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New High-yield Cooking Banana Cultivars with Multiple Resistances to Pests and Diseases ('NAROBan1', 'NAROBan2', 'NAROBan3', and 'NAROBan4') Released in Uganda

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'NAROBan1', 'NAROBan2', 'NAROBan3', and 'NAROBan4' are secondary triploid cooking banana cultivars. They were bred by the National Agricultural Research Organisation (NARO) in Uganda, and officially released and added to the national cultivar list by the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) in 2017. The cultivars are highly resistant to black Sigatoka, a fungal disease caused by *Mycosphaerella fijiensis* (Morelet), which was the main breeding target. In addition, they are resistant to the banana weevil *Cosmopolites sordidus* (Germar) and nematodes, the pests of most economic concern in banana production, especially in the lowland areas of central and eastern Uganda. Compared with the local cultivars, which have an average bunch yield of less than 30% of their potential of 60 to 70 t/ha/year, 'NAROBan1', 'NAROBan2', 'NAROBan3', and 'NAROBan4' produce average bunch yields of 54.9 t/ha/year, 60.4 t/ha/year, 64.7 t/ha/year, and 68.8 t/ha/year, respectively. Moreover, they have soft, tasty, aromatic, and near-yellow food color, which make them appreciated like the existing farmer-accustomed local cooking banana cultivars that have, however, a low yield and are susceptible to pests and diseases.

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Origin

Banana (*Musa* spp.) is an important food and cash crop grown extensively in the tropical and subtropical regions of the world (FAOSTAT, 2016). In Uganda, the cooking type of banana commonly known as East African highland banana occupies the largest cultivated area among staple food crops and is grown by more than 75% of the farmers. The current productivity of cooking banana cultivars in the country is less than 30% of their potential of 60 to 70 t/ha/year (Tushemereirwe et al., 2001). Moreover, their plantation life in some areas of Uganda has reduced enormously to less than 5 years (Tushemereirwe et al., 2001). The reduced productivity and plantation life are largely attributed to susceptibility of the local cultivars to the banana weevil *Cosmopolites sordidus* (Germar), burrowing nematodes, and black Sigatoka (Brown et al., 2017). One of the key strategies for addressing these challenges in the country is by developing resistant cultivars through breeding. This article presents four new cooking banana cultivars (NAROBan1, NAROBan2, NAROBan3, and NAROBan4) bred and released in Uganda.

'NAROBan1', 'NAROBan2', 'NAROBan3', and 'NAROBan4' (Fig. 1) are secondary triploid banana hybrids derived from interspecific interploidy crosses made by scientists of NARO in Uganda. 'NAROBan1' originated from a cross of '917K-1' ('Enzirabahima' × 'Calcutta4') × 'SH3217', 'NAROBan2' from '365K-1' ('Kabucuragye' × 'Calcutta4') × 'SH3362', 'NAROBan3' from '917K-2' ('Enzirabahima' × 'Calcutta4') × 'SH3217' and 'NAROBan4' from '246K-1' ('Kabucuragye' × *Musa balbisiana*) × 'TMB2X7197-2'. Four hundred botanical seeds of each cross were harvested and their embryos germinated in vitro as described by Vuylsteke et al. (1990). A total of 500 hardened seedlings pooled from all the crosses were established in a single-site, nonreplicated, on-station early-evaluation trial at the National Agricultural Research Laboratories-Kawanda, Uganda, from 2005 to 2008. Fifteen cooking-type triploid hybrid bananas identified by flow cytometry (Karamura et al., 2016), with pendent bunches, resistance to black Sigatoka, and a bunch weight of ≥10 kg/plant were selected and multiplied in vitro for further evaluation in replicated randomized complete block design (RCBD) preliminary yield trials (PYTs) at three locations. The PYTs were established in 2009 and the hybrids were evaluated for bunch yield; response to black Sigatoka, weevils, and nematodes; and consumer acceptability for three cycles. Four promising hybrids combining high bunch yield; resistance to black Sigatoka, weevils, and nematodes; and high-quality fruit attributes were selected from PYTs of the 15 hybrids evaluated. The four hybrids selected, together with four other closely similar and already adopted cultivars (Kisansa, Enjagata, Mbwazirume, and Kabana 6H), were further evaluated in six regional on-farm trials in Nakabango, Nakaseke, Mukono, Ntungamo, Hoima, and Kawanda for two ratoon crop cycles from 2014 to 2017. The average rainfall received in Nakabango was 1150 mm; Nakaseke, 1240 mm; Mukono, 1390; Ntungamo, 900 mm; Hoima, 1371 mm; and Kawanda, 1280 mm. The trial at each site was laid out in an RCBD, with three replications using 2-month-old tissue culture plants that were planted in deep holes (0.4 m deep and 0.6 m wide) spaced at 3 × 3 m, giving a plant population density of 1111 plants/ha. Line plots of eight plants per genotype per block were used. At planting, 5 kg of well-decomposed organic manure were applied to each hole. Blocks were surrounded by 'Mbwazirume', a check cultivar susceptible to black Sigatoka, weevils, and nematodes. The trials were conducted without supplemental irrigation and the areas were weeded regularly. The new hybrids were evaluated under codes M19, M20, M25, and M27, and later released by MAAIF in 2017 as 'NAROBan1', 'NAROBan2', 'NAROBan3', and 'NAROBan4', respectively. 'NAROBan' denotes the institution NARO, which developed these hybrids. Genotypic response to black Sigatoka infection as the main target constraint was assessed using the index of nonspotted leaf (INSL) as described by Orjeda (1998). Their response to weevil damage was assessed according to Gold et al. (1998), and that of nematode damage according to Speijer and De Waele (2001). Growth and yield parameters were evaluated at flowering and at harvest according to Swennen and De Langhe (1985). Consumer acceptability tests of the genotypes' cooked food were completed by a panel of 60 trained banana farmers (35 women and 25 men)

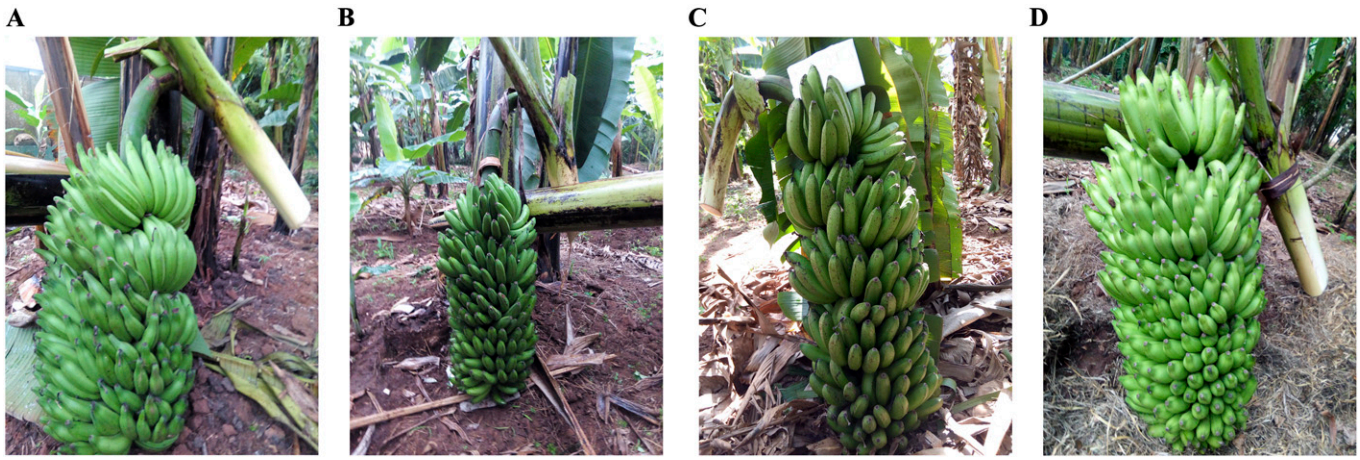

Fig. 1. Bunches of the four new cooking banana cultivars released in Uganda in 2017: (**A**) NAROBan1, (**B**) NAROBan2, (**C**) NAROBan3, and (**D**) NAROBan4.

Table 1. Mean performance of eight banana cultivars, including new hybrids, evaluated for bunch yield, number of hands, plant height, plant girth, number of functional leaves, and index of nonspotted leaf across two ratoon crop cycles and six sites in Uganda from 2014 to 2017.

Genotype	Bunch yield (t/ha/yr)	No. of hands	Plant ht (cm)	Plant girth (cm)	No. of functional leaves	Index of nonspotted leaf
NAROBan1 (M19)	54.9	10.5	281.1	48.0	12.8	76.1
NAROBan2 (M20)	60.4	10.1	320.0	55.4	11.6	77.9
NAROBan3 (M25)	64.7	10.3	339.9	53.8	11.4	82.9
NAROBan4 (M27)	68.8	11.0	341.8	56.3	11.0	78.4
Kabana 6H (M9)	60.0	9.7	341.0	54.6	11.9	76.2
Mbwazirume	24.3	8.5	255.1	51.4	8.2	48.2
Enjagata	23.4	7.4	281.3	46.2	7.0	46.3
Kisansa	34.4	8.0	280.6	45.1	9.0	41.9
Mean	48.9	9.4	305.1	51.4	10.4	66.0
$LSD_{0.05}$	2.9	0.3	14.2	1.8	0.53	4.0
F-probability	<0.001	0.001	<0.001	<0.001	<0.001	<0.001

LSD = least significant difference.

Table 2. Mean performance of seven cultivars evaluated for cross-sectional corm damage by weevils, and percentage of root necrosis by nematodes for two ratoon crop cycles at the National Agricultural Research Laboratories-Kawanda in Uganda from 2014 to 2017.

Cultivar	Total cross-sectional damage to corm by weevils (%)	Root necrosis by nematodes (%)
NAROBan1 (M19)	3.85	7.3
NAROBan2 (M20)	2.01	2.9
NAROBan3 (M25)	4.07	5.6
NAROBan4 (M27)	5.61	4.4
Kabana 6H (M9) (Hybrid check)	4.13	6.3
Mbwazirume (Susceptible local check)	10.32	16.9
Yangambi-KM5 (Resistant local check)	0.28	4.1
Mean	4.32	6.8
$LSD_{0.05}$	2.91	8.9
F-probability	<0.001	0.03

LSD = least significant difference.

Table 3. Mean performance of the four new cooking banana cultivars, local check cultivar 'Mbwazirume', and hybrid check cultivar 'Kabana 6H' evaluated for fruit sensory attributes across two ratoon crop cycles and six sites in Uganda from 2014 to 2017.

	Fruit sensory attributes[z]				
Cultivar	Taste	Aroma	Mouth feel	Color	Overall acceptability
NAROBan1 (M19)	5.17	4.87	4.83	4.87	5.03
NAROBan2 (M20)	5.24	4.83	4.87	4.53	4.87
NAROBan3 (M25)	4.22	4.33	4.53	3.27	4.13
NAROBan4 (M27)	4.87	5.33	5.23	5.53	5.13
Kabana 6H (M9)	4.13	4.23	4.43	3.33	4.03
Mbwazirume	5.73	5.52	5.63	5.63	5.63
Mean	4.89	4.86	4.92	4.53	4.81
$LSD_{0.05}$	0.11	0.09	0.09	0.10	0.09
F-probability	<0.001	<0.001	<0.001	<0.001	<0.001

[z]Hedonic scale of 1 to 6, where 1 = dislike extremely, 2 = dislike, 3 = like fairly, 4 = like, 5 = like very much, and 6 = like extremely.
LSD = least significant difference.

based on five sensory attributes—taste, aroma, mouth feel, color, and overall acceptability—using a scale of 1 to 6, where 1 = dislike extremely, 2 = dislike, 3 = like fairly, 4 = like, 5 = like very much, and 6 = like extremely. Data collected across six sites and two ratoon crop cycles were averaged and analyzed using GenStat, version 14 (Payne et al., 2011). Trait means were separated using least significance differences at $P < 0.05$ (Payne et al., 2011).

Description

The field trial performance results (Table 1) show that 'NAROBan1', 'NAROBan2', 'NAROBan3', and 'NAROBan4' are medium to tall cultivars with wide pseudostem