International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 10-01-2025, Accepted: 09-02-2025, Published: 25-02-2025
Volume 10, Issue 2, 2025, Page No. 36-40

Identify the effect of seed rates on plant growth and yield of popular rice variety BG 94-1 in Sammanthurai Area, Ampara District, Sri Lanka

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Abstract

Rice, as a staple food, holds a significant position in Sri Lanka's agricultural landscape, cultivated across all districts. The dry zone, in particular, contributes significantly to the national rice supply. The direct sowing of sprouted paddy to the field is a widely adopted practice in Sri Lankan paddy farming compared to other establishment techniques. Seed rate, a critical factor, profoundly impacts plant density, crop stand competitiveness, tiller development, time to maturity, and overall yield. Low plant density and improper sowing methods are major agronomic constraints affecting yield in rice cultivation. This study addresses the prevalent issue of utilization of seed which was higher than recommended seed rates, with most using 4-6 bushels of paddy seeds per acre although the Department of Agriculture's recommendation was 2.5 bushels per acre. Therefore, the study was predominantly directed to evaluate the effect of different seed rates on plant growth and yield of the popular rice variety BG 94-1 in the Sammanthurai Area of Ampara District. The experiment was conducted at the Rice Research Station, Department of Agriculture, Sammanthurai, using a Randomized Complete Block Design with five treatments ranging from seed rate 2.5 to 4.5 bushels per acre. Data collection was performed at vegetative and reproductive stages, assessing plant density, tiller count, plant height, flowering maturity, panicle length, and seed quality parameters. Statistical analysis using SAS Software revealed that no significant differences were found between treatments in terms of tiller number, plant height, flowering maturity, panicle length, and filled and unfilled grains. Notably, plant height at maturity displayed significant variation, with the lowest seed rate (2.5 bushels per acre) resulting in the tallest plants. These findings emphasize that proper seed rate management can potentially enhance rice cultivation practices and contribute to improved agricultural productivity.

Keywords: Paddy cultivation, seed rate, BG 94-1, dry zone, plant growth and yield

Introduction

Rice (*Oryza sativa* L.), a member of the Poaceae family, stands as one of humanity's most vital food crops, particularly across Asia where it serves as the primary dietary staple. The cereal crop, characterized by its diploid chromosome structure (2n = 24), provides approximately 20% of the world's dietary energy requirements, with 90% of global production concentrated in Asian regions (Francesca, 2012) [5]. As the global population surges toward an anticipated 11 billion by 2100, the agriculture sector faces mounting pressure to increase food production by approximately 40% while simultaneously addressing environmental concerns, particularly the sector's 35% contribution to annual anthropogenic greenhouse gas emissions (Gouel and Guimbard, 2019) [8]. This challenge is especially pertinent for rice production, which currently yields over 700 million tons annually across 161 million hectares worldwide (FAOSTAT, 2015) [4].

According to the Central Bank (2012), in Sri Lanka, rice cultivation has achieved remarkable success, leading to national self-sufficiency in 2010. The crop occupies 47% of the agricultural area and contributes 11% to the agricultural gross domestic product, supporting approximately 1.5 million farming families. This success stems from technological advancements, supportive government policies, and the development of improved rice varieties. Jayawardena *et al*., (2010) [11] has been reported that among the various rice varieties released by the Department of Agriculture, BG 94-1 has emerged as one of the four dominant varieties in Sri Lankan agriculture, alongside BG 300, BG 352, and BG 358.

However, optimal production faces challenges related to agronomic practices, particularly regarding seeding rates. While the Department of Agriculture recommends 2.5 bushels of paddy seeds per acre, many farmers in the Sammanthurai area of Ampara district use significantly higher rates of 4-6 bushels per acre, overlooking variety-specific tillering potential. Research indicates that rice yield is influenced by various factors including effective tillers per plant, spikelets per plant, branches per panicle, panicle length, and thousand grain weight (Hamid *et al*., 2011) [9]. This study therefore aims to investigate the effect of different seed rates on the growth and yield parameters of BG 94-1 rice variety in the Sammanthurai area, contributing to the development of area-specific seeding recommendations for optimal crop productivity.

Materials and Method

Experimental Location

The study was conducted at the Rice Research Station under the Department of Agriculture, situated in, Sammanthurai area in Ampara District of Sri Lanka. This area falls under DL2b of Agro Ecological zones in Sri Lanka.

Experimental structure

The experiment designed in Randomized Complete Block Design (RCBD) to face potential field variability. Five different seed rate treatments were used as treatments, each replicated four times across the experimental area. The treatments ranged from 2.5 to 4.5 Bushels per Acre, specifically: T1 - 2.5, T2 - 3.0, T3 - 3.5, T4 - 4.0, and T5 - 4.5 Bushels/Acre. Each experimental plot was carefully measured and established at 6m x 3m, providing an adequate area of 18 square meters for comprehensive observation and data collection.

Land Preparation

The land preparation process began with initial ploughing on 1st week of May 2024, followed by a secondary land preparation phase conducted two weeks later. This timing allowed for optimal soil conditions and decomposition of remaining crop residues. After thorough preparation, the field was systematically divided into experimental plots according to the predetermined treatment structure, ensuring uniform conditions across all treatments.

Seed Preparation and Sowing

The BG 94-1 rice variety used in a specific pre-germination treatment protocol. Seeds were initially soaked in water for a 24-hour period to initiate the germination process. Following the soaking period, the water was drained, and the seeds were incubated for an additional 48 hours to ensure uniform germination. The pre-germinated seeds were then broadcasted directly onto the prepared plots according to designated seed rate treatments.

Irrigation and Weed Management

The irrigation system utilized small channels to ensure consistent water supply throughout the growing period. Weed control was implemented through a two-stage approach. Initially, Pretilachlor, a pre-emergence herbicide (300 g/L EC), was applied at a rate of 80 mL per 16 L of water three days after seed broadcasting. This was followed by manual weeding one month after sowing to control any subsequent weed growth.

Fertilizer Application

Fertilizer management strictly followed the Department of Agriculture's recommendations for rice cultivation in the region. The application rates and timing were maintained consistently across all treatments to isolate the effects of varying seed rates.

Data Collection and Measurements

Plant Population Density

Plant population measurements were conducted using a systematic sampling approach. A 50 cm × 50 cm quadrat was randomly placed three times within each plot. All plants within the quadrat were counted, and the results were extrapolated to determine plant density per square meter.

Tiller Count

Tiller assessment followed the same quadrat sampling methodology used for plant population density. All tillers, including the mother plant, were counted within the 50 cm × 50 cm quadrat, with three random samples taken per plot.

Morphological Parameters

Plant development was monitored through several key morphological measurements. Plant height was measured from the base to either the tip of the panicle or the uppermost leaf, using a meter tape with measurements recorded in centimeters. Panicle length was similarly measured using a meter tape. Flowering time was carefully monitored through daily morning observations of panicle emergence.

Grain Parameters

Grain development was assessed through multiple parameters. Both filled and unfilled grains per panicle were counted to determine grain filling efficiency. Additionally, thousand-grain weight was measured in both fresh and dry conditions.

Statistical Analysis

The collected data were statistically analyzed using SAS software. This analysis included variance assessment to determine treatment effects and mean separation to identify significant differences between seed rate treatments.

Results and Discussion

Seedling number

Table 1 : Mean seedling number, Tiller number and plant height of different treatments

Treatment	Seedling number	Tiller number	Plant Height
T1- 2.5 Bushels / Acr	**299.25±1.99 ^{d}**	461.00±3.43 ^{a}	90.75±0.27 ^{a}
T2- 3.0 Bushels / Acr	323.50±1.01 ^{cd}	507.50±3.77 ^{a}	89.75±0.11 ^{a}
T3- 3.5 Bushels / Acr	346.00±0.58 ^{c}	447.75±2.83 ^{a}	92.00±0.24 ^{a}
T4- 4.0 Bushels / Acr	424.00±0.89 ^{b}	443.25±4.43 ^{a}	91.00±0.15 ^{a}
T5- 4.5 Bushels / Acr	469.25±0.75 ^{a}	460.00±2.51 ^{a}	91.75±0.26 ^{a}
Sig	*****	**Ns**	**Ns**

Values represent mean± standard error of four replicates. Means followed by the same superscripts in a same column are not significantly different at 0.05 probability level according to DMRT. '*' and 'ns' represents significant at P<0.05 and not significant, respectively.

It was observed that there were significant differences (P<0.05) among the treatments in terms of seedling number (Table 01). The treatment with the highest seed rate of 4.5 bushels/acre (T5) exhibited the significantly maximum number of seedlings. This suggests that a higher seed rate resulted in a more significant number of germinated seeds and subsequently a higher seedling count. This could be attributed to a denser initial seeding leading to a greater number of viable seeds germinating and establishing as seedlings. Conversely, the treatment with the lowest seed rate of 2.5 bushels/acre (T1) showed the lowest seedling number as significant level. A lower seed rates likely resulted in fewer seeds available for germination and establishment, thus leading to a lower seedling count. The experiment highlighted the importance of seed rate in determining the initial seedling count in paddy growth. Higher seed rates, such as 4.5 bushels/acre, tended to promote a greater number of seedlings, indicating potential benefits in terms of establishing a robust plant population early in the growth cycle.

Tiller number

As showed in Table 01, it was observed that there were no significant differences (P>0.05) in tiller number across the various treatments. This suggests that the different seed rates (ranging from 2.5 to 4.5 bushels/acre) did not have a statistically significant impact on the tillering capacity of the paddy plants.

Thus, lower seeding rate may results plants with enough space they would get more radiation, nutrient and moisture to produce more tillers per plant. This work was in agreement with the findings of Oghalo (2011) [17] who declared significant differences in number of tillers per plant caused by the interaction effect of rice variety and plant spacing.

The difference response of variety in producing tillers per plant was due to the variation in genetic makeup of the variety (Sohel *et al*., 2009). The result was also supported by Anyang (2011) [1], who reported that tillering per plant were significantly (p < 0.001) influenced by variety and plant density. There were also significant influences in terms of total tillers per plant due to interaction effect of variety and plant density (Sohel *et al*., 2009). The result was in agreement with Jember *et al*. (2016) who reported that significant variation in the number of productive tillers per plant was observed among rice varieties.

Plant Height

It was observed that there were no significant differences (P>0.05) in plant height across the different treatments (Table 01). This indicates that the range of seed rates tested, spanning from 2.5 to 4.5 bushels/acre, did not lead to statistically significant variations in the height of the paddy plants.

This result was also in agreement with the results of Merkebu, and Techale (2015) [15] as well as Anyang, 2011) [1] who reported that plant height was significantly (P < 0.01) different among rice varieties. Lack (2012) [14] revealed that, late maturing cultivars have longer development periods and taller in height in comparison with early maturing cultivars.

However different seeding rates did not cause significant change in plant height of all the varieties. This result is in agreement with previous researches who reported that plant height was not significantly influenced by plant spacing. It was also stated that planting density had no significant effect on plant height (Gizework, 2010) [7]. In contrary, Asif *et al*., (2014) [2] reported the presence of statistically significant plant height differences different among seeding rate treatments. In addition, Esmaeil *et al*. (2012) [13] also recorded the tallest plants at lower plant density while plant height decreased when the density was increased.

Flower maturity, Plant height at maturity and Panicle number

Table 2: Mean time taken for Flower maturity, Plant height at maturity and Panicle number

Treatment	Flower maturity	Plant height at maturity	Panicle no
T1- 2.5 Bushels / Acr	43.75±0.63 b	**99.50±0.28 a**	95.50±0.29 c
T2- 3.0 Bushels / Acr	62.50±1.25 ab	95.00±0.13 b	104.00±0.26 bc
T3- 3.5 Bushels / Acr	75.00±1.02 ab	90.25±0.13 c	**131.50±1.21 a**
T4- 4.0 Bushels / Acr	87.50±0.72 a	86.75±0.05 cd	123.25±0.43 ab
T5- 4.5 Bushels / Acr	62.50±1.61 ab	85.00±0.16 d	**127.00±0.18 a**
Sig	Ns	*	*

Values represent mean± standard error of four replicates. Means followed by the same superscripts in a same column are not significantly different at 0.05 probability level according to DMRT. '*' and 'ns' represents significant at P<0.05 and not significant, respectively.

There were no significant differences (P>0.05) observed in flower maturity across the various treatments (Table 02). This implies that the range of seed rates tested did not result in a statistically significant impact on the timing or uniformity of flower maturation in the paddy plants.

The lack of significant differences in flower maturity among the treatments suggests that the varying seed rates did not distinctly influence the flowering process. Other factors such as environmental conditions (temperature, humidity, photoperiod), soil quality, nutrient availability, and genetics might have played a more dominant role in determining the timing and uniformity of flower maturation. While the experiment revealed significant differences in seedling number based on varying seed rates, it was observed that there were no significant differences in flower maturity. This emphasizes the complexity of plant growth and development, where multiple factors can influence different stages of the plant's life cycle, and a comprehensive understanding of these factors is essential for successful crop management.

Plant height at maturity

The results of the experiment demonstrated a significant difference (P<0.05) in plant height at maturity among the different treatments (Table 02). This implies that the seed rates employed had a notable influence the ultimate height of the paddy plants when they reached maturity. Specifically, the treatments with lower seed rates, T1 (2.5 Bushels/Acre) was displayed higher significant values in plant height at maturity. This suggests that a relatively lower seed rate resulted in taller paddy plants at the maturity stage. In contrast, the treatment with the highest seed rate of 4.5 bushels/acre exhibited the lowest plant height at maturity. This suggests that an increase in seed rate led to a decrease in the height of the paddy plants when they reached the maturity stage. The experiment revealed a significant relationship between seed rate and plant height at maturity. Lower seed rates were associated with taller paddy plants at maturity, while higher seed rates resulted in a decrease in plant height. These findings provide valuable insights into the influence of seed rate on paddy plant growth and can guide optimal seed rate selection for achieving desired plant height characteristics at maturity.

Panicle number

The results of the experiment demonstrated significant differences (P<0.05) in the number of panicles across the various seed rate treatments (Table 02). This implies that the seed rates used had a notable influence on the quantity of panicles, which is a critical factor contributing to overall crop yield.

Among the different seed rate treatments, the seed rates of 3.5 bushels/acre, and 4.5 bushels/acre were associated with higher numbers of panicles. This suggests that using these seed rates resulted in a greater number of panicles per unit area, which is advantageous for potential yield. Conversely, the lowest number of panicles was recorded in the treatment with the lowest seed rate, which was 2.5 bushels/acre. This indicates that a lower seed rate led to a reduction in the number of panicles. The experiment revealed a significant correlation between seed rate and the number of panicles. Higher seed rates (3.5, and 4.5 bushels/acre) were associated with an increased number of panicles, suggesting a positive impact on potential crop yield.

Table 3: Mean panicle length, filled grains number and unfilled grains number

Treatment	Panicle length	Filled grains	Unfilled grains
T1- 2.5 Bushels / Acr	22.96±0.03 ^{a}	534.75±4.75 ^{a}	219.25±1.50 ^{a}
T2- 3.0 Bushels / Acr	22.90±0.04 ^{a}	523.75±1.67 ^{a}	262.25±2.64 ^{a}
T3- 3.5 Bushels / Acr	22.89±0.07 ^{a}	491.50±1.96 ^{a}	267.50±4.05 ^{a}
T4- 4.0 Bushels / Acr	21.57±0.11 ^{a}	487.50±7.87 ^{a}	188.50±5.31 ^{a}
T5- 4.5 Bushels / Acr	22.34±0.06 ^{a}	511.00±5.47 ^{a}	221.50±2.87 ^{a}
Sig	**Ns**	**Ns**	**Ns**

Values represent mean± standard error of four replicates. Means followed by the same superscripts in a same column are not significantly different at 0.05 probability level according to DMRT. '*' and 'ns' represents significant at P<0.05 and not significant, respectively

Panicle length, Filled grains and Unfilled grains

The results of the experiment revealed that there were no significant differences (P>0.05) in panicle length, as well as in the number of filled and unfilled grains, across the various seed rate treatments (Table 03). This implies that the different seed rates did not have a statistically significant impact on these particular aspects of the paddy plant. Panicle length is a key factor that can influence the overall yield and quality of the crop. In this experiment, the absence of significant differences in panicle length suggests that varying the seed rates within the specified range did not lead to variations in panicle length.

Similar results were recorded by Mondal and Puteh (2013) and Gizework (2010) [7] indicating that panicle length was not significantly influenced by spacing. Opposite results were also reported by Hamid *et al*. (2011) [9] in which the maximum panicle length was measured from wider plant spacing and minimum from narrower, while Khalifa *et al*. (2014) [13] reported higher panicle length from increased seeding rates.

The increase in plant competition over the uptake of water, nutrients and other resources may be decrease in individual plant leaf area, and the increase in shading and respiration which may results loss of individual plant grain per panicle under higher seeding rates. Ganie *et al*., (2013) [6] who revealed that number of grains per panicle was increased at lower seeding rate, but the number of filled spikelets reduced with an increase in seeding rate. At a wider spacing more availability of growth resources, i.e. nutrients, moisture, and light might have resulted in increase in chlorophyll which might have led to higher photosynthetic rate and ultimately availability of more of photosynthetic for sink during grain formation. When rice plants were planted wider, they could get more enough to grow and produce more tillers which would become fertile and produce more grains. With more space where they grow, rice plants' roots became larger and could be better able to draw nutrients from the soil to produce more grains. Similar results were reported by Yordanos (2013) who stating that wider row spacing led to significantly higher number of grains per panicle than the closer spacing.

Table 4: Mean seed dry weight and thousand seed weight

Treatment	Thousand seeds weight	Dry weight
T1- 2.5 Bushels / Acr	26.48 ± 0.04 ^{a}	8016.25± 38.98 ^{a}
T2- 3.0 Bushels / Acr	24.49 ± 0.12 ^{a}	7915.00± 56.46 ^{a}
T3- 3.5 Bushels / Acr	25.55 ± 0.12 ^{a}	6862.50± 94.71 ^{a}
T4- 4.0 Bushels / Acr	26.77 ± 0.18 ^{a}	7830.00± 37.16 ^{a}
T5- 4.5 Bushels / Acr	27.03 ± 0.15 ^{a}	8145.00± 46.99 ^{a}
Sig	**Ns**	**Ns**

Values represent mean± standard error of four replicates. Means followed by the same superscripts in a same column are not significantly different at 0.05 probability level according to DMRT. '*' and 'ns' represents significant at P<0.05 and not significant, respectively.

Dry weight and Thousand Seeds weight

There were no significant differences (P>0.05) observed in the dry weight and thousand seed weight of the paddy crop across the various seed rate treatments (Table 04). This implies that altering the seed rates within the specified range did not result in statistically significant variations in the dry weight and the weight of a thousand seeds of the harvested paddy.

Similar findings have been reported by Mondal and Puteh (2013); and Sohel *et al*., (2009) in which thousand grains weight was not significantly influenced by spacing. In the contrary, Yordanos (2013) declared that maximum thousand grains weight in wider spacing which was also supported by Tekle and Wedajo (2014) who reported that increased plant density decreased thousand grains weight of rice.

Conclusions

The study indicated a significant difference in seedling number among the treatments, with the highest seedling count observed in the treatment using 4.5 bushels per acre and the lowest in the treatment with the lowest seed rate of 2.5 bushels per acre. However, there were no significant differences observed between the treatments regarding tiller number, plant height, flower maturity, panicle length, and filled and unfilled grains. Interestingly, it was found that plant height at maturity exhibited significant variation among the treatments, with treatments T1 (2.5 bushels per acre) displaying the highest values. Conversely, the treatments with the highest seed rate of 4.5 bushels per acre recorded the lowest plant height at maturity, indicating an inverse relationship between seed rate and plant height. Moreover, the study highlighted a significant difference in the number of panicles based on different seed rates, with higher panicle numbers observed at seed rates of 3.5 and 4.5 bushels per acre. According to the results, it was revealed that the 2.5 bushels per acre was showed the promising result for the growth and yield parameters of BG 94-1 rice variety in the Sammanthurai area, contributing to the development of area-specific seeding recommendations for optimal crop productivity.

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