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Effects of Ridge Size on the Growth and Yield of Potatoes (Solanum Tuberosum L.) in Chilanga District, Zambia

[1] **Edina Musukuma,** [2] **Danny Chisanga Musenge**

[1, 2] Department of Agriculture and Environmental Science, Information and Communication University, Zambia Research and Development Centre, Lusaka, Zambia

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Corresponding Author: **Edina Musukuma**

Abstract

This study investigated the effect of ridge size on the growth and yield of potato (Solanum tuberosum L.) under field conditions in Chilanga District, Zambia. An experimental design was employed, testing five ridge widths (30 cm, 50 cm, 61 cm, 75 cm, and 90 cm) in a Randomized Complete Block Design (RCBD) with three replications. Data was collected on plant growth parameters (height, canopy width) and yield parameters (tuber count, average tuber weight, total yield). The findings revealed that ridge size had a highly significant ($p<0.0001$) effect on all measured variables. Increased ridge width resulted in enhanced plant height and canopy diameter. Crucially, wider ridges significantly increased the average weight of individual tubers and the total yield per hectare. The 90 cm ridges produced the highest average tuber weight (163.67 g), while the 75 cm and 90 cm ridges yielded the highest total yields (35.8 t/ha and 36.2 t/ha, respectively), significantly outperforming the 30 cm ridges (25.1 t/ha). The study concludes that ridge size is a critical agronomic factor for potato production. It is recommended that farmers in similar agro-ecological zones adopt a ridge width of 75 cm as it provides an optimal balance between maximizing yield and managing land preparation costs, thereby enhancing productivity and profitability for small and medium-scale farmers.

Keywords: Agronomic Performance, Potato (Solanum Tuberosum L.), Ridge Size, Tuber Weight, Tuber Yield, Zambia

1. Introduction

The potato (Solanum tuberosum L.) stands as a cornerstone of global food security and economic stability, serving as a vital staple crop and a significant source of income for millions of smallholder farmers worldwide. Maximizing its productivity is therefore a critical agricultural imperative, with cultivation practices playing a determinative role in achieving optimal yields. Among these practices, the choice of ridge size is a crucial agronomic variable, as it directly influences the root zone environment by affecting soil temperature, moisture retention, nutrient distribution, and overall crop health (Dagne *et al*., 2019) [7]. The manipulation of ridge geometry can either create a favorable setting for tuber development or impose constraints that limit a plant's potential, making its optimization a key lever for enhancing potato production systems. This is particularly relevant in regions like Zambia, where potatoes significantly contribute to the agricultural economy and local food security (Kaguongo *et al*., 2018) [10], underscoring the necessity of understanding and refining such determinants of yield for sustainable agricultural development.

Ridge farming itself is an ancient practice, historically employed for drainage and flood protection (Rubaihayo *et al*., 2016) [19], which has evolved into a sophisticated technique tailored to the specific needs of various crops and environments. Globally, research led by institutions such as the International Potato Center (CIP) has demonstrated that the effect of ridge size on potato yield is not universal but is instead highly context-specific, varying with soil type, climate, and rainfall patterns (Phiri *et al*., 2017) [18]. For instance, while wider ridges may enhance yields in well-drained, sandy soils or drier conditions by improving water retention, narrower ridges can be more effective in areas with high rainfall or clay soils by preventing waterlogging and ensuring better aeration (Asfaw *et al*., 2017) [2]. This body of work underscores a consensus towards adaptive, location-specific agricultural strategies to maximize both yield and sustainability (Beshir *et al*., 2020) [4]. Beyond the technical agronomics, the selection of an optimal ridge size carries profound socio-economic implications, as the adoption of efficient ridge farming techniques can directly influence poverty alleviation, food availability, and the resilience of smallholder farmers who form the backbone of the agricultural sector in many developing nations (Khan *et al*., 2019) [11].

In the Zambian context, and specifically in the Chilanga District, the pursuit of an optimal ridge size for potato cultivation remains a pressing yet inadequately resolved issue. While the practice of ridge farming has been promoted to address challenges like soil erosion and low crop yields, local farmers and extension services often lack precise, evidence-based guidelines tailored to the district's unique agro-ecological conditions. Existing studies within Zambia, such as those in the Eastern and Southern Provinces, highlight this very ambiguity, showing conflicting results where the performance of different ridge sizes is contingent on localized factors (Beshir *et al*., 2020; Rubaihayo *et al*., 2016) [4, 19]. This gap in localized knowledge means that farmers may be using sub-optimal ridge sizes, thereby constraining their productivity and profitability. It is against this backdrop that this study is situated, aiming to systematically assess the effects of different ridge sizes on the growth and yield of potatoes in Chilanga District. By identifying the most effective ridge width, this research seeks to provide clear, actionable recommendations that can empower farmers, guide policy, and ultimately contribute to a more productive, sustainable, and resilient potato sector in the region.

1.1 Main Objective

The aim of the study was to assess how ridge size impacts potato yield. A case study chilanga district.

1.1.1 Specific Objectives

1. To determine the role played by ridge size in potato i.e potato size, weight of the plant height and conopy width.
2. To determine the role played by ridge size on potato yield i.e number of tubers per plant, size distribution and total weight of harvested crop.
3. To determine the correlation between ridge size and potato growth and yield.

1.2 Hypothesis

Null Hypothesis (H0):

There is no actual difference in potato yield between different ridge sizes in the Chilanga District.

Alternative Hypothesis (H1):

There exists an actual difference in potato yield between different ridge sizes in the Chilanga District.

1.3 Theoretical Framework

This study is grounded in an integrated theoretical framework comprising the Resource-Based View (RBV), Environmental Resource Theory (ERT), and Agro-Ecological Systems Theory to holistically analyze the impact of ridge size on potato yield. The Resource-Based View (RBV), as articulated by Barney (1991) [3], provides a lens through which the ridge itself is conceptualized as a valuable and strategic resource; larger ridge sizes can offer a competitive advantage for plant growth by enhancing soil water holding capacity and nutrient availability, meeting VRIN criteria (Valuable, Rare, Inimitable, Non-substitutable) for sustained yield improvement. Complementing this, the Environmental Resource Theory (ERT) emphasizes that the effectiveness of this resource is contingent upon local environmental conditions (Dietz, Ostrom, & Stern, 2003) [8], framing ridge size as a variable whose success is mediated by the specific climate, soil type, and water dynamics of Chilanga District. Finally, the Agro-Ecological Systems Theory (Altieri, 1995) [1] situates this relationship within the broader ecosystem, asserting that ridge size must be evaluated not only for its direct effect on yield but also for its influence on long-term agro-ecological processes, thereby ensuring the sustainability and resilience of the entire potato production system. Together, these theories provide a multi-faceted understanding of how ridge size strategically interacts with resources, the immediate environment, and the wider agro-ecosystem to determine ultimate yield outcomes.

1.4 Conceptual Framework

The conceptual framework for this study outlines the hypothesized relationships between ridge size and potato yield, accounting for key mediating, moderating, and intervening variables. The independent variable is the ridge size (manipulated at 30 cm, 50 cm, 61 cm, 75 cm, and 90 cm), which is investigated for its direct effect on the dependent variable, potato yield (measured in terms of quantity and quality per unit area). The core relationship between ridge size and yield is not direct but is influenced by a set of mediating variables, primarily soil characteristics (e.g., fertility, texture, water retention) and environmental factors (e.g., rainfall, temperature), which directly affect how a given ridge size translates into plant growth and tuber production. Furthermore, this relationship is subject to moderating variables that can alter its strength or form, including the specific agro-ecological zone and farmers' management practices (e.g., irrigation, fertilization). Simultaneously, intervening variables specifically water management and nutrient availability within the ridge act as the crucial mechanisms through which ridge size ultimately impacts yield, determining the water and nutrients accessible to the potato plants. This framework provides a comprehensive model for analyzing how ridge size influences potato yield within the complex and interacting biophysical and management context of Chilanga District.

2. Literature Review

2.1 The Effect of Ridge Size on Crop Growth Parameters

Globally, the optimization of ridge size is recognized as a critical agronomic practice for enhancing potato productivity, with research demonstrating its profound influence on the crop's micro-environment. Wider ridges provide a larger volume of loose soil, which facilitates superior root development and penetration (Kouwenhoven, 2003) [12], leading to more vigorous vegetative growth and a larger canopy size (Vitos, 2013) [23] that maximizes photosynthetic capacity. However, the optimal ridge dimension is highly context-specific, varying significantly with local conditions. Research from the International Potato Center (CIP) in diverse locations like Ethiopia, Peru, and the Philippines has shown that while greater ridge widths often correlate with higher yields, smaller ridges can be preferable in other environments, underscoring the importance of soil type and ambient conditions (Phiri *et al*., 2017; Dagne *et al*., 2019) [18, 7]. This global perspective emphasizes adaptive agriculture, where ridge size is customized to regional and microclimate-specific factors to maximize both yield and sustainability (Beshir *et al*., 2020) [4]. Beyond biophysical factors, the global discourse also encompasses the socio-economic impact of ridge farming, noting that the adoption of yield-enhancing techniques can significantly influence poverty alleviation and food security for smallholder farmers (Khan *et al*., 2019) [11].

Within the African context, the interplay between ridge size and the continent's diverse agro-ecological zones has been a key focus of research, often aimed at addressing soil degradation and climate variability. Studies consistently highlight that the effectiveness of ridge size is contingent upon local rainfall patterns and soil characteristics. For instance, Rubaihayo *et al*. (2016) [19] found that in areas with higher rainfall and better soil fertility, smaller ridges could be more effective, whereas Asfaw *et al*. (2017) [2] demonstrated that larger ridges improved yields in regions with poor soil water retention. This has led to a continental school of thought that strongly advocates for tailored ridge farming methods, positioning them as a vital intervention for building resilient potato production systems against economic and environmental uncertainties (Dagne *et al*., 2019) [7]. The role of institutions like the Alliance for a Green Revolution in Africa (AGRA) has been pivotal in advancing this research, facilitating the development of context-specific recommendations and practical tools for farmers across the continent (Asfaw *et al*., 2017) [2].

In Zambia specifically, the pursuit of an optimal ridge size for potato cultivation is a recognized research priority, given the crop's significant contribution to the agricultural economy and national food security (Kaguongo *et al*., 2018) [10]. Localized studies reveal a complex picture similar to the broader regional trends, where the performance of different ridge sizes is heavily dependent on specific agro-ecological zones. Research in Zambia's Southern and Eastern Provinces has shown that low ridges were more suitable in sandy soils for enhancing water retention, while big ridges were more effective in clay soils to prevent waterlogging and improve aeration (Asfaw *et al*., 2017; Beshir *et al*., 2020) [2, 4]. This underscores the critical need for location-specific recommendations within the country itself. Furthermore, the Zambian perspective extends to the practical challenges of adoption, emphasizing that the effectiveness of ridge size is also a function of farmers' capacity, knowledge transfer, and the support provided by extension services (Phiri *et al*., 2017) [18]. Consequently, bridging the gap between empirical research and on-farm implementation through targeted policy and institutional support is considered essential for harnessing the full potential of ridge size optimization to improve smallholder livelihoods and sustainable potato production in Zambia (Kaguongo *et al*., 2018; Mwansa, 2011) [10, 17].

2.2 The Impact of Ridge Size on Yield Components

Globally, the primary mechanism through which ridge size influences potato yield is by altering the trade-off between tuber size and tuber number, a fundamental relationship in crop physiology. Wider ridges, which typically result in lower plant density per unit area, provide each plant with a greater volume of soil for root exploration and tuber bulking, leading to significantly heavier individual tubers (Van Casteele *et al*., 2001; Blauer *et al*., 2024) [22, 5]. This phenomenon is attributed to reduced inter-plant competition for resources, allowing for better assimilate partitioning into fewer, larger tubers (Sen *et al*., 2010) [20]. Conversely, narrower ridges accommodate more plants, which can increase the total tuber count per plot, but often at the expense of average tuber size, resulting in a higher proportion of unmarketable tubers (Kumar *et al*., 2019; Jatav *et al*., 2014) [13, 9]. The ultimate impact on total yield is therefore a balance between these two components, influenced by soil structure and environmental conditions. Research by Smith *et al*. (2015) [21] and Müller *et al*. (2016) [15] confirms that wider ridges often enhance overall yield by optimizing this balance, provided that water and nutrient availability are non-limiting, as the yield gain from larger tuber size generally outweighs the loss from a slightly reduced tuber count.

In the African regional context, the yield response to ridge size is further mediated by prevalent challenges such as unpredictable rainfall and variable soil fertility. Studies across the continent have demonstrated that the optimal ridge size for maximizing marketable yield is highly dependent on moisture regimes. For example, in drier regions or during periods of water stress, wider ridges have been shown to act as a moisture-harvesting technique, concentrating limited rainfall and leading to superior yields compared to flat planting or narrow ridges (Li & Gong, 2002; Dagne *et al*., 2019) [14, 7]. However, in high-rainfall areas, excessively wide ridges may not provide a yield advantage, and narrower ridges can be sufficient, as the risk of waterlogging is lower and plant population is maximized (Rubaihayo *et al*., 2016) [19]. This underscores the critical interaction between ridge size and water availability, a key factor for smallholder farmers who rely on rain-fed agriculture. The socio-economic dimension is also prominent, as the choice of ridge size must not only be agronomically sound but also labor-feasible and economically viable for resource-constrained farmers, making the pursuit of an optimal size a matter of both productivity and practicality (Beshir *et al*., 2020; Khan *et al*., 2019) [4, 11].

Focusing on Zambia, empirical evidence highlights the direct implications of ridge size optimization for the productivity and profitability of the local potato sector. Research within the country has corroborated the global and regional trends, showing that ridge size significantly affects key yield components like tuber weight and size distribution. A study by Mwansa (2011) [17] on the effect of seed tuber size and spacing a closely related factor to ridge width—found that wider spacing (and by extension, wider ridges) produced better-quality, larger tubers with higher dry matter content. Furthermore, localized trials in regions like the Southern Province have shown that the yield advantage of wider ridges (e.g., 75 cm) is most pronounced in soils where they can improve aeration and prevent waterlogging, directly impacting tuber set and bulking (Asfaw *et al*., 2017) [2]. Despite these findings, a significant gap remains in translating this research into standardized, locally-validated recommendations for farmers in specific districts like Chilanga. The challenges noted in Zambian studies, including access to inputs and varying management practices (ZIPAR, 2013; Phiri *et al*., 2017) [24, 18], reinforce the need for targeted research to determine the ridge size that delivers the optimal combination of high tuber weight, acceptable tuber number, and ultimately, maximum marketable yield for Zambian smallholders (Kaguongo *et al*., 2018) [10].

2.3 Contextualizing Ridge Farming in Zambia

In Zambia, ridge farming is not merely an agronomic technique but a pivotal component of the national strategy to promote sustainable agriculture and bolster food security, particularly for staple crops like potatoes. The practice has been widely promoted by government extension services and development partners as a key intervention to address pervasive challenges such as soil erosion, low crop yields, and the inefficient use of limited water resources, especially in the face of increasing climate variability (Phiri *et al*., 2017; ZIPAR, 2013) [18, 24]. The adoption of ridge cultivation is seen as a practical method to enhance soil conservation, improve water infiltration, and create a more favorable physical environment for root development and tuber bulking, thereby directly contributing to the productivity and resilience of the smallholder sector, which forms the backbone of Zambian agriculture (Kaguongo *et al*., 2018) [10]. This national perspective positions ridge farming as a cornerstone for achieving broader developmental goals, including poverty reduction and rural economic stability, by enabling farmers to maximize returns from their land and labor.

The effectiveness of ridge farming, however, is not uniform across Zambia's diverse agro-ecological regions, and research has highlighted significant variations in optimal practices. Studies conducted in different provinces underscore that the success of a specific ridge size is highly dependent on local soil types and rainfall patterns. For instance, research in the Eastern Province demonstrated that larger ridges yielded more tubers in areas with poor soil water retention, whereas in the higher-rainfall regions of the Southern Province with better soil fertility, smaller ridges were sometimes more effective at achieving maximum potato yield (Asfaw *et al*., 2017; Rubaihayo *et al*., 2016) [2, 19]. This spatial variability necessitates a decentralized and location-specific approach to agricultural extension, as a one-size-fits-all recommendation for ridge size is likely to be ineffective and could even be counterproductive, leading to sub-optimal yields and wasted resources for farmers operating in different local contexts (Beshir *et al*., 2020) [4].

Beyond biophysical factors, the contextualization of ridge farming in Zambia must also account for critical socio-economic and institutional dimensions that influence adoption and effectiveness. Smallholder farmers, who dominate potato production, often face a complex web of constraints, including limited access to credit, quality inputs, and modern equipment, which can hinder their ability to implement optimal ridge practices consistently (CBN, 2010) [6]. Furthermore, the capacity of farmers and the knowledge disseminated by extension services play a decisive role; the potential benefits of an optimized ridge size can only be realized if farmers have the requisite skills and understanding (Khan *et al*., 2019) [11]. Therefore, contextualizing ridge farming in Zambia involves more than just agronomic research; it requires integrated efforts that include policy support for input access, strengthened agricultural extension systems, and the development of tailored recommendations that resonate with the local realities and resource endowments of Zambian smallholders (Dagne *et al*., 2019; Muyasani, 2018) [7, 16].

2.4 Literature Gap

Despite a substantial body of local, regional, and international research on ridge farming and its influence on potato cultivation, a clearly defined literature gap persists regarding a holistic and location-specific analysis for Chilanga District, Zambia. While global studies establish the principle of context-dependence (Phiri *et al*., 2017; Dagne *et al*., 2019) [18, 7], and regional and national research in Zambia confirms significant variation in optimal ridge size across different agro-ecological zones (Asfaw *et al*., 2017; Beshir *et al*., 2020) [2, 4], the existing literature lacks a focused investigation that integrates the precise soil, environmental, and socio-economic conditions of Chilanga. Previous studies, such as those by Mwansa (2011) [17] and Kaguongo *et al*. (2018) [10], have addressed spacing and yield components broadly, but none have systematically isolated and quantified the effectiveness of a range of ridge sizes (from 30 cm to 90 cm) on both growth and yield parameters within this specific district. Furthermore, while the socio-economic challenges are acknowledged (ZIPAR, 2013; Muyasani, 2018) [24, 16], there is a gap in linking these constraints directly with empirical data on ridge size performance to provide actionable, evidence-based recommendations tailored to the unique needs and capacities of smallholder farmers in Chilanga. This study aims to fill this critical gap by providing a comprehensive assessment to determine the optimal ridge size for enhancing potato productivity in the district.

3. Description of the Study Area

The field experiment was conducted in Chilanga District, Lusaka, situated in agro-ecological zone II. The site is characterized by a warm climate with high annual rainfall (900-1000mm) and sandy loam soil with slight acidity, providing a representative environment for the study.

3.1 Soil Sampling

A systematic soil sampling approach was employed across the experimental site to capture soil diversity. Standardized methods, including pH analysis, were used to characterize soil properties and establish a baseline for understanding nutrient availability and soil health.

3.2 Experimental Design

A Randomized Complete Block Design (RCBD) with three replications was used. The experiment comprised five treatments ridge widths of 30 cm, 50 cm, 61 cm (control), 75 cm, and 90 cm each applied to 12m² plots, totaling fifteen experimental units.

3.3 Land Preparation

The land was manually cleared and ploughed to soften the soil and remove weeds. Chicken and goat manure was incorporated at 3kg/m² before constructing ridges of uniform height (30 cm) but varying widths according to the treatment specifications.

3.4 Planting

Certified disease-free potato seeds were sterilized, sprouted, and germinated before planting. Seed potatoes were planted uniformly along pre-formed ridges at a depth of 10-15 cm and a spacing of 30-38 cm along the ridge.

3.4.1 Irrigation and Fertilization

Plants were regularly irrigated using a hose pipe. Fertilization involved an initial application of Compound D, followed by a nitrogenous fertilizer during the flowering stage to support plant development and tuber initiation.

3.4.2 Weed and Pest Management

Weeds were controlled manually to minimize competition. Integrated pest and disease management strategies, including chemical controls and sanitation, were implemented to protect crop health.

3.4.3 Harvesting

Potatoes were harvested manually after a four-month growth cycle, ensuring careful extraction to assess yield parameters accurately.

3.5 Data Collection

Data was systematically collected on growth parameters (plant height, canopy width) and yield parameters (tuber count, weight, and size distribution) throughout the growing season to evaluate treatment effects.

3.6 Data Analysis

Data were analyzed using descriptive statistics and Analysis of Variance (ANOVA). The Tukey HSD post-hoc test was applied to identify significant differences between treatment means, with analysis conducted using statistical software.

3.7 Ethical Considerations and Limitations

The study adhered to ethical guidelines, including obtaining informed consent. Limitations such as climatic variability, soil heterogeneity, and differences in management practices were acknowledged as factors that could influence the generalizability of the results.

4.1 Plant Height

The results show that the width of the ridge directly influenced Irish potato plant height, wherein higher plants were often observed on wider ridges. Potato plants grown on the widest of the ridge sizes, 90 cm, produced the highest average, at 56–57 cm, followed by the 75 cm ridges where it grew about 52 cm. Intermediate ridge widths such as 61 cm produced moderately tall crops with an average of almost 50 cm, and the 50 cm and 30 cm ridges always had the shortest haulm heights of about 48 cm and 45 cm respectively. The trend shows that wider ridges experience better soil conditions such as deeper rooting depth, enhanced aeration, and improved moisture retention that facilitate vigorous vegetative development. Conversely, narrow ridges tend to restrict plant growth, likely due to a lack of root space and competition for nutrients, which is detrimental to haulm development.

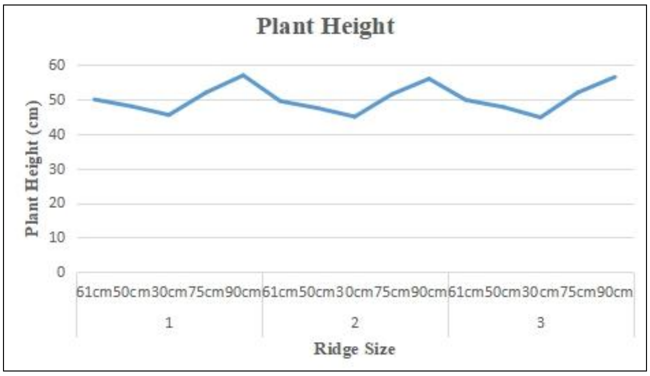

Table 1: Plant height

Replicate	Ridge Size (cm)	Plant Height (cm)
1	61	50
1	50	48
1	30	45.5
1	75	52
1	90	57
2	61	49.5
2	50	47.5
2	30	45
2	75	51.5
2	90	56
3	61	49.8
3	50	47.8
3	30	44.8
3	75	52
3	90	56.5

4.2 Canopy Diameter

The results indicated that ridge size also influenced the canopy width of Irish potato plants. The widest canopies were consistently recorded on the 90 cm ridges, where plants spread to about 49.5 - 50 cm, followed by the 75 cm ridges with canopy widths ranging between 46.5 - 47.5 cm. Intermediate ridge sizes such as 61 cm showed moderate canopy development averaging around 46 cm, while narrower ridges of 50 cm and 30 cm recorded the smallest canopy widths, averaging about 44 cm and 42 cm respectively. This trend suggests that wider ridges provide more space for horizontal vegetative expansion, likely due to reduced inter-plant competition and improved soil resource availability, thereby enhancing canopy growth. Narrow ridges, on the other hand, restricted canopy spread, which could potentially limit light interception, photosynthetic activity, and ultimately tuber bulking.

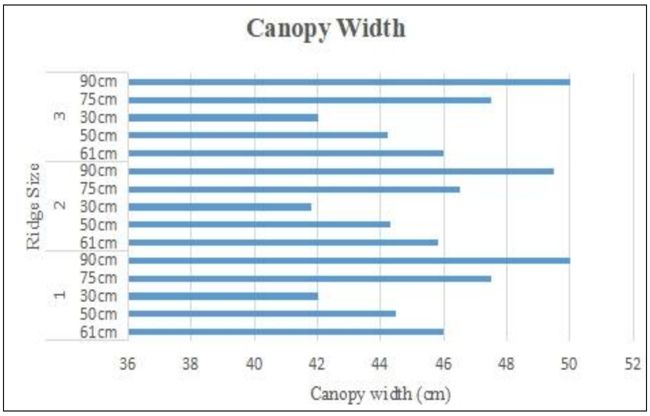

Table 2: Leaf canopy diameter

Replicate	Ridge Size (cm)	Canopy width (cm)
1	61	46
1	50	44.5
1	30	42
1	75	47.5
1	90	50
2	61	45.8
2	50	44.3
2	30	41.8
2	75	46.5
2	90	49.5
3	61	46
3	50	44.2
3	30	42
3	75	47.5
3	90	50

4.3 Total Tuber Count

The results show the effect of ridge size on the total tuber count of Irish potatoes across three replications. Overall, the highest tuber counts were consistently recorded on the wider ridges, particularly at 75 cm, which produced around 73–74 tubers per plot across all replications. The 61 cm (control) ridges also maintained relatively high tuber numbers, averaging about 71–72 tubers. In contrast, the narrowest ridges (30 cm) had the lowest tuber counts, averaging between 67 and 69 tubers across the replications, suggesting that overcrowding on small ridges limited tuber initiation and development. Intermediate ridge sizes such as 50 cm and the largest ridges at 90 cm produced moderate tuber numbers, falling between 69 and 71 tubers. These results indicate that ridge size influences tuber formation, with wider ridges (especially 75 cm) promoting optimal tuber initiation by reducing plant competition and improving soil aeration, while excessively narrow ridges (30 cm) constrain yield potential.

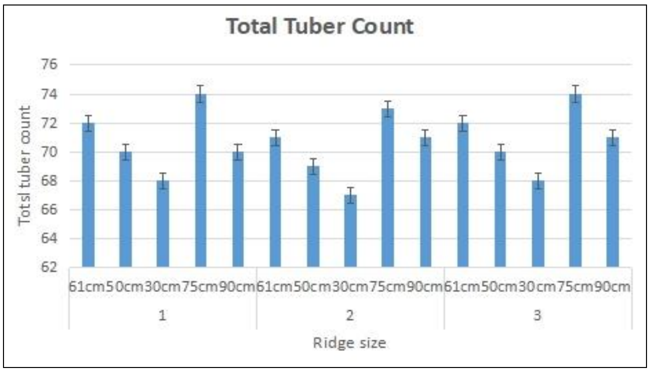

Fig 5: Total tuber counts per plot of the various ridge sizes

4.4 Average Tuber Weight

The trend shows that the heaviest tubers were consistently obtained from the widest ridges (90 cm), where average weights ranged between 162–166 g, followed closely by 75 cm ridges at about 160-164 g. The standard 61 cm ridges produced moderate tuber weights averaging around 154-156 g, while the 50 cm ridges yielded slightly lower values between 148-152 g. The narrowest ridges (30 cm) consistently produced the lightest tubers, averaging only 141-145 g across replications. These findings suggest that wider ridges provide favorable conditions for tuber bulking, likely due to improved soil volume, aeration, and nutrient availability per plant, which allow for better assimilate partitioning into tubers. Conversely, smaller ridges restrict tuber growth, leading to reduced average tuber size. Overall, the results highlight that ridge sizes of 75–90 cm optimize tuber weight, which is a critical determinant of marketable yield and profitability for potato farmers.

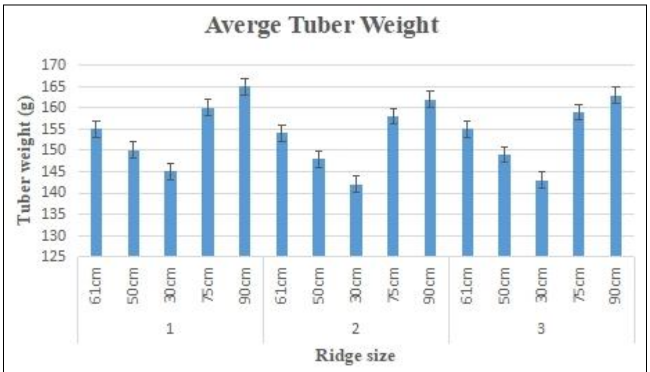

Fig 6: Weight of a single tuber

4.5 Total Yield Per Plot

Yields were generally highest on the wider ridges (75 cm), which consistently produced about 19 kg per plot, while the control (61 cm) and the 50 cm ridges followed closely with yields ranging between 18–19 kg. The 90 cm ridges also performed fairly well, though their yields were slightly lower and more variable compared to the 75 cm ridges. In contrast, the narrowest ridges (30 cm) recorded the lowest yields, averaging about 16–17 kg per plot, which suggests that overcrowding and competition for nutrients in smaller ridges restricted tuber bulking and overall productivity. These results imply that ridge size has a clear effect on yield performance, with 75 cm ridges emerging as the most productive and efficient in balancing plant population with resource availability. For smallholder farmers, adopting wider ridge sizes (around 75 cm) could therefore enhance potato yield and profitability under conditions similar to those in Chilanga District.

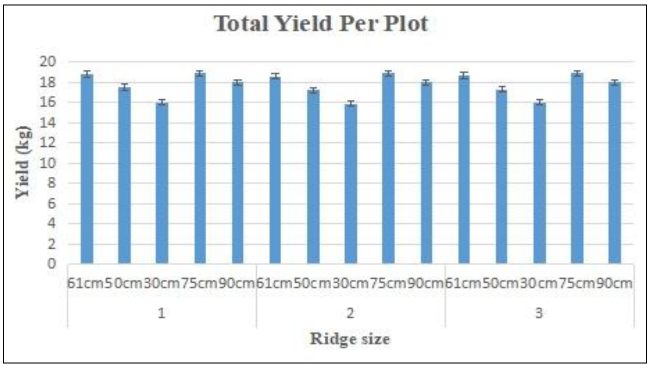

Fig 7: Yield per plot

4.6 ANOVA Summary

The ANOVA results revealed highly significant differences among ridge size treatments for all three traits: plant height ($F(4,10)=473.37$, $p<0.0001$), average tuber weight ($F(4,10)=134.60$, $p<0.0001$), and total yield ($F(4,10)=576.50$, $p<0.0001$). This indicates that ridge size had a substantial effect on potato growth and productivity. The very high F-values and extremely low p-values suggest that the observed differences were not due to random variation but rather the influence of ridge size on plant development. Thus, ridge size is a critical agronomic factor influencing plant vigor, tuber formation, and overall yield performance.

Table 3: ANOVA summary for plant height, average tuber weight and yield

Variable	Source	Sum Sq	Df	F	PR(>F)
Plant Height	C(Treatment)	64.82	4	473.37	<0.0001
	Residual	0.34	10		
Avg Tuber Weight	C(Treatment)	874.13	4	134.6	<0.0001
	Residual	16.22	10		
Yield	C(Treatment)	15.56	4	576.5	<0.0001
	Residual	0.07	10		

4.7 Tukey HSD Post-hoc Results (Plant Height)

The post-hoc test showed that all pairwise comparisons of ridge sizes were significantly different ($p<0.05$), with larger ridge sizes producing taller plants. Specifically, 90 cm ridges consistently supported the greatest plant height, significantly outperforming smaller ridges such as 30 cm and 50 cm. The differences were particularly large between 30 cm ridges and wider ridges, highlighting the negative effect of restricted ridge volume on aboveground growth. This suggests that wider ridges provide better soil structure, aeration, and nutrient availability, which in turn enhances vegetative growth and height development.

Table 4: Poc Hoc test for plant height

group1	group2	meandiff	p-adj	lower	Upper	Reject
30	50	-2.23	0.001	-3.07	-1.39	TRUE
30	61	-4.37	0.001	-5.21	-3.53	TRUE
30	75	-6.57	0.001	-7.41	-5.73	TRUE
30	90	-11.23	0.001	-12.07	-10.39	TRUE
50	61	-2.13	0.001	-2.97	-1.29	TRUE
50	75	-4.33	0.001	-5.17	-3.49	TRUE
50	90	-9	0.001	-9.84	-8.16	TRUE
61	75	-2.2	0.001	-3.04	-1.36	TRUE
61	90	-6.87	0.001	-7.71	-6.03	TRUE
75	90	-4.67	0.001	-5.51	-3.83	TRUE

4.8 Tukey HSD Post-hoc Results (Average Tuber Weight)

For average tuber weight, significant differences were also found between all ridge sizes, with tuber weight increasing steadily with ridge width. The smallest ridge (30 cm) produced significantly lighter tubers compared to all other treatments, while the 90 cm ridge consistently supported the heaviest tubers. These results imply that larger ridges promote better root development and tuber bulking by providing sufficient soil depth and volume for expansion. The clear progression from smaller to larger ridges demonstrates the importance of ridge size in optimizing potato tuber size and market quality.

Table 5: Showing the Tukey HSD Post –hoc results for average tuber weight

group1	group2	meandiff	p-adj	lower	upper	Reject
30	50	-4	0.001	-6.34	-1.66	TRUE
30	61	-9.67	0.001	-12.01	-7.33	TRUE
30	75	-15	0.001	-17.34	-12.66	TRUE
30	90	-19.67	0.001	-22.01	-17.33	TRUE
50	61	-5.67	0.001	-8.01	-3.33	TRUE
50	75	-11	0.001	-13.34	-8.66	TRUE
50	90	-15.67	0.001	-18.01	-13.33	TRUE
61	75	-5.33	0.001	-7.67	-3	TRUE
61	90	-10	0.001	-12.34	-7.66	TRUE
75	90	-4.67	0.001	-7.01	-2.33	TRUE

4.9 Tukey HSD Post-hoc Results (Yield)

The Tukey HSD analysis for yield also revealed significant differences across ridge sizes. Plots with 75 cm ridges and 90 cm ridges recorded the highest yields, which were significantly greater than those of 30 cm and 50 cm ridges. Interestingly, while 90 cm ridges supported higher plant height and tuber weight, the yield differences between 75 cm and 90 cm were relatively small, suggesting diminishing returns at extremely large ridge sizes. This pattern indicates that while increasing ridge size improves yield potential, there may be an optimal size (around 75–90 cm) where maximum productivity is achieved without unnecessary increases in land preparation costs.

Table 6: Showing the Tukey HSD Post –hoc results for yield

group1	group2	meandiff	p-adj	lower	Upper	Reject
30	50	-1.2	0.001	-1.38	-1.02	TRUE
30	61	-2.63	0.001	-2.81	-2.45	TRUE
30	75	-3.03	0.001	-3.21	-2.85	TRUE
30	90	-2.03	0.001	-2.21	-1.85	TRUE
50	61	-1.43	0.001	-1.61	-1.25	TRUE
50	75	-1.83	0.001	-2.01	-1.65	TRUE
50	90	-0.83	0.001	-1.01	-0.65	TRUE
61	75	-0.4	0.001	-0.58	-0.22	TRUE
61	90	0.6	0.001	0.42	0.78	TRUE
75	90	1	0.001	0.82	1.18	TRUE

5. Discussion of Results

The findings of this study strongly affirm that ridge size plays a fundamental role in determining the vegetative growth and architecture of the potato plant. Consistent with the first specific objective, the results demonstrated a clear positive correlation between ridge width and key growth parameters. Plants cultivated on wider ridges (75 cm and 90 cm) exhibited significantly greater plant height and canopy diameter compared to those on narrower ridges (30 cm and 50 cm). This can be attributed to the larger soil volume in wider ridges, which facilitates a more extensive and deeper root system, thereby enhancing the plant's capacity to access water and nutrients (Kouwenhoven, 2003) [12]. The resulting vigorous vegetative growth, as evidenced by the larger canopy, is crucial for maximizing photosynthetic capacity, which in turn produces the assimilates necessary for tuber development (Vitos, 2013) [23]. The highly significant ANOVA results ($p<0.0001$) for plant height confirm that these observed differences were not due to chance but were a direct consequence of the treatment, underscoring that ridge size is a critical management factor for establishing a strong physiological foundation for yield.

In relation to the second objective, which focused on yield components, the study revealed a more nuanced relationship. While narrower ridges showed a tendency for a higher tuber count per plot a consequence of higher plant density this advantage was offset by a significantly lower average tuber weight. Conversely, wider ridges, particularly the 75 cm and 90 cm treatments, produced substantially heavier individual tubers, leading to the highest total marketable yield per hectare. This trade-off between tuber number and tuber size is a classic response to plant density and resource availability per plant (Sen *et al*., 2010) [20]. The results indicate that the wider ridges reduced inter-plant competition, allowing for better resource allocation and assimilate partitioning into fewer, but larger and more marketable, tubers (Van Casteele *et al*., 2001) [22]. The post-hoc analysis confirmed that the yields from the 75 cm and 90 cm ridges were statistically superior to those from the narrower ridges, demonstrating that the yield gain from increased tuber size far outweighs the benefit of a marginally higher tuber count in this agronomic context.

Synthesizing these findings to address the third objective, a clear and significant correlation exists between ridge size and the integrated system of potato growth and final yield. The superior vegetative growth on wider ridges directly supported the enhanced tuber bulking, creating a positive cascade effect from source to sink. The highly significant ANOVA results for all measured variables (plant height, tuber weight, and yield) provide robust statistical evidence for this overarching relationship. Importantly, the study identifies an optimal point of diminishing returns; while the 90 cm ridges supported the tallest plants and heaviest individual tubers, the 75 cm ridges produced a statistically equivalent total yield. This suggests that a ridge width of 75 cm strikes an optimal balance, providing sufficient soil volume for root and tuber development without under-utilizing land area, making it the most agronomically efficient and likely more economically viable recommendation for farmers in Chilanga District. This finding aligns with the principles of Agro-Ecological Systems Theory (Altieri, 1995) [1], highlighting that the optimal agricultural practice is one that maximizes productivity while maintaining resource-use efficiency for long-term sustainability.

6. Conclusion

This study successfully addressed its specific objectives, revealing that ridge size plays a fundamental and multifaceted role in potato cultivation. In line with the first objective, the findings demonstrate that ridge width significantly influences potato growth, with wider ridges directly promoting increased plant height and a broader canopy width, which are indicators of vigorous vegetative development. Regarding the second objective, the study established that ridge size critically determines the components of yield; narrower ridges resulted in a higher number of tubers per plant, while wider ridges dramatically improved the average tuber weight and size distribution, leading to a greater total weight of the harvested crop.

Synthesizing these findings to address the third objective, a strong and definitive correlation exists between ridge size and the integrated system of potato growth and final yield. The enhanced vegetative growth on wider ridges provided the physiological foundation for superior tuber bulking. The study concludes that a ridge width of 75 cm represents the optimal balance for potato production in the Chilanga District, as it maximizes marketable yield by effectively reconciling the trade-off between tuber number and tuber size. Therefore, adopting this ridge size is recommended as a key agronomic practice to enhance productivity for smallholder farmers in the region.

7. References

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