‘Gikungu’ Quinoa

Figure 1. Gikungu at maturity stage

‘Gikungu is the Kinyarwanda word for “economy”. This name was chosen by Olivier Ndayiramije due to quinoa’s high nutritional profile and its important role in socioeconomic development. Healthier populations contribute to a stronger local economy, and a stronger local economy contributes to a healthier population—quinoa embodies this.

Breeding Team

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Parentage, Breeding History, and Line Selection in the USA

Gikungu (39-51) was developed from a cross between 'NL6' and '0654'. Crosses occurred in July 2004. The F_1 seed was grown in 8-inch diameter round pots in the greenhouse at Brigham Young University (Provo, Utah) in Sunshine Mix II (Sun Gro, Bellevue, WA, USA) supplemented with Osmocote fertilizers (Scotts, Marysville, OH, USA) under broad-spectrum halogen lamps, with 12-h photoperiods and daytime temperatures of 20°C and nighttime temperatures of 18°C. The F_1 plant was allowed to reach physiological maturity and then threshed. A total of 100 F_2 seeds were planted separately in 4-inch diameter pots and advanced to the $F_{7:8}$ generation using a single-seed decent protocol (one seed per head) under conditions described previously from 2006-2011.

In 2014, approximately 980 $F_{7:8}$ breeding lines from four distinct populations were planted as 1.5-m headrows at Tukey Organic Farm at WSU. Two years of vigorous selection for seed yield, early maturity, tolerance to lodging, adaptation to the long-day photoperiod, and other agronomic traits led to the selection of Cougar for further testing in Rwanda.

Evaluation in Replicated Yield Trials in Rwanda

Gikungu was evaluated in Rwanda from 2016 to 2021 for seed yield, days to flowering, days to maturity, and plant height. The trials were conducted in two of Rwanda's major agroclimatic zones: the Eastern lowland region, Ngoma and Kirehe Districts, Eastern Province, and the Northern highland region, Musanze and Burera Districts, Northern Province. The Eastern lowlands range from 1,000 to 1,500 m.a.s.l., receive mean average rainfall ranging from 740 to 1,000 mm, and mean annual temperatures between 19 and 22°C. The highlands—which include the Congo-Nile Ridge and volcanic chains of Birunga—range from 2,000 to 4,500 m.a.s.l., receive 1,300 to 1,550 mm annual rainfall, and mean annual temperature range between 10 and 14°C (Gotanegre et al., 1974; Ilunga et al., 2004; REMA, 2015; Ilunga & Muhire, 2010; David et al., 2011; Muhire et al., 2015).

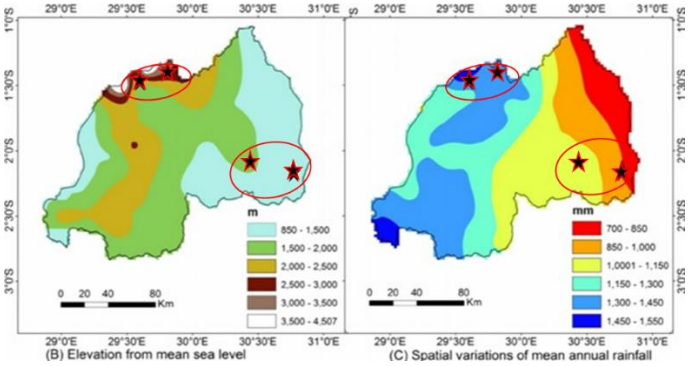

Figure 2. Elevation from mean sea level and spatial variations of mean annual rainfall of locations where Gikungu quinoa variety trials were conducted in Rwanda (marked red circles) and black stars with red outlines represents Districts. Source (Muhire et al., 2015).

From 2016 to 2017, Gikungu was grown alongside other nineteen quinoa cultivars in a randomized complete block design (RCBD) with four replicates in Rwanda. The treatments were genotypes and locations—Eastern lowlands and Northern highlands. Each plot was hand planted into two rows, in 4 × 1.2 m plots, using 5 g seed per plot (Habiyaremye et al., 2022). The phenotypic data were recorded according to Sosa-Zuniga et al. (2017) and Stanschewski et al. (2021). Days to flowering, days to maturity, and plant height were recorded according to Habiyaremye et al. (2022). Grain yield was measured as the weight of the grain harvested from the whole plot. The plots were harvested individually using sickles to cut the stems of the plants. All plants were bundled and threshed by hand. The seeds were processed by winnowing, using the wind to separate smaller particles and immature seeds from the mature seeds and for the final removal of any foreign plant material.

Gikungu was evaluated on 21 farms in Rwanda from 2017 to 2021. Of the 21 farms, 15 were located in the Eastern lowland region and 6 in the Northern highland region. A comparison of cultivars' grain yield and agronomic performance to other quinoa check cultivars was done with an emphasis on 'QQ74', 'Kaslaea', 'NL-6', and 'Titicaca'; these cultivars were all new to Rwanda's climate. Seed yield evaluations were based on grain harvested from each farm.

Seed Purification and Increase

In February 2022 Gikungu was sown in a 5 × 20 m strip at one of the QuinoaHub farms situated in Kigabiro Cell, Murama Sector, Ngoma District, Eastern Province for the elimination of off types. Identified off types were rogued and rows that appeared uniform and clean were harvested and bulked and planted in October 2022, creating foundation seed.

Figure 3. From left to right is Gikungu at flowering and maturity stages, respectively, in Ngoma District, Eastern Province of Rwanda in 2022.

Grain Yield, Days to Flowering, Days to Maturity, and Plant Height

When tested in Rwanda from 2016 to 2021 Eastern lowland region, Gikungu had a mean grain yield higher than all the control cultivars QQ74, Kaslaea, Titicaca, and NL-6 (Table 1). However, in the Northern highland region, Kigungu has the lowest grain yield compared to the control cultivars (Table 2).

Table 1. Mean grain yield, days to flowering, days to maturity, and plant height of quinoa cultivar Gikungu, QQ74, Kaslaea, NL-6, and Titicaca in replicated field trials and farming communities in Eastern lowland region (Ngoma and Kirehe) in Rwanda 2016-2021.

Cultivars	GY (kg ha^{-1})	DF (day)	DM (day)	PH (cm)
Gikungu	1,551 a	46 a	135 a	89
QQ74	1,158 b	41 b	89 d	84
Kaslaea	993 bc	42 b	117 c	73
NL-6	932 c	41 b	130 b	73
Titicaca	929 c	40 b	85 e	77
LSD (p <0.05)	208	2	1	32

GY: Grain yield; DF, days to flowering; DM, days to maturity; PH, plant height; LSD: least significant difference. LSD comparisons are significant at the 0.05 level. Dissimilar letters in a column are significantly different at $p \leq 0.05$

When comparing cultivars across all years and locations, the results showed a difference in grain yield between Gikungu and control cultivars (Table 3). Gikungu and Titicaca had lower yields compared to QQ74, Kaslaea, and NL-6 (Table 4).

Gikungu was the latest flowering cultivar in both locations across all years (Table 1, 2). However, days to flowering and days to maturity differed between the Eastern lowland and Northern highland regions; on average days to flowering of Gikungu were 46 and 52 days in the Eastern lowland and Northern highland regions, respectively (Table 3). Across all locations and years, the earliest flowering cultivars were Titicaca and NL-6 with an average of 42 days each (Table 4). Gikungu was the latest maturing cultivar with an average of 135 days to maturity in both the Eastern lowland and Northern highland region (Table 1, 2).

Table 2. Mean grain yield, days to flowering, days to maturity, and plant height of quinoa cultivar Gikungu, QQ74, Kaslaea, NL-6, and Titicaca in replicated field trials and farming communities in the Northern highland region (Musanze and Burera) in Rwanda 2016-2021.

Cultivars	GY (kg ha^{-1})	DF (day)	DM (day)	PH (cm)
Gikungu	702 c	52 a	135 a	88 bc
QQ74	2,021 a	48 b	98 d	114 a
Kaslaea	2,005 a	47 b	116 c	98 b
NL-6	2,015 a	43 c	126 b	88 bc
Titicaca	1,178 b	43 c	96 d	75 c
LSD (p <0.05)	417	2	5	16

GY: Grain yield; DF, days to flowering; DM, days to maturity; PH, plant height; LSD: least significant difference. LSD comparisons are significant at the 0.05 level. Dissimilar letters in a column are significantly different at $p \leq 0.05$.

In the Eastern lowland, there was no significant difference in plant height among cultivars (Table 1). However, in the Northern highland region there was a difference in plant heights among cultivars, Gikungu was among the shortest cultivars similar to NL-6 and Titicaca with an average plant height of 88, 88, and 75 cm, respectively (Table 2). The location did not affect the plant height of Gikungu and Titicaca (Table 3).

Table 3. Location differences in grain yield, days to flowering, days to maturity, and plant height of quinoa cultivar Gikungu, QQ74, Kaslaea, NL-6, and Titicaca, across all years.

Cultivars	GY (kg ha^{-1})		DF (day)		DM (day)		PH (cm)	
	L	H	L	H	L	H	L	H
Gikungu	1,551	702	46	52	135	135	89	88
QQ74	1,158	2,021	41	48	89	98	84	114
Kaslaea	993	2,005	42	47	117	116	74	98
NL-6	932	2,015	41	43	130	126	73	88
Titicaca	929	1,178	40	43	85	96	77	75
Mean	1,113	1,584	42	47	111	114	79	93
LSD (p <0.05)	130		1		2		11	

GY: Grain yield; DF, days to flowering; DM, days to maturity; PH, plant height; L, lowland; H, highland; LSD: least significant difference. LSD comparisons are significant at the 0.05 level.

When comparing cultivars across all locations and years, Gikungu was among the tallest cultivars (Table 4).

Table 4. Mean grain yield, days to flowering, days to maturity, and plant height of Gikungu, QQ74, Kaslaea, NL-6, and Titicaca across all locations and years.

Cultivars	GY (kg ha^{-1})	DF (day)	DM (day)	PH (cm)
Gikungu	1,201 ab	49 a	135 a	88 ab
QQ74	1,446 a	45 b	93 d	99 a
Kaslaea	1,332 a	45 b	116 c	86 ab
NL-6	1,299 a	42 c	128 b	80 b
Titicaca	1,014 b	42 c	90 d	76 b
LSD (p < 0.05)	244	2	3	18

GY: Grain yield; DF, days to flowering; DM, days to maturity; PH, plant height; LSD: least significant difference. LSD comparisons are significant at the 0.05 level. Dissimilar letters in a column are significantly different at $p \leq 0.05$.

Consumption and Use

Gikungu serves as a multi-purpose crop for vegetable, grain, and livestock feed production. Growers consume its nutritious leaves and grains; both its leaves and grains are used in different dishes and are also used to make various food and drink products. The straws are used as livestock feed.

Availability

Foundation seeds will be available from QuinoaHub Ltd (www.QuinoaHub.com) to farmers starting in September 2023.

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References

David, K., Megan, C., Christian, C., Jillian, D., Ryan, H., Robert, M., Mathew, W., Sally, T., Andrew, A. B., & Michael, H. (2011). Green growth and climate resilience national strategy for climate change and low carbon development. *Republic of Rwanda, Kigali*. Retrieved from http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/1602.pdf

Gotanegre, J. F., Prioul, C., & Sirven, P. (1974). Géographie du Rwanda, A. de Boeck-Bruxelles. Retrieved from https://lib.ugent.be/catalog/rug01:001342372

Habiyaremye, C., Ndayiramije, O., D'Alpoim Guedes, J., & Murphy, K. M. (2022). Assessing the Adaptability of Quinoa and Millet in Two Agroecological Zones of Rwanda. Frontiers in Sustainable Food Systems, 130. https://doi.org/10.3389/fsufs.2022.850280

Ilunga, L. & Muhire, I. (2010) Comparison of the Rwandan annual mean rainfall fluctuations with the El Nino/La Nina events and sunspots. Geo-Eco-Trop, 34, 75–86. Retrieved from http://www.geoecotrop.be/uploads/publications/pub_341_05.pdf

Ilunga, L., Mbaragijimana, C., & Muhire, I. (2004). Pluviometric seasons and rainfall origin in Rwanda. *Geo-Eco-Trop*, *28*(1-2), 61-68. Retrieved from https://www.researchgate.net/publication/293286363_Pluviometric_seasons_and_rainfall_origin_in_Rwanda

Muhire, I., Ahmed, F., & MMM, A. E. (2015). Spatio-temporal variations of rainfall erosivity in Rwanda. *Journal of Soil Science and Environmental Management*, *6*(4), 72-83. doi:10.5897/JSSEM14.0452

REMA-Rwanda Environment Management Authority. (2015). Rwanda state of environment and outlook report. Kigali, Rwanda. Retrieved from https://www.nmbu.no/sites/default/files/pdfattachments/state_of_environment_and_outlook_report_2015.pdf

Sosa-Zuniga, V., Brito, V., Fuentes, F., and Steinfort, U. (2017). Phenological growth stages of quinoa (Chenopodium quinoa) based on the BBCH scale. Ann. Appl. Biol. 171, 117–124. https://doi.org/10.1111/aab.12358

Stanschewski, C. S., Rey, E., and Fiene, G. (2021). Quinoa phenotyping methodologies: An international consensus. Plants 10, 54. https://doi.org/10.3390/plants10091759