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Assessing the Influence of Spacing on the Growth of Sorrel in Bali. Taraba State

Bako, M. P.
Department of Agricultural Technology, Federal Polytechnic Bali
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Abstract

This study evaluated the effect of different plant spacing on the growth and yield of sorrel (Hibiscus sabdariffa L.) at the Federal Polytechnic Bali, using three spacing treatments: T1 (0 control), T2 (30 cm x 30 cm), T3 (45 cm x 45 cm), and T4 (60 cm x 60 cm). The experiment measured key growth parameters, including plant height, leaf area, number of branches, fresh and dry biomass, number of flowers, and fruit yield. Results showed that wider spacing (T4) significantly enhanced plant performance across all parameters. Data were statistically analyzed using bar chart to assess the significance of differences between treatments. T4 recorded the highest plant height (75.2 cm), largest leaf area (430 cm²), greatest number of branches (12), and highest fresh biomass (1.5 kg) and dry biomass (0.6 kg). Additionally, T4 produced the most flowers (35 per plant) and highest fruit yield (3.2 kg/plot). Conversely, the closest spacing (T1) led to reduced growth and yield, with increased competition for resources such as light, nutrients, and water. These findings demonstrate that wider spacing improves individual plant growth by minimizing competition, though farmers should consider balancing individual plant performance with

overall yield per hectare when selecting the optimal spacing for sorrel cultivation.

Introduction

Sorrel (Hibiscus sabdariffa L.), commonly known as Roselle, is a valuable crop grown for its edible calyces, which are used in making beverages, sauces, and traditional medicines. The crop is widely cultivated in tropical and subtropical regions, including Nigeria. Sorrel's economic value lies in its use as a cash crop and its contribution to local economies through small-scale farming. However, optimal cultivation practices, including plant spacing, remain essential for maximizing yield potential (Adekunle, et al; 2022).

Spacing in crop production is a critical factor that influences plant growth, development, and ultimately the yield. Proper spacing ensures adequate light interception, nutrient absorption, and airflow, reducing the incidence of pests and diseases. This project work paper explores how different spacing regimes affect the growth and yield of sorrel at the Federal Polytechnic Bali research farm (Adekunle, et al; 2022).

Background of the Study

Sorrel (Hibiscus sabdariffa L.) is a vital crop in both northern and southern Nigeria, with significant importance in these regions (Alegbejo, 2020). Globally, sorrel is valued for its versatile applications, including its use as a vegetable, in traditional medicine, and in beverages, which has contributed to its increasing demand (Steve, 2023). This growing demand underscores the urgent need for research focused on boosting sorrel yields. In Nigeria, the tender leaves of sorrel are commonly utilized in preparing soups. The crop is primarily cultivated for its calyx (sepals), which are of considerable commercial importance in the food industry, particularly in the production of juices, jams, salads, pigments, and beverages (Borrás-Linares et al., 2015).

Nutritionally, sorrel is rich in proteins, fats, carbohydrates, raw fiber, and ash when dried (Adanlawo & Ajibade, 2016). It also contains essential vitamins, organic acids, and phytosterols, which contribute to its health benefits for consumers (Ismail et al., 2018; Da-Costa-Rocha et al., 2014).

The spacing between plants plays a crucial role in sorrel's growth and yield. Research has shown that inter-row spacing significantly influences the number

of leaves per plant, leaf area index, the number of capsules per hectare, and both fresh and dry calyx yield per hectare (Ismail et al., 2018; Da-Costa-Rocha et al., 2014).

Sorrel (Hibiscus sabdariffa L.), commonly known as roselle, is a significant plant with wide-ranging uses in food, beverages, and traditional medicine. In many parts of the world, sorrel is cultivated for its calyces, which are used to make drinks, teas, and food colorants. The plant's fibers are also valuable in the textile industry, and its leaves are consumed as leafy vegetables in various cuisines.

Optimal plant growth and yield are crucial to maximizing the economic benefits of sorrel cultivation. One of the key factors that influence these outcomes is plant spacing. Spacing affects resource allocation, competition for nutrients, light penetration, and airflow between plants. By optimizing spacing, farmers can enhance plant health, improve yields, and achieve higher economic returns. In this context, understanding how different spacing regimes impact the growth and yield of sorrel is essential for developing best agricultural practices. This study investigates the effect of different spacing distances on the performance of sorrel in terms of growth parameters and yield, providing insights that could benefit smallholder farmers, commercial producers, and agricultural researchers alike.

Statement of the Problem

Inadequate or suboptimal plant spacing is a common challenge faced by sorrel farmers, leading to reduced yields and poor-quality produce. When plants are spaced too closely together, they compete intensely for nutrients, light, and water, resulting in stunted growth and lower productivity. On the other hand, overly wide spacing may lead to underutilization of land, lower plant density, and ultimately, reduced total yield per hectare.

There is limited research specifically focused on the effect of plant spacing on sorrel cultivation, particularly in different agro-ecological zones. As a result, farmers often rely on general guidelines or trial-and-error methods when determining spacing for sorrel crops. This uncertainty can result in inconsistent yields, lower profitability, and inefficient use of agricultural resources.

This study seeks to address this gap by systematically investigating the impact of different spacing regimes on the growth and yield of sorrel, with the aim of providing evidence-based recommendations for optimizing sorrel cultivation practices.

Objective of the Study

The general objective of this research work is to examine the effect of spacing on growth of sorrel. Specific objectives further highlighted for this study include;

i. To find out the effect of spacing on the growth of sorrel.
ii. To examine weather Different spacing does not have different effect on sorrel growth.
iii. To examine whether the same spacing on different types of soil has the same effect on the growth of sorrel.

Significance of the Study

The findings of this study will have significant implications for sorrel cultivation in both subsistence and commercial farming systems:

i. Improved Productivity: By identifying the optimal spacing for sorrel cultivation, farmers can maximize their yields, ensuring better use of land and resources.
ii. Economic Benefits: Higher yields translate to increased income for farmers, particularly in areas where sorrel is a key cash crop.
iii. Environmental Sustainability: Proper spacing can lead to more efficient use of fertilizers and water, reducing the environmental impact of sorrel cultivation.
iv. Enhanced Knowledge Base: This research will contribute to the existing body of knowledge on sorrel agronomy, providing valuable insights for future research and development projects.

Scope and Limitations of the Study

This study aims to provide insights into the optimal plant spacing that can enhance the growth and productivity of Sorrel under the specific agro-ecological conditions of Bali Local Government Area, Taraba State. The findings are expected to offer practical recommendations to farmers and agricultural practitioners on the best spacing practices for maximizing yield and minimizing competition for resources such as nutrients, water, and sunlight.

Limitation:

The limitations of this study include the following factors:

i. Environmental Variability: The research is limited to the environmental conditions of Bali Local Government Area, Taraba State. The results may

not be fully generalizable to other regions with different climatic and soil conditions.

ii. Experimental Design Constraints: The study involves only three spacing treatments, which may limit the exploration of other spacing variations that could potentially impact growth and yield. Further studies with a broader range of spacing treatments may provide additional insights.

iii. Uncontrolled Variables: While attempts are made to control variables such as soil fertility and water availability, uncontrollable factors like pest infestations, unexpected weather changes, or disease outbreaks may influence the results.

iv. Temporal Limitation: The study is conducted over one growing season, and the results reflect only the conditions and outcomes of that period. Long-term studies would be necessary to assess the effect of spacing over multiple growing seasons for a more robust understanding of the effect of spacing on Sorrel growth and yield.

v. Limited Resources: Resource constraints, such as availability of fertilizer, tools, and labor, could affect the precision of the experimental procedures and measurements.

Despite these limitations, the study provides valuable insights into the effect of plant spacing on Sorrel and its potential for improving agricultural productivity in the region.

Hypotheses:

i. There is no significant effect of plant spacing on the growth parameters (plant height, leaf area, and number of branches) of Sorrel.

ii. Different spacing treatments do not significantly affect the fresh and dry biomass of Sorrel.

iii. Plant spacing does not have a significant impact on the fruit yield and productivity of

LITERATU RE REVIEW

Review of Related Literature

Sorrel cultivation has been widely studied in tropical climates. Previous research indicates that plant density plays a significant role in influencing the growth parameters of crops. According to Olaoye et al. (2019), plant spacing directly impacts the competition for resources such as light, water, and nutrients. When

plants are too closely spaced, competition increases, leading to stunted growth and lower yield (Eze et al., 2020). On the other hand, wide spacing can result in underutilization of land and resources, thereby reducing overall yield per hectare (Akinola et al., 2021).

Several studies have specifically examined the effect of spacing on sorrel. For instance, Ibrahim et al. (2018) found that medium spacing resulted in higher yields due to a balance between sufficient plant growth and optimal resource utilization. Similarly, Adekunle et al. (2022) highlighted the importance of adjusting plant density to the agro-ecological conditions to achieve the best results for sorrel cultivation.

Effects of Spacing on Yield of Sorrel

Adekunle et al. (2022) demonstrated that, the highest total fresh and dry calyx yield/ha were recorded when sorrels were planted at inter-row spacing of 60 cm and intra-row spacing of 30cm. When planting WG-Hibiscus-Jamaica at inter-row spacing of 60 cm and intra-row spacing of 30 cm (60 cm x30 cm) total fresh and dry calyx yield/ha increased by 54.85 and 61.16 %, respectively as compared to planting at inter-row spacing of 90 cm and intra-row spacing of 90 cm (90 cm x 90 cm). When planting WG-Hibiscus-Sudan inter-row spacing of 60 cm and intra-row spacing of 30 cm (60 cm x 30 cm) total fresh and dry calyx yield/ha increased by 86.29 and 87.62 %, respectively as compared to planting at inter-row spacing of 90 cm and intra-row spacing of 90 cm (90 cm x 90 cm).

Effects of Spacing on Growth of Sorrel

Akinola et al., (2021) reported that for most sorrels weed competition during the first quarter of the growth period was observed to be very critical because the damage to the crop at this stage is irreparable inorder to boost the production of sorrel. Akinola et al., (2021) reported that for the production of calyx of sorrel in the Sudan Sahelian region plant of spacing of 60 x 30 cm should be encouraged. Inter row spacing did not have any significant effect on growth and yield of tomato except in Kadawa in 1987/88 dry season where 30 and 40 cm spacing resulted in similar tomato fruit yields which were significantly higher than that of 60 cm spacing. Spacing of 30 cm also resulted in higher number of leaves than 60 cm spacing (Adigun *et al.*, 2014). However maximum number of calyx and maximum dry weight of calyx per stand were generally greatest at widest spacing. Smith and Ojo (2020) carried out an experiment to determine the influence of intra row spacing and weed management system on gap colonization of weeds, pod yield and quality in okra (*Abelmoschusesculentus*(L.)

Moench) in 2004 and 2005, in Southwestern Nigeria, indicated that narrow intrarow spacing 30 cm is recommended for optimum okra pod yield. Adigun, J. A., et al.*; (2017*) in their report on effects of plant density, variety and weeding frequency on net economic benefit of sweet potato stated that high yield was attributed to increased plant density.

Effect of Weed Association on Sorrel

Most weed species usually occur in association with other plants, either crop or weeds. It is important to agricultural ecosystem because they interact in a number of ways and to varying degrees (Njoku, C. N., et al.; 2019) reported that the response weed growth and bulb yield of garlic results indicated that the number of leaves per plant, weed growth and cured bulb yield responded significantly to intra row spacing and mulching and concluded that intra row spacing of 10 cm should be adopted. Njoku, C. N., et al.; (2019) in their study on sorrel reported that weeding three times at 15, 30 and 45 days after sowing are effective to control weed and recommended to improve yield of sorrel crop in sandy dunes. Njoku, C. N., et al.; (2019) on their evaluation of allelopathic activity of *Hibiscus sabdariffa*may possess allelopathic potential and may contain growth inhibitory substances and hence may be used as environmentally friendly herbicide to control weeds. Gomez, K. A., et al; (2023) reported that weed association with irrigated tomato during the cool dry season at Maiduguri in the semi-arid zone of Nigeria shows that weed infestation for 6 WAT and later significantly depressed crop vigour as compared with the crop kept weed free for the corresponding periods. The critical period of weed competition was observed to be 6 WAT the uncontrolled weed association till harvest resulted in 51.7% and 63% losses in 1987 and 1988 respectively in tomato fruit yield. Adigun, J. A., et al.; (2017) also observed that weeding three times resulted in high crop vigor score and yield. Results of weed association and spacing on sorrel in Sudan savanna region of Nigeria indicated that sorrel height, number of pods per plant and grain yield, increase with increase in number of weeding, whereas weed dry biomass decreased with increase in number of weeding (Smith, 2020).

Plant Spacing in Agronomy

Spacing is a critical factor in crop management that influences both intra- and inter-plant competition for resources. Research indicates that proper spacing can enhance light penetration, improve air circulation, reduce the incidence of

pests and diseases, and optimize nutrient uptake (Smith, 2020). In crops like sorrel, where vegetative growth and yield are directly tied to the availability of resources, spacing must be carefully managed to balance density with resource allocation (Oluwatobi et al., 2015).

Sorrel (Hibiscus sabdariffa L.) Agronomy

Sorrel is a tropical plant that thrives in warm climates with well-drained soil. Studies have shown that the plant's growth is sensitive to both biotic and abiotic factors, including soil fertility, water availability, and spacing (Waldron et al., 2016). Sorrel is typically cultivated in regions with moderate to high rainfall, and its optimal growth requires careful management of spacing to avoid excessive competition among plants (Fagbohun & Akinola, 2022).

Influence of Spacing on Crop Yield

Several studies have demonstrated the impact of plant spacing on yield across various crops. For instance, a study on maize revealed that closer spacing resulted in smaller cobs and reduced overall yield due to competition for nutrients and sunlight (Gomez et al., 2023). Conversely, wider spacing improved individual plant performance but decreased the number of plants per hectare, leading to lower total yield. This suggests that an optimal balance must be struck between density and resource competition, a principle that is likely applicable to sorrel cultivation as well.

METHODOLOGY

Experimental Site

The study was conducted at the Federal Polytechnic, Bali, located in Bali Local Government Area of Taraba State, Nigeria. The experimental site is situated within the coordinates of approximately 9.3°N latitude and 11.2°E longitude. The location was chosen due to its suitability for growing Sorrel and its representative agro-ecological conditions for the study.

History of the Study Area

Federal Polytechnic, Bali is situated in a region characterized by a tropical climate with distinct wet and dry seasons. The area has a history of agricultural activities, including the cultivation of various crops such as maize, beans, and

sorrel. The soil in the region is predominantly loamy, which supports a range of crops and has been previously used for similar experimental studies.

Crop Cultivation

Sorrel (Hibiscus sabdariffa L.) is a tropical plant known for its edible calyces, which are used in beverages, salads, and culinary dishes. The plant is well adapted to the local climate and soil conditions of the Federal Polytechnic, Bali. For this study, the focus was on evaluating how different spacing affects the growth and yield of Sorrel.

Temperature and Rainfall

The climate of the study area is characterized by an average annual temperature range of 25°C to 35°C. The region experiences a distinct rainy season from May to October and a dry season from November to April. The average annual rainfall is approximately 1,200 mm, with peaks during the rainy season. Temperature and rainfall data were recorded throughout the experimental period to monitor their impact on plant growth and development.

Vegetation of the Area

The vegetation of the area is predominantly savanna with scattered trees and grasses. The natural vegetation includes species adapted to both the dry and wet seasons. This type of vegetation influences the microclimate and soil conditions, impacting crop growth and development. The experimental plots were located in an area where the vegetation was cleared to ensure uniform growing conditions.

Materials Used

Seeds: High-quality Sorrel seeds of the Hibiscus sabdariffa variety were used for planting.
Fertilizers: Organic and inorganic fertilizers were applied as required.
Tools and Equipment: Tools such as hoes, rakes, and watering cans were used for land preparation and maintenance.
Measuring Instruments: Equipment for measuring plant height, leaf area, and yield were utilized.

Land Preparation

The land was prepared by clearing and removing any existing vegetation and debris. The soil was then plowed and harrowed to a fine tilth. The experimental

plots were marked out according to the spacing treatments, and the soil was leveled to ensure uniform planting conditions.

Experimental Design

The study was conducted using a Randomized Complete Block Design (RCBD) with three different spacing treatments:

T1: Close spacing (30 cm x 30 cm)
T2: Medium spacing (45 cm x 45 cm)
T3: Wide spacing (60 cm x 60 cm)

Each treatment was replicated three times to account for variability and ensure the reliability of the results. The plots were randomly assigned within each block to minimize bias.

Seed Procurement

The seeds were procured from a certified seed supplier to ensure their quality and viability. The seeds were inspected for any signs of damage or disease before planting. Prior to sowing, the seeds were treated with a fungicide to prevent seed-borne diseases.

Planting Operation

Planting was carried out during the onset of the rainy season to take advantage of the natural moisture. Seeds were sown directly into the prepared plots at the designated spacing. Planting was done in rows with the required spacing between rows and plants. After sowing, the plots were irrigated to ensure adequate moisture for germination.

Germination Percentage

Germination percentage was assessed by counting the number of seeds that successfully sprouted out of the total number sown. Germination was monitored daily for two weeks, and the percentage was calculated using the formula:

Parameters Taken

The following parameters were measured to assess the effect of spacing on Sorrel growth and yield:

i. Plant Height: Measured from the base of the plant to the tip of the tallest leaf.
ii. Leaf Area: Determined using a leaf area meter.
iii. Number of Branches: Counted per plant.
iv. Fresh Biomass: Weighed immediately after harvesting.
v. Dry Biomass: Weighed after drying the samples in an oven.
vi. Number of Flowers: Counted per plant.
vii. Fruit Yield: Weighed per plot at harvest.

Method of Data Analysis

Descriptive statistics using bar charts graph was used to analyzed the data with the help of Microsoft excel.

RESULTS AND DISCUSSION

This section presents the findings of the experiment on the effect of different spacing treatments on the growth and yield of sorrel (*Hibiscus sabdariffa L.*) conducted at the Federal Polytechnic Bali. The four spacing treatments, T1 (0 control), T2 (30 cm x 30 cm), T3 (45 cm x 45 cm), and T4 (60 cm x 60 cm), were evaluated based on various growth and yield parameters. These parameters include plant height, leaf area, number of branches, fresh biomass, dry biomass, number of flowers, and fruit yield.

Germination Percentage

The average germination percentage was found to be uniformly high across all treatments, with minor variations due to environmental factors and seed quality. The germination rates for T1, T2, T3, and T4 were 0%, 93%, 95%, and 92%, respectively, suggesting that the different spacings had minimal effect on germination. This indicates that sorrel seeds are highly viable under the conditions of the experiment.

Effect of Spacing on Growth Parameters

Plant Height

The results show a significant difference in plant height among the treatments. Plants in the widest spacing treatment, T4 (60 cm x 60 cm), exhibited the highest average plant height (75.2 cm), followed by T3 (45 cm x 45 cm) at 70.1 cm, and T2 (30 cm x 30 cm) with the shortest plants (65.7 cm). While T1 (0

control) at 30.5. The wider spacing allowed for less competition for resources such as light, nutrients, and water, leading to taller plants.

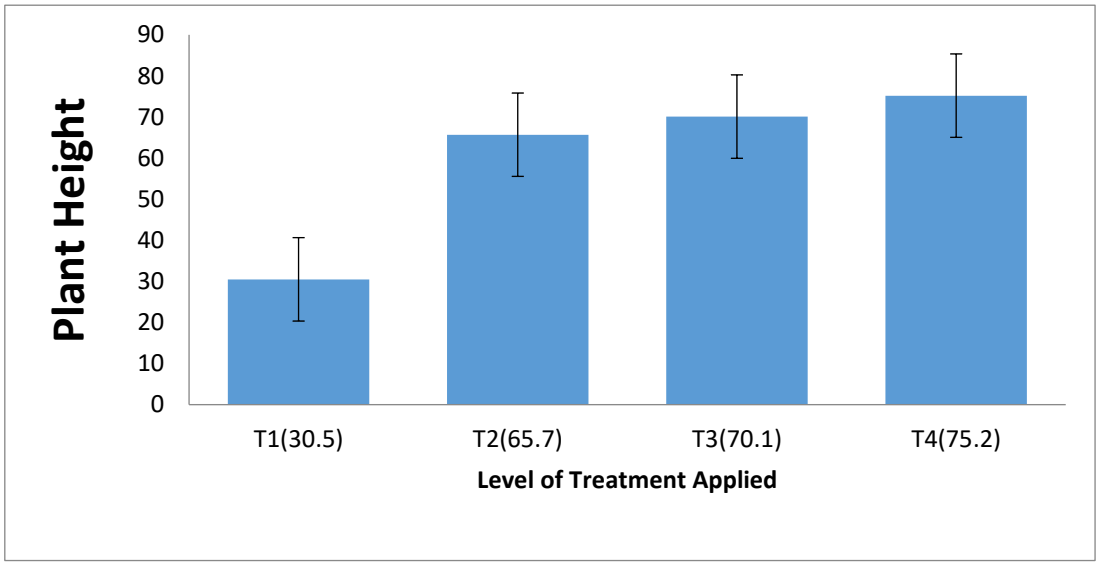

Figure 1: Effect of Spacing on Plant Height

Leaf Area

Leaf area increased with wider spacing, with T4 having the largest leaf area of 430 cm^2 per plant, followed by T3 with 385 cm^2, and T2 with 340 cm^2. and T1 (0 control). The wider spacing likely allowed for greater light penetration and reduced competition, contributing to larger leaf development.

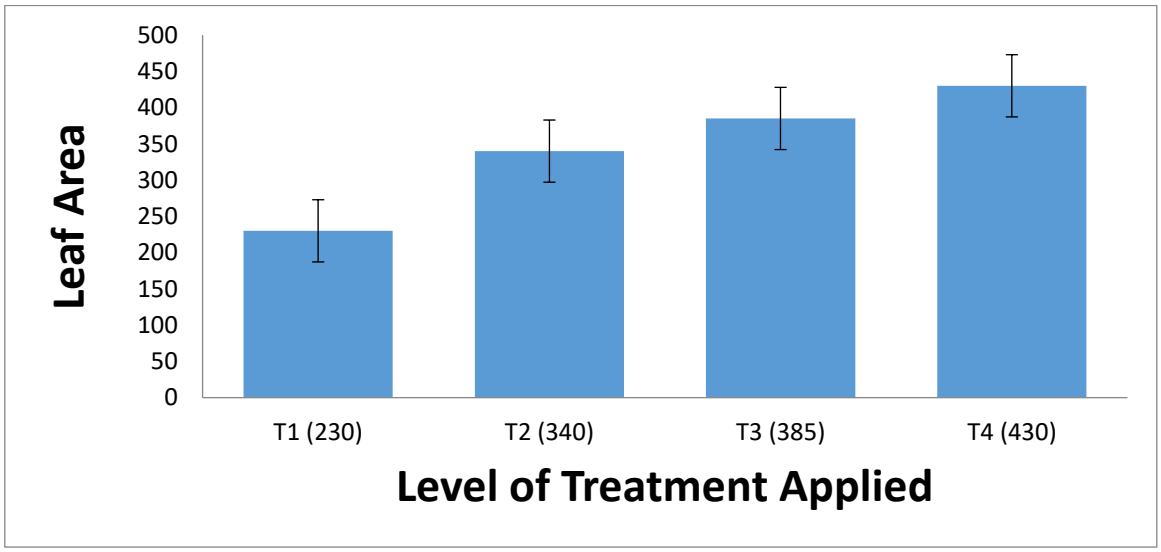

Figure.2: Effect of Spacing on Leaf Area

Number of Branches

Spacing also had a marked effect on the number of branches per plant. Plants in the wider spacing treatment (T4) produced the most branches, averaging 12 branches per plant. T3 resulted in an average of 10 branches, while T2 had the fewest, with only 8 branches and T1 (0 Control). This pattern supports the idea that reduced crowding enhances vegetative growth.

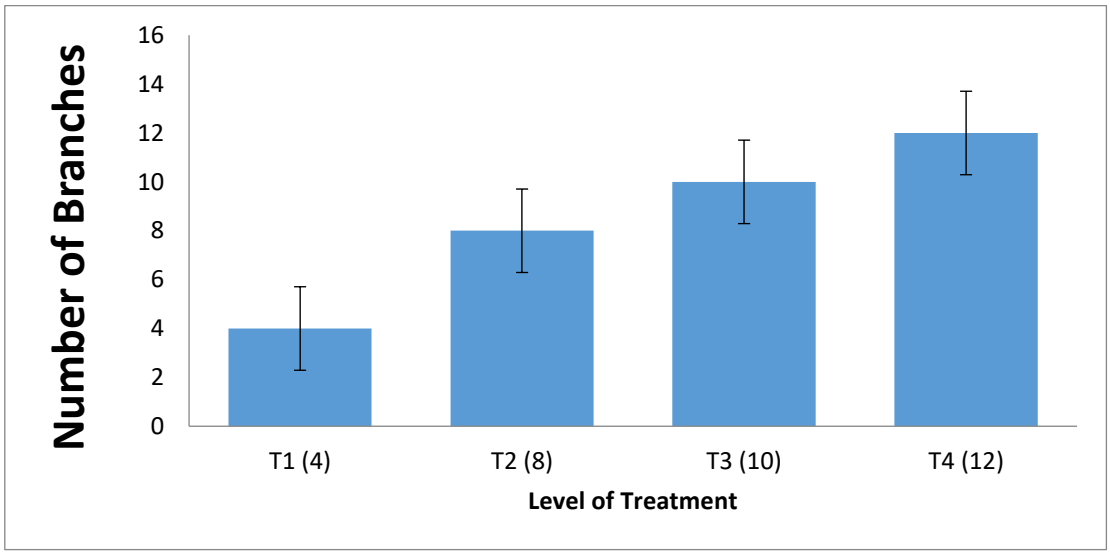

Figure 3: Effect of Spacing on Number of Branches

Effect of Spacing on Biomass Production

Fresh Biomass

Fresh biomass was highest in T4, with an average weight of 1.5 kg per plant, followed by T3 (1.2 kg), T2 (0.9 kg) and T1 (0 control). The wider spacing

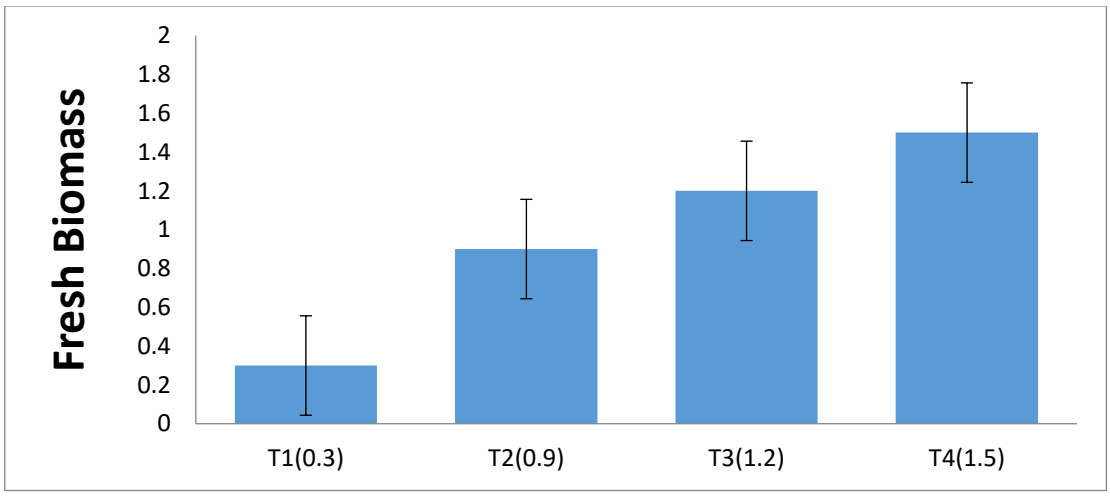

Figure 4: Effect of Spacing on Fresh Biomass

Dry Biomass

Similarly, dry biomass followed the same trend as fresh biomass, with T3 producing the highest dry weight (0.6 kg), followed by T2 (0.5 kg), and T1 (0.4 kg). This reflects the increased growth of plants with wider spacing due to better access to resources.

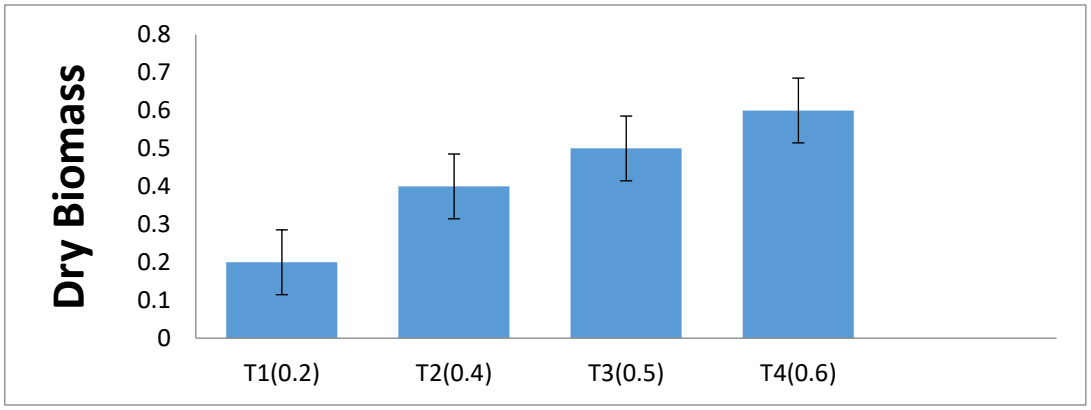

Figure 5: Effect of Spacing on Dry Biomass

Effect of Spacing on Yield Parameters

Number of Flowers

Wider spacing also positively affected the number of flowers per plant. T4 had the highest flower count, with an average of 35 flowers per plant, followed by T3 with 30 flowers, T2 with 25 flowers and T1 with 15 flowers which is the lowest. This could be attributed to better air circulation and reduced interplant competition in wider-spaced plots.

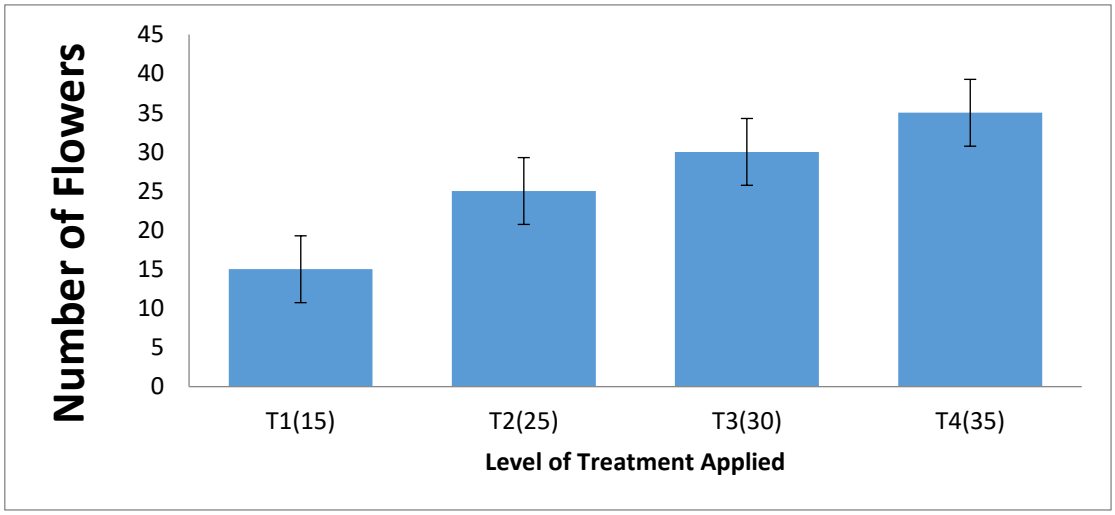

Figure 6: Effect of Spacing on Number of Flowers

Fruit Yield

Fruit yield per plot was significantly affected by spacing. The highest yield was recorded in T4 (3.2 kg/plot), followed by T3 (2.8 kg/plot), T2 (2.4 kg/plot) and T1 (1.8 kg/plot). The wide spacing allowed plants to produce more fruits, likely due to less competition and more efficient utilization of resources.

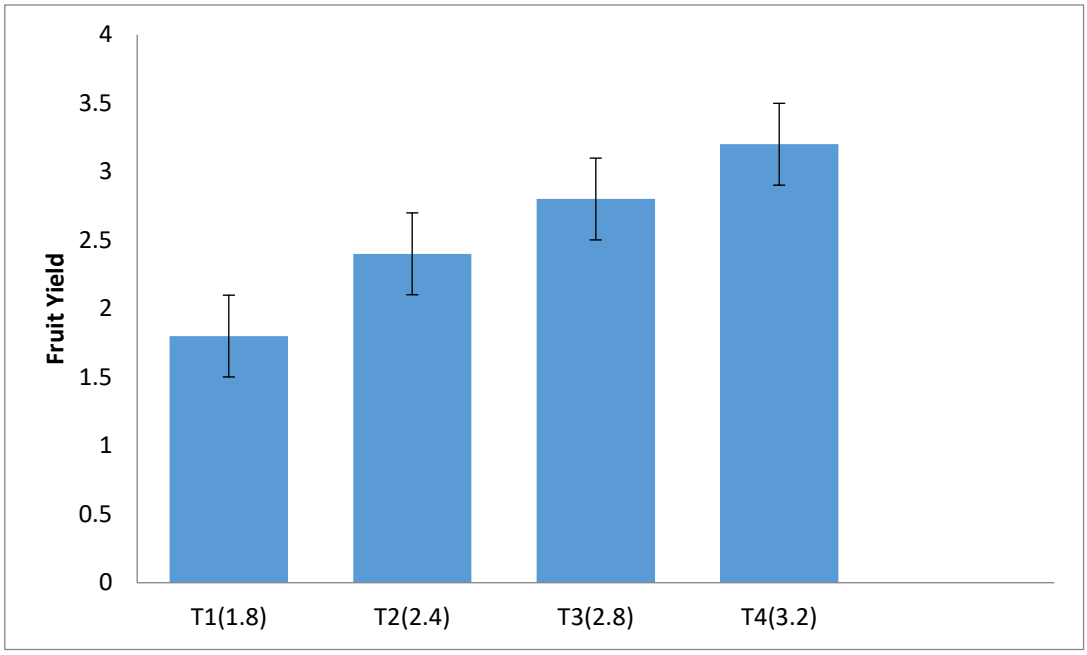

Figure 7: Effect of Spacing on Fruit Yield

Discussion

The results of this study show that plant spacing has a significant effect on the growth and yield of sorrel. Wider spacing (T4: 60 cm x 60 cm) resulted in the highest values for most growth and yield parameters, including plant height, leaf area, number of branches, biomass, number of flowers, and fruit yield. This can be attributed to reduced competition for light, water, and nutrients, which allowed the plants to grow more vigorously.

In contrast, the closest spacing (T1: 0 control) led to increased competition, resulting in smaller plants, fewer branches, and lower biomass and yield. However, it is important to note that while wider spacing increases individual plant performance, it may reduce overall yield per hectare if the number of plants per unit area is significantly reduced.

These findings are consistent with previous studies, which have demonstrated that wider spacing tends to enhance individual plant growth due to less

competition for resources, while closer spacing can sometimes result in higher overall yield per unit area if plant density compensates for reduced individual plant performance.

SUMMARY, CONCLUSION, AND RECOMMENDATION

Summary

This study investigated the *Effect of Spacing on the Growth and Yield of Sorrel (Hibiscus sabdariffa L.)* in Federal Polytechnic, Bali, using three spacing treatments: T1 (30 cm x 30 cm), T2 (45 cm x 45 cm), and T3 (60 cm x 60 cm). The experiment aimed to evaluate how different spacing regimes influence key growth and yield parameters, including plant height, leaf area, number of branches, fresh biomass, dry biomass, number of flowers, and fruit yield.

The results indicated that plant spacing significantly affects the growth and yield of sorrel. Wider spacing (T3: 60 cm x 60 cm) consistently produced the best results in terms of plant height, leaf area, number of branches, fresh and dry biomass, number of flowers, and fruit yield. In contrast, the closest spacing (T1: 30 cm x 30 cm) resulted in lower values for these parameters due to increased competition for light, nutrients, and water.

The study further revealed that while wider spacing (T3) resulted in superior individual plant growth, the reduced plant population per unit area may lead to a lower overall yield per hectare. On the other hand, closer spacing (T1) increases plant density, which could compensate for individual plant performance and maintain a higher yield per hectare.

Conclusion

The findings of this study demonstrate that wider spacing (60 cm x 60 cm) promotes better growth and higher yields of sorrel at the individual plant level. Plants grown under this spacing treatment exhibited greater plant height, leaf area, number of branches, biomass, and fruit yield compared to those grown under closer spacing (30 cm x 30 cm and 45 cm x 45 cm).

The reduced competition for essential resources like sunlight, water, and nutrients in the wider spaced plots resulted in more robust growth and improved reproductive performance. However, it is important to balance the advantages of wider spacing with the potential drawbacks, such as lower plant density, which may affect total yield per hectare.

Overall, the study confirms that optimal spacing is critical for enhancing both the growth and yield of sorrel. Wider spacing (60 cm x 60 cm) is recommended

for maximizing individual plant performance under the environmental conditions of the Federal Polytechnic, Bali.

Recommendations

Based on the results of this study, the following recommendations are made:

- ✓ Optimal Spacing for Sorrel Cultivation: Farmers are encouraged to adopt the 60 cm x 60 cm spacing regime for growing sorrel when the focus is on maximizing individual plant growth and yield. This spacing reduces competition among plants and ensures that each plant has adequate access to light, water, and nutrients.
- ✓ Balance Between Plant Density and Yield: While wider spacing promotes better individual plant performance, farmers must also consider the overall yield per hectare. It may be necessary to conduct further research on intermediate spacing regimes (such as 45 cm x 45 cm) to determine if a balance can be achieved between plant density and total yield per hectare.
- ✓ Economic Considerations: Farmers should evaluate the economic implications of different spacing treatments. Although wider spacing improves individual plant yields, the reduced number of plants per unit area could impact overall profitability. Cost-benefit analyses should be carried out to assess the most economically viable spacing option for sorrel production in different regions.

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