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Breeding and Cultivation Techniques for New Edible Orange-Fleshed Sweet Potato Variety Nanshu 012

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Abstract The carotenoid in sweet potato has a high health value for the human body, and HarvestPlus has also carried out the breeding to improve the nutritional quality of sweet potatoes in order to address the health problems of people nutrient-deficient areas. Nanshu 012 is a new high-quality orange-fleshed sweet potato variety rich in carotenoid, bred by Nanchong Academy of Agricultural Sciences from the "Boga × Sanheshu" hybrid. In the regional test of sweet potato varieties in Sichuan Province during 2009 - 2010, the average fresh potato yield was 24600 kg/ha, the average dry matter percentage was 29.0% and the average preserved sweet potato yield was 7152.0 kg/ha; in the production test, the average fresh potato yield was 28410.0 kg/ha and the average preserved sweet potato yield was 8734.5 kg/ha. The multi-point sampling analysis showed that the total sugar content of fresh potato was 5.28%, protein content was 1.43%, vitamin C content was 28.9 mg/100g and carotenoid content was 5.21 mg/100g. This variety was identified by Sichuan Crop Variety Approval Committee in March 2012, with high fresh potato yield, sweetness, rich carotenoid and resistance to black spot. It is an orange-fleshed sweet potato variety suitable for eating and food processing, and it should be planted in the plot with moderate fertility or above, and should be planted and harvested as early as possible.

Key words Sweet potato, Nanshu 012, Carotenoid, Cultivation techniques

1 Introduction

According to the FAO statistics in 2010, China's potato growing area accounted for about 50% of total potato growing area in the world. The sweet potato growing area is about 1 million ha in Sichuan Province, and sweet potato is one of the important economic crops in Sichuan Province. The orange-fleshed sweet potato rich in carotenoid is mainly grown in the hills and mountains, with unique nutritional value[1-2] and medicinal value[3-5], and especially the varieties rich in carotenoid have higher health value, so they are much favored by consumers and processing enterprises. In recent years, the development of the new health-based orange-fleshed sweet potato variety rich in carotenoid becomes one of the important goals of sweet potato breeding. The breeding units across the country have launched a series of breeding projects about high-carotene varieties to bring out some varieties such as Yanshu 5, Longshu 9, Guangshu 87 and Weiduoli[6-9], which pass the national or local testing and approval. Nanshu 012 is the orange-fleshed sweet potato variety bred by Nanchong Academy of Agricultural Sciences by introducing outside resources. This variety has red skin and orange flesh, and the fresh potato has high yield, good shape, resistance to black spot and wide adaptability, so it is an ideal new sweet potato variety suitable for eating and food processing. The variety passed the identification of Sichuan Crop Variety Approval Committee in March 2012, with approval No. of Chuan Shen Shu 2012008.

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2 Breeding of Nanshu 012

2.1 Parental origin The breeding of Nanshu 012 focuses on the use of excellent resources introduced from abroad. There is a distant genetic relationship between two parents Boga and Sanheshu. Boga is the high-quality edible variety introduced from Xuzhou Sweet Potato Center and bred by Nanchong Academy of Agricultural Sciences in 2002, and Sanheshu is the variety introduced from Zhejiang Academy of Agricultural Sciences in the 1990s.

2.2 Breeding process In 2004, Nanchong Academy of Agricultural Sciences selected Boga as female parent and Sanheshu as male parent to be hybridized and the seeds were harvested. In 2005, the seedlings were screened, and the potato shape was good, and it was orange-fleshed with high dry matter. During 2006 - 2008, it took part in the variety comparison test and showed good performance. During 2009 - 2010, it took part in the regional test of new sweet potato varieties in Sichuan Province. In 2011, it took the sweet potato variety production test of Sichuan Province. In March 2012, it was identified by Sichuan Crop Variety Approval Committee, with name of Nanshu 012 and No. of Chuan Shen Shu 2012008. The parental breeding process can be shown in Table 1. Years of multi-point test results show that Nanshu 012 has high fresh potato yield, good shape and rich carotenoid. The cooked potato taste is good, and the processed candied potato has

bright color. It is an orange-fleshed sweet potato variety suitable for eating and food processing.

Table 1 Breeding process of Nanshu 012

Time	Measures
Winter 2004 (Hainan)	Boga Sanheshu
Spring 2005	Sowing hybrid seeds
Winter 2005	Selecting excellent line number 5 – 155 after planting
Winter 2006	Doing the second generation comparison test
Winter 2007	Doing variety comparison test
Winter 2008	Doing variety comparison test
2009	Participating in Sichuan regional sweet potato test
2010	Participating in Sichuan regional sweet potato test
2011	Participating in Sichuan sweet potato production test
2012	Passing the Sichuan variety approval, with name of Nanshu 012 and No. of Chuan Shen Shu 2012008
After approval in 2012	Completing introduction and demonstration of Nanshu 012

3 Main characteristics

3.1 Morphological characteristics The germination of Nanshu 012 is good, the vine is long and the stalk is of medium diameter. The growth of stems and leaves is strong and there are about three branches in the base part. The top leaves are purple and the leaf blade is heart-shaped and dark green. The leaf vein is light purple and the vine is green. The tuber is neat and concentrated and is spindle-shaped or sphere-shaped. The potato shape is beautiful and the one single plant may have 4 potatoes, with high rate of commercial potato. The potato skin is red and the potato flesh is orange.

3.2 Resistance After two years of indoor artificial seeding and black spot identification by Nanchong Academy of Agricultural Sciences, the results indicated that Nanshu 012 had resistance to black spot. The storage test results showed that it was resistant to storage.

3.3 Quality The multi-point sampling quality analysis results showed that the the drying rate of Nanshu 012 potato was about 29%, and the average drying rate was 1% higher than that of the control variety Nanshu 88. The starch rate was 19.21%; the total sugar content of fresh potato was 5.28%; the protein content was 1.43%; the vitamin C content was 28.9 mg/100 g; the carotenoid content was 5.21 mg/100 g.

4 Tuber yield

4.1 Variety comparison test The multi-point variety comparison test was done in Nanchong City in 2006. The results showed that the annual average yield of Nanshu 012 fresh potato was 31200.0 kg/ha at 3 points, basically the same as that of the control variety Nanshu 88; the drying rate was 1% – 2% higher than that of Nanshu 88; the average yield of preserved sweet potato was 6975.0 kg/ha, basically the same as that of the control variety Nanshu 88.

4.2 Regional test of sweet potato varieties in Sichuan Province In 2009, Nanshu 012 participated in the regional test of sweet potato varieties in Sichuan Province, and the average fresh potato yield at 7 points was 31099.5 kg/ha, 13.2% lower than that of the control variety Nanshu 88; the average preserved sweet potato yield was 7869.0 kg/ha, 16.8% lower than that of the control variety Nanshu 88. The test results in 2010 showed that the average fresh potato yield of Nanshu 012 was 24375.0 kg/ha, 14% lower than that of the control variety Nanshu 88; the average preserved sweet potato yield was 7125.0 kg/ha, 7.6% lower than that of the control variety Nanshu 88. The average fresh potato yield of Nanshu 012 in two years was 24600 kg/ha, 15% lower than that of the control variety Nanshu 88; the average preserved sweet potato yield was 7152.0 kg/ha, 10.0% lower than that of the control variety Nanshu 88; the average dry matter percentage was 29.0%, 1.6% higher than that of the control variety Nanshu 88.

4.3 Sweet potato variety production test in Sichuan Province Nanshu 012 participated in Sichuan's sweet potato variety production test in 2011 and the results showed that the average fresh potato yield was 28410.0 kg/ha at 6 points, 18% lower than that of the control variety Nanshu 88; the average preserved sweet potato yield was 8734.5 kg/ha, 13.6% lower than that of the control variety Nanshu 88. For the edible sweet potato, it reaches the approval standard of edible varieties.

5 Cultivation techniques

5.1 Deep soil plowing In the planting process of sweet potato, the soil properties have a great impact on yield, soil compaction can cause slow growth of sweet potato and poor tuber development, and it is difficult to increase yield by topdressing. The loose soil is conducive to the survival and nutrient absorption of sweet potato and can lead to many vines and rapid tuber enlargement. The deep plowing is conducted in sunny days and the depth is required to be 25 to 30 cm. Too shallow soil is not conducive to the soil nutrient decomposition, but the excessively deep plowing will damage soil properties and structure, reduce soil fertility and impede plant growth.

5.2 Ridge forming and fertilizer application Ridging cultivation can thicken the soil layer, loosen soil, enhance soil permeability, maintain soil temperature and moisture, expand the scope of root activity and promote underground tuber enlargement. Ridge forming should be conducted in sunny days, with ridge height of 20 – 25 cm, ridge width of 50 – 70 cm and ridge spacing of 80 – 90 cm. Fertilizers mainly include organic fertilizer, supplemented by phosphate and potassium fertilizers. The heavy base fertilizer should applied and the top dressing should be applied as early as possible.

5.3 Culture of seedling Nanshu 012 has good germination properties and the potato seedlings grow fast. The seeding rate of

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Regions		Inner Mongolia	Heilongjiang	Jilin	Hebei	Shandong
	Bound sterol	8.79 ± 4.04^{b}	4.95 ± 2.84^{b}	7.33 ± 1.21^{b}	6.32 ± 1.27^{b}	61.54 ± 6.03^{a}
Stigmasterol	Total sterol	69.79 ± 6.81^{a}	14.82 ± 0.64^{d}	16.7 ± 4.15^{d}	37.51 ± 2.02^{c}	56.37 ± 6.67^{b}
	Free sterol	34.45 ± 3.16^{a}	8.72 ± 0.40^{b}	9.94 ± 0.94^{b}	34.62 ± 1.66^{a}	11.96 ± 1.88^{b}
	Bound sterol	35.34 ± 9.12^{a}	6.10 ± 0.25^{b}	6.76 ± 3.30^{b}	2.89 ± 0.79^{b}	44.41 ± 6.16^{a}
Sitostanol	Total sterol	0.33 ± 0.12^{a}	0.03 ± 0.01^{b}	0.03 ± 0.01^{b}	0.24 ± 0.01^{a}	0.1 ± 0^{b}
	Free sterol	0.01 ± 0^{a}	ND^{a}	ND^{a}	ND^{a}	ND^{a}
	Bound sterol	0.32 ± 0.12^{a}	0.03 ± 0.01^{b}	0.03 ± 0.01^{b}	0.24 ± 0.01^{a}	0.1 ± 0^{b}
Cycloartanol	Total sterol	20.57 ± 0.69^{c}	17.58 ± 3.44^{c}	12.36 ± 0.53^{d}	36.23 ± 1.43^{a}	30.64 ± 1.71^{b}
	Free sterol	15.29 ± 0.73^{a}	5.47 ± 0.66^{c}	3.55 ± 0.31^{d}	10.42 ± 0.48^{b}	4.17 ± 0.6^{d}
	Bound sterol	5.28 ± 0.82^{d}	12.11 ± 0.83^{b}	8.8 ± 0.58^{c}	25.81 ± 1.73^{a}	26.46 ± 1.37^{a}
Cycloartenol	Total sterol	1.69 ± 0.21^{c}	0.97 ± 0.07^{d}	0.21 ± 0.06^{e}	10 ± 0.84^{a}	3.5 ± 0.17^{b}
	Free sterol	0.48 ± 0.16^{a}	0.05 ± 0^{c}	0.05 ± 0^{c}	0.26 ± 0.02^{b}	0.06 ± 0.01^{c}
	Bound sterol	1.21 ± 0.35^{a}	0.92 ± 0.07^{a}	0.17 ± 0.06^{a}	9.74 ± 0.69^{a}	3.44 ± 3.18^{b}
2,4-methylenecycloartanol	Total sterol	16.7 ± 1.74^{b}	16.32 ± 0.67^{b}	0.72 ± 0.19^{d}	20.41 ± 1.65^{a}	8.58 ± 0.68^{c}
	Free sterol	2.62 ± 0.56^{a}	0.45 ± 0.04^{c}	0.55 ± 0.17^{c}	1.43 ± 0.16^{b}	0.5 ± 0.04^{c}
	Bound sterol	14.08 ± 2.18^{b}	15.88 ± 0.62^{b}	0.17 ± 0.05^{d}	18.98 ± 0.56^{a}	8.07 ± 0.72^{c}

Note: Data are expressed as mean ± standard deviation (mean ± *SD*, $n=3$); ND represents "Not Detected"; the same letter in the same row indicates no significant difference ($p>0.05$), different letters indicate significant difference ($p<0.05$), a is a maximum value.

Table 7 The content of 11 kinds of sterols in the soybeans from different producing areas (unit: mg/100 g)

Regions		Inner Mongolia	Heilongjiang	Jilin	Hebei	Shandong
Cholesterol	Total sterol	30.7 ± 0.29^{a}	18.51 ± 1.03^{b}	20.99 ± 1.02^{b}	27.32 ± 0.67^{ab}	22.01 ± 2.09^{b}
	Free sterol	24.1 ± 0.99^{a}	12.48 ± 2.22^{bc}	9.18 ± 0.97^{c}	18.8 ± 3.99^{b}	11.36 ± 2.99^{bc}
	Bound sterol	6.6 ± 0.72^{a}	6.03 ± 1.48^{ab}	11.81 ± 1.54^{ab}	8.52 ± 1.59^{b}	10.65 ± 1.22^{b}
Cholestanol	Total sterol	0.15 ± 0.03^{a}	0.15 ± 0.07^{ab}	0.01 ± 0.01^{b}	0.08 ± 0.02^{a}	0.01 ± 0.02^{b}
	Free sterol	ND^{a}	ND^{a}	ND^{a}	ND^{a}	ND^{a}
	Bound sterol	0.15 ± 0.03^{a}	0.15 ± 0.07^{ab}	0.01 ± 0.01^{b}	0.08 ± 0.02^{a}	0.01 ± 0.02^{b}
Brassicasterol	Total sterol	12.95 ± 1.57^{a}	32.52 ± 0.29^{a}	6.96 ± 0.59^{a}	10.96 ± 3.47^{a}	7.46 ± 1.55^{a}
	Free sterol	11.09 ± 1.55^{a}	2.10 ± 0.14^{a}	4.05 ± 0.46^{a}	8.02 ± 1.49^{a}	1.12 ± 0.65^{a}
	Bound sterol	1.86 ± 0.43^{e}	30.42 ± 3.43^{a}	2.91 ± 0.86^{d}	2.94 ± 0.95^{c}	6.33 ± 2.9^{b}
Ergosterol	Total sterol	0.35 ± 0.06^{b}	0.57 ± 0.4^{a}	0.12 ± 0.02^{b}	0.51 ± 0.06^{b}	0.67 ± 0.25^{b}
	Free sterol	0.04 ± 0.03^{a}	0.01 ± 0^{a}	0.01 ± 0.01^{a}	0.02 ± 0.02^{a}	0.01 ± 0.01^{a}
	Bound sterol	0.31 ± 0.08^{b}	0.56 ± 0.39^{a}	0.11 ± 0.02^{b}	0.49 ± 0.04^{b}	0.66 ± 0.25^{b}
Spinasterol	Total sterol	26.74 ± 3.41^{c}	66.9 ± 1.60^{a}	20.21 ± 0.64^{bc}	28.81 ± 0.53^{b}	15.77 ± 1.59^{c}
	Free sterol	26.7 ± 3.40^{a}	13.17 ± 0.67^{c}	9.81 ± 1.07^{d}	21.26 ± 0.86^{b}	6.7 ± 0.89^{e}
	Bound sterol	0.05 ± 0.02^{e}	53.73 ± 1.04^{a}	10.39 ± 1.38^{b}	7.55 ± 0.34^{d}	9.07 ± 1.01^{c}
Campesterol	Total sterol	26.21 ± 1.2^{b}	6.91 ± 0.39^{e}	24.61 ± 0.55^{c}	27.34 ± 2.40^{a}	11.93 ± 2.01^{d}
	Free sterol	24.41 ± 1.28^{a}	2.49 ± 0.28^{e}	8.10 ± 2.72^{c}	16.99 ± 4.10^{b}	5.69 ± 1.22^{d}
	Bound sterol	1.8 ± 0.20^{e}	4.42 ± 1.05^{d}	16.51 ± 2.25^{a}	10.34 ± 4.03^{b}	6.24 ± 0.64^{c}
Stigmasterol	Total sterol	25.39 ± 3.68^{b}	42.18 ± 7.62^{a}	16.04 ± 1.51^{d}	20.19 ± 0.76^{c}	12.64 ± 2.35^{e}
	Free sterol	20.62 ± 2.64^{a}	8.17 ± 5.21^{c}	7.77 ± 0.9^{d}	16.11 ± 1.69^{b}	5.26 ± 0.85^{e}
	Bound sterol	4.78 ± 1.75^{d}	34.02 ± 2.6^{a}	8.27 ± 0.9^{b}	4.08 ± 1.54^{e}	7.38 ± 2.08^{c}
Sitostanol	Total sterol	0.34 ± 0.03^{a}	0.11 ± 0.02^{b}	0.01 ± 0^{d}	0.04 ± 0.01^{c}	0.03 ± 0.03^{c}
	Free sterol	ND	ND	ND	ND	ND
	Bound sterol	0.34 ± 0.03^{a}	0.11 ± 0.02^{b}	0.01 ± 0^{d}	0.04 ± 0.01^{c}	0.03 ± 0.03^{c}
Cycloartanol	Total sterol	62.06 ± 0.81^{a}	41.44 ± 1.46^{b}	2.86 ± 0.21^{e}	8.32 ± 1.11^{d}	11.54 ± 1.09^{c}
	Free sterol	7.84 ± 0.96^{a}	5.36 ± 2.23^{c}	2.72 ± 0.25^{d}	5.49 ± 0.93^{b}	1.43 ± 0.12^{e}
	Bound sterol	54.22 ± 0.7^{a}	36.08 ± 0.83^{b}	0.14 ± 0.04^{e}	2.83 ± 1.1^{d}	10.11 ± 0.58^{c}
Cycloartenol	Total sterol	1.63 ± 0.35^{b}	0.94 ± 0.02^{c}	0.15 ± 0.02^{e}	0.36 ± 0.10^{d}	3.68 ± 0.61^{a}
	Free sterol	0.18 ± 0.03^{a}	0.06 ± 0.01^{c}	0.07 ± 0^{c}	0.17 ± 0.03^{a}	0.13 ± 0.04^{b}
	Bound sterol	1.45 ± 0.32^{b}	0.87 ± 0.02^{c}	0.09 ± 0.03^{d}	0.19 ± 0.08^{d}	3.55 ± 0.68^{a}
2,4-methylenecycloartanol	Total sterol	8.06 ± 1.62^{d}	8.86 ± 0.07^{c}	1.92 ± 0.08^{e}	16.25 ± 0.93^{b}	25.74 ± 0.80^{a}
	Free sterol	1.72 ± 0.78^{a}	0.47 ± 0.45^{c}	0.53 ± 0.20^{c}	1.33 ± 0.07^{b}	0.28 ± 0.09^{d}
	Bound sterol	6.34 ± 1.04^{d}	8.39 ± 0.24^{c}	1.39 ± 0.25^{e}	14.92 ± 0.3^{b}	25.46 ± 1.00^{a}

Note: Data are expressed as mean ± standard deviation (mean ± *SD*, $n=3$); ND represents "Not Detected"; the same letter in the same row indicates no significant difference ($p>0.05$), different letters indicate significant difference ($p<0.05$), a is a maximum value.