

REGISTRATION

Cultivar

Registration of 'Naronut 1R' groundnut

David K. Okello¹  | C. Michael Deom² | Naveen Puppala³ ¹National Semi-Arid Resources Research Institute, P.O. Box 56, Soroti, Uganda²Dep. of Plant Pathology, Univ. of Georgia, Athens, GA 30602, USA³Agricultural Science Center at Clovis, New Mexico State Univ., Clovis, NM 88101, USA

Correspondence

C. M. Deom, Dep. of Plant Pathology, Univ. of Georgia, Athens, GA 30602, USA.
Email: deom@uga.eduAssigned to Associate Editor Gloria Burow.
Registration by CSSA.

Funding information

United States Agency for International Development, Grant/Award Number: AID-ECG-A-00-07-0001

Abstract

'Naronut 1R' (Reg. no. CV-150, PI 693985) is a high-yielding, Spanish-type groundnut (*Arachis hypogaea* L. subsp. *fastigiata* var. *vulgaris*) cultivar with a red seed coat and two seeds per pod. The cultivar was selected from a cross between International Crops Research Institute for the Semi-arid Tropics advanced lines 'ICGV-SM 90704' and 'ICGV-SM 86715'. Naronut 1R was developed for groundnut rosette disease resistance, late leafspot resistance, yield, red seed coat, and early maturity. Naronut 1R matures in 75–80 d after planting, compared with 90 d for the widely grown and popular landrace Erudu red (Spanish-type groundnut). Naronut 1R has much higher yields (1,473 kg ha⁻¹) than Erudu red (554 kg ha⁻¹). The overall groundnut rosette disease rating was 44% lower in Naronut 1R (2.8 disease rating) compared with Erudu red (5.0 disease rating). Similarly, the overall late leafspot disease rating was 28% lower in Naronut 1R (3.6 disease rating) compared with Erudu red (5.0 disease rating). Similar to Erudu red, Naronut 1R seed testa is red, but the seed is larger. The sound mature kernel weight was 9.42% higher for Naronut 1R than for Erudu red. The shelling percentage for Naronut 1 was 49.3%, whereas Erudu red was 60%. Naronut 1R has lower protein (18.1 vs. 21.3%) and oil content (36.0 vs. 44.3%) than Erudu red. Naronut 1R will allow for broad adoption of a high yielding, early maturing, red seed coat cultivar that carries resistance to groundnut rosette disease and late leaf spot disease.

1 | INTRODUCTION

'Naronut 1R' (Reg. no. CV-150, PI 693985) is a high-yielding, very early-maturing, Spanish-type groundnut (*Arachis hypogaea* L. subsp. *fastigiata* var. *vulgaris*) cultivar. Naronut 1R has resistance to groundnut rosette disease (GRD), the most important viral disease of groundnut in sub-Saharan Africa (Busolo-Bulafu, 2004; Okello et al., 2010). Groundnut rosette disease is caused by a synergistic

interaction among three different agents: *Groundnut rosette assistor virus* (member of the genus *Polevirus*), *Groundnut rosette virus* (GRV, member of the genus *Umbravirus*), and a satellite RNA of GRV (Murant & Kumar, 1990; Naidu et al., 1999; Robinson et al., 1999). The disease is transmitted by the cowpea or groundnut aphid (*Aphis craccivora* Koch.) In addition, Naronut 1R has resistance to late leafspot disease [LLD; caused by the foliar pathogen *Nothopassalora personata* (Berk. & M.A. Curtis) S.A. Khan & M. Kamal].

Both diseases are major constraints to groundnut production in Uganda and East Africa. Because of this, improved cultivars developed in Uganda routinely have GRD resistance

Abbreviations: DAP, days after planting; GRD, groundnut rosette disease; GRV, Groundnut rosette virus; LLD, late leafspot disease; NaSARRI, National Semi-Arid Resources Research Institute.

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or LLD resistance. Naronut 1R was also developed for very early maturity, 75–80 days after planting (DAP), which allows it to avoid production losses from extended abiotic and biotic stresses (i.e., drought and diseases), and for red seed color, to satisfy consumer preferences.

Groundnut is grown primarily by smallholder farmers as a rainfed crop during two rainy seasons in Uganda (Deom & Okello, 2018; Okello et al., 2010). As recent as 2019, groundnut was harvested from 3.20×10^5 ha, producing $\sim 1.60 \times 10^5$ Mg (FAO, 2019). Ugandan farmers prefer cultivars that mature early (to avoid late season drought), have resistance to GRD and LLD, and are easy to harvest and easy to hand shell. In addition, consumers in north and eastern Uganda prefer tan seed cultivars, while those in western, central, and southern Uganda prefer red seed cultivars.

Here we report the development of Naronut 1R. This cultivar provides a very early-maturing, high-yielding, red seed with resistance to GRD and LLD that is broadly adapted for western, central, and southern Uganda. In addition, Naronut 1R has a thick, white cushion that surrounds and protects the seed within the pods similar to that described for 'Naronut 2T' (Okello et al., 2021).

2 | METHODS

2.1 | Parental lines and pedigree

Naronut 1R was selected from a cross between International Crops Research Institute for the Semi-Arid Tropics advanced lines, 'ICGV-SM 90704' (van der Merve et al., 2001) as pollen parent and 'ICGV-SM 86715' (PI 598133) (Moss et al., 1998) as the maternal parent. ICGV-SM 90704 was released in 1999 in Uganda as 'Serenut 2' (Busolo-Bulafu, 1999). The cultivar is drought tolerant, resistance to GRD and leafspot diseases and matures in 100 DAP in Uganda (Deom & Okello, 2018; van der Merve et al., 2001). ICGV-SM 86715 has a red seed coat, moderate resistance to GRD and LLD and matures in 100–110 DAP, depending on the location and season in sub-Saharan Africa (Moss et al., 1998). Improvements of ICGV-SM86715 were made for higher yields, resistance to GRD, early maturity, seed size, red seed color, and sweetness.

2.2 | Breeding, selection, and evaluation

The cross between ICGV-SM 90704 (male) and ICGV-SM 86715 (female) was performed at the National Semi-Arid Resources Research Institute (NaSARRI), Serere, Uganda (1.4970° N, 33.3935° E) (Supplemental Table S1). F_1 seed, together with parents, was planted in a single row 100 cm apart. Hybrids were phenotypically identified by comparing their growth habit, leaf size and shape, and pod reticula-

Core Ideas

- Naronut 1R is a high-yielding, very early-maturing peanut cultivar.
- Naronut 1R is resistant to groundnut rosette disease and late leaf spot disease.
- Naronut 1R is broadly adaptable across sub-Saharan Africa.

tion with parents grown side by side in the field (Table 1). The F_2 - F_4 seed were planted approximately 15 cm apart in 4-row plots, 3 m long $\times$ 2 m wide. Pedigree selection (Knauff et al., 1987) was practiced from F_2 - F_4 generations. Selections for resistance to GRD and LLD were practiced in early generations (F_2 - F_4) at Serere and Nakabango, Uganda (Supplemental Table S1). Both sites are hotspots for GRD and LLD. Disease-resistant plants in each generation were further segregated based on growth habit, stem-peg pigmentation, pod yield, maturity (as determined by the shell out method) (Okello et al., 2013; Sanders et al., 1980), red seed color, and advanced following pedigree selection. Subsequently, bulk selection was practiced from F_5 - F_8 . The F_5 - F_8 progeny rows were planted approximately 15 cm apart in two-row plots, 5 m long $\times$ 3 m wide. After harvest, individual progeny rows were bulked as a pure line for subsequent preliminary yield tests. One line with resistance to GRD and LLD, and a red seed coat was selected for further analysis and designated Naronut 1R. Naronut 1R was evaluated with Erudu red (red seed control) for pod yield and other agronomic and grade characteristics in 11 replicated field trials conducted in randomized complete block designs over five seasons (2014–2017).

2.3 | Performance test

Replicated trials for yield and grade characteristics of Naronut 1R was performed 2014–2017, covering five growing seasons, at 1–4 on-farm National Performance Trial locations under rainfed conditions in Uganda. The performance of Naronut 1R was compared to Erudu red. Erudu red is a widely grown and popular landrace in Uganda because it matures in ~ 90 DAP and has a red seed coat. However, Erudu red is low-yielding and has no resistance to GRD or LLD. Experimental trial details and global position system locations are in Supplemental Table S1. The design was a randomized complete block with four replicates. All locations experience a bimodal rainfall distribution and are within the Kyoga Plains agro-ecological zone of Uganda. Growing season 1 (designated A) runs from April to July/August. Growing season 1 generally has heavy rainfall amounts

TABLE 1 The morphological traits of groundnut varieties

Morphological traits	ICGV-SM 90704 (pollen/male parent)	ICGV-SM 86715 (pistillate/female parent)	Naronut 1R	Erudu red
Seed coat color	Tan	Red	Red	Red
Seed size	Large	Medium	Medium	Small
Leaf color	Green	Dark green	Green	Dark green
Peg pigmentation	Green	Green	Purple	Green
Leaf shape	Large ovate green leaves	Medium elliptical green leaves	Small to medium elliptical green leaves	Small to medium ovate green leaves
Reticulation on pod surface	Moderate to none	Prominent	Prominent	Moderate to none
Pod constriction	None to slight	Moderate to deep	Moderate to deep	None to slight
Pod beak	Moderate to none	Prominent	Prominent	Moderate to none
Pod texture and thickness	Hard and thick	Soft and thin	Soft and thin	Soft and thin
Peg strength	Strong	Very strong	Very strong	Strong
Growth habit	Semi-erect	Decumbent-3	Decumbent-3	Semi-erect
Maturity, DAP	110	100–110	75–80	90
Groundnut rosette resistance	Resistant (1–3)	Moderate resistant (4–6)	Resistant (1–3)	Moderate resistance (4–6)
Late leaf spot resistance	Resistant (1–3)	Moderate resistant (4–6)	Resistant (1–3)	Moderate resistant (4–6)

Note. DAP, days after planting.

uniformly spread throughout the season. Growing season 2 (designated B) runs from September to December/January and has less rainfall that is sporadic. Growing season 2 is usually dry in December and January. Eleven trials were planted with the onset of rains. Year 1 trials (2014B) were planted in September 2014 at Serere; Year 2 trials (2015A) were planted in April 2015 at Serere; Year 3 trials were planted in April 2016 at Nakabango and Serere (2016A) and in September 2016 at Abi, Nakabango and Serere (2016B); and Year 4 trials (2017A) were planted in April 2017 at Abi, Bulindi, Nakabango, and Serere. No fertilizer or fungicides were applied in any of the locations. Plot size consisted of eight rows 5.0 m long spaced at 30 cm between rows and 10 cm between plants within rows, giving a plant population of 400 plants per plot (50 seedlings per row). Erudu red was used as a control in all trials. Plants were harvested when 80% of the pods showed dark brown discoloration inside the pods. Yields were determined from pods having a 10–12% moisture content

To determine shelling percentage, 100 randomly selected pods were shelled, and hulls and seeds were weighted separately. The shelling percentage was calculated as the ratio of seed weight divided by pod weight (total of hull and seed) multiplied by 100. A 7.1-mm screen was used to segregate the sound mature kernels, which were used to record the 100-seed weight. Protein, sugar, oil, and flavor scores were conducted by J. Leek and Associates (Albany, GA). Five hundred grams of seed was used to determine the flavor score by a trained flavor panel.

The GRD severity rating used to evaluate Naronut 1R is based on a 1–9 scale, where 1–3 is resistant (a gradient scale of

no rosette to mild rosette with a range of 0 to 1/4 of the entire plant stunted), 4–6 is moderately resistant (a gradient scale of severity with a range of 1/4 to 3/4 of each infected plant stunted), and 7–9 is susceptible (a gradient scale of severity with a range of 3/4 to the entire plant stunted) (Mugisa et al., 2015; Okello et al., 2014). The LLD severity rating is based on a 1–9 scale. A lengthy description of each score from 1–9 is described in Subrahmanyam et al. (1982).

Net profits for Naronut 1R and Erudu red were determined by multiplying pod yields $\times$ shelling percentage $\times$ price per kilogram of shelled foundation seed. Shelled foundation seed paid for Naronut 1R in 2020 was 20,000 Uganda shillings (US\$5.56) and 6,000 Uganda shillings (US\$1.63) for Erudu red.

2.4 | Statistical analysis

Before running a separate analysis by year, a Bartlett test of homogeneity of variance test was conducted. The biological explanation for the separate analysis by year was also provided by different edaphic and environmental factors. Within each year, the location and location $\times$ variety were used as random factors, and appropriate error terms were used to calculate the mean sum of squares of each variable factor. Data for each variable were analyzed using PROC ANOVA procedure in Statistical Analysis System (Version 9.4) (SAS Institute, 2012). Analysis of variance for all traits was done with SAS PROC MIXED in the Statistical Analysis System (Version 9.4) (SAS Institute, 2012). In the yield trials conducted from 2014 to 2017 by the NaSARRI breeding program

in Serere (Okello, 2019), within any individual year, location and replication were considered random effects and varieties fixed. The LS means for various main and interaction effects were calculated using the 'LSMEANS' statement in SAS. Mean separation tests for LS means were conducted using the 'PDIFF' option in SAS. As the PDIFF option in SAS gives only the probability differences between the treatments, letters for mean separation in PROC MIXED were assigned by invoking macro 'PDMIX 800' (Saxton, 1998). Appropriate error terms were used to calculate the F-values for both main and interaction effects. Within a year, the entries for a particular trial were constant. The means compared can be either simple main effect means or interaction means. We have specified multiple means comparison adjustment in the LSMEANS statement (such as PDIFF adjust = Tukey). If the F-value is significant, a mean separation test was conducted using the LSMEANS procedure in SAS (SAS Institute, 2012). In the LSMEANS procedure, additional PDIFF and PDMIX 800 options were used to evaluate the probability significance among various main and interaction effects. Means were considered statistically different if the *p* value was $\leq .05$, $.01$, and $.001$. In Tables 2, 3 and 4, a Student's *t* test was used to compare Naronut 1R and Erudu Red.

3 | CHARACTERISTICS

3.1 | Plant, yield, and grade characteristics

Naronut 1R is a Spanish market-type cultivar with a red seed color, which matures in 75–80 d, depending on the season and location in Uganda. Naronut 1R has a decumbent-3 growth habit (Kumari et al., 2014) with alternate branching and medium-sized elliptic green leaves. The cultivar has an average of seven primary and four secondary branches. Naronut 1R produces medium-sized pods (34.7-mm average length, 11.2-mm average width) with prominent reticulation, moderate beak, and moderate to deep prominent constriction. Roots are extensive and long, and reticulated pods hold soil. Most of the pods contain two seeds (occasionally, one or three). Naronut 1R has a white seed bed-cushion in the inner pod where the seeds sit. Their pegs are very strong even at maturity, plants are easy to hand harvest, and pods are soft and easy to shell by hand or machines.

The ANOVA summaries for all five traits analyzed are given in Table 2. Pod yield for Naronut 1R was significantly more than Erudu red in all growing seasons. Averaged across 5 growing seasons, Naronut 1R produced a 165.9% higher pod yield (1,473 kg ha⁻¹) than Erudu red (554 kg ha⁻¹). The shelling percentage was significantly lower for Naronut 1R than Erudu red in 2016A, 2016B, 2017A. The overall shelling percentage (combined years) for Naronut 1R and Erudu red were 49.3 and 60.0%, respectively, a decrease of

17.8% for Naronut 1R. Significant differences were observed for 100-seed weight (combined year mean) between Naronut 1R (30.2 g) and Erudu red (27.6 g) (Table 2). The net profit for growing Naronut 1R is US\$4,038 ha⁻¹ compared with US\$542 ha⁻¹ for Erudu red. These numbers factor in the reduced shelling percentage of Naronut 1R. The net profits represent a 7.5× increase in additional income for Naronut 1R. Based on 2020 market prices, growers in Uganda can benefit from growing Naronut 1R because it has higher pod yields and more durable resistance to GRD compared with Erudu red (see Section 3.2).

3.2 | Disease resistance

Naronut 1R had significantly lower GRD scores in all five seasons compared with Erudu red (Table 2). The overall GRD rating (combined years) was significantly lower in Naronut 1R (2.8 GRD score) compared with Erudu red (5.0 GRD score), a decrease of 44.0% (Table 2). Similarly, the LLD rating was lower in all five seasons, with significantly lower scores for Naronut 1R compared with Erudu red in 2016A, 2016B, and 2017A. The overall LLD rating (combined years) was significantly lower in Naronut 1R (3.6 LLD score) compared with Erudu red (5.0 LLD score), a decrease of 28.0% (Table 2). Therefore, Naronut 1R performs much better with lower GRD and LLD incidence compared with Erudu red, resulting in higher yields.

3.3 | Quality analysis

The mean roasted peanut and sweetness flavor intensities of Naronut 1R were greater than Erudu red (Table 3). Naronut 1R contained 15.0% less protein compared with Erudu red, 18.1 and 21.3%, respectively, and had 19.8% lower oil concentration, 36.0 and 44.9%, respectively (Table 4). Naronut 1R and Erudu red were similar in sugar content, 4.0 and 4.2%, respectively (Table 4).

4 | CONCLUSION

The successful integration of early maturity, high yield, resistance to GRD and LLD, and a red seed coat into a Spanish-type groundnut provides great value to smallhold farms growing groundnut under rain fed conditions in western, central, and southern Uganda. The cultivar, as well as its sister variety Naronut 2 T (a tan seed cultivar grown primarily in northern and eastern Uganda) (Okello et al., 2021), also has potential for other groundnut growing regions of Sub-Saharan Africa, for use in breeding programs for introgression of selected traits into local landraces, and to improve

TABLE 2 Peanut cultivar Naronut 1R compared with Erudu red during 2014–2017

Years/site	No. of test sites	Entries	Pod yield kg ha ⁻¹	Shelling %	Pr > t	100 seed weight g	Rosette disease rating	Pr > t	Late leaf spot disease rating	Pr > t
2014B Ser	1	Naronut 1R	1148 a	48.3	0.0313*	30.7	2.0 b	0.08429	3.0	0.0377*
		Erudu red	741 b	63.0		30.0	3.7 a		3.3	
2015A Ser	1	Naronut 1R	1514	54.0	0.3168	30.0	4.0 b	0.3534	3.8	0.0273*
		Erudu red	551	54.8		25.0	7.5 a		4.8	
2016A Nak, Ser	2	Naronut 1R	2653 a	43.8 b	0.0314*	28.1	2.8	0.2669	4.6 b	0.0062***
		Erudu red	784 b	59.3 a		27.1	5.1 a		6.3 a	
2016B Abi, Nak, Ser	3	Naronut 1R	976 a	55.6	0.0010***	33.6 a	1.7 b	0.0371	2.4 b	0.0441*
		Erudu red	318 b	64.9 a		27.3 b	3.8 a		5.3 a	
2017A Abi, Bul, Nak, Ser	4	Naronut 1R	1072 a	44.9 b	0.0063**	28.8	3.4 b	0.8512	4.4 b	0.0288*
		Erudu red	375 b	58.2 a		28.4	4.7 a		5.1 a	
Combined	11	Naronut 1R	1473 a	49.3 b	< .001***	30.2 a	2.8 b	0.0184*	3.6 b	< .001***
		Erudu red	554 b	60.0 a		27.6 b	5.0 a		5.0 a	

Note. Abi, Abi; Bul, Bulundi; Nak, Nakabango; Ser, Serere. Letter “A” after the year in column refers to season 1, April–August planting season, and “B” refers to season 2, September–January planting season. Student’s t-test was used to compare among genotypes.
*Significant at $p \leq .05$.
**Significant at $p \leq .01$.
***Significant at $p \leq .001$.

TABLE 3 Flavor components of Naronut 1R and Erudu red groundnut seeds

Genotype	Flavor intensity			
	Roasted	Sweet	Aromatic	Bitter
	0–10 ^a			
Naronut 1R	4.3 a	4.0 a	2.0 b	2.3 a
Erudu red	3.3 b	2.7 b	2.7 a	0.7 b

Note. Data are mean values from selected locations harvested in 2019 in Clovis, New Mexico. Means followed by distinct letters are different at the $p = .05$ level of probability. Student's t-test was used to compare.

among genotypes.

^aFlavor intensity units rated on a 0 (none) to 10 (strong) scale.

TABLE 4 Two-year average protein, sugar, oil, and moisture concentration of Naronut 1R and Erudu red seed

Genotype	Protein	Sugar	Oil	Moisture
	%			
Naronut 1R	18.1 b	4.0	36.0 b	3.0
Erudu red	21.3 a	4.2	44.9 a	2.8

Note. Data are mean values from selected locations harvested in 2019 in Clovis, New Mexico. Means followed by the same letter are not different at the $p = .05$ probability level. Student's t-test was used to compare among genotypes.

previously released cultivars developed for smallholder farmers.

5 | AVAILABILITY

Seed of Naronut 1R has been deposited with the USDA-ARS National Center for Genetic Resources Preservation, Fort Collins, CO, and will be freely available for research purposes immediately upon publication. The nucleus seed will be maintained by NaSARRI, P.O. Box 56, Soroti, Uganda. The cultivar must be sold as a class of certified seed, by cultivar name only. Small samples of seed for research purposes may be obtained from the corresponding author.

ACKNOWLEDGMENTS

This research was supported in part by NaSARRI, Uganda, USDA-NIFA-Hatch funds provided to New Mexico Agricultural Experiment Station, and the U.S. Agency for International Development (USAID) through the Award number AID-ECG-A-00-07-0001 to the University of Georgia as the management entity for the U.S. Feed the Future Innovation Lab on Peanut Productivity and Mycotoxin Control. We thank ICRISAT-Malawi for providing germplasm and NaSARRI for providing fields and facilities used in this study. The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the U.S. Government.

AUTHOR CONTRIBUTIONS

David K. Okello: Conceptualization, Analysis, Funding, Investigation, Methodology, Writing & editing, Project administration. C. Michael Deom: Conceptualization, Funding, Investigation, Project administration, Writing & editing. Naveen Puppala: Data Analysis & Validation; Writing & editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

David K. Okello  <https://orcid.org/0000-0001-5705-6898>

Naveen Puppala  <https://orcid.org/0000-0001-8794-1345>

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Okello, D. K., Deom, C. M., & Puppala, N. (2023). Registration of ‘Naronut 1R’ Groundnut. *Journal of Plant Registrations*, 17, 40–46. <https://doi.org/10.1002/plr2.20248>