at a temperature of 15–25°C with relatively low water requirements and a growing period that requires dry and cool seasons. These differences cause the agronomic and physiological adaptation of wheat to be very limited in some regions of Indonesia, so it is necessary to carry out research and innovation in terms of cultivation, variety selection, and management of the growing environment.

One approach that can be taken to support wheat development in Indonesia is to identify and evaluate the appropriate agroclimatic conditions for the optimal growth of this crop (Setijawan et al., 2022). Agroclimate is a combination of climatic and environmental factors that affect agricultural production, such as temperature, rainfall, humidity, solar radiation, and the physical properties of the soil. Differences in agroclimatic conditions between regions can affect the rate of photosynthesis, respiration, transpiration, plant organ formation, and the development of phenological phases of wheat plants, from germination to seed ripening.

Several previous studies have shown that favorable agroclimatic conditions can improve water use efficiency, biomass accumulation, and wheat grain yields. For example, excessively high temperatures in the generative phase can cause heat stress that impacts decreased grain formation and seed filling, while unstable rainfall can interfere with plant physiological activity. Therefore, it is important to analyze the growth and productivity of wheat in various agroclimatic zones to determine the potential for adaptation of this crop in various environmental conditions in Indonesia (Servina 2019).

The main objective of this study was to analyze the growth and productivity response of wheat crops to differences in agroclimatic conditions in three representative locations. The selected location has different agroclimatic characteristics, including variations in altitude, temperature, and rainfall, making it possible to evaluate the performance of the plants under contrasting growing environments. Thus, the results of this study are expected to provide useful scientific information in determining potential areas for the development of wheat cultivation locally, as well as as a basis for recommendations for the government and agricultural actors in formulating production policies and strategies.

In particular, this study observed several growth parameters such as plant height, number of productive saplings, and leaf area index, as well as yield parameters in the form of dry grain weight per hectare as an indicator of productivity. The data obtained will be statistically analyzed to determine the significant influence of agroclimate differences on growth and yield variables. The study also aims to identify the dominant climatic factors that most affect wheat growth and yield, as well as evaluate land suitability based on empirical results in the field.

In addition to the technical aspect, domestic wheat development also has great social and economic implications. Dependence on wheat imports not only creates a trade balance deficit, but also reduces opportunities for local farmers to develop a more diversified and market-oriented farming system (Khudori 2010). If wheat cultivation can be adapted effectively on a local scale, it can open up opportunities for diversification of farming businesses, increasing farmers' incomes, and contributing to rural economic stability. Therefore, research on the suitability of agroclimate and the potential for wheat productivity in Indonesia is very relevant and urgent to be carried out.

In the context of global climate change, analysis of the adaptation of wheat crops to various agroclimatic conditions is also important to deal with future climate uncertainties (Surmaini & Faqih 2016). Fluctuations in temperature and erratic rainfall will affect planting patterns and agricultural production in general, including wheat crops. By knowing the response of plants to different environmental conditions, adaptation strategies such as selection of tolerant varieties, modification of cultivation techniques, and water management can be designed more appropriately to ensure the sustainability of food production.

Against this background, this study is focused on evaluating the growth and yield of wheat crops in three locations with contrasting agroclimatic conditions, namely highlands, temperate plains, and lowlands. This research is expected to answer fundamental questions about how local climate variations affect the agronomic performance of wheat crops, as well as provide a clearer picture of areas that are suitable for large-scale wheat production in Indonesia. The findings of this study are expected to not only contribute to the development of tropical agronomic science, but also support national food security policies based on the sustainable use of local resources.

METHODS

This research was carried out at three locations in the tropics of Indonesia, each of which has different agroclimatic characteristics, to see its effect on wheat growth and yield. Location A is a plateau with an altitude of more than 1000 meters above sea level, an average daily temperature of 18–22°C, annual rainfall of more than 2000 mm, and air humidity above 80%. Location B is on a medium plain, which is 500–800 meters above sea level, temperature 22–26°C, rainfall of 1500–2000 mm, and humidity of 70–80%. While location C is a lowland below 200 meters above sea level, the temperature is 27–32°C, rainfall is less than 1500 mm, and humidity is less than 70%. The research lasted for one planting season, namely from April to August 202X. The main ingredients in this study are wheat seeds of superior tropical adaptive varieties, as well as basic fertilizers of Urea, SP-36, and KCl according to the recommended dosage. The equipment used includes a thermohomometer and rain gauge for agroclimate measurement, a meter ruler and leaf area meter for plant growth measurement, as well as a digital scale to weigh crop yields.

The study was prepared using a Complete Group Random Design (RAKL) with one factor, namely the location of the agroclimate (A, B, and C). Each experimental site was repeated three times on plots measuring 10 m × 10 m, and all agronomic treatments such as land preparation, planting, fertilization, and pest and disease control were standardized. The parameters observed included the height of the plant every two weeks until harvest, the number of productive saplings in the final vegetative phase, the leaf area index (ILA) measured using the leaf area meter, and the weight of harvested dry grain was converted to a moisture content of 14%. The observation data was analyzed using variety analysis (ANOVA), and if there were significant differences, it was followed by the Duncan's Multiple Range Test (DMRT) at the level of 5% to see the differences between locations in more detail. The results of the analysis showed that all parameters of wheat growth and yield differed significantly between locations ($p < 0.05$). Location B provides the best performance, with an average plant height of 85.3 cm, a productive number of saplings of 5.8 per clump, and dry grain productivity of 5.8 tons/ha. On the other hand, location C showed the lowest yield, which was only 3.5 tons/ha. These findings show that the moderate agroclimatic environment at location B plays an important role in supporting the formation of seedlings and panicle filling, thus having a direct effect on crop yields. Thus, the balance of temperature and rainfall is a key factor to maximize wheat productivity in the tropics.

RESULT AND DISCUSSION

This study aimed to evaluate the growth and productivity response of wheat plants (Triticum aestivum L.) to various agroclimatic conditions in three different locations. The observed agroclimate includes average air temperature, humidity, and rainfall during the plant growth period. All three sites have significantly different agroclimatic characteristics, allowing for an in-depth analysis of how wheat crops adapt and produce under varying environmental conditions.

Vegetative Growth of Wheat Plants

Plant height is one of the important indicators in assessing the vegetative growth of wheat plants. The results of the observations showed that the highest plant height was achieved at location B, with an average of 85.3 cm. Location A ranks second with an average of 78.6 cm, while location C has the lowest plant height, which is 69.2 cm. The difference in height of these plants is closely correlated with the temperature and rainfall received during the growing period. Location B has an average air temperature of 20–24°C with relatively even rainfall throughout the growing season, creating optimal conditions for plant growth. Meanwhile, location C experiences higher air temperatures (28°C) and lower, uneven rainfall, which inhibits vegetative growth of plants.

The number of productive saplings also differs significantly between locations. Location B again showed the highest value, with an average of 5.8 saplings per clump, followed by location A (4.9 saplings) and location C (3.6 saplings). Productive saplings are greatly influenced by the availability of water and environmental temperature. The high temperature at location C is thought to accelerate the life cycle of plants, thereby shortening the vegetative phase and reducing the formation of seedlings. In contrast, the balanced microclimatic conditions at site B prolong the vegetative phase and allow the plant to form more saplings.

The Leaf Area Index (ILA) as an important parameter to describe the photosynthesis capacity of plants shows similar results. Location B has an average ILA of 3.45, while location A is 3.02 and location C is only 2.58. A high ILA value at location B indicates that the plant has an optimal leaf area to capture sunlight and support the photosynthesis process efficiently. Higher humidity levels in location B also prevent physiological stress that can inhibit leaf formation and expansion.

Wheat Yield Productivity

The productivity of wheat crops, measured by dry grain weight per hectare, shows a marked difference between locations. Location B produced the highest dry grain, which was 5.8 tons/ha, while locations A and C produced 4.9 tons/ha and 3.5 tons/ha, respectively. This difference is due to the accumulation of the influence of environmental factors during the growth and filling period of the seeds.

Excessively high temperatures such as those that occur at location C can disrupt the seed filling process and lead to premature ripeness, which ultimately lowers yields. Meanwhile, temperatures that are too low such as in location A can slow down the plant's metabolic process. Site B, which has moderate temperatures and adequate rainfall, offers an ideal environment for optimal seed growth and filling.

In addition to temperature and precipitation, the air humidity factor also plays an important role in determining the outcome. Sufficient moisture helps maintain the turgor pressure of the cells, thus supporting the physiological processes of the plant. At location C, low humidity results in increased evaporation and higher plant transpiration, thereby reducing water use efficiency and lowering plant biomass accumulation.

Correlation Between Growth and Productivity

The results of the analysis showed a positive correlation between vegetative growth parameters such as plant height, number of productive saplings, and ILA with crop productivity. This shows that good vegetative growth will make a positive contribution to the yield potential of wheat crops. For example, a high number of productive saplings will produce more panicles per clump, which will ultimately increase the amount of grain harvested.

Site B which has the highest value on all three vegetative growth parameters also has the highest yield. This reinforces the hypothesis that an environment that supports optimal vegetative growth will increase crop yields. In contrast, location C that showed the lowest values on all growth parameters also had the lowest productivity, indicating that extreme agroclimatic conditions are a major limiting factor for crops.

Agronomic Implications and Adaptation Strategies

The results of this study show that agronomic adaptation based on agroclimate is very important in the development of wheat cultivation in the tropics. Strategies such as selecting varieties that are tolerant to high temperatures and drought, the use of mulch to maintain soil moisture, and the application of efficient irrigation technology can be used to increase productivity in locations with less than ideal conditions.

In addition, proper planting time scheduling is also an important strategy to avoid critical phases of plants from extreme environmental conditions. For example, at location C, planting can be scheduled so that the plant's generative phase does not coincide with the annual maximum temperature. The use of medium-term weather forecasts can help farmers plan planting time more adaptively.

Land management also plays an important role. The application of balanced fertilization based on soil tests and the addition of organic matter can increase the capacity of the soil to store water and nutrients. In locations with low rainfall, the combination of efficient fertilization and micro-irrigation can increase groundwater availability and support optimal plant growth.

Comparison with Previous Research Results

The results of this study are consistent with the findings of several previous studies. For example, research by Yadav et al. (2019) shows that the optimum temperature for the growth of wheat plants is in the range of 20–25°C. Above this range, there is a decrease in the rate of photosynthesis and disruption in the seed filling process. This is in line with the results obtained at location C, where high temperatures negatively impact productivity.

Research by Farooq et al. (2014) also supports the finding that sufficient rainfall and air humidity support photosynthesis efficiency and reduce water loss due to transpiration. Site B, which has good humidity and rain distribution, shows optimal productivity.

Limitations and Suggestions for Advanced Research

Although the results of this study show a clear relationship between agroclimatic conditions and wheat productivity, there are some limitations that need to be noted. This study was only conducted in one growing season, so it does not include the seasonal variations that may occur. Therefore, long-term research is needed to observe the response of plants to climate variations between years.

In addition, this study has not explored the interaction between climate factors and agronomic management in detail. The combination of agronomic treatments (such as fertilizer types, irrigation techniques, and planting distances) with environmental conditions needs to be further studied to identify the most suitable cultivation technology package for each agroclimatic zone.

Practical Recommendations

Based on the results of this study, several practical recommendations can be conveyed:

1. The development of wheat cultivation should be focused on areas with moderate temperatures (20–25°C) and an even distribution of rainfall.
2. In areas with high temperatures or low rainfall, adaptive technologies such as drip irrigation, the use of drought-tolerant varieties, and organic mulching need to be applied.
3. Planting time needs to be adjusted to local climate patterns to avoid stress in the plant's generative phase.
4. Increasing the capacity of farmers to understand and utilize agroclimatic information will support more appropriate cultivation decision-making.

Table 1 Average Growth and Yield Parameters of Wheat Crops in Three Agroclimatic Locations

Parameters	Location A (Highlands)	Location B (Medium Square)	Location C (Lowlands)
Plant height (cm)	78.6 ± 3.2	85.3 ± 2.8	69.2 ± 3.5
Number of productive saplings	4.7 ± 0.4	5.8 ± 0.5	3.9 ± 0.6
Leaf Area Index (ILA)	3.2 ± 0.2	3.9 ± 0.3	2.7 ± 0.3
Productivity (tons/ha)	4.9 ± 0.3	5.8 ± 0.4	3.5 ± 0.2

Remarks: The value is the average ± standard deviation of 3 repetitions.

Table 2 Results of Variance Analysis (ANOVA) Effect of Location on Growth Parameters and Wheat Yield

Parameters	Free Degree (db)	F Value Calculate	Table F-Value (5%)	Information
Plant height	2, 6	12,84	5,14	Real difference (**)
Number of productive saplings	2, 6	15,21	5,14	Real difference (**)
Leaf Area Index (ILA)	2, 6	10,76	5,14	Real difference (**)
Productivity (tons/ha)	2, 6	18,92	5,14	Real difference (**)

Remarks: (**) shows a noticeable difference at 5% based on the F test

- F Calculation = F value of the calculation result
- Testing at a real level of 5%
- The value of the F calculation compared to the F table (5%; 2.6) = 5.14 → all the F calculations > F tables ⇒ significantly different.

CONCLUSION

This study shows that agroclimatic conditions have a very significant influence on the growth and productivity of wheat plants (Triticum aestivum L.). Differences in planting locations with microclimatic variations, such as temperature, humidity, and rainfall, affect the physiological response of plants in a real way, which is reflected in both vegetative growth and yield parameters.

Location B, which represents an area with a moderate agroclimate (moderate temperature, relatively stable humidity, and fairly even rainfall), gives the best results compared to the other two locations. In this location, the plants show optimal stem height, a greater number of productive saplings, a high leaf area index, and crop productivity of 5.8 tons/ha. These conditions indicate that the not too extreme temperatures, accompanied by sufficient water availability during the critical growth phase (vegetative to seed filling), strongly support the optimal growth and development of wheat crops.

In contrast, location C with high temperatures and low rainfall shows the lowest crop performance. The height of the plant, the number of seedlings, and the yield have decreased significantly. This suggests that high temperature stress and lack of water during the growth phase cause physiological disturbances of the plant, accelerate ripening, and decrease seed yields substantially.

The results of this study indicate that the selection of the right cultivation location based on agroclimatic characteristics is very important in the development of wheat in the tropics. Taking into account local climatic factors, such as average temperature and rainfall distribution, wheat productivity can be significantly improved. Therefore, areas with moderate temperatures and evenly distributed rainfall throughout the growing season are highly recommended as priority locations for the development of wheat crops in Indonesia. Further studies can focus on climate stress mitigation strategies, such as the selection of tolerant varieties and the application of adaptive aquaculture technologies, to support the success of national food diversification programs.

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