7-23-2020

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Received: 6 April 2020 | Accepted: 8 June 2020 | Published online: 23 July 2020

DOI: 10.1002/plr2.20072

Journal of Plant Registrations

DESCRIPTION OF GENETIC PLANT MATERIAL

Description of Baetao-Manteiga 41 and 'Yunguilla' superior Andean common beans for Tanzanian production environments

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Funding information
Norman Borlaug Cooperative Research Initiative (NBCRI) Grain Legumes Project of the US Agency for International Development, Grant/Award Number: Project no. 0210-22310-004-96R

Abstract

An international effort was initiated with the evaluation of a diverse set of large-seeded Andean common beans (*Phaseolus vulgaris* L.), the Andean Diversity Panel, in sub-Saharan Africa. Several entries in the panel have been selected for extensive characterization on the basis of high performance across multiple location × year trials in Tanzania—conducted both on station and on farm. Baetao-Manteiga 41, tested as ADP-190, has a commercial Kablanketi (light purple speckled) seed type, and 'Yunguilla', tested as ADP-447, has a commercial Calima (red mottled) seed type. Both lines exhibited yield stability, vigorous growth under low fertility conditions, angular leaf spot resistance, and moderate common bacterial blight resistance; Yunguilla also possessed rust resistance. These two lines were tested, selected, and characterized cooperatively by Sokoine University of Agriculture (SUA), the Tanzanian Agricultural Research Institute (TARI), the USDA-ARS, and the Agricultural Research Council (ARC) of South Africa, and in collaboration with local farmers in Tanzania.

1 | INTRODUCTION

A worldwide collaborative effort to improve large-seeded dry beans (*Phaseolus vulgaris* L.) under the Norman Borlaug Cooperative Research Initiative (NBCRI) Grain Legumes Project (http://arsftfbean.uprm.edu/bean/) was initiated in 2012 with the generation and extensive evaluation of the Andean Diversity Panel (ADP), a diverse international collection of Andean bean germplasm (Cichy et al., 2015). Evaluations of the ADP were conducted in South Africa, Tanzania, Malawi, Mozambique, Zambia, and Uganda in sub-Saharan Africa, as well as in the United States, the Caribbean, and Central America. These multiyear evaluations of the ADP resulted in the elucidation of the genetic diversity of this collection and in the identification of key constraints for Andean bean productivity (Cichy et al., 2015), training and capacity

Abbreviations: ADP, Andean Diversity Panel; ARC, Agricultural Research Council; BCMV, *Bean common mosaic virus*; CIAT, International Center for Tropical Agriculture; SUA, Sokoine University of Agriculture; TARI, Tanzanian Agricultural Research Institute.

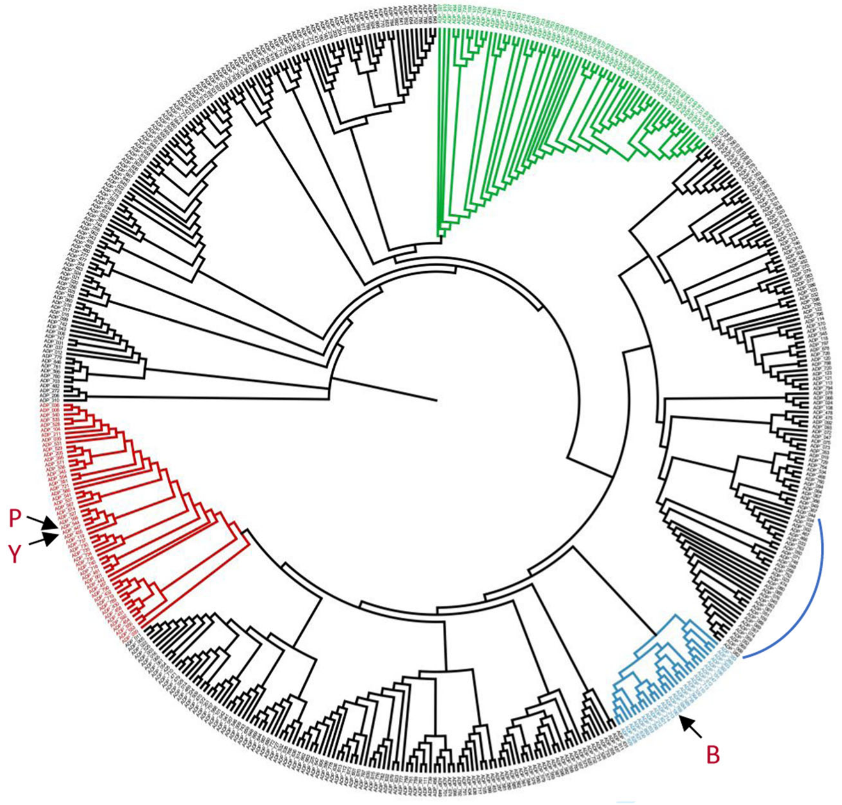

FIGURE 1 Neighbor joining tree diagram generated by NGSEP using the VCFDistanceMatrix Calulator command for 463 Andean Diversity Panel lines using 17,969 single nucleotide polymorphisms (filtered by >0.05 MAF, minor allele frequency) (http://arsftfbean.uprm.edu/bean/?p=472). Blue branches represent the cluster with Baetao-Manteiga 41, designated as "B", while the majority of Kablanketi lines of African origin are within the blue curved line. Yunguilla designated as "Y" and PVA 773 as "P" are within the red branch cluster, and lines with >80% admixture from the Middle American gene pool are represented by the green branch cluster

development, and a deeper understanding of the genetic architecture of halo blight (Tock et al., 2017), caused by *Pseudomonas syringae* pv. *phaseolicola* (Burkholder) Young et al.; root rot (Binagwa, Bonsi, & Msolla, 2016), caused by a complex of fungal pathogens; biological nitrogen fixation (Kamfwa, Cichy, & Kelly, 2015); anthracnose (Zuiderveen, Padder, Kamfwa, Song, & Kelly, 2016), caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) Briosi & Cavara; angular leaf spot (Miklas et al., 2020), caused by *Pseudocercospora griseola* (Sacc.) Crous & U. Braun; and cooking and nutritional characteristics (Bassett, Cichy, & Ambechew, 2017), among other ongoing efforts.

The ADP, with about 400 accessions, is composed primarily of Andean gene pool germplasm but also a small number of Middle American and intergene pool hybrids (Figure 1). The largest number of entries in the ADP are from Africa, followed by North America, South America, and the Caribbean, and they represent landraces, breeding lines, and released germplasm lines and cultivars (Cichy et al., 2015). Thus, the ADP represents broad potential adaptation, diverse seed types and plant architecture, and lines representing unique sources of stress tolerance and biotic resistance. Lines within the ADP possess tolerance to drought, high temperature stress, and low soil fertility; resistance to angular leaf spot, rust, anthracnose, root rot complex, ashy stem blight (caused by *Macrophomina phaseolina*), common bacterial blight [caused by *Xanthomonas axonopodis* pv. *phaseoli* (Smith) Vauterin et al.], halo blight, and *Bean common mosaic virus* (BCMV); and superior germplasm combining multiple stress tolerance. The extensive multicountry evaluations of the ADP resulted in the identification of superior and locally adapted germplasm by national breeding programs with specific production constraints (http://arsftfbean.uprm.edu/bean/?page_id=207).

Tanzania is the largest common bean producer in Africa, with a production area of 1,177,400 ha planted to dry beans in 2018 (FAO, 2020); however, the production environment is primarily small-scale and low-input, specifically with minimal input of pesticides, herbicides, and fertilizers, resulting in average yields <500 kg ha^{-1} (Hillocks, Madata, Chirwa, Minja, & Msolla, 2006). Nitrogen and phosphorus are constraints in 50% (Graham et al., 2003) and 65% (Kimani et al., 2001), respectively, of eastern African production areas. Farmers have little access to irrigation, and the rainfed environment often leads to both intermittent and terminal drought stress depending on the agro-environmental zone and year. Angular leaf spot, rust, BCMV, anthracnose, and common bacterial blight are some of the main biotic constraints (Hillocks et al., 2006). Through collaboration between breeding programs at the Sokoine University of Agriculture (SUA) and the Tanzanian Agricultural Research Institute (TARI), Tanzania has a long history of common bean releases from two TARI Research Centers, in Arusha (Selian) and Mbeya (Uyole). Germplasm evaluations have frequently resulted in the release of ex situ breeding lines, while novel population development in Tanzania has led to development and release of locally developed cultivars resulting from farmer participatory selection, such as 'Mshindi' (Nchimbi-Msolla et al., 2008a) and 'Pesa' (Nchimbi-Msolla et al., 2008b).

The goal of this effort is to describe superior, commercial, and adapted Andean germplasm from the ADP with production potential in Tanzania. These germplasm were tested, selected, and characterized cooperatively by SUA, TARI, USDA-ARS, and Agricultural Research Council (ARC) of South Africa, and with farmer participation in villages near Arusha and Mbeya. Here we describe two superior ADP accessions, Baetao-Manteiga 41 and 'Yunguilla'.

2 | METHODS

The screening of the ADP panel was conducted to identify and describe promising lines that could be increased and released directly for the main Tanzanian production zones. Early trials involved the screening of a large subset of the ADP including 415 lines. For Tanzania, these evaluations of the ADP were conducted on progressively smaller subsets of superior lines that were selected from annual evaluations from 2013 to 2017, with a genotype plus genotype-by-environment biplot analysis conducted on field trials conducted in three locations (Arusha, Mbeya, and Morogoro) in 2013 and 2014 (Mndolwa, Nchimbi-Msolla, Porch, & Miklas, 2019).

Yunguilla (PI 693220), tested as ADP-447, was originally developed as PVA 773 (or G51137) at the International Center for Tropical Agriculture (CIAT) from the cross ICA Línea 24//ICA 10009/Mulato Gordo. It has seed with a red-mottled pattern on a cream background, which fits the Calima market type. ADP-447 was provided by the Instituto Nacional de Investigaciones Agropecuarias (INIAP) and identified as the cultivar Yunguilla (or INIAP 414), released in southern Ecuador in 1993 (Lépiz Ildefonso, G., Jiménez Ruiz, & Villacís, 1993) and released again in 2004 in northern Ecuador (Peralta, Mazón, Murillo, & J Pinzón, 2004). The release publication indicates resistance to anthracnose, intermediate resistance to rust, and adaption to elevations between 1,400 and 2,400 m asl. PVA 773 was also released as 'ICA Caucaya' in Colombia in 1991, in Bolivia as 'Rojo Oriental' in 1995, in Panama as IDIAP C-1, and in Mozambique as PVA 773 (Voysest, 2000a; Voysest, 2000b). Voysest (2000b) indicated that Rojo Oriental was resistant to angular leaf spot and common bacterial blight, in addition to the rust and anthracnose resistance mentioned above. In a diallel study on biological nitrogen fixation in Tanzania, G51137A, a non-nodulating variant of PVA 773 developed through backcrossing at CIAT, was included as a non-nodulating parent but showed the highest general combining ability for yield per plant among the six lines studied (Ndimbo, Nchimbi-Msolla, & Semu, 2017), indicating its potential breeding value. These multiple releases for PVA 773, spanning three decades, demonstrates its broad adaptation and superior performance across five countries and three continents.

Landrace Baetao-Manteiga 41 (PI 306148), tested as ADP-190, is from Brazil and was donated to the USDA-ARS GRIN collection in 1965 and is identified in the CIAT collection as G1678. It has a light purple-speckled seed that fits in the Kablanketi market type. It was originally collected at 860 m asl in Minas Gerais, a state located in southeastern Brazil. There is limited research on Baetao-Manteiga 41, but a study on iron and zinc content of the seed showed midrange performance for these elements (Welch, House, Beebe, & Cheng, 2000).

Field evaluations were conducted in three regions of Tanzania, including Arusha in the north, Morogoro in the center, and Mbeya in the southern highlands. Detailed site descriptions for these locations were presented by Mndolwa et al. (2019), but briefly, SUA's Morogoro field site is located at 526 m asl with Ultisol soils; the TARI Selian Research Center in Arusha is at 1,387 m asl with Nitisol soils; and the TARI Uyole Research Center in Mbeya is at 1,780 m asl with Haplic Andosol soils. The ARC trials were conducted in Cedara, South Africa, at approximately 1,100 m asl on Hutton soils (Haplic Arenosol).

A randomized complete block design was used in the on-station trials. Specifically, the 2013 and 2014 trials in Tanzania were conducted with single row plots 8 m in length, 0.5 m between rows, and two replications; the 2013 trials in Cedara, South Africa, were conducted with one-row plots, 4 m in length, 0.75 m between rows and two replications. The 2016 and 2017 trials in Tanzania were conducted with four-row plots, 5 m in length, 0.5 m between rows and three replications. The plant densities ranged from 90,000 plants ha^{-1} in Tanzania to 200,000 in South Africa. Performance data including yield (kg ha^{-1}), seed weight (g 100 seeds^{-1}), disease response (rated from 1 = no symptoms to 9 = completed disease), days to flower, and days to maturity were collected.

On-farm trials were conducted in villages near the TARI Selian Research Station in Arusha and the TARI Uyole Research Station in Mbeya in 2016, 2017, 2018, and 2019. The final selection of two lines from a small subset of 19 lines from the original ADP was in participation with farmers. The farmer evaluation of the lines and ranking were key for our final selection and for ensuring adoption and use of these lines. Trials were evaluated in farmers' fields in Nambala, Nasholi, Sakila, and Kikatiti villages near Arusha and in the Ivwanga village near Mbeya in collaboration with local TARI extension agents. The trials were organized in a randomized complete block design with two-row plots that were 5 m in length, 0.5 m between rows, and with three replications in 2016, while in the subsequent trials three-row plots that were 4 m in length, 0.5 m between rows, and with three replications were used. Yield, seed weight, and disease response data were collected.

Disease evaluations were conducted using the standard 1-9 scale system for common bean (Van Schoonhoven & Pastor-Corrales, 1987) response to angular leaf spot, rust, and common bacterial blight. These evaluations were conducted between flowering and plant maturity.

The statistical analyses were performed using SAS (SAS Institute, Cary, NC, USA) for each trial individually. Fisher's protected LSD ($p = .05$) was used to compare line means in trials that had significant F-tests for lines. Local checks were included in each trial and varied from trial to trial based on local farmer preferences in on-farm trials or on standard checks for on-station trials.

3 | CHARACTERISTICS

Yunguilla had yields that were above the trial means in the on-station and on-farm trials, but they were not statistically different from the checks included in the trials (Table 1). For both on-farm and on-station trials, farmers commented about its high agronomic value. Yunguilla had high seed weights of 41.7 and 39.3 g 100 seed^{-1} in on-station and on-farm trials (Table 2), respectively, and produced a commercially desirable red mottled seed for the Calima market class.

In trials conducted in South Africa and Tanzania, Yunguilla was consistently superior for its level of disease resistance compared with the other germplasm tested. This multiple resistance, including previously published anthracnose resistance, included above average resistance to angular leaf spot (Table 3) and rust (Table 4) and moderate resistance to common bacterial blight (Table 5) in the on-station field trials. For on-farm trials in 2019, farmers were asked to select the genotypes they would choose to grow in their own fields based on field performance and seed traits. From this evaluation, Yunguilla was ranked first in farmer preference among 14 lines and 5 checks tested (Table 6). Yunguilla has a determinate bush, Type I plant habit. It flowered in 42 d and matured in 90 d in on-station trials conducted in 2013 and 2014 in Tanzania (data not shown). A cluster analysis (Figure 1) revealed that Yunguilla (ADP-447) was nearly identical to PVA 773 (ADP-544), which validates its derivation from PVA 773. But the lack of a complete match between Yunguilla and PVA 773 may reveal some genetic drift since Yunguilla (INIAP 414) was derived from PVA 773 more than 27 yr

TABLE 1 Seed yield produced in on-station trials at the Tanzania Agriculture Research Institute (TARI) Uyole Station in Mbeya, Tanzania, the TARI Selian Station in Arusha, Tanzania, and at the Sokoine University Station (Sokoine) in Morogoro, Tanzania; and in on-farm trials on farmer fields in the Legeruki, Sakila, Nambala, and Kikatiti villages in the Arusha region and in the Ivwanga village in the Mbeya region, 2013–2017

			On-station trials (2013–2017)											On-farm trials (2016–2017)						
Line	ADP ID	Market type	Mbeya Uyole 2013	Morogoro Sokoine 2013	Mbeya Uyole 2014	Morogoro Sokoine 2014	Arusha Selian 2014	Mbeya Uyole 2016	Arusha Selian 2016	Arusha Selian 2017	Morogoro Sokoine 2017	Mbeya Uyole 2017	Mean	Arusha Legeruki 2016	Arusha Sakila 2016	Mbeya Ivwanga 2016	Arusha Nambala 2016	Arusha Sakila 2017	Arusha Kikatiti 2017	Mean
			kg ha^{-1}																	
Baetao-Manteiga 41	190	Kablanketi	805	305	1032	920	638	816	492	2126	384	1635	915	623	804	91	1192	745	722	696
Yunguilla	447	Calima	969	360	1785	734	346	906	472	1630	1068	1419	969	437	618	219	1006	555	1204	673
Kablanketi ndefu (check)	84	Kablanketi	410	119	1695	694	847	1327	621	2362	646	1520	1024	490	718	156	1067	535	314	547
Uyole 98 (check)	111	Yellow	866	302	1533	1185	557	796	329	2150	653	1542	991	577	778	228	1058	527	1010	696
Local check			–	–	–	–	–	–	–	–	–	–	NT	586	766	252	785	702	735	637
Mshindi (check)	107	Kablanketi	242	608	1470	517	205	–	–	1202	679	659	698	–	–	–	–	–	–	NT
Rojo (check)	96	Large Red	118	144	1101	763	236	–	–	1060	940	644	626	–	–	–	–	–	–	NT
Mean			741	460	1092	770	775	1032	452	1771	791	1196	908	552	743	262	893	650	730	639
LSD			326	345	347	475	460	NS	NS	643	524	299		NS	NS	168	236	378	425	
CV			22	40	17	32	31			22	40	15				38	16	35	35	

Note. ADP, Andean Diversity Panel; NT, not tested.

TABLE 2 Seed weight produced in on-station trials at the Tanzania Agriculture Research Institute (TARI) Uyole Station in Mbeya, Tanzania, the TARI Selian Station in Arusha, Tanzania, and at the Sokoine University Station (Sokoine) in Morogoro, Tanzania; and in on-farm trials on farmer fields in the Sakila, Nambala, and Kikatiti villages in the Arusha region and in the Ivwanga village in the Mbeya region, 2013–2017

			On-station trials										On-farm trials				
			Mbeya	Morogoro	Mbeya	Morogoro	Arusha	Mbeya	Arusha	Morogoro	Mbeya	Mean	Arusha	Mbeya	Arusha	Arusha	Mean
	ADP	Market	Uyole	Sokoine	Uyole	Sokoine	Selian	Uyole	Selian	Sokoine	Uyole		Nambala	Ivwanga	Sakila	Kikatiti	
Line	ID	type	2013	2013	2014	2014	2014	2016	2017	2017	2017		2016	2016	2017	2017	
			g 100 seeds^{-1}														
Baetao-Manteiga 41	190	Kablanketi	36.5	26.6	44.4	38.0	48.5	48.7	50.9	39.6	41.9	41.7	33.4	29.3	50.0	38.0	37.7
Yunguilla	447	Calima	35.2	25.8	42.6	38.7	49.9	45.5	48.2	46.4	42.9	41.7	38.1	29.1	49.9	40.0	39.3
Kablanketi ndefu (check)	84	Kablanketi	32.5	20.3	37.8	38.8	48.3	43.5	49.6	44.5	45.8	40.1	32.0	33.9	40.1	20.8	31.7
Uyole 98 (check)	111	Yellow	29.8	28.5	36.9	38.7	39.3	37.4	42.0	38.6	38.8	36.7	30.8	28.1	38.5	31.4	32.2
Local check												NT	26.3	25.1	25.5	26.6	25.9
Mshindi (check)	107	Kablanketi	27.1	29.9	28.4	24.8	34.3	–	32.9	29.8	28.8	29.5	–	–	–	–	NT
Rojo (check)	96	Large Red	22.0	26.8	32.4	34.3	37.9	–	36.8	33.7	31.2	31.9	–	–	–	–	NT
Mean			33.0	28.0	38.0	38.0	45.0	39.7	45.3	39.1	39.4	40.9	32.6	27.5	43.6	33.5	34.3
LSD			4.8	9.1	4.1	9.8	8.3	3.4	2.8	4.2	6.9		2.9	3.6	5.8	9.6	
CV			7.2	17.3	5.6	13.0	9.8	5.0	3.7	6.4	10.4		5.4	7.9	7.8	17.0	

Note. ADP, Andean Diversity Panel; NT, not tested.

TABLE 3 Angular leaf spot disease response at the Agricultural Research Council (ARC) Station, Cedara, South Africa, at the Tanzania Agriculture Research Institute (TARI) Uyole Station in Mbeya, Tanzania, at the TARI Selian Station in Arusha, Tanzania, and at the Sokoine University Station (Sokoine) in Morogoro, Tanzania, from 2014 to 2017

Line	ADP ID	Market type	Cedara ARC 2014	Mbeya Uyole 2015	Mbeya Uyole 2017	Morogoro Sokoine 2017	Arusha Selian 2017	Mean
			1–9[a]					
Baetao-Manteiga 41	190	Kablanketi	3.5	5.3	4.3	5.0	6.3	4.9
Yunguilla	447	Calima	3.5	3.7	4.7	5.3	6.0	4.6
Kablanketi ndefu (check)	84	Kablanketi	3.0	5.7	4.7	5.7	5.3	4.9
Uyole 98 (check)	111	Yellow	5.5	2.0	2.3	4.3	1.7	3.2
Mshindi (check)	107	Kablanketi	–	6.3	6.0	5.7	4.0	5.5
Rojo (check)	96	Large Red	6.0	7.0	5.7	5.7	6.0	6.1
Mean			4.2	5.7	5.0	5.3	5.2	5.1
LSD			1.7	1.9	0.97	1.1	0.99	
CV			20.6	20.3	11.5	12.9	11.4	

Note. ADP, Andean Diversity Panel.
[a]Scale of 1–9, where 1 = resistant.

TABLE 4 Rust disease response in common bean trials at the Agricultural Research Council (ARC) Station, Cedara, South Africa, and at the Tanzania Agriculture Research Institute Uyole Station in Mbeya, Tanzania, from 2013 to 2017

Line	ADP ID	Market type	Cedara ARC 2013	Cedara ARC 2014	Mbeya Uyole 2015	Mbeya Uyole 2017	Mean
			1–9[a]				
Baetao-Manteiga 41	190	Kablanketi	3.3	3.5	7.0	3.0	4.2
Yunguilla	447	Calima	2.5	2.5	1.3	1.0	1.8
Kablanketi ndefu (check)	84	Kablanketi	1.5	1.5	3.7	2.3	2.3
Uyole 98 (check)	111	Yellow	3.0	7.0	2.0	1.0	3.3
Mshindi (check)	107	Kablanketi	–	–	5.3	1.3	3.3
Rojo (check)	96	Large Red	4.0	6.0	2.3	1.0	3.3
Mean			2.9	5.1	3.9	1.6	2.9
LSD			1.7	1.9	2.2	1.3	
CV			23.8	19	34.5	48.9	

Note. ADP, Andean Diversity Panel.
[a]Scale of 1–9, where 1 = resistant.

TABLE 5 Common bacterial blight disease response in common bean trials at the Tanzania Agriculture Research Institute (TARI) Uyole Station in Mbeya, Tanzania, at the TARI Selian Station in Arusha, Tanzania, and at the Sokoine University Station (Sokoine) in Morogoro, Tanzania, in 2017

Line	ADP ID	Market type	Mbeya Uyole 2017	Morogoro Sokoine 2017	Arusha Selian 2017	Mean
			1–9[a]			
Baetao-Manteiga 41	190	Kablanketi	1.0	3.3	4.0	2.8
Yunguilla	447	Calima	1.0	2.7	2.3	2.0
Kablanketi ndefu (check)	84	Kablanketi	1.0	6.3	5.0	4.1
Uyole 98 (check)	111	Yellow	1.7	4.0	2.0	2.6
Mshindi (check)	107	Kablanketi	1.0	5.0	4.7	3.6
Rojo (check)	96	Large Red	2.0	3.0	6.0	3.7
Mean			1.3	4.0	4.0	3.1
LSD			0.93	1.1	1.4	
CV			42.5	16.9	21.4	

Note. ADP, Andean Diversity Panel.
[a]Scale of 1–9, where 1 = resistant.

TABLE 6 Farmer evaluation of 19 lines tested (7 lines shown) in on-farm field trials in the Sikila, Nasholi, and Kikatiti villages in the vicinity of Arusha, Tanzania, in 2019

Line	ADP ID	Market type	Frequency[a] Sikila	Nasholi	Kikatiti	Mean	Rank
Baetao-Manteiga 41	190	Kablanketi	3	4	5	4	3
Yunguilla	447	Calima	5	6	7	6	1
Lyamungo 90 (check)	529	Calima	6	6	2	4.7	2
Soya Njano	Local check	Yellow	1	5	1	2.3	5
Calima Uyole	Local check	Calima	1	1	1	1.0	8
Mshindi (check)	107	Kablanketi	0	0	2	0.7	9
C. Wonder (check)	546	Large Red	1	0	0	0.3	10

Note. ADP, Andean Diversity Panel.
[a]Number of farmers choosing a line as the best, indicating that they would grow the cultivar in their own fields.

ago. Many other red mottled lines with bush growth habit reside within the same cluster as Yunguilla.

Baetao-Manteiga 41, as with Yunguilla, had yields slightly above the trial means in the on-station and on-farm trials, although these differences were not significantly different from the checks. The seed weight of Baetao-Manteiga 41 was 41.7 and 37.7 g 100 seed^{-1} in on-station and on-farm trials (Table 2), respectively, and it has a light purple speckled seed type with a slightly flat elongated shape that fits the Kablanketi market class.

Baetao-Manteiga 41 exhibited good angular leaf spot resistance (Table 3), was moderately susceptible to rust (Table 4), and had moderate resistance to common bacterial blight (Table 5). For on-farm trials in 2019, farmers ranked Baetao-Manteiga 41 third in terms of farmer acceptance (Table 6). Baetao-Manteiga 41 has an indeterminate Type III plant habit with purple flowers. It flowered in 42 d and matured in 90 d in on-station trials conducted in 2013 and 2014 in Tanzania (data not shown). Baetao-Manteiga 41 showed consistently high vegetative vigor in trials conducted under low fertility conditions. Baetao-Manteiga 41 is within the same cluster as many other Brazilian landraces with indeterminate growth habits, including JALO EEP558, which is a parent of the widely used BAT93/JALO EEP558 core mapping population (Galeano et al., 2011). The distinctiveness of this cluster possessing Baetao-Manteiga 41 from other ADP lines from Africa, especially those of the Kablanketi market types, reveals Baetao-Manteiga 41 as a unique germplasm for broadening the genetic base of the Kablanketi market class in Africa.

Due to the paucity of genetic diversity present in most Andean breeding programs in the United States, a second step was then taken to identify key genotypes from the ADP for use in breeding efforts to broaden the genetic base of Andean beans and to combine key abiotic and biotic stress tolerances. For this effort, bulk Phaseolus Improvement Cooperative (PIC) breeding populations (http://arsftfbean.uprm.edu/bean/?page_id=2) were developed from crosses between selected ADP lines. Selections were made in target environments, and advanced lines are currently being evaluated.

4 | AVAILABILITY

Seed of the tested versions of Baetao-Manteiga 41 (PI 306148) and Yunguilla (PI 693220) have been deposited in the USDA-ARS National Plant Germplasm System (https://www.ars-grin.gov/npgs/index.html), where they are available in limited quantities for research purposes, including development and commercialization of new cultivars. A limited quantity of seed of these lines may be obtained by writing to orders@ars-grin.gov or to the corresponding author (timothy.porch@usda.gov). Both lines will also be deposited in the National Gene Bank in Tanzania.

ACKNOWLEDGMENTS

We thank Steve Beebe at CIAT and Angel Murillo at INIAP for providing permission for release of Yunguilla (PVA 773) in Tanzania, and to the breeder of PVA 773, Shree Singh, for developing this superior line. We appreciate the financial support from the Norman Borlaug Cooperative Research Initiative (NBCRI) Grain Legumes Project of the United States Agency for International Development (Project no. 0210-22310-004-96R). Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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How to cite this article: Nchimbi Msolla S, Miklas P, Fourie D, Kilango M, Porch T. Description of Baetao-Manteiga 41 and 'Yunguilla' superior Andean common beans for Tanzanian production environments. *J. Plant Regist.* 2020;14:234–241. https://doi.org/10.1002/plr2.20072