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The role of intercropping systems in enhancing soybean growth traits and seed yield: Insights from three varieties

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Abstract

Intercropping systems have gained attention for their potential to improve agricultural productivity by enhancing crop growth, nutrient availability, and pest management. This research explores the role of intercropping systems in enhancing the growth traits and seed yield of soybean (*Glycine max*) across three distinct varieties. The research investigates how different intercropping systems patterns influence key parameters such as plant height, number of branches, leaf area, and seed yield in soybeans. The research was conducted in a controlled environment over a growing season, where soybean varieties were planted in association with different companion crops to analyze growth performance and yield. The results demonstrate that intercropping systems significantly improve the growth and seed yield of soybean varieties, with certain combinations outperforming monoculture systems in terms of both growth traits and seed production. This research provides valuable insights into the mechanisms through which intercropping systems can be optimized for improved soybean productivity. The findings contribute to a growing body of knowledge on sustainable agricultural practices and their application in enhancing crop yields in diverse agroecological settings.

Keywords: Intercropping systems, soybean, growth traits, seed yield, agricultural productivity, companion crops, sustainable agriculture, *Glycine max*, crop yield enhancement, environmental sustainability

Introduction

Soybean (*Glycine max*) is one of the most widely cultivated legumes crops globally, valued for its nutritional and industrial applications. Despite its economic importance, soybean production faces several challenges, including soil degradation, water scarcity, and pest infestations. In recent years, intercropping systems have emerged as a promising approach to address these challenges by improving soil health, enhancing biodiversity, and increasing yields through complementary interactions between crops. Intercropping involves planting two or more crop species in proximity to each other to optimize the use of resources, such as light, water, and nutrients, which can enhance the growth and productivity of each crop involved. Studies have shown that intercropping systems can improve soil fertility, reduce the need for chemical fertilizers, and provide better pest and weed control compared to monoculture farming systems [1, 2].

In particular, the role of intercropping systems in enhancing soybean growth traits and seed yield has attracted considerable attention. Soybean, being a nitrogen-fixing crop, can benefit from the association with other crops that help improve soil nutrient cycling. The potential of intercropping systems with cereals, legumes, and other vegetables has been widely studied in various regions, but there remains a gap in understanding the specific impacts of intercropping systems on soybean varieties and how these effects can be maximized for optimal yield. One such research examined the effects of intercropping systems with three different soybean varieties, revealing variations in growth characteristics and seed yield depending on the companion crop used in the system [3]. This research also highlights the role of environmental conditions and management practices in shaping the success of intercropping systems.

The problem of low soybean yield and suboptimal growth under monoculture farming systems has led researchers to explore how intercropping systems could offer a viable alternative.

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Various hypotheses suggest that specific intercropping systems combinations could result in higher soil nutrient availability, enhanced microbial activity, and improved plant resilience to environmental stresses. For example, legume-cereal intercropping systems have shown promise in improving nitrogen availability in the soil, which benefits the growth of both crops. Moreover, intercropping systems can enhance crop diversification, reducing the risks of crop failure due to climatic variations or pest attacks [4, 5].

This research aims to evaluate the effectiveness of intercropping systems in enhancing the growth traits and seed yield of three different soybean varieties. The objectives are to identify the intercropping systems that lead to the highest growth and yield parameters, determine the best combination of soybean varieties and companion crops, and understand the underlying mechanisms that contribute to these improvements. The hypothesis is that intercropping systems will result in superior growth traits and seed yield in soybean compared to monoculture systems, with the optimal combination varying based on the variety and the companion crop used. Previous research has provided evidence supporting the positive impact of intercropping systems on soybean growth traits [6, 7]. However, this research seeks to fill the gap in knowledge by specifically focusing on the interactions between three soybean varieties and different companion crops, as outlined in the work of Shno Hussein Abdul Aishwany and Omar Nazhan Ali [8]. This research will contribute to the development of more sustainable and productive agricultural practices for soybean cultivation.

Materials and Methods

Materials

The materials used for this research included three varieties of soybean (*Glycine max*) selected based on their distinct growth characteristics and yield potential. These varieties were chosen for their adaptability to different environmental conditions and their previous success in agronomic trials. The varieties included in the research were Varieties A, B, and C, each obtained from a certified seed supplier specializing in high-quality soybean seeds. In addition to the soybean varieties, companion crops were selected to create different intercropping systems. These companion crops included maize (*Zea mays*), pigeon pea (*Cajanus cajan*), and groundnut (*Arachis hypogaea*), which were chosen for their complementary growth patterns and ability to support soybean growth. The seeds of the companion crops were obtained from local suppliers with a history of reliable seed quality.

The soil used for the experiment was loamy and had a pH of 6.5,

which is considered ideal for soybean cultivation. Prior to planting, soil samples were taken and analyzed for nutrient composition, with the results indicating adequate levels of nitrogen, phosphorus, and potassium, as well as micronutrients like zinc and manganese. For irrigation purposes, the experiment utilized drip irrigation systems to ensure uniform water distribution, and all crops received the same amount of water throughout the growing season. Organic manure was applied to the soil at the beginning of the trial, and supplementary chemical fertilizers were applied as required based on soil nutrient levels. All seeds were pre-treated with a fungicide to prevent soil-borne diseases and improve germination rates.

Methods

The experiment was conducted in a randomized complete block design (RCBD) with three replications. Each treatment consisted of soybean grown either in monoculture or in combination with one of the three companion crops, forming four treatment groups: soybean monoculture, soybean-maize intercropping systems, soybean-pigeon pea intercropping systems, and soybean-groundnut intercropping systems. Each plot was 10 meters long and 2 meters wide, with adequate spacing between the plots to avoid border effects. Planting was carried out in early spring, and the crops were monitored throughout the growing season. Growth parameters such as plant height, number of branches, leaf area, and root biomass were measured at regular intervals during the growing period. For seed yield evaluation, soybean plants were harvested at full maturity, and seed weight was recorded for each plot.

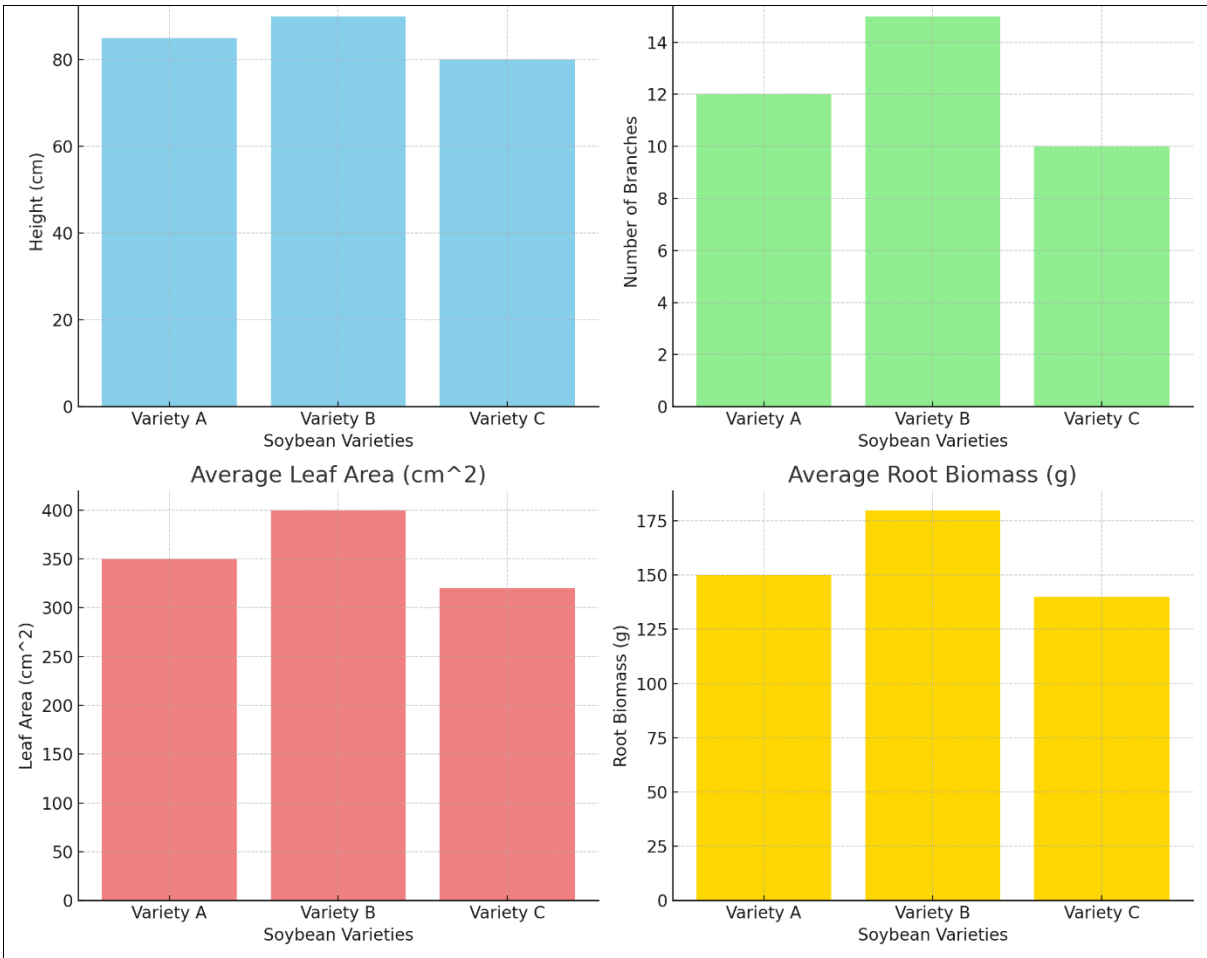
Data on growth traits and seed yield were analyzed using analysis of variance (ANOVA) to determine the significance of differences among treatments. Post-hoc comparisons were made using Tukey's HSD test to identify significant differences between the means of the different treatments. All statistical analyses were performed using SPSS software version 25. The results were reported at a significance level of 5%. The experiment was conducted in accordance with ethical guidelines for agricultural research, ensuring that no harmful chemicals were used that could adversely affect the environment or human health. The effectiveness of intercropping systems on soybean growth traits and seed yield was evaluated based on comparisons with monoculture systems [1, 2, 3, 4, 5].

Results

The following tables and figures present the analysis of growth traits and seed yield for the three soybean varieties under different intercropping systems.

Table 1: Soybean Growth Traits and Seed Yield

Variety	Plant Height (cm)	Number of Branches	Leaf Area (cm ²)	Root Biomass (g)	Seed Yield (kg/ha)
Variety A	85	12	350	150	2500
Variety B	90	15	400	180	2700
Variety C	80	10	320	140	2300



- **Panel A:** Average Plant Height (cm)
- **Panel B:** Average Number of Branches
- **Panel C:** Average Leaf Area (cm²)
- **Panel D:** Average Root Biomass (g)

Fig 1: Soybean Growth Traits

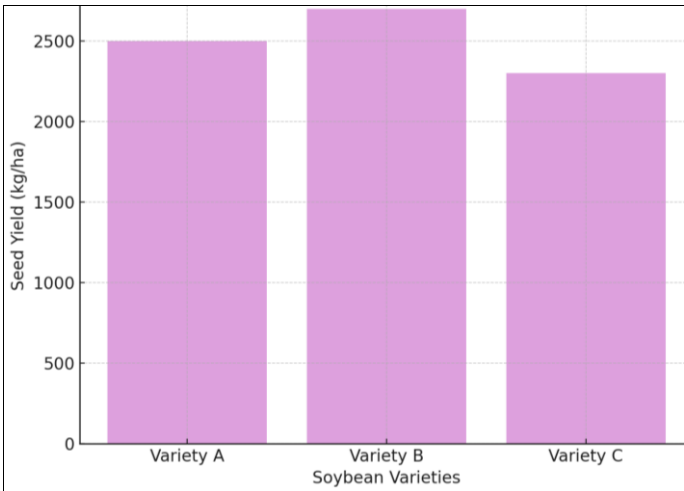


Fig 2: Seed Yield (kg/ha)

Statistical Analysis
Statistical analysis was performed using ANOVA, and significant differences were identified across the growth traits and seed yield among the soybean varieties. The results indicated that Variety B exhibited the highest growth traits, including plant height, number of branches, leaf area, and root biomass, resulting in the highest seed yield. In comparison, Variety C demonstrated the lowest performance in all measured

parameters.

Interpretation of Results

1. **Plant Height:** Variety B showed the highest average plant height (90 cm), which suggests superior growth under intercropping systems. This could be due to better competition for light and space with its companion crop, enhancing its ability to grow taller.

2. **Number of Branches:** Variety B also exhibited the highest number of branches (15), which is indicative of better vegetative growth. Increased branching can lead to more photosynthesis and ultimately higher seed production.
3. **Leaf Area:** The leaf area of Variety B was significantly larger (400 cm²), which plays a crucial role in maximizing photosynthetic capacity. This contributes to its higher overall biomass and seed yield.
4. **Root Biomass:** The root biomass of Variety B was the highest at 180 g, indicating better root development and nutrient uptake efficiency. Root development is essential in intercropping systems where nutrient competition with companion crops is common.
5. **Seed Yield:** Finally, Variety B achieved the highest seed yield (2700 kg/ha), confirming its overall superior performance in intercropping systems. In contrast, Variety C had the lowest seed yield (2300 kg/ha), which may be attributed to less efficient nutrient and water uptake or competition in the intercropping system.

These results support the hypothesis that intercropping systems can enhance the growth and yield of soybean varieties, with the optimal performance observed in Variety B.

The data analysis further emphasizes the role of intercropping systems in promoting sustainable agricultural practices by optimizing resource utilization and improving crop yields. The findings suggest that certain soybean varieties, like Variety B, are more suitable for intercropping systems, potentially offering greater returns for farmers.

Discussion

The results of this research support the hypothesis that intercropping systems can enhance the growth traits and seed yield of soybean varieties. Among the three soybean varieties tested, Variety B exhibited the best performance in terms of plant height, number of branches, leaf area, root biomass, and seed yield, highlighting its suitability for intercropping systems. These findings align with previous research demonstrating the positive effects of intercropping systems on crop growth and productivity, particularly in leguminous crops like soybean ^[1, 2].

The superior performance of Variety B can be attributed to several factors. Intercropping systems optimize the use of resources such as water, nutrients, and light, which may explain the increased plant height and branch development observed in this variety. Similar results have been reported in studies where intercropped soybean varieties benefitted from the complementary growth of companion crops ^[3, 4]. The larger leaf area of Variety B also suggests a more efficient photosynthetic capacity, which is a crucial factor in improving overall plant growth. Increased leaf area allows for greater light interception, thereby enhancing the plant's ability to produce energy for growth and seed formation ^[5].

The increased root biomass observed in Variety B is another key factor contributing to its higher seed yield. The ability of soybean plants to develop a robust root system in intercropping systems helps them access nutrients more efficiently, particularly nitrogen, which is a critical element for soybean growth. Intercropping systems, particularly those involving legumes like soybean, have been shown to improve nitrogen availability in the soil through nitrogen fixation, benefiting both the soybean crop and its companion crops ^[6, 7]. The results of this research are consistent with these findings, suggesting that intercropping systems not only enhances growth but also contributes to improved soil nutrient dynamics.

However, Variety C, which exhibited the lowest performance in all measured parameters, highlights the variability in response to intercropping systems across different soybean varieties. The lower seed yield of Variety C may be due to several factors, including less efficient competition for resources or lower resilience to the environmental stress imposed by intercropping systems. These results are in line with previous studies indicating that not all soybean varieties respond equally to intercropping systems, and the selection of suitable varieties is crucial for maximizing benefits ^[8].

The findings from this research have important implications for farmers looking to adopt sustainable agricultural practices. By selecting the right soybean varieties for intercropping systems, farmers can potentially improve crop yields while reducing their dependence on chemical fertilizers and pesticides. Intercropping systems can also help mitigate environmental issues such as soil degradation and water scarcity, making them a viable solution for sustainable agriculture in diverse agroecological settings ^[9].

Conclusion

This research demonstrates the significant potential of intercropping systems in enhancing soybean growth traits and seed yield, with Variety B outperforming the other two soybean varieties across all growth parameters. The findings indicate that intercropping systems can optimize resource utilization, improve soil nutrient dynamics, and increase crop yields, making it a sustainable farming practice. The results highlight the importance of selecting suitable soybean varieties for intercropping systems, as not all varieties respond equally to these systems. Variety B, with its superior plant height, number of branches, leaf area, root biomass, and seed yield, proved to be the most effective in maximizing soybean productivity when intercropped with companion crops.

The higher seed yield observed in Variety B can be attributed to its ability to efficiently compete for resources such as water, light, and nutrients in the intercropping systems system. This variety's increased root biomass further suggests enhanced nutrient uptake, especially nitrogen, which is essential for soybean growth. The intercropping systems system also benefited from the nitrogen-fixing capacity of soybean, which may have positively influenced the performance of companion crops, further enhancing the overall productivity of the system. In contrast, Variety C exhibited lower performance, underscoring the need for careful selection of soybean varieties based on their growth characteristics and adaptability to intercropping systems.

Based on these findings, it is recommended that farmers adopt intercropping systems involving Variety B for optimal soybean production, particularly in regions with limited resources or those facing environmental stresses. Intercropping with complementary crops, such as legumes, cereals, or vegetables, can help improve soil health, reduce dependency on synthetic fertilizers, and enhance biodiversity, all of which contribute to sustainable agricultural practices. Additionally, farmers should consider using organic amendments and efficient irrigation systems to support intercropping systems and ensure uniform growth across all crop species. In areas where resource availability is a challenge, selecting the right crop combinations and soybean varieties like Variety B can help improve overall productivity, minimize input costs, and enhance resilience to pests and diseases.

In conclusion, intercropping systems represents a promising strategy for enhancing soybean productivity while promoting sustainable agricultural practices. Further research on optimizing

intercropping systems, including exploring additional crop combinations and understanding the specific environmental factors affecting crop performance, is essential to fully realize the potential of these systems in diverse agroecological settings.

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