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Agronomic Evaluation of Alternative Lowland Rice Varieties for Farmers in Uganda; A Case of Aromatic Rice

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Abstract Rice has recently become an important crop for tackling food insecurity and poverty in Uganda. Over three-quarters of the country's local rice production occurs in irrigated and rain-fed lowlands in eastern and northern Uganda. However, breeding programs and seed systems have only partially met farmers' expectations for new lowland rice varieties and seeds recently, so farmers are sticking with old varieties. However, a new high-yielding, early-maturing, and most importantly, aromatic variety, NARORICE-1, released in 2019, seems to offer a new ray of hope for lowland rice farmers. This study compared the agronomic performance of NARORICE-1 and two promising KAFACI lines to a popular farmer's variety, WITA-9, in central, eastern, and northern Uganda. These varieties were evaluated for growth and yield response to higher seedling counts per hill when transplanted. Doho was the most productive location with an average rice yield of 6.1 t ha^{-1}, significantly higher than NaCRRI and Olweny with 3.9 and 3.7 t ha^{-1}, respectively. The yield performance of NARORICE-1 was comparable to that of the popular farmer's variety WITA-9. Increasing the number of seedlings per hill from three to seven during transplanting had no clear effect on the paddy yield of NARORICE-1. Besides higher yield potential, NARORICE-1's other additional beneficial traits such as aroma, shorter growing time, and higher milling efficiency have made it one of the growers' favorites.

Keywords: *fragrant rice, aromatic rice, Supa, PR107, KOPIA Uganda, NaCRRI*

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1. Introduction

Rice has recently emerged as a critical crop for combating food insecurity and poverty in Uganda [1]. It is the second most important cereal after maize [2,3], with per capita consumption growing at 6% per year.

Consumption is now estimated at 8 kilograms per person per year for rural dwellers and 15 kilograms for city dwellers [3,4]. This growth in rice consumption presents tremendous economic opportunities for Ugandan farmers, who can produce all the rice the country needs by taking advantage of the bimodal rainfall pattern that can support two rice crops in a year [5], the high potential for irrigation (16% of the land is covered by freshwater) [6] and the existence of upland and lowland rice ecologies in the country. However, current government policies appear to favor rice imports [7], hurting the economy and discouraging many small farmers from growing rice. Uganda imports 120,000 MT of milled rice worth US$105 million annually from Asia and Tanzania [8,9]. With food and fuel prices soaring, importing rice is not a sustainable strategy, and the government must support farmers to increase local production and limit import dependency.

Given that rice is a relatively new crop in the country, attempts by farmers to increase local production have been held back by limited access to improved varieties and their seeds and insufficient knowledge of good rice agronomic practices [10,11]. The development and release of lowland rice varieties in Uganda have only been recent [12], meaning farmers are stuck with old rice varieties such as K-85, K-98, K-5, Supa, and Sindano, which were introduced many years ago from elsewhere. These old rice varieties did not undergo the rigorous formal evaluation often required for registration, making them vulnerable to prevailing biotic and abiotic constraints that limit yields. Uganda's earliest registered rainfed and irrigated lowland rice varieties were NERI-CA-6, WITA-9, Okile, Agoro, and Komboka in 2014 [12]. However, some of these varieties, such as Agoro and Okile, Komboka did not catch on with farmers and have since disappeared from production because they were either unavailable (due to limited access to seed) or did not meet farmers' expectations. More recently, however, the release of a high-yielding, early-maturing, and most notably aromatic variety, NARORICE-1, seems to offer a new glimmer of hope to growers. Within just two years of its official release, NARORICE-1 has been adopted by up to 20% of farmers in the Doho rice scheme in eastern Uganda and is rapidly growing in popularity in the Olweny irrigation scheme in northern Uganda [13]. Doho and Olweny are Uganda's largest hubs for lowland irrigated and rainfed rice cultivation. They are typically where new low-land-rice varieties and cultivation technologies are introduced and later expanded to other surrounding rice-growing areas. Farmers and traders in Doho and Olweny desire NARORICE-1 because of its aromatic nature, high milling recovery (approximately 70% white rice), and head rice recovery (more than 50% of the grains retain 75% of their length after milling) [13]. The Manafwa Basin Farmers' Cooperative Society, one of the largest rice millers in the Doho Rice Scheme, now brands NARORICE-1 and markets it in outlying urban areas such as Mbale, Jinja, Kampala, and Mbarara as Supa, a popular aromatic rice variety in the country.

So, the objectives of this study were twofold; 1) to compare the agronomic performance of NARORICE-1 and two promising KAFACI lines with a popular farmer variety, WITA-9, at 3 locations. 2) Investigate the growth and yield response of NARORICE-1 to higher seedling rates. One of the negative points of NARORICE-1 is low tillering, and farmers are demanding an improved variant of NARORICE-1 with improved tillering ability. Therefore, in an attempt to provide farmers with an immediate short-term solution, this study investigated how increasing the number of seedlings per hill of NARORICE-1 during transplanting could compensate for low tillering and thus increase yields.

2. Materials and Methods

2.1. Description of Experimental Locations

The experiments were conducted in the second season of 2021 (September to December) on farmers' fields under irrigated lowland conditions in Doho, Butaleja district, and under lowland rainfed water conditions in Olweny in Lira and NaCRRI in Wakiso districts (Figure 1). The rain-fed lowland fields at Olweny and NaCRRI are either bunded or un-bunded, but there is no water control, with drought and flooding posing potential problems. In Doho, fields are bunded with adequate irrigation water to support two to three crops yearly. The Doho rice scheme lies at an altitude of 1100–1220 m with the following central co-ordinates: 0° 52′ 59″ N (0.88°) 34° 0′ 0″ E (34.00°).

Doho lies at an altitude of 1100 m above sea level, and the average annual temperature in the region is 22.7°C and ranges from 15.4°C to 30.7 C. The precipitation pattern is bi-modal, with peaks in March to May and August to October and mean annual precipitation of 1186 mm [14]. Soils here are plinthosols, reddish brown in color, sandy loam, and loam textured [14], with a pH range of 5.6 to 6.6 and soil organic matter content range of 2.2 to 3.7% [15]. Because the Manafwa River, which supplies irrigation water to the study area, flows through the fertile slopes of Mt. Elgon and carries some nutrients and sediments [16], the soils in the study area are quite fertile, with all major micro- and macronutrients above critical levels that cause deficiencies in rice except for nitrogen, boron, and copper [17].

NaCRRI lies at an altitude of 1160 m above sea level and is characterized by a tropical, humid, and dry climate with long-term mean annual precipitation of 1280 mm. The precipitation pattern is bimodal, with two distinct rainy and dry seasons. December, January, and February are dry, followed by rain in March, April, and May. June and July are dry, while August, September, October, and November are wet. The average minimum and maximum temperatures are 25 °C and 31 °C, respectively. Soils at NaCRRI consist of umbric Gleysols, gleyian Fluvisols, and Histosols, with a predominantly silty loam soil texture [18].

The Olweny irrigation scheme is at an altitude of 1,060 m above sea level and is located at longitude 33.074451 and latitude 2.168389 [19]. The average annual rainfall in Olweny is 1340 mm, and rainfall above 50 mm is received for at least nine months of the year, with a peak in August. The maximum temperature in Olweny is between 27.5 and 32.6°C, while the minimum temperature is between 17.1 and 18.4°C [14].

Figure 1. Map of Uganda highlighting the districts of Wakiso, Butaleja, and Lira, where the experimental sites of NaCRRI, Doho, and Olweny are located, respectively

2.2. Experimental Design, Setup, and Data Collection

The seeds of NARORICE-1, WITA-9, KAFACI-167, and KAFACI-287 were sown and grown in the farmer's fields in a wet-bed nursery for 21 days. The seedlings were then carefully uprooted, and the roots rinsed to get rid of the soil before transplanting. The seedlings were transplanted in well-watered and puddled fields at a spacing of 30 cm x 14 cm. A two-factor randomized complete block (RCBD) design with three replicates at each of the three sites was used. The four varieties

(NARORICE-1, WITA-9, KAFACI-167, and KAFACI-287) constituted Factor 1, while Factor 2 comprised three seedling rates (3, 5, and 7 seedlings per hill). Plant height was measured at harvest from 20 hills selected from the inner rows of each plot, excluding the first two rows and the first two plants in a row to minimize the border effect [20]. Plant height was taken to be the height of the plants from the base above the ground to the tallest part of the plant, the tip of the leaf or panicle. The same plants used to determine plant height were also harvested, and the panicles were counted to calculate the panicle number per square meter. Ten panicles were then selected at random from all the panicles harvested in each plot, and their lengths were measured and averaged to give the plot value. All panicles harvested from each plot were then dried, threshed, and immersed in plain tap water to separate the floating unfilled grains from the filled ones that sink below. The filled and unfilled grains were dried and weighed separately to give the total weight of the empty grain and the total weight of the filled grain. Three 5 g samples of the filled grains were then drawn and counted, and their average number was used to calculate the 1000 grain weight and the total number of filled grains. Similarly, three 1 g samples of the empty grains were drawn and counted, and their average number was used to calculate the total number of empty grains. The total number of filled grains and empty grains was then used to calculate the grain filling ratio expressed as a percentage. The rice yield was determined from the weight of the filled grains and expressed in kg ha^{-1} at 14% moisture content.

2.3. Statistical Analysis

The data were subjected to a 2-factor analysis of variance (ANOVA) in a randomized complete block design (RCBD) with varieties as factor 1 and seedling number per hill as factor 2. The analysis was performed using an R package “shiny’ web-based program freely available online at https://houssein-assaad.shinyapps.io/TwoWayANOVA/ [21]. Before analysis, the data were subjected to a one-sample Kolmogorov-Smirnov normality test and Bartlett's K-square test for homogeneity of variances (i.e., homoscedasticity). Multiple comparisons of means were made using Fisher's least significant difference (LSD) method. Each location was considered an independent site and analyzed separately.

3. Results

There was no significant interaction effect of variety and seedling number on lowland rice growth and yield at any trial sites (Table 1, Table 2, and Table 3). However, the growth and yield response of the tested varieties to increasing seedlings counts per hill appeared to vary by location. For example, in Olweny and NaCRRI, increasing the number of seedlings per hill positively affected panicle number but negatively affected plant height, panicle length, and rice yield for all varieties. While in Doho, the plant height and panicle length of all rice varieties remained essentially unchanged based on the number of seedlings transplanted per hill, increasing the number of seedlings per hill led to mixed varietal responses in terms of panicle number and rice yield. In contrast, the panicles of KAFACI-167 and WITA-9 increased slightly with increasing seedling numbers, and those of KAFACI-287 and NARORICE-1 decreased. On the other hand, increasing the number of transplanted seedlings per hill led to an increase in rice yield of only KAFACI-167 and a decrease in all other varieties.

Table 1. Growth and yield response of lowland rice varieties to different numbers of transplanted seedlings per hill in the Doho rice scheme in eastern Uganda

Seedlings per hill	Variety	Plant height (cm)	Panicle length (cm)	Panicles m^{-2}	Paddy yield (kg ha^{-1})	Grain filling (%)
Three (3)	KAFACI-167	88.2^{b}	20.8^{cd}	364^{c}	3.67^{e}	76.8^{c}
	KAFACI-287	116^{a}	26^{a}	322^{c}	5.89^{bce}	85.4^{ab}
	NARORICE-1	77.8^{de}	21.9^{bc}	620^{b}	6.86^{acd}	88.8^{a}
	WITA-9	73.6^{e}	19^{de}	865^{a}	8.63^{a}	82.4^{ac}
Five (5)	KAFACI-167	86.2^{bc}	21^{cd}	484^{bc}	4.67^{ce}	78.8^{bc}
	KAFACI-287	110^{a}	25.4^{a}	343^{c}	5.37^{bce}	84.9^{ab}
	NARORICE-1	78.7^{cde}	23.7^{ab}	459^{bc}	6.99^{ac}	88.8^{a}
	WITA-9	73.3^{e}	18.2^{e}	868^{a}	7.61^{ab}	82.6^{ac}
Seven (7)	KAFACI-167	85.2^{bd}	21.2^{cd}	495^{bc}	5.18^{bce}	82.7^{ac}
	KAFACI-287	113^{a}	25^{a}	286^{c}	4.24^{de}	82^{ac}
	NARORICE-1	77.9^{de}	22.7^{bc}	480^{bc}	6.39^{acd}	86.6^{a}
	WITA-9	73.4^{e}	19.4^{de}	894^{a}	7.69^{ab}	81.5^{ac}
Pooled SEM		3.76	1.05	97.1	1.22	3.62
P-value	Seedlings (S)	0.592	0.938	0.994	0.808	0.948
	Variety (V)	<0.001	<0.001	<0.001	0.001	0.01
	S×V	0.878	0.565	0.474	0.65	0.645

Values are means and pooled SEM, n = 2 per treatment group.
[a-e]Means in a column without a common superscript letter differ ($P < 0.05$) as analyzed by two-way ANOVA and the LSD test.
[1]S × V = Seedlings × Variety interaction effect.

Table 2. Growth and yield response of lowland rice varieties to different numbers of transplanted seedlings per hill in the Olweny irrigation scheme in northern Uganda

Seedlings per hill	Variety	Plant height (cm)	Panicle length (cm)	Panicles m^{-2}	Paddy yield (kg ha^{-1})
Three (3)	KAFACI-167	95.4^{b}	21.3^{acd}	111^{d}	3.26^{ab}
	KAFACI-287	117^{a}	23.3^{a}	125^{cd}	3.98^{a}
	NARORICE-1	72.7^{c}	20.8^{bcd}	128^{cd}	3.52^{ab}
	WITA-9	70.9^{c}	19.2^{deg}	195^{b}	4.02^{a}
Five (5)	KAFACI-167	91^{b}	19.5^{cef}	183^{bc}	3.54^{ab}
	KAFACI-287	117^{a}	22.9^{ab}	149^{bd}	4.32^{a}
	NARORICE-1	75.2^{c}	21^{acd}	170^{bd}	3.66^{ab}
	WITA-9	71.9^{c}	18.4^{eg}	200^{b}	3.96^{a}
Seven (7)	KAFACI-167	91.1^{b}	17^{g}	155^{bd}	2.68^{b}
	KAFACI-287	109^{a}	21.7^{ac}	150^{bd}	3.73^{ab}
	NARORICE-1	70.2^{c}	20.2^{ce}	202^{b}	3.39^{ab}
	WITA-9	68.4^{c}	17.9^{fg}	280^{a}	3.76^{ab}
Pooled SEM		3.74	1.08	28.2	0.55
P-value	Seedlings (S)	0.077	0.012	0.005	0.25
	Variety (V)	<0.001	<0.001	0.001	0.072
	S×V	0.748	0.392	0.244	0.977

Values are means and pooled SEM, n = 2 per treatment group.
$^{a-g}$Means in a column without a common superscript letter differ ($P < 0.05$) as analyzed by two-way ANOVA and the LSD test.
[1]S × V = Seedlings × Variety interaction effect.

Table 3. Growth and yield response of lowland rice varieties to different numbers of transplanted seedlings per hill in NaCRRI in central Uganda

Seedlings per hill	Variety	Plant height (cm)	Panicle length (cm)	Panicles m^{-2}	Paddy yield (kg ha^{-1})	Grain filling (%)
Three (3)	KAFACI-167	110^{a}	21.5^{cd}	191^{de}	4.19^{ab}	90.8^{acd}
	KAFACI-287	116^{a}	24.5^{ab}	180^{e}	4.12^{ab}	89.8^{bce}
	NARORICE-1	80.6^{b}	$22.2b^{c}$	236^{ce}	3.81^{ab}	93^{ab}
	WITA-9	75.9^{b}	19.3^{de}	342^{ab}	4.64a	88.2^{ce}
Five (5)	KAFACI-167	106^{a}	21.5^{cd}	205^{de}	3.53^{ab}	91.1^{acd}
	KAFACI-287	111^{a}	24.6^{a}	184^{de}	3.67^{ab}	89.9^{bce}
	NARORICE-1	77.8^{b}	21^{cd}	250^{cd}	3.27^{b}	93.9^{a}
	WITA-9	71.4^{b}	17.6^{e}	367^{a}	4.16^{ab}	87.2^{e}
Seven (7)	KAFACI-167	106^{a}	22.6^{ac}	231^{ce}	4.09^{ab}	89.7^{bce}
	KAFACI-287	113^{a}	24.3^{ab}	216^{ce}	3.87^{ab}	87.2^{e}
	NARORICE-1	75.4^{b}	21.8^{c}	280^{bc}	3^{b}	91.4^{ac}
	WITA-9	70.6^{b}	17.8^{e}	351^{a}	4.12^{ab}	87.8^{de}
Pooled SEM		3.76	6.66	1.1	30.3	0.589
P-value	Seedlings (S)	0.369	0.457	0.143	0.203	0.121
	Variety (V)	<0.001	<0.001	<0.001	0.099	0.001
	S×V	0.999	0.68	0.922	0.961	0.787

Values are means and pooled SEM, n = 2 per treatment group.
$^{a-e}$Means in a column without a common superscript letter differ ($P < 0.05$) as analyzed by two-way ANOVA and the LSD test.
[1]S × V = Seedlings × Variety interaction effect.

There was no significant main influence of the number of seedlings on all measured growth and yield parameters in all trial locations except for the panicle lengths, which decreased significantly, and the panicles per square meter, which increased significantly with the number of seedlings in Olweny. Out of the four varieties evaluated, only KAFACI-167 exhibited a significant decrease in panicle length due to increasing seedling number per hill from 21.3 cm with three seedlings to 17 cm with seven seedlings (Table 2), while panicles lengths remained unchanged in the rest of the varieties. Of the four varieties evaluated, only KAFACI-167 showed a significant reduction in panicle length due to increasing seedling count per hill from 21.3 cm in 3 seedlings to 17 cm in 7 seedlings, while panicle lengths remained unchanged in the remaining varieties (Table 2). On the other hand, increasing the number of seedlings per hill significantly increased the number of panicles per square meter in KAFACI-167, NARORICE-1, and WITA-9 (Table 2).

The main variety effects were significant for almost all growth and yield parameters studied, except paddy yield in NaCRRI and Olweny (Table 1, Table 2, and Table 3). The variety ranking for height from shortest to tallest was WITA-9, NARORICE-1, KAFACI-167, and KAFACI-287, with mean heights across the sites of 95, 114, 76, and 72 cm, respectively. Similarly, the varieties ranking in terms of panicle length from shortest to longest were WITA-9, KAFACI-167, NARORICE-1, and KAFACI-287, with mean panicle lengths of 19, 21, 22, and 24 cm, respectively.

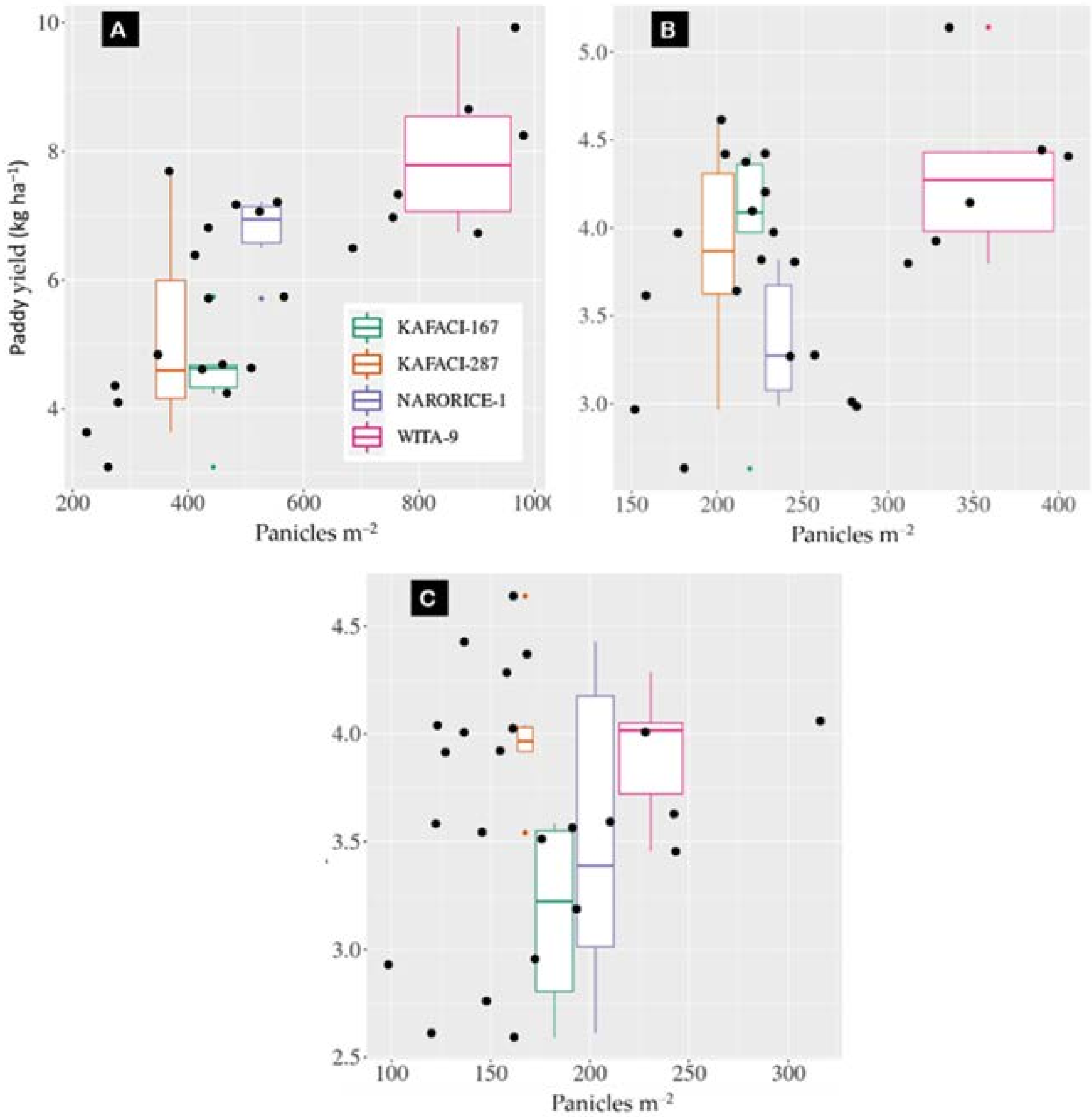

Figure 2. Relationship between the number of panicles per square meter and paddy yield of different rice varieties in Doho (A), NaCRRI (B), and Olweny (C)

Paddy yields averaged across sites were 3.9, 4.4, 4.5, and 5.4 t ha^{-1} for KAFACI-167, KAFACI-287, NARORICE-1, and WITA-9, respectively. No significant varietal differences in rice yield were found in Olweny and NaCRRI. However, in Doho, there were significant varietal differences in paddy yield, with the highest-yielding variety being WITA-9, which produced 8 t ha^{-1}, which was not significantly different from NARORICE-1, which ranked second with 6.8 t ha^{-1}. KAFACI-287 ranked third at 5.2 t ha^{-1}, while KAFACI-167 was the lowest-yielding at 4.5 t ha^{-1}. The paddy yield of KAFACI-167 and KAFACI-287 was statistically similar, but both differed significantly from WITA-9 and NARO-RICE-1. Unlike in Olweny and NaCRRI, varietal differences in paddy yields in Doho were strongly associated with the variety's ability to produce panicles ($r = 0.76$, $P<0.01$), with the varieties with a higher number of panicles per square meter also yielding more (Figure 2). There was a weak non-significant Pearson's correlation coefficient between rice yield and panicles per square meter in Olweny ($r = 0.07$) and NaCRRI ($r = 0.38$).

4. Discussion

The main purpose of this study was to compare the agronomic performance of a new aromatic rice variety, NARORICE-1, and two promising KAFACI lines with a popular farmer variety, WITA-9. The study was conducted in NaCRRI, Doho, and Olweny in central, eastern, and northern Uganda. This section summarizes and discusses the main findings of the study.

Of the three trial locations, we found Doho to be the most productive for lowland rice production, with a significantly higher average paddy yield of 6.1 t ha^{-1} compared to 3.9 and 3.7 t ha^{-1} in NaCRRI and Olweny, respectively (Figure 2). Yields were a direct reflection of the number of panicles per square meter at each of the three sites. Tillering is one of the most important agronomic traits in rice, as the number of tillers determines the number of panicles, a key component of grain yield [22]. Water stress in the vegetative stage and nitrogen deficiency are the two major abiotic factors simultaneously or individually limiting tillering of rice

[23,24]. Thus, differences in soil fertility and soil moisture duration most likely account for the yield differences between the experimental locations. The rice in Doho was grown under irrigation with a constant supply of water, while that in Olweny and NaCRRI were rain-fed, meaning that it experienced occasional dry spells.

No significant interaction effects of varieties and seedlings per hill were found on all measured growth and yield parameters at any trial sites. Likewise, there were no significant main effects of the seedling number on all measured growth and yield parameters at all trial sites, except Olweny, where panicle lengths decreased significantly, and the panicles per square meter increased significantly when the number of seedlings per hill was increased. A key observation, however, was that raising the number of seedlings per hill affected panicle number positively but negatively impacted plant height, panicle length, and rice yield for all varieties. Our observations echo those of another study which found that increasing seedlings per hill from two to five resulted in a reduction in plant height from 94 to 91 cm, an increase in panicles per square meter and paddy yield from 110 to 123, and 1 .9 to 3.0 t ha^{-1} respectively [25]. On the contrary, while they reported an increase in paddy yields when the number of seedlings per hill was increased, we saw yields decrease instead. This differential yield response to seedling number per hill could be due to differences in the varieties used in the two studies; While we used lowland adapted rice varieties that are inherently higher tiller-ing, they used NERICA-1, which is adapted to the uplands [26,27] with low tillering potential. Several studies recommend transplanting three seedlings per hill for lowland rice [28,29] and sowing five seeds per hill for upland rice to compensate for low tillering ability.

Generally, the number of panicles, determined by the number of seedlings trans-planted per hill and tillers produced per seedling, plays a crucial role in determining rice yield [30,31,32]. A study examining the relationships between yield and yield-related traits for rice varieties released in China from 1978 to 2017 found that the relationship between panicle number and rice yield depended on the rice ecotype and was positive for the japonica's and negative for the indica's [33]. They found that panicle number increased significantly as plant density increased within a given unit area, but there was a trade-off between grain filling and panicle number. Dynamic compensation of grain filling appears to limit potential grain yield benefits as panicle number increases, particularly for the indica ecotypes. When tillering density is high, tiller development is hampered by competition, in some cases causing tillers to die even before panicles form.

Across locations, WITA-9 yielded the highest among the four rice varieties with 5.4 t ha^{-1}, and NARORICE-1 ranked second with 4.5 t ha^{-1}, which was not statistically different from WITA-9. KAFACI-287 and KAFACI-167 ranked third and fourth with yields of 4.4 and 3.9 t ha^{-1}, respectively, which did not differ significantly from NARORICE-1. Again, yield differences between varieties were strongly associated with differences in tillering, with WITA-9 producing the highest number of effective tillers per square meter at 485, which was significantly higher than that of NARORICE-1, KAFACI-287 and KAFACI-167 at 314, 218 and 269 panicles per square meter. Rice varieties vary markedly in their tillering ability, so tillering is considered a varietal trait closely related to plant type [34]. High-tiller varieties usually have a higher number of panicles and a higher yield than low-tiller varieties. As a result, the former and latter varieties are classified into a panicle number type and a panicle weight type [34]. WITA-9 and NARORICE-1 exhibited panicle number types characterized by a relatively higher number of panicles per unit area and average spikelet number, while KAFACI-167 exhibited a panicle weight type with many spikelets per panicle but fewer panicles per unit area. KAFACI-287 seemed to be intermediate between the panicle number and panicle weight types (Figure 3). The yield of varieties with small panicles is highly dependent on panicle number, which is greatly reduced under water-limited conditions [14] such as NaCRRI and Olweny rainfed conditions.

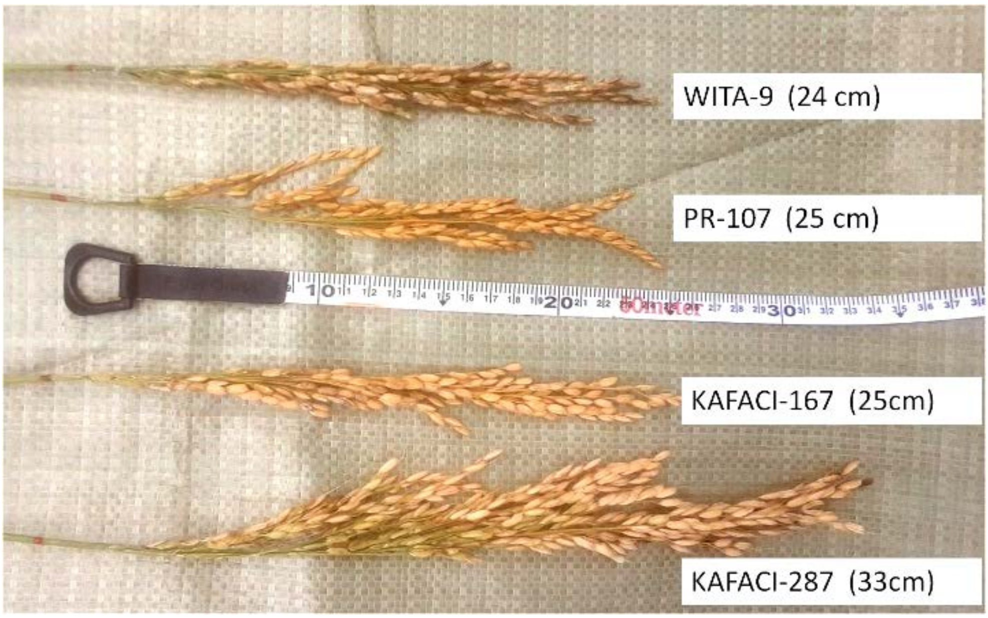

Figure 3. Panicle type of NARORICE-1, KAFACI-167, and KAFACI-compared with popular farmer's variety WITA-9. The indicative panicle lengths for each variety are inset, besides the name

5. Conclusion

The main conclusions of this study are that the response of the varieties to the number of seedlings per hill depends on the location. Increasing the number of seedlings per hill in Olweny and NaCRRI had a positive effect on panicle number but negative effects on plant height, panicle length, and rice yield for all varieties, while in Doho, plant height and panicle length of all rice varieties remained essentially unchanged. Across sites, however, we found that increasing the number of seedlings per hill increased panicle count, although plant height, panicle length, and rice yield were negatively affected for all varieties. The ranking of varieties by yield from highest to lowest was WITA-9, NARORICE-1, KAFACI-287, and KAFACI-167. Yield differences between varieties were strongly associated with differences in effective tillering. WITA-9 and NARORICE-1 showed panicle number types, while KAFACI-167 showed panicle weight. KAFACI-287 was intermediate in panicle number and panicle weight types. The yield performance of NARORICE-1 was comparable to that of the famous farmer's variety WITA-9. Therefore, the higher yield potential of NARORICE-1 and the other additional beneficial traits such as aroma, shorter growing time, and higher milling efficiency has made it one of the growers' favorites.

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