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Effect Of Planting Method On Growth And Yield Of Rice Ratoon At Tana Delta Kenya

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Abstract
Rice remains a fundamental staple food that sustains a significant portion of the Kenyan population. With the population on rise, it is projected that Kenya's rice production must expand to satisfy the ever-growing food demand. To achieve this, it is essential for Kenya to enhance sustainable rice production per unit of land. Owing to this, the cultivation of rice ratooning presents a viable option. Nevertheless, it is crucial to assess various planting methods of the main crop to facilitate the successful cultivation of ratoon crops. A field experiment was conducted utilizing AT054 and Komboka rice varieties within Tana Delta Irrigation Project-Rice (TDIP-R) scheme, comparing four planting techniques: machine test transplanting, line transplanting, random transplanting and direct seeding of the main crop on the performance of ratoon crops. This study spanned from mid-January to early April, 2024. The experiment was organized in a Randomized Block Design (RBD). Data on plant stand, height, number of tillers, fertile tillers, panicle length, number of spikelets and dry grain yield were collected and analyzed using statistical analysis of variance (ANOVA) to determine the mean effects of planting methods of the main crop on the regeneration of ratoon crop. Further, an analysis using Pearson's correlation coefficients was performed to determine the association between grain contributing characters and the dry grain of the ratoon crops. The direct seeding of the main crop of AT054 (3.57 ton/ha) and Komboka (3.48) varieties exhibited higher dry grain yields in the ratoon crop, however, the lowest dry grain yield recorded from line transplanting of the main crop of AT054 (3.09 ton/ha) variety was not were not significantly different. The grain yield of the ratoon crop showed a positive correlation with hills density/m^2, tillers/hill, fertile tillers/hill, total spikelets/panicle and filled spikelets/panicle, while it exhibited negative correlation with plant height, panicle length, non-filled spikelets/panicle and affected spikelets/panicle. Hence, these characters may serve as selection criteria for achieving high grain yields in relation to planting methods. The findings indicate that direct seeding of the main crop can be utilized for better cultivation of the ratoon crop in the area. Furthermore, these findings highlight the potential for improving the aforesaid crop traits through appropriate agronomic practices in ratooning of AT054 and Komboka varieties.

Keywords: *Planting, Mechanical, Manual, Direct seeding, Ratoon crop*

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I. Introduction

Ratoon rice – one planting and two harvests cropping system – refers to the practice of utilizing a second harvest of tillers that regenerate from stubbles lasting after reaping the main rice crop[1]. This process enables the regrowth and production of panicles[2]. Previous studies have indicated that gains in rice yield are reliant on higher grain yield and more recurrent harvests on the current land[3,4]. Ratooning technology has been implemented in countries such as India, China, Thailand, Phillipines, Taiwan and United States[5,6].

The utilization of ratoon cropping is perceived as a hopeful system to expand rice production, since supplementary grain yield can be gained from the renewing crop without incurring the cost of land preparation, seed acquisition, sowing and transplanting[7,8,9,10]. Reports indicate that, depending on the geographical area, cultivation of ratoon crop can lead to reduction in harvest time, water consumption and production inputs by 40%, 60% and 38%, respectively[11]. Furthermore, in other contexts, nurturing of ratoon crop has been shown to reduced labour and seed inputs by 29% and 52%, respectively[12].

In light of swelling population, it is essential to double rice production to satisfy the increasing food demand. Achieving this goal necessitates improvements in crop production, either by enhancing the yield per unit area of land[13] or by harvesting current crops more recurrently[14]. Considering this, cultivating rice ratooning emerges as a viable option, regarded a green, efficient and simplified planting pattern to improve multiple cropping index of rice on a limited land resources[15].

Obtainable data indicate that the soil richness within Tana Delta Irrigation Project-Rice (TDIP-R) scheme[16] is apposite for rice cultivation[17,18]. In this context, it is essential to explore innovative strategies aimed at minimizing inputs such as seeds, fertilizers, chemicals and labour while simultaneously doubling rice yields on the same land to ensure sustainability. To safeguard food security and total rice output, it is crucial to develop effective approaches for upgrading yields from ratoon crops. Nevertheless, there is little knowledge regarding rice ratooning practices in Kenya. To answer this, the current study was undertaken to evaluate the ratooning potential of AT054 and Komboka rice varieties, as well as assess the effect of different planting techniques of the main crop on the grain yield of ratoon crop for these selected varieties.

II. Materials And Methods

Description of experimental site

The study concentrated within Tana Delta Irrigation Project-Rice (TDIP-R) scheme near Kulesa Village in Tana River County, with geographical coordinates of latitude 2°10′ – 2°30′S and longitude 40°10′ – 40°20′E, positioned at an elevation of 20m (65.6168 feet) above sea level[19]. Initially, the soil in the trial area was categorized as Fluvisoils, which area further divided into eutric and vertic types, characterized by black cotton soils composed of clay, loam and alluvial deposits, exhibiting moderate to high fertility[16]. However, due to the frequent flooding from meandering and change in course of The Tana River, accompanied with depositions, the soils are often stratified with yellowing-brown sands and clay rich in Micas[20]. The Tana Delta area experiences a semi-arid climate, marked by low and inconsistent rainfall. The mean annual rainfall ranges between 300 – 900 mm, with average temperature of 30 °C and average humidity level of 85%[20].

Description of land preparation

The land preparation process for establishing the primary crop prior to ratoon crop involved the removal of trees, shrubs, bushes and other vegetations present, as well as extraction of tree stumps. This land clearing was accomplished through both mechanical and manual techniques. A variety of mechanical equipment were utilized during the land preparation phase. These included a D8 bulldozer felling trees and removing tree stumps, an 80Hp tractor equipped with a disc plough for tilling, and an 80Hp tractor equipped with a heavy harrow disc for initial harrowing to refine the soil and break up clumps. Subsequently, a 120Hp grader was used for leveling the land to ensure consistent flood irrigation throughout the crop growth period. To achieve a uniform level, a dumpy level was utilized to identify points on a horizontal plane, which were then adjusted according to surveyor’s specifications. To keep the fields free from weeds, a pre-plant non-selective herbicide, specifically 4 L/ha Kausha 480 SL (Gylphosate 480g/L) was applied aerially using drone equipped with tank and standard flat fan spray nozzles.

Description of experimental materials

The ratoon crops examined in this study were derived from the primary crops of AT054 and Komboka varieties, of which their seeds were sourced from Afritec and Kenya Agricultural and Livestock Research Organization (KALRO), respectively. Both varieties are characterized by their aromatic qualities and moderate resistance to rice blast, with yield potential of 8 ton/ha. The maturation periods for AT054 and Komboka varieties are 125 and 145 days, respectively.

Preparation of the seedbeds

In preparation for manual transplanting treatments, nurseries measuring 10 m x 1.5 m for AT054 variety main crop were established adjacent to the main fields. The beds were elevated 4 – 6 cm above the ground surface and well leveled. Seeds were soaked for 24 hours at the rate of 50kg/ha and subsequently incubated in polythene bags for 48 hours. The pre-germinated seeds were then evenly distributed on a puddled nursery beds in the evening. The seedlings became ready for transplanting after a period of 14 – 21 days. For machine test transplanting treatment, seeds of AT054 variety underwent similar conditions and raised on modified polythene, which served as mat-type nurseries to facilitate machine transplanting. The nurseries were maintained with adequate moisture, nutrient application and crop protection products application. Prior to transplanting, the nurseries were irrigated, healthy seedlings uprooted, followed by washing the seedlings in running water, transporting, and transplanting them in well-leveled flooded fields.

Experimental layout

The experiment was structured using a Randomized Block Design (RBD). This involved approach entailed planting the larger fields of paddy rice using consistent planting techniques, after which the larger blocks were subdivided into smaller sections for the purpose of data collection. The smaller sections, measuring 2 m x 2 m, were randomly assigned within the larger blocks, with each containing five sampling units.

Description of planting methods as treatments

The study evaluated four distinct planting techniques: machine test transplanting, line transplanting, random transplanting and direct seeding, focusing on the main crop from which the performance of ratoon crop was assessed. The main crop was established using the following methods. Machine test transplanting of AT054 variety seedlings was conducted with an adjustable 21Hp Kubota NSD8 8-Row rice transplanter (rotary type), maintaining a spacing of 30 cm x 15 cm, with one seedling/hill planted at a depth of 1.7 – 5 cm. This rice transplanter utilized modified mat-type seedlings. Line/straight row transplanting of AT054 variety was performed manually along marked transplanting lines, with a spacing of 20 cm x 20 cm, allowing for 2 – 3 seedlings/hill, contingent upon the characteristics of the seedlings. Random transplanting of AT054 variety involved the manual placement of seedlings at the rate of 2 – 3 seedlings/hill, without a definite space between plants, although spacing was limited to a minimum of 10 cm and a maximum of 25 cm. The seedlings placed at a depth of 2 – 3 cm. Empty spaces were filled with seedlings within 7 – 10 days post-transplanting, utilizing surplus seedlings from the nurseries. Direct seeding (dry) was executed by broadcasting 25 Kg/acre of both AT054 and Komboka varieties using an 80Hp tractor equipped with a PTO-driven flicker-type spreader. The spreader was calibrated to ensure even seed distribution across the experimental area. The young seedlings were regularly flashed with irrigation water to maintain soil moisture prior to the permanent flooding in the fields.

Management of the ratoon crop

The main crop from which ratoon crop in the study was raised was harvested by a 120Hp FMWorld Ruilong Plus 4LZ-6.0P (sack-type) rice combine harvester. The main crop was cut at a height of 20 – 30 cm above the ground, contingent upon the varying levels of the field. Stubbles were removed manually to facilitate the management of the ratoon crop. The crop was managed under flood irrigation system. At 14 days after harvest (DAH) of the main crop, the ratoon crop received a top dress of 80 Kg N/ha Urea fertilizer. The management of insect pests, fungal diseases and weeds within experimental plots were conducted in timely manner using 0.5 L/ha Escort 19 EC (Emamectin benzoate 19g/L) insecticide, 0.5 L/ha Twiga-Epox 250 SC (Epoxiconazole 250g/L) fungicide and 3.5 L/ha Topshot 60 OD (Cyhalofop-butyl 500g/L + Penoxsulam 100g/L) selective herbicide, respectively. Additionally, manual weeding was utilized to complement selective herbicide application during reproductive stages of the crop development.

Collection of the data

Data collection occurred at weekly intervals utilizing a simple random sampling technique[21], with parameters assessed within 1m^2 area in each designated plot. The assessment of the ratoon crop included various parameters such as plant stand, plant height, number of tillers, tillering ability, plant vigour, fertile tillers, panicle length, total spikelets, filled spikelets, non-filled spikelets, affected spikelets and dry grain yield, as detailed in Appendix I. The evaluation of tillering ability and plant vigour was conducted according to the scales described by[22], as referenced in Appendix II.

Statistical analysis of the data

The data gathered underwent statistical analysis of variance (ANOVA) utilizing GenStat 15th Edition software. The effect of the main crop's planting methods on the regeneration of ratoon crop was distinguished using Fisher's Protected Least Significant Difference at a significance level of $p<0.05$. Additionally, a Pearson's correlation coefficients analysis was performed with IBM SPSS Statistics Version 21 package to determine the relationship between grain contributing characters and the dry grain of the ratoon crop.

III. Results

Plant height

The growth of ratoon crop is shown in Table 3.1. The height of ratoon crops varied between 91.24 and 101.74 cm across various planting methods at maturity, which was assessed 66 days after harvest (DAH). Among the transplanting techniques, the machine test achieved height of 101.36 cm, while line transplanting achieved 101.74 cm for AT054 variety, both of which were significantly taller than the direct seeding method which achieved a height of 91.92 cm for the same variety. the average plant height for random transplanting of AT054 variety and direct seeding of Komboka variety were recorded at 98.24 cm and 97.56 cm, respectively. Throughout the growing season, the direct transplanting of Komboka variety produced shorter plants.

Table 3.1: Mean plant height (cm) of ratoon crop from different planting methods

	DAH	16	27	34	48	58	66
Variety	**Planting**	**Tillering**		**PI/B**	**H/M**	**Dough**	**Mature**
AT054	Machine test	64.48[b]	81.50[c]	79.86[c]	93.26[bc]	95.32[c]	101.36[bc]
AT054	Line transplant	72.38c	73.88[b]	89.60[d]	97.84[c]	98.98[c]	101.74[c]
AT054	Random transplant	65.24[b]	76.12[b]	81.82[c]	91.96[b]	95.10[c]	98.24[bc]
AT054	Direct seeding	61.78[b]	72.24[b]	66.76[b]	90.98[b]	89.26[b]	91.92[a]
Komboka	Direct seeding	46.16[a]	49.20[a]	57.56[a]	68.44[a]	80.18[a]	97.56[b]
LSD		**3.78**	**4.49**	**4.14**	**5.19**	**4.30**	**3.99**
CV (%)		**3.70**	**4.50**	**5.90**	**2.70**	**1.50**	**2.00**

Data are means of five samples per block. Values within the same column with the same letter(s) are not significantly different at p<0.05 significance level. PI/B – Panicle initiation/Booting, H/M – Heading/Milk, DAH – Days after harvesting.

Number of tillers

Table 3.2 indicates results pertaining to tillers count. The regeneration of tillers from stubbles exhibited a gradual increase, reaching a peak at various stages of the ratoon crop, which was influenced by the planting method used. Subsequently, the number of tillers declined with exception of the direct seeding of Komboka variety. This observation underscores the significant impact of planting method on tiller regeneration. Among the ratoon crops, the machine test transplanting (17.14) and random transplanting (18.56) of AT054 variety recorded the highest number of tillers/hill at 34 DAH, followed by the direct seeding of AT054 variety, which recoded 20.06 tillers/hill at 48 DAH. Additionally, the ratoon crop from line transplanting of AT054 variety (16.62) and direct seeding of Komboka variety (15.42) achieved the highest number of tillers/hill at 58 and 66 DAH, respectively. At maturity (66 DAH), ratoon crop from direct seeding of AT054 variety (18.88) demonstrated a significantly higher number of tillers/hills compared to other plant methods.

Table 3.2: Mean tillers per hill of ratoon crop from different planting methods

	DAH	16	27	34	48	58	66
Variety	**Planting**	**Tillering**		**PI/B**	**H/M**	**Dogh**	**Mature**
AT054	Machine test	8.84[c]	12.20[c]	17.14[c]	13.56[c]	13.66[ab]	15.74[a]
AT054	Line transplant	8.58[bc]	11.92[c]	14.04[b]	12.02[bc]	16.62[c]	13.36[a]
AT054	Random transplant	6.40[a]	11.98[c]	18.56[c]	10.82[ab]	17.78[c]	14.04[a]
AT054	Direct seeding	8.88[c]	9.66[b]	14.60[b]	20.06[d]	16.24[bc]	18.88[b]
Komboka	Direct seeding	7.56[ab]	7.96[a]	8.98[a]	9.54[a]	11.70[a]	15.42[a]
LSD		**1.20**	**1.70**	**2.24**	**1.92**	**2.63**	**2.74**
CV (%)		**8.40**	**7.60**	**6.80**	**8.40**	**8.20**	**6.40**

Data are means of five samples per block. Values within the same column with the same letter(s) are not significantly different at p<0.05 significance level. PI/B – Panicle initiation/Booting, H/M – Heading/Milk, DAH – Days after harvesting.

Tillering ability

Results for tillering capacity are shown in Table 3.3. The tillering ability, as indicated by the number of tillers/hill, varied across various planting methods. The ratoon crop derived from the direct seeding of AT054 variety achieved a score of 3.84 (good), demonstrating a significant difference in tillering ability compared to other planting methods at 66 DAH. Conversely, the line transplanting of AT054 regenerated ratoon crop with the lowest tillering ability, receiving a score of 5.32 (medium).

Table 3.3: Mean tillering ability per hill of ratoon crop from different planting methods

	DAH	16	27	34	48	58	66
Variety	**Planting**	**Tillering**		**PI/B**	**H/M**	**Dough**	**Mature**
AT054	Machine test	6.40[a]	5.36[a]	4.16[a]	5.36[b]	5.16[bc]	4.72[b]
AT054	Line transplant	6.40[a]	5.52[a]	5.08[b]	5.56[b]	4.56[ab]	5.32[b]
AT054	Random transplant	7.32[b]	5.48[a]	4.04[a]	5.84[bc]	4.16[a]	5.08[b]
AT054	Direct seeding	6.40[a]	6.28[b]	5.00[b]	3.84[a]	4.56[ab]	3.84[a]
Komboka	Direct seeding	6.84[ab]	6.68[b]	6.32[c]	6.32[c]	5.64[c]	4.64[b]
LSD		**0.49**	**0.52**	**0.63**	**0.51**	**0.61**	**0.68**
CV (%)		**4.20**	**4.20**	**3.90**	**4.10**	**5.20**	**3.70**

Data are means of five samples per block. Values within the same column with the same letter(s) are not significantly different at p<0.05 significance level. PI/B – Panicle initiation/Booting, H/M – Heading/Milk, DAH – Days after harvesting. Tillering Ability Scale: 1 – Very high, 3 – Good, 5 – Medium, 7 – Low, 9 – Very low (Source: IRRI, 2002).

Plant vigour

Results for tillering capacity are shown in Table 3.4. The planting methods used had a significant influence on the vigour of the ratoon crop. As the ratoon crop progressed from 16 to 66 DAH, there was a notable increase in plant vigour. At the point of maturity (66 DAH), the ratoon crop from machine test transplanting of AT054 exhibited the highest vigour achieving a score of 4.52. Conversely, the lowest vigor was observed in the ratoon crop from line transplanting of AT054 variety and direct seeding of Komboka variety, both of which recorded a score of 5.00.

Table 3.4: Mean plant vigor per hill of ratoon crop from different planting methods

	DAH	16	27	34	48	58	66
Variety	**Planting**	**Tillering**		**PI/B**	**H/M**	**Dough**	**Mature**
AT054	Machine test	5.60^{a}	5.16^{a}	5.08^{a}	4.92^{a}	5.00^{ab}	4.52^{a}
AT054	Line transplant	5.96^{a}	5.28^{a}	5.48^{ab}	5.00^{a}	5.08^{b}	5.00^{c}
AT054	Random transplant	6.52^{b}	5.04^{a}	5.32^{a}	5.00^{a}	4.72^{a}	4.92^{bc}
AT054	Direct seeding	6.00^{a}	5.16^{a}	5.36^{ab}	5.00^{a}	5.00^{ab}	4.68^{ab}
Komboka	Direct seeding	7.04^{c}	6.20^{b}	5.76^{b}	6.80^{b}	5.40^{c}	5.00^{c}
LSD		**0.48**	**0.35**	**0.4**	**0.23**	**0.3**	**0.29**
CV (%)		**4.20**	**3.60**	**4.00**	**0.40**	**0.60**	**1.30**

Data are means of five samples per block. Values within the same column with the same letter(s) are not significantly different at p<0.05 significance level. PI/B – Panicle initiation/Booting, H/M – Heading/Milk, DAH – Days after harvesting. Vigour Scale: 1 – Extra vigorous, 3 – Vigorous, 5 – Normal, 7 – Weak, 9 – Very weak (IRRI, 2002).

Tillers fertility

Data concerning the fertility of tillers are demonstrated in Table 3.5. An analysis of various plant methods applied to the ratoon crop revealed that there were no significant differences in the following parameters; hills/m^2, tillers/hill, fertile tillers/hill, non-fertile tillers/hill and the percentage fertile tillers/m^2.

Table 3.5: Mean tillers fertility of ratoon crop from different planting methods

		Mature Grains (71 DAH)				
Variety	**Planting**	**H/m^2**	**T/H**	**FT/H**	**NFT/H**	**%FT/m^2**
AT054	Machine test	16.20^{a}	17.93^{a}	13.47^{a}	4.47^{a}	73.66^{a}
AT054	Line transplant	15.60^{a}	15.40^{a}	11.53^{a}	3.87^{a}	74.91^{a}
AT054	Random transplant	16.40^{a}	16.53^{a}	12.67^{a}	3.87^{a}	74.96^{a}
AT054	Direct seeding	15.60^{a}	17.47^{a}	12.67^{a}	4.80^{a}	70.59^{a}
Komboka	Direct seeding	17.40^{a}	16.80^{a}	13.13^{a}	3.67^{a}	76.51^{a}
LSD		**2.37**	**3.68**	**3.61**	**1.43**	**10.06**
CV (%)		**9.20**	**11.40**	**12.50**	**15.30**	**4.50**

Data are means of five samples per block. Values within the same column with the same letter(s) are not significantly different at p<0.05 significance level. H/m^2 – Hills/m^2, T/H – Tillers per hill, FT/H – Fertile tillers per hill, NFT/H – Non-fertile tillers per hill, DAH – Days after harvesting.

Panicle characteristics

The findings pertaining to the panicle components area shown in Table 3.6. The analysis of panicle characteristics of the ratoon crop; the total number of spikelets/panicle and the number of filled spikelets/panicle did not exhibit significant variations across the various planting techniques. However, panicle length, the number of non-filled spikelets/panicle, the number of affected spikelets/panicle, the percentage of filled spikelets/panicle and the percentage of affected spikelets/panicle demonstrated significant variations among the various planting techniques used. The ratoon crop derived from the line transplanting of AT054 variety exhibited the greatest panicle length at 25.94 cm, followed closely by random transplanting of AT054 variety at 25.48 cm, machine test transplanting of AT054 variety at 25.24 cm, direct seeding of Komboka variety at 24.62 cm and direct seeding of AT054 variety at 24.00 cm. The highest number of non-filled spikelets/panicle was noted in the ratoon crop from machine test transplanting of AT054 variety (20.16), and followed by line transplanting of the same variety (18.70), which were comparable to the direct seeding of AT054 variety (16.48), but significantly different from the direct seeding of Komboka variety (14.58) and random transplanting of AT054 variety (14.18). The number of affected spikelets/panicle varied significantly among the planting techniques, with highest incidence recorded in the ratoon crop from machine test transplanting of AT054 variety (16.98), while the lowest was observed in the ratoon crop from direct seeding of Komboka variety (3.38). The percentage of filled spikelets/panicle for the ratoon crop from direct seeding of Komboka variety, random transplanting of AT054 variety, direct seeding of AT054 variety, line transplanting of AT054 variety and machine test transplanting of AT054 variety was recorded at 87.50%, 87.31%, 85.23%, 83.92% and 82.05%, respectively. The highest and lowest percentage of affected spikelets/panicle were recorded in the machine test transplanting of AT054 variety and direct seeding of Komboka variety at 14.78% and 3.47%, respectively.

Table 3.6: Mean panicle attributes of ratoon from different planting methods

		Mature Grains (71 DAH)						
Variety	**Planting**	**PL (cm)**	**TS/P**	**FS/P**	**NFS/P**	**AS/P**	**%FS/P**	**%AS/P**
AT054	Machine test	25.24^{ab}	118.4^{a}	98.2^{a}	20.16^{b}	16.98^{d}	82.05^{a}	14.78^{d}
AT054	Line transplant	25.94^{b}	119.1^{a}	100.4^{a}	18.70^{b}	10.28^{bc}	83.92^{a}	9.27^{bc}

AT054	Random transplant	25.48^{b}	120.1^{a}	105.9^{a}	14.18^{a}	8.46^{b}	87.31^{b}	8.10^{b}
AT054	Direct seeding	24.00^{a}	114.6^{a}	98.1^{a}	16.48^{ab}	12.74^{c}	85.23^{ab}	11.46^{c}
Komboka	Direct seeding	24.62^{ab}	122.3^{a}	107.7^{a}	14.58^{a}	3.98^{a}	87.50^{b}	3.47^{a}
LSD		**1.37**	**12.55**	**12.42**	**3.75**	**3.22**	**3.30**	**2.84**
CV (%)		**2.00**	**9.30**	**10.40**	**13.80**	**19.10**	**2.50**	**29.10**

Data are means of five samples per block. Values within the same column with the same letter(s) are not significantly different at p<0.05 significance level. PL – Panicle length, TS/P – Total spikelets per panicle, FS/P – Filled spikelets per panicle, NFS/P – Non-filled spikelets per panicle, AS/P – Affected spikelets per panicle, DAH – Days after harvesting.

Dry grain yield

As for the yields, the findings are presented in Table 3.7. While the variations in yield across the four distinct planting methods were not statistically significant, the ratoon crop resulting from the direct seeding of AT054 variety achieved the highest dry grain yield of 3.57 ton/ha. This was followed by the ratoon crop from the direct seeding of Komboka variety at 3.48 ton/ha, the random transplant of AT054 variety at 3.42 ton/ha, the machine test transplanting of AT054 variety at 3.42 ton/ha, and finally, the line transplanting of AT054 variety at, 3.09 ton/ha, listed in order of decreasing yield.

Table 3.7: Mean yield of dry grains of ratoon rice crop from different planting methods

		Yield			
Variety	**Planting**	**g/m^2**	**Kg/Acre**	**Ton/Ha**	**% MC**
AT054	Machine test	340.00^{a}	1360.00^{a}	3.40^{a}	14.00
AT054	Line transplant	308.50^{a}	1234.00^{a}	3.09^{a}	14.00
AT054	Random transplant	342.00^{a}	1370.00^{a}	3.42^{a}	14.00
AT054	Direct seeding	357.00^{a}	1428.00^{a}	3.57^{a}	14.00
Komboka	Direct seeding	348.00^{a}	1392.00^{a}	3.48^{a}	14.00
LSD		**174.63**	**698.51**	**1.75**	
CV (%)		**5.30**	**5.30**	**5.30**	

Data are means of five samples. Means with the same letter(s) are not significantly different from each other at p<0.05 level of significance. Error lines represent standard deviation of the mean.

Correlation between grain yield and plant traits

Results showing relationship between grain yield and plant characters are presented in Table 3.8. The correlation between the number of tillers/hill (r=0.777, p=0.122), hills/m^2 (r=0.346, p=0.569), fertile tillers/hill (r=0.736, p=0.156) and the percentage fertile tillers/m^2 with the grain yield of ratoon crop was found to be positive, albeit not statistically significant. Differently, plant height (r=-0.774, p=0.124) exhibited a negative correlation with grain yield, which was also not statistically significant. These results indicate that, collectively, plant population, the number of tillers and plant height affect the grain yield of the ratoon crop.

Table 3.8: Pearson's correlation coefficients between grain yield and plant traits

	Height	**Tillers**	**Ability**	**Vigour**	**Hills/m^2**	**FT/H**	**NFT/H**	**%FT/m^2**	**Ton/Ha**
Height									
Tillers	-0.833 p = 0.080								
Ability	0.867 p = 0.057	-0.994** p = 0.001							
Vigour	0.135 p = 0.829	-0595 p = 0.289	0.522 p = 0.366						
Hills/m^2	0.076 p = 0.903	-0.179 p = 0.774	0.086 p = 0.890	0.332 p = 0.585					
FT/H	-0.155 p = 0.803	0.415 p = 0.487	-0.436 p = 0.463	-0.577 p = 0.309	0.567 p = 0.318				
NFT/H	-0.500 p =	0.815 p = 0.093	-0.746 p = 0.148	-0.858 p = 0.063	-0.602 p = 0.282	0.255 p = 0.679			

	0.391								
FT/m²	0.628 p = 0.257	-0.800 p = 0.104	0.738 p = 0.155	0.676 p = 0.210	0.712 p = 0.178	-0.026 p = 0.967	-0.954* p = 0.012		
Ton/Ha	-0.774 p = 0.124	0.777 p = 0.122	-0.819 p = 0.090	-0.405 p = 0.499	0.346 p = 0.569	0.736 p = 0.156	0.441 p = 0.457	0.396 p = 0.510	

** = Correlation is significant at the 0.01 level (2-tailed), * = Correlation is significant at the 0.05 level (2-tailed), p = p-value/Sig. (2-Tailed), N = 5. T/H – Tillers per hill, FT/H – Fertile tillers per hill, NFT/H – Non-filled tillers per hill, FT/m^2 – Filled tillers per m^2.

Correlation between grain yield and panicle traits

Results indicating relationship between grain yield and panicle attributes are indicated in Table 3.9. The total number of spikeletes/panicle (r=0.243, p=0.694), the number of filled spikelet/panicle (r=0.114, p=0.855), and the percentage of filled spikelets/panicle (r=0.375, p=0.534) exhibited a positive yet non-significantly correlation with the grain yield of ratoon crop. Differing, panicle length (r=-0.873, p=0.053), the total number of non-filled spikelets/panicle (r=-0.465, p=0.430), the number of affected spikelets/panicle (r=-0.302, p=0.959) and the percentage affected spikelets/panicle demonstrated a negative and non-significant correlation with the grain yield of the ratoon crop. Overall, these findings indicate that all these characters are central for yield improvement.

Table 3.9: Pearson's correlation coefficients grain yield and panicle traits

	PL	TS/P	FS/P	NFS/P	AS/P	%FS/P	%AS/P	Ton/Ha
PL								
TS/P	0.427 p = 0.473							
FS/P	0.087 p = 0.890	0.842 p = 0.074						
NFS/P	0.318 p = 0.603	-0.364 p = 0.547	-0.809 p = 0.097					
INS/P	0.042 p = 0.947	-0.688 p = 0.199	-0.903* p = 0.036	0.807 p = 0.099				
%FS/P	-0.264 p = 0.667	0.444 p = 0.454	0.854 p = 0.065	-0.990** p = 0.001	-0.881 p = 0.048			
%INS/P	0.058 p = 0.926	-0.706 p = 0.183	-0.898* p = 0.039	0.779 p = 0.121	0.997** p = 0.000	-0.857 p = 0.064		
Ton/Ha	-0.873 p = 0.053	0.243 p = 0.694	0.114 p = 0.855	-0.465 p = 0.430	-0.302 p = 0.959	0.375 p = 0.534	-0.036 p = 0.954	

** = Correlation is significant at the 0.01 level (2-tailed), * = Correlation is significant at the 0.05 level (2-tailed), p = p-value/Sig. (2-Tailed), N = 5. PL – Panicle length (cm), TS/P – Total spikelets per panicle, FS/P – Filled spikelets per panicle, NFS/P – Non-filled spikelets per panicle, AS/P – Affected spikelets per panicle, %FS/P = ((FS/P)/(TS/P))*100, %AS/P = ((AS/P)/(TS/P))*100.

IV. Discussion

The variance analysis indicated the presence of a significant difference among the various planting methods of the main crop concerning plant height, tillers/hill, panicle length, tillering ability, plant vigour, non-filled spikelet/panicle and affected spikelets/panicle in the ratoon crop. Conversely, no significant differences were revealed in hills density/m^2, fertile tillers/hill, non-fertile tillers/hill, total spikelets/panicle, filled spikelets/panicle and the grain yield. Although, hills density/m^2, tillers/hill, fertile tillers/hill, total spikelets/panicle, and filled spikelets/panicle did not show significant variation among the planting methods, the analysis of Pearson's correlation coefficients revealed that they had positive impact on grain yield, with the exception of non-filled spikelets/panicle, which had a negative impact on grain yield.

The transplanting (machine test, line, random) methods of AT054 variety of the main crop produced taller plants compare to direct seeding of both AT054 and Komboka varieties in the ratoon crop. This observation aligns with findings from[23], which indicated that transplanted rice exhibited significant greater plant height than that of direct seeded rice. The variation observed in plant height in the ratoon crop may be attributed to the planting method of the main crop, plant density and fertilizer application, as noted in previous studies[24,25].

The observed variation in tillering (tillers number, tillering ability) within the ratoon crop across various planting methods indicates that the methods used for the main crop have a significant influence on the regeneration of the ratoon crop. These findings resonate with studies conducted by[5], which indicated that various cultivation methods (such as transplanting, direct seeding, seedling throwing), significantly affected tillering ability of ratoon crops and translocation of the stubble dry matter, with transplanting proving to be the most effective method. Among the planting methods of the main crop, the ratoon crop derived from transplanted main crop exhibited lower numbers of tillers/hill in comparison to those from direct seeding method. These findings are corroborated by[26] who reported lower number of tillers in transplanted rice relative to that of directed seeded. The fluctuations in tillers/hill along the development cycle of the ratoon crop can be associated with previous findings indicating that excessive tillering can result in increased senescence, tiller abortion and higher population density, thereby elevating the risk of lodging due to diminished culm quality[27,28].

The tillering characteristic of ratoon crops is majorly influenced by the levels of nitrogen and nonstructural carbohydrates present in the stubble of the main crop, as indicated by various studies[29,30,31]. This characteristic is therefore a subject of genetic factors, the growth conditions of main crop and crop management practices that pertain to photosynthetic efficiency[32].

The findings in this study indicated the grain yield of ratoon crop was not significantly influenced by the planting methods of the main crop across the two varieties examined. Despite the lack of a notable difference in the grain yield of the ratoon crop, a positive relationship was observed between the number of tillers/hill and hills density/m^2 on grain yield. These findings indicate that enhancing the number of tillers/hill and hills density/m^2 is a feasible approach to boost the grain production in both planting methods used. Such findings were documented by[33,34] who noted that the rise in grain yield of hybrid rice was ascribed to and increased number of tillers. Furthermore, these outcomes align with previous studies on hybrid rice, which indicated that increased grain yield correlates with higher hill density, potentially due to the number of panicles/m^2 being the crucial yield component for achieving elevated grain yields[35]. Consequently,[36] emphasized that tillering in rice is a vital agronomic attribute influencing the number of panicles/unit area of land and overall grain making. While the rate of panicle-bearing tiller influences the grain yield of rice[37], excessive tillering can result in high rates of tiller abortion, inadequate grain setting, small panicle size, and ultimately diminish grain yields[9,38].

This study identified a positive correlation between grain yield of ratoon crops and various agronomic traits, in particular; the number of tillers/hill, fertile tillers/hill, total spikelets/panicle and filled spikelets/panicle across various plant methods. These findings concur with previously studies that demonstrated a significant positive association between the grain yield of both main crop and ratoon crop and the number of tillers/hill, fertile tillers/hill and fertile grain/panicle[39]. Likewise,[40,41] reported that rice yield directly depends on the degree of grain filling. The grain filling rate and weight accumulation in rice largely depends on spikelets position – superior spikelets located on the apical primary branches, which flower earlier, exhibit a faster grain filling process ultimately producing larger and heavier grains, as opposed to inferior spikelets situated on proximal secondary branches, which flower later, which tend to experience slower grain filling or may even be sterile, hence producing inferior grains[42].

Contrary, a negative correlation was observed between the grain yield of ratoon crops and plant attributes; notably, plant height, panicle length, the number of non-filled spikelets/panicle and the number of affected spikelets/panicle. These findings are in agreement with the findings of[43], who identified a negative correlation between plant height and grain weight of rice. However, they diverge from the findings of[39], who indicated that plant height positively influenced the yield of both main and ratoon rice crops. additionally,[32] reported that plant height and panicle length, as indicators of developmental duration, had an indirect effect on the spikelet number, thereby adversely impacting the yield weight of ratoon rice crops. This phenomenon may be attributed to rapid ear emergence and aggressive tillering, which can negatively influence stem elongation, panicle differentiation and nutrition availability, resulting in fewer spikelets/panicle[32]. Contrary to negative impact of panicle length on grain yield of ratoon crop observed in this study,[44] reported that panicle length exhibited the utmost consistent and closest positive association with grain yield of rice.

V. Conclusion And Recommendations

The direct seeding the main crop of AT054 variety, the direct seeding the main crop of Komboka variety, random transplanting of the main crop of AT054 variety, machine test transplanting of the main crop of AT054 variety and line transplant of the main crop of AT054 variety yielded dry grain outputs of 3.57, 3.48, 3.42, 3.40 and 3.09 ton/ha in the ratoon crop, respectively. The dry grain yield was influenced by factors such as plant height, panicle length, number of tillers and number of spikelets. In this study, the grain yield of the ratoon crop from various planting methods of the main crop exhibited a positive correlation with hill density/m^2, tillers/hill, fertile tillers/hill, total spikelets/panicle and filled spikelets/panicle. Conversely, it showed a negative correlation with plant height, panicle length, non-filled spikelets/panicle and affected spikelets/panicle. Hence, these characters may serve as criteria for selecting high grain yields in relation to planting methods. These findings suggest a significant potential for enhancing the aforesaid traits through agronomic practices in the ratooning of AT054 and Komboka varieties.

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Conflicts of interest
The authors affirm that they possess no recognized competing interests that may have had an impact on this work.

Appendices

Appendix I: Description of data collection on rice parameters

Parameter	Description
Plant stand	Manual counting of hills/m^2 emerging from stubbles
Plant height	The actual measurements (cm) from the soil surface to the apex of the tallest 10 plants for 10 hills/1m^2 were recorded as whole numbers, utilizing 1 m-ruler
Tillers	The number of tillers/hill was individually counted from 10 hills/sample, averaged and subsequently multiplied by the number of hills/m^2 to give the final tally of tillers/m^2
Tillering ability	The ability to till was assessed on 10 hills/m^2 based on the scale provided (Appendix II)
Plant vigor	The vigour of the plants was also evaluated on 10 hills/m^2 based on the scale provided (Appendix II)
Fertile tillers	The number of fertile tillers/hill was individually counted from ten hills/sample, averaged and subsequently multiplied by the number of hills/m^2 to give the final quantity of fertile tillers/m^2
Panicles length	The actual measurements (cm) from panicle neck to the tip of panicle of were recorded as whole numbers for 10 panicles/plot, utilizing a 30 cm ruler
Grain filling/spikelet fertility	A total of 10 panicles were chosen from an area 1m^2 to assess the quantity of total, filled and non-filled spikelets/panicle. The identification of fertile spikelets conducted by gently pressing the spikelets with the fingers and noting those that contained grains
Affected spikelets	Within 1m^2 area, the same 10 panicles were chosen, and the affected spikelets/panicle were identified and counted
Grain yield	Yield (Kg) was assessed following the threshing and sun-drying of mature grains/m^2 area of each plot. The grains were weighed using a Ramtons 5KG-RM/299 electronic digital gram scale. The moisture content (%) was measured with a Dramisnski® Gram Moisture Meter. Subsequently, the yields were expressed in Tons/Ha
Yield standardization formula	The grain yield was modified to a standard moisture content (14%) utilizing the formula outlined by[45], as demonstrated below; $W_f = W_i \times \frac{(100 - M\,C_i)}{(100 - MC_f)}$ Where; W_i = Initial weight, Wf = Final weight, MCi = Initial moisture content (%), MCf = Final moisture content (%)

Appendix II: Rice agronomic traits scoring key

Tillering Ability (Ti)	
Scale	**Description**
1	Very high (more than 25 tillers/plant)
3	Good (20-25 tillers/plant)
5	Medium (10-19 tillers/plant)
7	Low (5-9 tillers/plant)
9	Very low (less than 5 tillers/plant)
Seedling Vegetative Vigor (Vg)	
Scale	**Description**
1	Extra vigorous (very fast growing; plants at 5-6 leaf stage have 2 or more tillers in majority of population)
3	Vigorous (fast growing; plants at 4-5 stage have 1-2 tillers in majority of population)
5	Normal (plant at 4-leaf stage)
7	Weak (plants somewhat stunted; 3-4 leaves; thin population; no tiller formation
9	Very weak (stunted growth; yellowing of leaves

(Source: IRRI, 2002)

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