 DOI: 10.19601/j.cnki.issn1943 - 9903.2021.12.010

Screening of New High Quality and High Yield Sweet Potato Varieties in Zaozhuang of Shandong Province

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Abstract [**Objectives**] To compare the growth period, dry matter content and yield of 12 different sweet potato varieties, so as to screen out new sweet potato varieties with high yield, high quality and high dry matter content suitable for cultivation in Zaozhuang of Shandong Province. [**Methods**] Field random arrangement, three replicates, and field observation were adopted, and data were surveyed and summarized. [**Results**] There were significant differences in the maturity period between varieties. Longshu 9, Hongxiangjiao, Sushu 8, Yanshu 25, and Yanshu 0747 in the fresh eating group were mature earlier, and Yuzi 7 was mature later; Xushu 32 in the starch group was mature earlier, while Xushu 22 (ck), Shangshu 19, Jishu 25, and Jishu 98 had moderate maturity period, and Jixu 23 was mature later. The difference in the yield between the fresh eating group and the starch group reached a very significant level. In the fresh eating group, Yanshu 25 had the highest yield, followed by Longshu 9, and then Yanshu 0747; in the starch group, Jishu 98 had the highest yield, followed by Shangshu 19, and then Jixu 23. Besides, there were significant differences in the dry matter content between varieties. In the fresh eating group, Yuzi 7 had the highest dry matter content (30.4%), followed by Yanshu 25 (28.1%), and then Yanshu 0747 (28.1%); in the starch group, Xushu 32 had the highest dry matter content (33.6%), followed by Jishu 25 (32%), and then Jishu 98 (31.5%). [**Conclusions**] Combining the maturity period, yield, dry matter content, appearance, taste and unique ecological conditions in Zaozhuang area, the varieties suitable for cultivation in Zaozhuang area were screened: in the fresh eating group, it was Yanshu 25 and Longshu 9; in the starch group, it was Jishu 98, Shangshu 19, and Jixu 23.

Key words Sweet potato, Dry matter content, High quality and high yield, Screening

1 Introduction

The cultivation area of sweet potato in Zaozhuang of Shandong Province is mainly concentrated in Shanting District of Zaozhuang City, and also distributed in Yicheng, Shizhong, Taierzhuang, and Xuecheng. The cultivation area is exceeding 10 000 ha. The cultivation area of sweet potato in Shanting District is mainly concentrated in production areas such as Xuzhuang Town, Dianzi Town, and Sangcun Town where the production is relatively concentrated, about 40% sweet potato varieties are high starch varieties, and 60% are fresh eating varieties. Most of the farmers cultivate old varieties of sweet potatoes, such as Xushu 18, Xushu 19, Beijing 553, Xinong 431, Laifu 1, *etc.*, which severely restricted the development of the sweet potato industry in Zaozhuang. In 2017, through the survey of new varieties of sweet potato, Zaozhuang Academy of Agricultural Sciences screened out new varieties with high yield, high quality and high dry matter content suitable for cultivation in Zaozhuang. This provided variety resources for sweet potato growers and variety support for the development of sweet potato industry in Zaozhuang area, and also promoted the development of sweet potato storage and processing industry in Zaozhuang area[1].

2 Materials and methods

2.1 Materials In the experiment, we selected a total of 12 varieties, including 6 in the fresh eating group, namely Longshu 9, Hongxiangjiao, Sushu 8, Yanshu 25, Yuzi 7, and Yanshu 0747; 6 in the starch group, namely: Xushu 22 (ck), Xushu 32, Shangshu 19, Jixu 23, Jishu 25 and Jishu 98.

2.2 Methods The field distribution was according to the fresh eating group and starch group. Two independent experiments were arranged, and each experiment was designed with 6 treatments. Xushu 22 was taken as the control variety. The plot area was 20 m^2 (4 m × 5 m, namely, 5-row plot, row length 5 m). The complete blocked randomization was adopted, and 3 replicates were performed. The field planting was carried out on May 16, with a row spacing of 80 cm and a plant spacing of 25 cm. sweet potatoes were harvested on November 6, all plots were harvested, and the fresh weight of root tuber was weighed. The dry matter content was measured within 7 d after harvest. Repeatedly took the medium-sized storage root (not less than 500 g for sampling) of each variety, and baked them to constant weight at 80 °C to calculate the dry matter content. A group of 5 people was formed to evaluate the quality: the appearance quality was scored according to the flesh color, storage root shape, storage root size, root uniformity, and market acceptance. The full score is 100 points, 5 points are one level, and the appearance quality of Xushu 22 product was uniformly scored as 70 points; the food quality was scored

Received: September 10, 2021 Accepted: November 21, 2021

Supported by Special Project for Tuber Crops Industry Technology System of Shandong Province (SDAIT-14).

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in accordance with the taste after cooking, the full score is 100 points, 5 points are one level, and the food quality of Xushu 22 was uniformly scored as 70 points[2]. The field distribution of the experiments is shown in Table 1 – 2.

Table 1 Field arrangement for comparison experiment of fresh-eating varieties

Replicate	Treatment					
I	Longshu 9	Hongxiangjiao	Sushu 8	Yanshu 25	Yuzi 7	Yanshu 0747
II	Yanshu 25	Yanshu 0747	Yuzi 7	Longshu 9	Hongxiangjiao	Sushu 8
III	Yanshu 0747	Yuzi 7	Hongxiangjiao	Sushu 8	Yanshu 25	Longshu 9

Table 2 Field arrangement for comparison experiment of starch type varieties

Replicate	Treatment					
I	Xushu 22	Xushu 32	Shangshu 19	Jixu 23	Jishu 25	Jishu 98
II	Jixu 23	Jishu 98	Jishu 25	Xushu 22	Xushu 32	Shangshu 19
III	Jishu 98	Jishu 25	Xushu 32	Shangshu 19	Jixu 23	Xushu 22

2.3 Field management and main weather conditions

2.3.1 Field management. The field planting was carried out on May 16. The experiment was performed at the experimental field of the Zaozhuang Academy of Agricultural Sciences. The soil was mortar black soil, and the previous crop was maize. The soil pH was 6.14, organic matter 18.18 g/kg, alkali hydrolyzed nitrogen was 69.70 mg/kg, available phosphorus was 45.59 mg/kg, available potassium was 205.16 mg/kg, exchangeable calcium was 3.27 g/kg, and exchangeable magnesium was 0.24 g/kg. At the time of field planting, 1.5 kg of compound fertilizer was applied to each plot, and no top dressing was required during the growth period. A total of 4 sprays of 4.5% Lambda-cypermethrin EC 1 000 times solution were applied to control various insect pests on August 10, August 21, September 18, and October 5 during the growth period. Weeded twice on May 17 and June 12, and seedlings were raised on August 13.

2.3.2 Weather conditions during the growth period. The light hours from May to October were 270, 132.7, 181.7, 162.3, 106.6, and 176.5 h, which were slightly lower than that of the same period in normal years. The precipitation from May to October was 81.9, 82, 106.3, 84.9, 132.6 and 37 mm, respectively, which was slightly lower than that of the same period in normal years. The main precipitation during the growth period was as follows: moderate rain on May 24, heavy rain on June 1 – 2, moderate rain on June 9, moderate rain on June 14, 15, and 20, light rain on June 25, light rain on July 16, torrential rain on July 19, heavy rain on July 20, moderate rain on July 21, heavy rain on July 26, light rain on July 31, August 4 and 5, heavy rain, heavy rain on August 11, 23, and 24, moderate rain on September 2, 15, 16, 17, and 18, moderate rain on September 19, 20, and 21, heavy rain on September 28 and 20, and frost on November 3.

3 Results and analysis

3.1 Fresh eating group

3.1.1 Comparison of biological characteristics. The comparison of biological characteristics of varieties in the fresh eating group is shown in Table 3.

Table 3 Comparison of biological characteristics of varieties in the fresh eating group

Variety	Leaf shape	Stem characteristics	Flowering	Drought tolerance	Storage root characteristics
Longshu 9	Cordate	Thin and weak	Yes	Tolerant	Light red skin, orange flesh, short ovate storage root
Hongxiangjiao	Palmate	Thin and weak	Yes	Not tolerant	Light red skin, orange flesh, short elliptic storage root
Sushu 8	Palmate	Short	–	Tolerant	Deep red skin, yellow flesh, elliptic storage root
Yanshu 25	Cordate	Thick and strong	–	Tolerant	Light red skin, yellow flesh, elliptic storage root
Yuzi 7	Palmate	Thick and strong	Yes	Tolerant	Deep red skin, purple flesh, long elliptic storage root
Yanshu 0747	Cordate	Thick and strong	Yes	Tolerant	Deep red skin, purple flesh, long elliptic storage root

3.1.2 Growth and development process and growth status (Table 4). Table 4 showed that Yuzi 7 had relatively late maturity period and had spindly growth and was more resistant to diseases and insect pests. Other varieties had relatively early maturity period and had no spindly growth. Some varieties had mild diseases and insect pests.

Table 4 Growth and development process and growth status of varieties in the fresh eating group

Treatment	Field planting Month/day	Ridge closure Month/day	Seedling turning Month/day	Harvest time Month/day	Spindly growth	Pests and diseases
Longshu 9	05 – 16	06 – 28	09 – 09	11 – 06	–	Mild
Hongxiangjiao	05 – 16	06 – 20	09 – 06	11 – 06	–	Mild
Sushu 8	05 – 16	06 – 26	09 – 05	11 – 06	–	No
Yanshu 25	05 – 16	06 – 15	09 – 08	11 – 06	–	No
Yuzi 7	05 – 16	06 – 19	09 – 15	11 – 06	Yes	No
Yanshu 0747	05 – 16	06 – 19	09 – 06	11 – 06	–	Mild

3.1.3 Yield measurement (Table 5). Table 5 and variance analysis of the yield in Table 6 showed that the differences between the varieties in the fresh eating group reached an extremely significant level, and the differences between the replicates were not significant. The results in Table 5 showed that Yanshu 25 had the highest yield, followed by Longshu 9, and then Yanshu 0747. The differences between the three varieties reached a significant level. At the extremely significant level, Yanshu 25 was at the same level as Longshu 9, and there was no extremely significant difference between Longshu 9 and Yanshu 0747.

Table 5 Comparison of the yield of varieties in the fresh eating group

Treatment	Plot yield//kg			Mean yield//kg	Converted yield//kg/ha
	I	II	III		
Longshu 9	106.25	113.5	116.0	111.9 bAB	55 953.0
Hongxiangjiao	78.50	84.5	72.5	78.5 cB	39 252.0
Sushu 8	69.00	82.5	73.0	74.8 cB	37 402.5
Yanshu 25	137.00	120.0	148.5	135.2 aA	67 603.5
Yuzi 7	84.50	85.5	70.5	80.2 cB	40 102.5
Yanshu 0747	101.50	74.0	79.0	84.8 cB	42 402.0

Note: The plot area is 4 m × 5 m; different uppercase and lowercase letters after the same column of data indicate differences at the 0.01 and 0.05 levels.

Table 6 Variance analysis of the yield

Source of variation	Degrees of freedom	Sum of squares	Variance	*F*	Theoretical *F*	
					0.05	0.01
Variety	5	8 695.10	1 739.02	14.88	3.33	5.64
Replicate	2	32.13	16.07	0.14	4.10	7.56
Random error	10	1 168.33	116.83			
Total variation	17	9 895.56				

3.1.4 Quality determination. Table 7 showed that Longshu 9 had poor appearance and good taste, Hongxiangjiao and Sushu 8 had medium appearance and good taste, Yanshu 25 had good appearance and good taste, and Yuzi 7 and Yanshu 0747 had medium appearance and poor taste.

3.1.5 Dry matter content determination. The dry matter content of varieties in the fresh eating group is shown in Table 8.

As shown in Table 8 – 9, the differences between the varieties in the fresh eating group reached an extremely significant level, and the differences between the replicates were not significant. The results in Table 8 showed that Yuzi 7 had the highest dry matter content, followed by Yanshu 25, and then Yanshu 0747. The differences between the three varieties were at the same level but not significant.

Table 7 Comparison of the quality of varieties in the fresh eating group

Variety	Appearance score	Taste score
Longshu 9	80	85
Hongxiangjiao	85	85
Sushu 8	85	85
Yanshu 25	90	85
Yuzi 7	85	75
Yanshu 0747	85	70

Table 8 Comparison of dry matter content of varieties in the fresh eating group %

Variety	Dry matter content			Mean
	I	II	III	
Longshu 9	21.7	23.3	25	23.3 bB
Hongxiangjiao	22.4	27.9	25.3	25.2 bB
Sushu 8	24.6	21.2	23.1	23.0 bB
Yanshu 25	28.3	28.5	27.6	28.1 aA
Yuzi 7	31.5	29.3	30.3	30.4 aA
Yanshu 0747	27.1	28.4	28.8	28.1 aA

Note: Different uppercase and lowercase letters after the same column of data indicate differences at the 0.01 and 0.05 levels.

Table 9 Variance analysis of dry matter content

Source of variation	Degrees of freedom	Sum of squares	Variance	*F*	Theoretical *F*	
					0.05	0.01
Variety	5	132.74	26.55	9.12	3.33	5.64
Replicate	2	1.75	0.88	0.30	4.10	7.56
Random error	10	29.10	2.91	–	–	–
Total variation	17	163.58	–	–	–	–

3.2 Starch group

3.2.1 Comparison of biological characteristics. The comparison of biological characteristics of varieties in the starch group is shown in Table 10.

Table 10 Comparison of biological characteristics of varieties in the starch group

Variety	Leaf shape	Stem characteristics	Flowering	Drought tolerance	Storage root characteristics
Xushu 22 (ck)	Palmate	Thick and strong	–	Not tolerant	Red skin, white flesh, short elliptic storage root
Xushu 32	Palmate	Short	–	Not tolerant	Red skin, light yellow flesh, short elliptic storage root
Shangshu 19	Cordate	Thick and strong	–	Not tolerant	Deep red skin, white flesh, elliptic storage root
Jishu 21	Cordate	Thin	–	Not tolerant	Light red skin, light yellow flesh, elliptic storage root
Jishu 25	Cordate	Thick and strong	–	Not tolerant	Deep red skin, white flesh, long elliptic storage root
Jishu 98	Cordate	Thick and strong	–	Not tolerant	Deep red skin, light yellow flesh, elliptic storage root

3.2.2 Growth and development process and growth status (Table 11). Table 11 showed that Xushu 32 was mature earlier, Xushu 22 (ck), Shangshu 19, Jishu 25, Jishu 98 had medium maturity period, Jixu 23 was mature later, Xushu 32 had early senescence, and Xushu 22 (ck) and Shangshu 19 had spindly growth.

Table 11 Growth and development process and growth status of varieties in the starch group

Treatment	Field planting Month/day	Ridge closure Month/day	Seedling turning Month/day	Harvest time Month/day	Spindly growth	Early senescence	Pests and diseases
Xushu 22 (ck)	05 – 16	06 – 26	09 – 08	11 – 06	Yes	–	No
Xushu 32	05 – 16	06 – 27	09 – 03	11 – 06	–	Yes	No
Shangshu 19	05 – 16	06 – 22	09 – 09	11 – 06	Yes	–	No
Jixu 23	05 – 16	06 – 20	09 – 13	11 – 06	–	–	No
Jishu 25	05 – 16	06 – 20	09 – 08	11 – 06	–	–	Mild
Jishu 98	05 – 16	06 – 20	09 – 09	11 – 06	–	–	No

3.2.3 Yield measurement (Table 12). Table 12 – 13 showed that the differences between varieties in the starch group reached a very significant level, and the differences between the replicates were not significant. The results in Table 12 showed that Jishu 98 had the highest yield, followed by Shangshu 19, and then Jixu 23. The differences between the three varieties were at the same level but not significant.

Table 12 Comparison of the yield of varieties in the starch group

Treatment	Plot yield//kg			Mean yield	Converted
	I	II	III	kg	yield//kg/ha
Xushu 22 (ck)	85.5	79.5	84.5	83.2 aA	41 602.5
Xushu 32	66.5	60.5	63.0	63.3 cC	31 651.5
Jixu 23	86.5	81.5	87.5	85.2 aA	42 601.5
Shangshu 19	81.0	94.0	96.5	90.5 aA	45 252.0
Jishu 25	72.5	77.0	78.5	76.0 bB	38 002.5
Jishu 98	88.0	92.0	94.0	91.3 aA	45 652.5

Note: The plot area is 4 m × 5 m; different uppercase and lowercase letters after the same column of data indicate differences at the 0.01 and 0.05 levels.

Table 13 Variance analysis of the yield of varieties in the starch group

Source of variation	Degrees of freedom	Sum of squares	Variance	*F*	Theoretical *F*	
					0.05	0.01
Variety	5	1 662.46	332.49	18.28	3.33	5.64
Replicate	2	54.25	27.13	1.49	4.10	7.56
Random error	10	181.92	18.19	–	–	–
Total variation	17	1 898.63	–	–	–	–

3.2.4 Quality determination (Table 14). Table 14 showed that Shangshu 19 and Jishu 25 had good appearance and good taste, Jixu 23 had good appearance and poor taste, Xushu 32 had good taste and poor appearance, and Jishu 98 had medium taste and poor appearance.

Table 14 Comparison of quality of varieties in the starch group

Variety	Appearance score	Taste score
Xushu 22 (ck)	70	70
Xushu 32	65	85
Shangshu 19	80	85
Jixu 23	75	70
Jishu 25	80	85
Jishu 98	65	80

3.2.5 Dry matter content determination (Table 15). Table 15 and Table 16 showed that the differences between the varieties of starch group were not very significant, and the differences between the replicates were not significant. The results in Table 15 showed that Xushu 32 had the highest dry matter content, followed by Jishu 25, and then Jishu 98. There was no significant difference between the three varieties.

Table 15 Comparison of dry matter content of varieties in the starch group %

Variety	Dry matter content			Mean
	I	II	III	
Xushu 22(ck)	25.8	31	32.8	29.9
Xushu 32	32.9	32.5	35.3	33.6
Shangshu 19	30.3	30.9	30.6	30.6
Jixu 23	29.2	30.4	27.9	29.2
Jishu 25	31.7	33.1	31.1	32.0
Jishu 98	30.8	30.1	33.5	31.5

Note: Different uppercase and lowercase letters after the same column of data indicate differences at the 0.01 and 0.05 levels.

Table 16 Variance analysis of dry matter content

Source of variation	Degrees of freedom	Sum of squares	Variance	*F*	Theoretical *F*	
					0.05	0.01
Variety	5	37.44	7.49	2.25	3.33	5.64
Replicate	2	9.65	4.83	1.45	4.10	7.56
Random error	10	33.22	3.32	–	–	–
Total variation	5	37.44	7.49	2.25	3.33	5.64

4 Conclusions

In this experiment, through comprehensive analysis of the biological characteristics, yield, quality, dry matter content, and taste of different varieties of sweet potatoes, we screened two fresh eating varieties and three starch varieties suitable for planting in Zaozhuang area. Fresh eating varieties are Yanshu 25 and Longshu 9. Three starch varieties are Jishu 98, Shangshu 19, and Jixu 23. These five varieties have comprehensive traits, high yield, high quality, high dry matter content, and high market acceptance. Their main traits and yield are as follows:

Yanshu 25: Light red skin, yellow flesh, elliptic storage root, moderate storage root, appearance quality score 90 points, taste score 95 points, yield 67 603.5 kg/ha, dry matter content 28.1%, the best fresh eating variety, and high market acceptance.

Longshu 9: Light red skin, orange flesh, short elliptic storage root, big storage root, appearance quality score 80 points, taste score 90 points, yield 55 953 kg/ha, dry matter content 23.3%, can be promoted as a fresh eating variety.

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analysis video are to further understand the knowledge points on the premise of mastering the task knowledge, requiring students to understand the practical problems in the development of the tourism reception industry by means of reading and discussion.

The online mode is used in the pre-class stage. According to the cognitive goal of the unit task, the teacher publishes the unit MOOC video and unit learning resources to the MOOC teaching platform. Students accept the unit learning task, watch the MOOC video under the guidance of clear learning goals, and learn to master the knowledge points of the unit.

4.3.2 Reaching the intermediate level at in-class stage—application and analysis. The in-class stage of the course "Tourism Reception Industry" uses the form of offline "group discussion + field research". According to the students' mastery of the unit knowledge, the teacher analyzes the key and difficult knowledge in class, and then puts forward the field research task, which is generally a practical problem customized for the knowledge point. After receiving the task, the students are divided into groups, to discuss and analyze problems within and between groups, cooperate within the group with the basic knowledge mastered before class, solve practical problems, and report the progress of the task after completing the unit task.

4.3.3 Following the advanced level at after-class stage—evaluation and creating. The stage of after-class knowledge consolidation uses the online form. The teacher publishes the final results of the tasks of each unit in the class on the MOOC platform to expand the learning tasks and unit test questions. First of all, students obtain the task results of other groups on the MOOC platform for comparison, scoring and evaluation of different groups, and mutual evaluation of students. Then the extended learning task is completed independently. The selection of extended tasks is based on the principles of semi-proposition, openness and innovation, to expand students' thinking and emphasize uniqueness and innovation.

4.3.4 Evaluation of teaching effect. The teaching effect evaluation method adopts the combination of diagnostic evaluation, process evaluation and comprehensive evaluation, as shown in Table 3.

Table 3 Evaluation method of teaching effect of mixed teaching course by promoting teaching using competition

Evaluation category	Evaluation object
Diagnostic evaluation	Downloads of teaching resources
	MOOC video watching record
	Number of online discussions
	Number of points in online unit exercises
Process evaluation	Number of points in unit task given by different groups
	Number of points in unit task given by teachers
Comprehensive evaluation	Unit pass test results
	Final comprehensive examination results

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Jishu 98: Deep red skin, light yellow flesh, elliptic storage root, big storage root, appearance quality score 65 points, taste score 80 points, yield 45 652.5 kg/ha, dry matter content 31.5%, suitable for promotion in Zaozhuang area as a starch variety.

Shangshu 19: Deep red skin, white flesh, elliptic storage root, big storage root, appearance quality score 80 points, taste score 85 points, yield 45 252 kg/ha, dry matter content 30.6%, suitable for planting as a starch (or fresh eating) variety.

Jixu 23: Light red skin, light yellow flesh, elliptic storage root, moderate storage root, appearance quality score 75 points, taste 70 points, yield 42 601.5 kg/ha, dry matter content 29.2%, suitable for planting as a starch variety.

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