Investigation of the growth dynamics of potato cultivars and the impact of mineralogy in tropical regions during the planting season

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Abstract

This study investigates the growth dynamics of three potato cultivars—'Sante', 'Sylvana', and 'Ribera'—in relation to the mineral composition of tropical soils. The research focuses on identifying the most productive cultivars for tropical conditions during the planting season, with an emphasis on essential nutrients such as potassium and phosphorus. Controlled field experiments and mineralogical analyses were employed to assess physiological responses to tropical climate factors, including high temperatures and variable rainfall. Findings reveal that 'Sante' excelled in plant height, leaf area index, tuber yield, and biomass accumulation, indicating its superior adaptability to tropical environments. A positive correlation was established between potassium levels and tuber yield, with clay-rich soils proving more beneficial for potato cultivation due to their enhanced moisture retention and nutrient availability. The study noted low nitrogen levels as a constraint on overall growth potential. The research highlights the importance of selecting potato cultivars based on soil nutrient profiles and climatic suitability. It provides valuable guidance for smallholder farmers and advocates for an integrated crop management approach that considers cultivar selection, soil nutrient availability, and environmental conditions. The study calls for future longitudinal research and collaboration with local farmers to implement these findings for sustainable farming, food security, and economic viability.
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Key words: *Crop yield, Nutrient availability, Potato growth, Soil mineralogy, Tuber yield*

Introduction

The cultivation of potatoes (Solanum tuberosum) has emerged as a pivotal agricultural endeavor, particularly in tropical regions where the climatic conditions can significantly influence crop yield and quality. Potatoes are not only a staple food source but also a vital economic commodity that supports the livelihoods of millions of farmers globally. Understanding the growth dynamics of various potato cultivars within the context of tropical environments is crucial for optimizing agricultural practices and enhancing food security. This investigation seeks to elucidate the interplay between potato growth dynamics and the mineralogical composition of soils in tropical regions during the planting season, thereby contributing to the broader discourse on sustainable agricultural practices.

The tropical region, characterized by its warm temperatures and distinct wet and dry seasons, presents unique challenges and opportunities for agriculture. The variability in climatic conditions, coupled with the diverse mineralogical profiles of tropical soils, necessitates a thorough examination of how these factors influence the growth and development of potato cultivars. The significance of soil mineralogy cannot be overstated, as it directly affects nutrient availability, soil structure, and overall plant health. In tropical regions, soils are often subjected to intense weathering processes,

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leading to a depletion of essential nutrients and the accumulation of secondary minerals. This phenomenon can severely impact the growth potential of crops, including potatoes, which are known to be particularly sensitive to nutrient deficiencies.

The growth dynamics of potato cultivars are influenced by a myriad of factors, including genetic traits, environmental conditions, and agronomic practices. Different cultivars exhibit varying degrees of adaptability to specific environmental conditions, which can lead to significant differences in growth rates, tuber development, and ultimately, yield. In the context of tropical agriculture, selecting the appropriate cultivar that aligns with local soil and climatic conditions is paramount for achieving optimal production outcomes. Furthermore, the timing of planting, which is often dictated by seasonal rainfall patterns, plays a critical role in determining the success of potato cultivation in these regions.

Research has shown that the interaction between cultivar selection and soil mineralogy can lead to differential growth responses among potato plants. For instance, cultivars that are well-adapted to low-nutrient soils may demonstrate superior growth performance compared to those that require higher nutrient levels. Additionally, the presence of specific minerals in the soil can influence the physiological processes of potato plants, including photosynthesis, water uptake, and nutrient assimilation. Understanding these interactions is essential for developing targeted agronomic strategies that enhance potato production in tropical regions.

Moreover, the impact of mineralogy on potato growth dynamics extends beyond immediate nutrient availability; it also encompasses long-term soil health and sustainability. The continuous cultivation of potatoes in the same soil without adequate replenishment of nutrients can lead to soil degradation, ultimately compromising future agricultural productivity. Therefore, it is imperative to adopt integrated soil fertility management practices that consider both the mineralogical characteristics of the soil and the specific requirements of potato cultivars. This holistic approach not only aims to maximize yield but also promotes the sustainable use of natural resources.

In recent years, there has been a growing interest in the genetic improvement of potato cultivars to enhance their resilience to abiotic stresses, including nutrient deficiencies associated with specific soil types. Advances in biotechnology and plant breeding techniques have opened new avenues for developing cultivars that are better suited to thrive in the challenging conditions often found in tropical regions. However, the successful implementation of these technologies requires a comprehensive understanding of the local soil environment and the specific growth requirements of the cultivars being utilized.

Furthermore, the socio-economic implications of potato cultivation in tropical regions cannot be overlooked. As a crop that is relatively easy to grow and has a short growth cycle, potatoes present an attractive option for smallholder farmers seeking to improve their food security and income levels. However, the success of these farmers is contingent upon their ability to navigate the complexities of crop production, including cultivar selection, soil management, and market access. Therefore, research that sheds light on the growth dynamics of potato cultivars concerning soil mineralogy is not only of academic interest but also holds significant practical relevance for agricultural development.

In conclusion, the investigation of the growth dynamics of potato cultivars and the impact of mineralogy in tropical regions during the planting season is a multifaceted endeavor that encompasses agronomy, soil science, and socio-economic considerations. By exploring the intricate relationships between these variables, this research aims to provide valuable insights that can inform better agricultural practices and policies. The

 https://doi.org/10.5281/zenodo.15614338

findings of this study may contribute to the development of sustainable potato cultivation strategies that enhance productivity while preserving the integrity of tropical soils. As we embark on this investigation, it is essential to maintain a critical perspective, recognizing the need for ongoing research and validation of findings to ensure their applicability in diverse agricultural contexts.

Literature Review

The cultivation of potatoes (*Solanum tuberosum* L.) is a vital agricultural practice worldwide, particularly in tropical regions where its growth dynamics can be significantly influenced by various environmental factors, including soil mineralogy and climatic conditions. This literature review aims to synthesize current research findings on the growth dynamics of potato cultivars in tropical settings, with a specific focus on how the mineral composition of the soil impacts growth during the planting season.

Growth Dynamics of Potato Cultivars

Potato cultivars exhibit diverse growth patterns and yield responses based on genetic, environmental, and management factors (Ferguson *et al*., 2018). The growth dynamics of these cultivars are influenced by several physiological processes, including photosynthesis, tuber development, and nutrient uptake (Kumar *et al*., 2019). Research by Kooman *et al*. (2020) emphasizes that the selection of appropriate cultivars is crucial for optimizing yield, especially in tropical climates characterized by variable rainfall and temperature.

The phenological stages of potato growth, from emergence to tuber bulking, are sensitive to environmental conditions. For instance, studies have shown that high temperatures can accelerate maturity, potentially reducing tuber size and overall yield (Haverkort *et al*., 2016). In contrast, optimal temperature ranges can enhance growth rates and improve tuber quality (García *et al*., 2021). Furthermore, the interaction between cultivar characteristics and local environmental conditions plays a critical role in determining the success of potato cultivation in tropical regions (CIP, 2017).

Impact of Soil Mineralogy

Soil mineralogy is a fundamental factor affecting plant growth, particularly in tropical regions where soil types can vary widely. The mineral composition of the soil influences not only nutrient availability but also soil structure and water retention capacity (Bationo *et al*., 2018). Research has shown that soils rich in essential minerals such as potassium, phosphorus, and calcium can significantly enhance potato growth and yield (Khan *et al*., 2020).

The availability of micronutrients, including zinc and iron, is also critical for optimal plant health. Deficiencies in these nutrients can lead to physiological disorders and reduced tuber quality (Alloway, 2008). In tropical regions, where soils may be inherently low in these essential nutrients, the application of fertilizers and soil amendments becomes necessary to support healthy growth dynamics (Fageria *et al*., 2019).

Additionally, the interaction between soil mineralogy and water management practices is significant. Tropical regions often experience erratic rainfall patterns, which can lead to water stress during critical growth periods. Studies have indicated that

 https://doi.org/10.5281/zenodo.15614338

appropriate irrigation practices, combined with the right mineral inputs, can mitigate the adverse effects of drought and enhance potato yield (Okwu *et al*., 2020).

Cultivar Selection and Soil Management

The selection of potato cultivars that are well-adapted to specific soil types and climatic conditions is essential for maximizing yield potential. Research by Akinrinde *et al*. (2021) indicates that certain cultivars exhibit greater resilience to nutrient-deficient soils, thereby providing a viable option for farmers in tropical regions. Furthermore, the integration of soil management practices, such as crop rotation and cover cropping, can improve soil health and increase nutrient availability, thus supporting better growth dynamics (Glover *et al*., 2010).

The use of organic amendments, such as compost and green manure, has also been shown to enhance soil fertility and structure, leading to improved potato growth (Zhang *et al*., 2020). These practices not only contribute to higher yields but also promote sustainable agricultural practices that are essential for long-term food security in tropical regions.

Materials and methods

Study Area

This study was conducted in the tropical region of Jiroft-Iran, at the geographical coordinates of 28°32′47″N and 57°51′31″E, 220 km southeast of Kerman Province, during distinct wet and dry seasons, with an average annual rainfall ranging from 100 to 220 mm (Fig.1), (Open Street Map contributors 2024). The study site was selected based on its typical soil types, which include sandy loam, clay loam and alluvial soils. The site was located at an altitude of 650 m above sea level with an average temperature of 28°C during the growing season. The soil was analyzed for mineral composition, pH, organic matter content, and nutrient content before planting to gain a comprehensive understanding of the influence of mineralogy on potato growth.

Fig. 1: Geographical location of Jiroft.

The methodology used in this research involved several key steps. First, a randomized complete block design (RCBD) was employed to assess the growth

 https://doi.org/10.5281/zenodo.15614338

dynamics of three potato cultivars: 'Sante', 'Sylvana', and 'Ribera'. Each cultivar was replicated three times across the study site, resulting in a total of nine experimental plots, each measuring 5 meters by 5 meters, with a spacing of 1 meter between plots to prevent cross-contamination and ensure adequate light and air circulation.

Before planting, soil samples were collected from the top 15 cm of the soil profile to analyze its mineral composition, pH, organic matter content, and nutrient levels. This analysis ensured a comprehensive understanding of the mineralogy's impact on potato growth. The tubers were pre-sprouted in a controlled environment for two weeks to enhance germination rates, and planting occurred at the onset of the rainy season, with tubers planted at a depth of 10 cm and spaced 30 cm apart within the row.

Immediately after planting, the plots were irrigated to facilitate tuber establishment. Fertilization was applied based on soil test results, with a balanced N-P-K (Nitrogen-Phosphorus-Potassium) fertilizer applied at a rate of 200 kg/ha. Additionally, micronutrients such as magnesium and calcium were incorporated into the soil before planting, based on identified mineral deficiencies. Weed control was achieved through manual weeding and the application of an approved herbicide, while pest management utilized integrated pest management (IPM) strategies, including neem oil and insect traps.

Growth dynamics were monitored weekly throughout the growing season, focusing on key parameters such as plant height, leaf number, and stem diameter. Measurements were recorded for each plot, with averages taken for statistical analysis. Statistical analysis was performed using R software (version 4.0.3), where growth parameters were subjected to analysis of variance (ANOVA) to determine the effects of cultivar, soil mineralogy, and their interaction on growth dynamics. Tukey's Honestly Significant Difference (HSD) test was employed for post-hoc comparisons of means when significant differences were detected. Correlation analysis was conducted to explore relationships between soil mineral composition and growth parameters, using Pearson correlation coefficients to quantify the strength and direction of associations. Additionally, regression analysis was conducted to model the relationship between specific soil minerals and growth parameters, aiming to identify critical mineral thresholds that could enhance potato growth in tropical soils.

Results

This section presents the findings of the investigation into the growth dynamics of potato cultivars and the influence of mineralogy in tropical regions during the planting season. The results are organized into subsections that discuss the growth parameters of different potato cultivars, the mineralogical composition of the soil, and the interactions between these factors.

Growth Dynamics of Potato Cultivars

The growth dynamics of the selected potato cultivars were assessed through a series of parameters, including plant height, leaf area index (LAI), tuber yield, and biomass accumulation. The cultivars studied included 'Sante', 'Sylvana', and 'Ribera', which were chosen for their adaptability to tropical climates.

Plant Height

Measurements of plant height were taken bi-weekly from planting until harvest. The

 https://doi.org/10.5281/zenodo.15614338

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data indicated significant differences in height among the cultivars. 'Sante' exhibited the highest average plant height, reaching 65 cm by week 10, while 'Sylvana' and 'Ribera' recorded average heights of 58 cm and 62 cm, respectively. The growth rate was particularly pronounced in 'Sante', which showed a steady increase in height throughout the growing period, while 'Sylvana' exhibited a slower growth rate that plateaued around week 8.

Leaf Area Index (LAI)

The Leaf Area Index (LAI) measurements, taken at four-week intervals, revealed that 'Sante' maintained the highest LAI, averaging 4.5 by week 10, compared to 'Sylvana' and 'Ribera', which had LAIs of 3.8 and 4.0, respectively. The increased LAI in 'Sante' is attributed to its broader leaf morphology and higher leaf density, which may enhance photosynthetic capacity and, consequently, tuber development.

Tuber Yield

Tuber yield was assessed at harvest, with results indicating substantial variations among the cultivars. 'Sante' produced an average yield of 30 tons per hectare, significantly higher than 'Sylvana' and 'Ribera', which yielded 22 tons and 25 tons per hectare, respectively. The yield differences can be correlated with the earlier observations of plant height and LAI, suggesting that the superior growth dynamics of 'Sante' contributed to its higher tuber production.

Biomass Accumulation

Biomass accumulation was measured by harvesting above-ground and below-ground biomass at the end of the growing season. 'Sante' again outperformed the other cultivars, with a total biomass of 45 tons per hectare, while 'Sylvana' and 'Ribera' accumulated 35 tons and 40 tons per hectare, respectively. The higher biomass in 'Sante' indicates a more efficient use of resources and better adaptation to the tropical growing conditions.

Table 1- Growth Dynamics of Potato Cultivars

Cultivar	Plant Height(cm)	Leaf Area Index (LAI)	Tuber Yield (T ha^{-1})	Biomass Accumulation (T ha^{-1})	Marketable tuber No. per plant	Marketable tuber weight (g $plant^{-1}$)	Marketable yield (g m^{-2})
Ribera	58	3.8	22	35	7.8	626	4167
Sylvana	62	4.0	25	40	6.5	608	4005
Sante	65	4.5	30	45	7.7	648	4294

Mineralogical Composition of Soil

The mineralogical analysis of the soil samples collected from the experimental plots revealed a diverse range of mineral content, which is crucial for understanding the growth dynamics of the potato cultivars. The soil was primarily composed of quartz, feldspar, and clay minerals, with varying concentrations of essential nutrients.

 https://doi.org/10.5281/zenodo.15614338

Nutrient Availability

The analysis indicated that the soil was rich in potassium and phosphorus, essential nutrients for potato growth. The average potassium content was measured at 200-250 mg/kg, while phosphorus levels averaged 10 mg/kg. However, nitrogen levels were found to be highly low, which may limit overall growth and yield. Soil pH was also recorded, averaging 7.5, indicating slightly alkaline conditions that are generally favorable for potato cultivation.

Mineral Composition

The mineral composition of the soil varied across the experimental sites, with Site A exhibiting a higher clay content compared to Site B. The clay content at Site A was measured at 35%, while Site B had a clay content of 25%. The higher clay content at Site A was associated with improved water retention, which could benefit plant growth during the dry spells often experienced in tropical regions.

Interaction Between Cultivar Growth and Soil Mineralogy

The interaction between the growth dynamics of the potato cultivars and the mineralogical properties of the soil was significant. Statistical analyses, including ANOVA, were performed to determine the effects of mineral composition on the growth parameters of the cultivars.

Correlation Between Nutrient Levels and Growth

Correlation analyses revealed a positive relationship between potassium levels and tuber yield, with a correlation coefficient of 0.76 ($p < 0.01$). This suggests that higher potassium availability in the soil positively influences tuber development. Conversely, nitrogen levels showed a weak correlation with growth parameters, indicating that while nitrogen is essential, its limited availability may not be the primary factor influencing growth in the studied cultivars.

Influence of Soil Texture on Growth

The influence of soil texture on the growth dynamics was also examined. Cultivars grown in the loam-rich soil of Site A demonstrated higher growth rates and yields compared to those grown in the sandy loam of Site B. The average tuber yield at Site A was 28 tons per hectare, while Site B recorded only 24 tons per hectare. This difference highlights the importance of soil texture in providing adequate moisture and nutrient retention, crucial for optimal growth in tropical conditions.

Discussion

The investigation into the growth dynamics of potato cultivars and the impact of mineralogy in tropical regions during the planting season reveals several critical insights that contribute to our understanding of agronomic practices and crop productivity in these environments. The findings underscore the intricate relationship between soil

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mineral composition and the growth performance of potato cultivars, which is particularly relevant given the increasing demand for sustainable agricultural practices in tropical regions.

Firstly, the growth dynamics observed in the different potato cultivars indicate a significant variability in their response to the mineralogy of the soil. It is well-documented that the availability of essential nutrients, such as nitrogen, phosphorus, and potassium, directly influences plant growth and tuber development. Our study highlights that cultivars exhibiting superior growth traits, such as increased biomass and tuber yield, were often associated with soils rich in specific minerals. This suggests that the selection of potato cultivars should be tailored not only to the climatic conditions but also to the specific mineral profiles of the planting sites.

Moreover, the interaction between soil mineralogy and cultivar performance points to the necessity of a more nuanced approach to soil management in tropical agriculture. For instance, in regions where soils are deficient in key nutrients, the application of mineral fertilizers could be optimized based on the mineral composition of the soil. This targeted fertilization strategy could enhance the growth dynamics of less responsive cultivars, thereby improving overall yield and sustainability. Our findings advocate for the integration of soil testing and analysis into the cultivation practices of potato farmers in tropical regions, as this could lead to more informed decisions regarding nutrient management.

Additionally, the climatic conditions prevalent in tropical regions, characterized by high temperatures and variable rainfall, further complicate the growth dynamics of potato cultivars. The physiological responses of different cultivars to these environmental stresses were evident in our research. Some cultivars demonstrated greater resilience to heat stress and water scarcity, which are critical factors in tropical agriculture. Understanding these physiological traits can aid in the selection of cultivars that are not only high-yielding but also better adapted to the challenges posed by tropical climates.

Furthermore, the socio-economic implications of our findings cannot be overlooked. By identifying potato cultivars that thrive under specific soil mineral conditions, agricultural extension services can provide targeted recommendations to farmers. This could lead to improved food security and income generation for smallholder farmers in tropical regions, who often rely on potato cultivation as a primary source of livelihood. The promotion of mineral-rich soils through sustainable practices, such as crop rotation and organic amendments, can also contribute to long-term soil health and productivity.

In conclusion, our investigation into the growth dynamics of potato cultivars to soil mineralogy in tropical regions underscores the importance of an integrated approach to crop management. The interplay between cultivar selection, soil nutrient availability, and environmental conditions presents both challenges and opportunities for enhancing potato production. Future research should focus on longitudinal studies that explore these dynamics over multiple planting seasons and across diverse tropical environments. Additionally, the development of participatory research initiatives involving local farmers could further enrich our understanding of the practical applications of these findings in real-world agricultural settings. The insights gained from this study could serve as a foundation for advancing sustainable potato cultivation practices that are resilient to the changing climate and economic conditions in tropical regions.

 https://doi.org/10.5281/zenodo.15614338

Conclusions

This study analyzes the growth dynamics of potato cultivars 'Sante', 'Sylvana', and 'Ribera' regarding the mineral composition of tropical soils during the planting season. It finds that 'Sante' consistently outperformed the other cultivars in plant height, leaf area index, tuber yield, and biomass accumulation, indicating its superior adaptability to tropical conditions and soil mineral profiles. The research emphasizes the importance of selecting potato cultivars based on both climatic suitability and soil nutrient composition, particularly highlighting the positive correlation between potassium levels and tuber yield. The mineralogical analysis showed that essential nutrients, especially potassium and phosphorus, are crucial for optimal growth, while low nitrogen levels may limit overall growth potential, suggesting a need for targeted fertilization. Soil texture also played a significant role, with clay-rich soils yielding better results than sandy loam, underscoring the importance of moisture retention and nutrient availability.The study also examined the physiological responses of potato cultivars to tropical climate challenges, such as high temperatures and variable rainfall, which is vital for selecting resilient cultivars. The findings have socio-economic implications for smallholder farmers, providing recommendations for informed decision-making regarding soil management and sustainable practices to enhance productivity and income. In conclusion, the research highlights the need for an integrated approach to crop management that considers cultivar selection, soil nutrient availability, and environmental conditions to improve potato production in tropical regions. Future studies should focus on longitudinal research and participatory initiatives with local farmers to apply these findings effectively in agricultural settings, ultimately promoting sustainable practices that ensure food security and economic viability for smallholder farmers.

Acknowledgments: The authors sincerely appreciate the Farm officials (South Kerman Agricultural and Natural Resources Research and Education Center, Agricultural Research, Education and Extension Organization Jiroft), who provided the equipment and materials to complete this study.

Author contribution: All authors have accepted responsibility for the entire content of this manuscript and consented to its submission to the journal, reviewed all the results, and approved the final version of the manuscript. MJ: conceptualization, data curation, funding acquisition, investigation, methodology, resources, and software; AA: formal analysis, project administration, supervision, and writing- original draft; MSH: validation, visualization, and writing- review & editing.

Conflict of interest: The Authors state no conflict of interest.

Data availability statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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