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SELECTION OF SWEETPOTATO CULTIVARS WITH HIGH YIELDS IN ALMATY REGION, KAZAKHSTAN

Sweetpotato (Ipomoea batatas [L.] Lam) is an attractive and industrial starch crop for ensuring global food and nutrition security in the face of the climate crisis. To select the proper cultivar with high yields at Almaty region, Kazakhstan, seven sweetpotato cultivars with different coloured tuberous roots were cultivated in 2018, 2019 and 2020. The results show that quantitative indicators of sweetpotato growth in southeast Kazakhstan are significantly dependent on cultivars and climatic conditions of cultivation years. 'A1' (31.2 t/ha) and 'Tainong 71' (22.1 t/ha) cultivars may be good candidates for the mass cultivation of sweetpotato in the Almaty region. The contents of vitamin C showed a diversity (1.0 ~ 6.7 g/100 g) depending on cultivars. Regarding sucrose content, the cultivars showed an average of 5.6 and 7.4 g/100 g in 2018 and 2019, respectively. Sucrose was a major component of total soluble solids in the studied cultivars, which corresponds with other literary data. The best cultivation practice of sweetpotato including plastic filum mulching and fertilization remains to be studied to increase yields for commercial production in Kazakhstan.

Key words: Sweetpotato (Ipomoea batatas L.), cultivar, yield, tuberous root quality, Kazakhstan.

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Қазақстанның Алматы облысындағы тәтті картоптың жоғары өнімді генотиптерін іріктеу

Тәтті картоп климаттық дағдарыс жағдайында ғаламдық азық-түлік пен тағамдық қауіпсіздік үшін тартымды өндірістік крахмалды дақыл. Өнімділігі жоғары қолайлы генотипті іріктеу үшін 2018, 2019 және 2020 жылдары Қазақстанның Алматы облысындағы тәтті картоптың түйнектері әр түрлі түсті жеті генотип өсірілді. Тәжірибеде алынған нәтижелері көрсеткендей, Қазақстанның оңтүстік-шығысында, яғни Алматы облысында тәтті картоп өсіру бойынша сандық көрсеткіштері генотип пен жылдың климаттық жағдайына едәуір тәуелді. A1 (31,2 т / га) және Tainong 71 (22,1 т / га) генотиптері Алматы облысында тәтті картопты жаппай өсіруге жақсы үміткерлер бола алады. Сахарозаның құрамына келетін болсақ, зерттелген генотиптер 2018 және 2019 жылдары сәйкесінше орташа 5,6 және 7,4 г / 100 г көрсетті. Сахароза зерттелген генотиптердегі TSS (жалпы еріген зат) негізгі компоненті болды, ол басқа әдебиеттермен сәйкес келеді. Тәтті картоп егінінің сапасы туралы мәліметтері жылдар бойынша және тәтті картоптың генотиптері арасындағы айырмашылықтардың маңызды болғанын көрсетті. Тәтті картоп өсірудің озық жаңа әдістері Қазақстанда коммерциялық өндірістің өнімділігін арттыру үшін әлі зерттеп енгізу керек.

Түйін сөздер: тәтті картоп (Ipomoea batatas L.), сорт, өнімділік, түйнектердің сапасы, Қазақстан.

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**Отбор генотипов высокоурожайного сладкого картофеля
в Алматинской области Казахстана**

Сладкий картофель (Ipomoea batatas [L.] Lam) – привлекательная культура для здорового питания и обеспечения глобальной продовольственной безопасности. Для выбора подходящего генотипа с высокой урожайностью семь генотипов сладкого картофеля с клубнями разных цветов были выращены в Алматинской области Казахстана в 2018, 2019 и 2020 годах. Результаты, полученные в эксперименте, показывают, что количественные показатели роста сладкого картофеля существенно зависят от генотипа и климатических условий года выращивания. Генотипы «A1» (31,2 т / га) и «Тайнонг 71» (22,1 т / га) могут быть хорошими кандидатами для массового выращивания сладкого картофеля в Алматинской области. При этом по содержанию сахарозы исследованные генотипы показали в среднем 5,6 и 7,4 г / 100 г в 2018 и 2019 годах соответственно. Сахароза была основным компонентом TSS (общее количество растворенных веществ) в изученных генотипах, что согласуется с другими литературными данными. Показано, что различия по качественным показателям между годами выращивания и генотипами сладкого картофеля были значительными. Для повышения урожайности при массовом производстве в Казахстане необходимо изучить и внедрить новые методы культивирования сладкого картофеля.

Ключевые слова: Сладкий картофель (Ipomoea batatas L.), сорт, урожайность, качество клубней, Казахстан.

Introduction

Sweetpotato belongs to the *Ipomoea* genus of the *Convolvulaceae* family, native to south and central America [1]. The optimum temperature for growth and development of sweetpotato is near 24°C [2], which means that it is relatively sensitive to low temperatures. Therefore, the minimum requirement for the cultivation of sweetpotato is a frost-free period lasting at least 4 months.

According to the World Food Organization, sweetpotato is planted on 9 million hectares annually and more than 112 million tons were harvested in 2017 [3]. The simplicity and high processability of sweetpotatoes are considered a part of food safety culture and a staple food in many countries [4, 5, 6]. The role of sweetpotato as a food crop is growing rapidly in other parts of the world, including sub-Saharan Africa and south America [3]. Sweetpotato has the high potential to address issues of food and nutrition security in the context of a changing global climate [7].

Sweetpotato is rich in complex carbohydrates, dietary fibre, potassium and antioxidants such as vitamin C, vitamin E, β-carotene (provitamin A), vitamin B2, polyphenols [8]. Studies have confirmed that sweetpotatoes are a low glycemic index (GI) food that can be beneficial for diabetics and fat people [9, 10]. With further research in this area, it may be possible to recommend the consumption of sweetpotato or extracts for people with diabetes or insulin resistance to control blood glucose concentrations. This therapy should be cheaper than conventional medicines and may have fewer side effects [11, 12].

For Kazakhstan, sweetpotato can become a new source of healthy nutrition food due to high antioxidant, antibacterial, anti-inflammatory, anti-diabetic and anti-inflammatory effects [13]. The problem of diabetes is relevant in Kazakhstan with over 300,000 people having diabetes, and this figure only includes patients who were directly diagnosed by doctors [14]. In Kazakhstan, sweetpotatoes are rarely consumed by the population. Sweetpotato in Kazakhstan is mostly imported from China and consumed by Kazakh repatriates and immigrants from east Asian countries. However, it has recently become known to the Kazakhstan people as a source of healthy nutrition. In this respect, the mass cultivation of sweetpotato is required for national food and nutrition security in southern Kazakhstan. For this purpose, we cultivated various cultivars of sweetpotatoes in the Almaty region to select proper cultivars for future commercial production.

Materials and methods

Plant materials

The main plant materials were provided for Kazakhstan in the framework of the "Memorandum of Cooperation in Research and Development between the Korean Research Institute of Bioscience and Biotechnology (KRIBB) and the Institute of Plant Biology and Biotechnology (IPBB)" which was signed on April 2,

2013. From this, 20 cultivars were transferred based on previous research and 6 promising cultivars were selected, including ‘Rizi0603’, ‘Beauregard’, ‘Tainong 71’, ‘Xushu 28’, ‘Xushu 25’, and ‘Sinzami’ [15, 16]. One cultivar (‘A1’) was provided by a local farmer.

Study area

The field trial with sweetpotato occurred on the experimental field of the Institute of Plant Biology and Biotechnology in the Almaty region, Uzynagash village (43°10’41.1” N 76°19’53.5” E) in 2018, 2019 and 2020. The experimental field was located at an absolute altitude of 829 m a.s.l. The average air temperature in Uzynagash is 7.9°C and the annual precipitation is 426 mm (climate-data.org). The soil composition is predominantly meadow-chestnut, according to the Almaty region soil map. The previous crop cultivation was onion (*Allium cepa*).

Growing sweetpotato plants in the field

For the production of 30 cm long sweetpotato plantlets, storage roots of sweetpotatos were planted horizontally in 2/3 parts soil with vermiculite. After the formation of vines, vines were cut into 4~5 internode plantlets, removing the bottom 2~3 leaves. The plantlets were then placed in water for root formation (5~6 days). Plantlets were planted according to the hillock system. The distances between hillock rows and between the plantlets was 0.8 m and 0.3 m, respectively, resulting in 41667 plants/ha. Planting was carried out at the end of May. Irrigation was done with an interval of 4~6 days. Hilling and weeding were carried out manually. Chemical and natural fertilisers were not used during the experiment. Sweetpotato harvesting was carried out in one step at the end of September.

Analyses of carbohydrate and vitamin C

A randomly selected 500 g fresh weight of each sweetpotato cultivar was used for qualitative carbohydrate analysis. Carbohydrate composition was measured by the research laboratory at the Almaty University of Technology according to State Union Standard number (31669-2012). The method is based on high-performance liquid chromatography (HPLC) with a refractometric detector and a thermostatic chromatographic column.

For qualitative analysis of vitamin C, 500 g of fresh weight of each sweetpotato cultivar was randomly selected. The content of vitamin C composition was measured by the “Nutritest” according to State Union Standard number (PEH 14130-2010). The method is based on the extraction of vitamin C from samples by metaphosphoric acid solution, subsequent reduction of L(+)-dehydroascorbic acid to L(+)-ascorbic acid, and determination of total content of L(+)-ascorbic acid by HPLC with spectrophotometric detection at a 265 nm wavelength.

Statistical analyses

The results were analysed by standard ANOVA techniques, using SPSS 23 software. Data are expressed as mean±standard error (total N=20). Means separation was done using the least significant difference (LSD) test when model and treatment effects were significant ($P < 0.05$).

Morphological parameters of cultivar

For each variety, the morphological parameters of tubers were evaluated (Table 1), using the corresponding international descriptor for sweetpotatos [17]. Assessment of morphological characteristics was carried out on tuberous roots of seven cultivars (Figure 1). The following parameters of tuberous roots were evaluated: shape, main skin colour, secondary skin colour, main flesh colour, intensity of main flesh colour, secondary flesh colour and depth of eyes. Variability in morphological features within each cultivar was not detected.

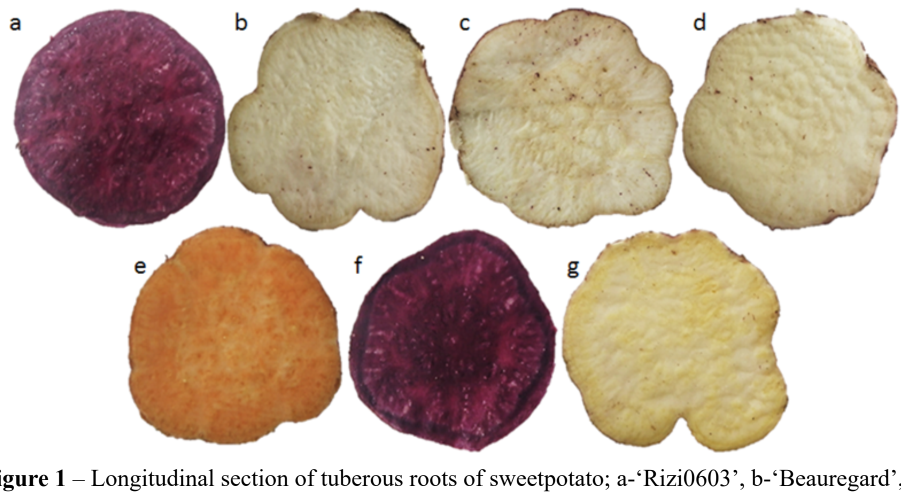

Figure 1 – Longitudinal section of tuberous roots of sweetpotato; a-‘Rizi0603’, b-‘Beauregard’, c-‘Tainong 71’, d-‘Xushu 28’, e-‘Xushu 25’, f-‘Sinzami’, g-‘A1’

Table 1 – Morphological characteristics of the studied sweetpotato cultivars

Cultivar	'Rizi0603'	'Beauregard'	'Tainong 71'	'Xushu 28'	'Xushu 25'	'Sinzami'	'A1'
Shape	Oblong	Obovate	Ovate	Oblong	Oblong	Oblong	Oblong
Main skin colour	Dark purple	Light purple	Purple-red	Light pink	Pink	Purple	Pink
Secondary skin colour	Absent	Purple	Red	Pink	Absent	Purple	Purple
Main flesh colour	Purple	Cream	White	White	Orange	Purple	Yellow
Secondary flesh colour	Red	Yellow	Yellow	Yellow	Yellow	Red	White
Intensity of main flesh colour	Intensive	Light	Light	Light	Medium	Intensive	Medium
Depth of eyes	Shallow	Medium	Medium	Deep	Deep	Shallow	Medium

Results

Quantity data of tuberous roots of sweetpotato harvest

Leaves and stems in all cultivars developed equally. The leaves of 'Rizi0603' and 'Sinzami' cultivars had a dark purple hue due to the high content of anthocyanins; the rest of the cultivars showed a standard green colour. Length of vines in all cultivars were 1.4 m on average. Within the experiment, production characteristics including tuber quantity and tuber weight per plant were evaluated (Fig. 2). According to statistical analysis, statistically significant differences were found between tested cultivars.

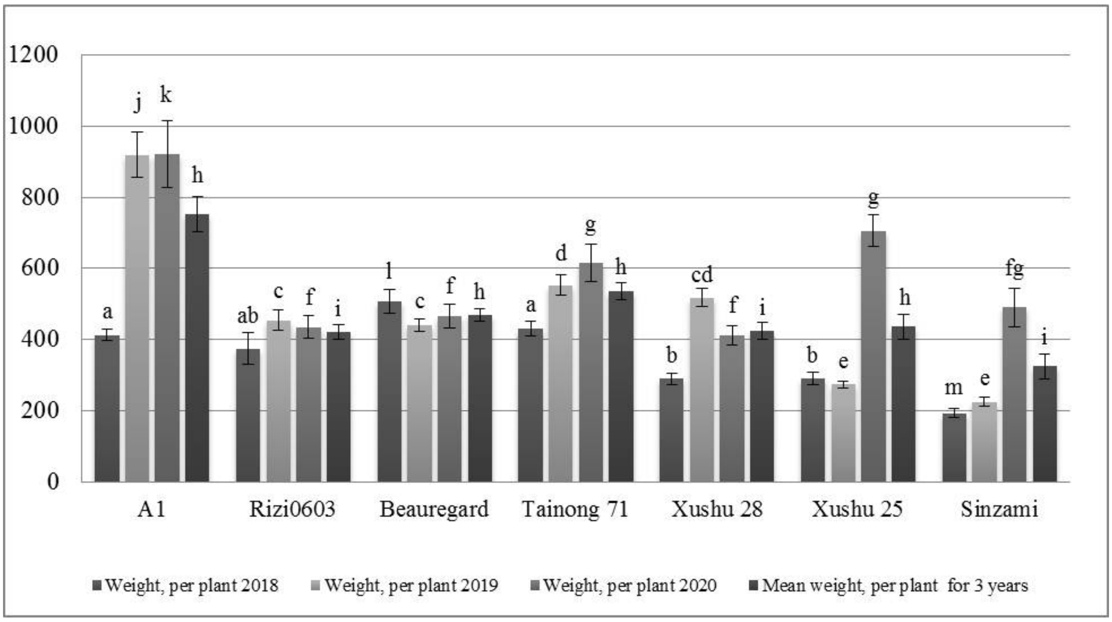

Figure 2 – Weight (gram) of tuberous roots per sweetpotato plant. Cultivars; 'Rizi0603', 'Beauregard', 'Tainong 71', 'Xushu 28', 'Xushu 25', 'Sinzami', and 'A1' in the Almaty region, Kazakhstan in 2018~2020 (n=20). The mean difference is significant at the p ≤ 0.05 level and error lines represent±standard error of the mean.

As can be seen in Fig. 2, 3, 4, the studied cultivars showed a significant difference in average weight per plant and number of tuberous per plant. For example, in 2018 'Beauregard' showed the highest result in average weight per plant (507.5±33.9 grams per plant), whereas in 2019 and 2020 cultivar 'A1' 919.5±64.5 and 922±93.6 grams per plant, respectively. The above-listed cultivars lead to calculating yields t/ha (Fig. 4). The tuberous roots of 'A1' and 'Beauregard' cultivars were cracked or oversized (jumbo size) in contrast to other studied cultivars. The lowest result in 2018 and 2019 was shown by the 'Sinzami' cultivar (192.5±12.3 and 224±12.1 grams per plant). However, in 2020, almost all cultivars showed an increase in the grams per plant indicator, including 'Sinzami' (489.5±53.6 grams per plant).

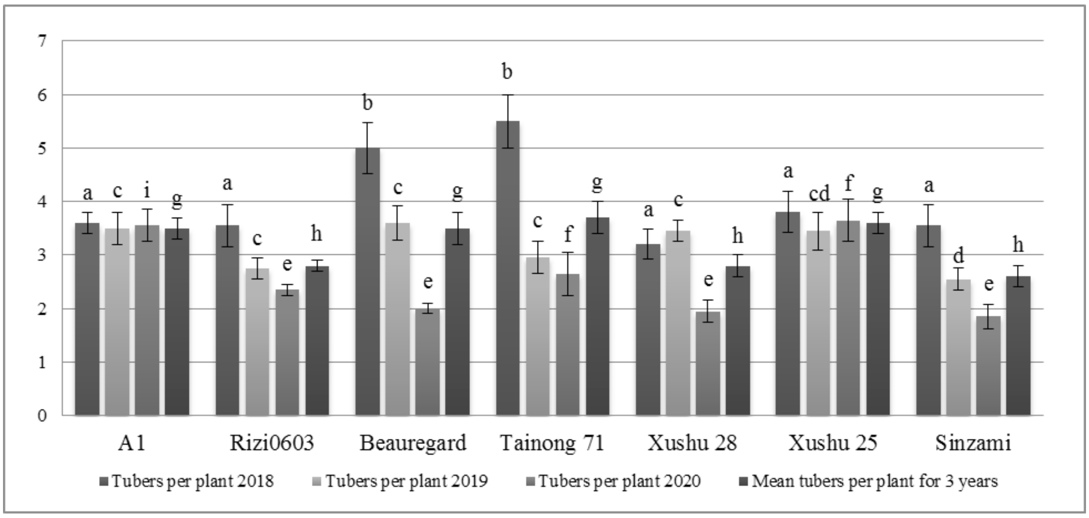

Figure 3 – Number of tuberous roots per sweetpotato plant. Cultivars; 'Rizi0603', 'Beauregard', / 'Tainong 71', 'Xushu 28', 'Xushu 25', 'Sinzami', and 'A1' in the Almaty region, Kazakhstan in 2018~2020 (n=20). The mean difference is significant at the p ≤ 0.05 level and error lines represent±standard error of the mean.

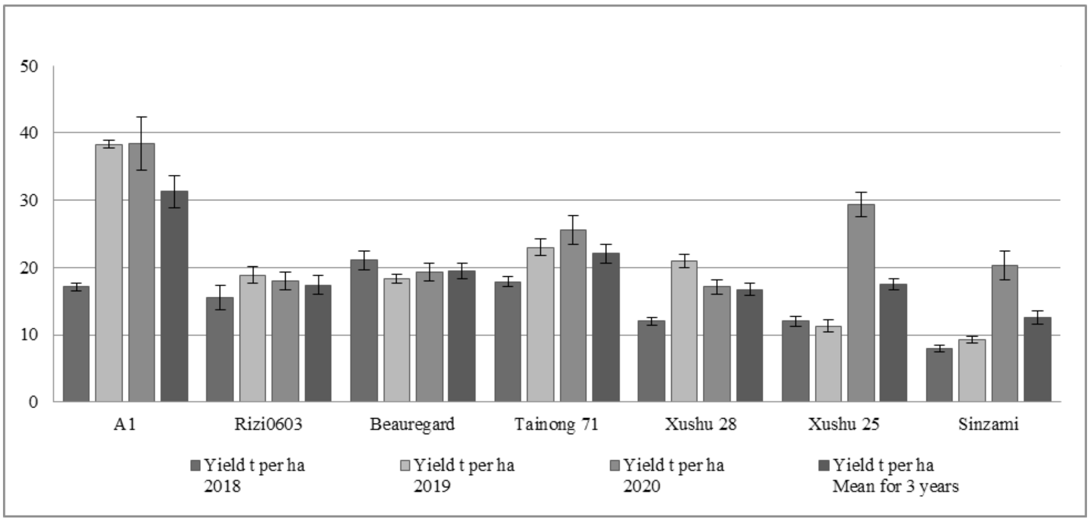

Figure 4 – Yield (ton/ha) of tuberous roots of sweetpotato cultivars; 'Rizi0603', 'Beauregard', 'Tainong 71', 'Xushu 28', 'Xushu 25', 'Sinzami', and 'A1' in the Almaty region, Kazakhstan in 2018~2020 (n=20). The mean difference is significant at the p ≤ 0.05 level and error lines represent±standard error of the mean

Based on the combined results of 3 years (Table 2), the cultivar 'A1' had the highest yield (31.2 t per ha) and average weight per plant (751.3 grams per plant). 'Beauregard' (19.5 t per ha) and 'Tainong 71' (22.1 t per ha) showed a high yield. If only the high yield is considered, these cultivars should be selected mostly for industrial purposes. It can be concluded in this experiments that cultivars with white flesh cultivar are more suitable and the most productive for the Almaty region of Kazakhstan. In contrast, purple and orange pulp cultivars ('Rizi0603', 'Sinzami' and 'Xushu 25') showed lower results but are more suitable for food purposes. The more cultivars using different colours of tuberous roots remains to evaluated for the final conclusion.

Quality data of sweetpotato harvest

It can be seen in Table 3 that the contents of vitamin C and carbohydrate between the years and the cultivars of sweetpotato were significantly dfferent. The contents of vitamin C showed 1.0~6.7 mg/100 g depending on cultivars during two years of 2018 and 2019. Regarding sucrose content (g per 100 g), the studied cultivars showed an average of 5.6 in 2018 and 7.4 in 2019. Fructose data ranged from 0.5 g ('Beauregard') to 1.3 g ('A1') in 2018 and from 0.3 g ('Xushu 25', 'Beauregard') to 0.9 ('Xushu 28') in 2019. Glucose data ranged from 0.6 g ('Sinzami') to 1.0 g ('Xushu 28') in 2018 and 4.3 g ('A1') to 5.7 g ('Xushu 25') in 2019. Sucrose was a major component of total soluble solids (TSS) in the studied cultivars, which corresponds with other literary data [18].

Table 2 – Combined average results of sweetpotato harvest based on data for 2018~**2020**

Cultivar	'A1'	'Rizi0603'	'Beauregard'	'Tainong 71'	'Xushu 28'	'Xushu 25'	'Sinzami'
Tuber weight*	**751.3± 58.1**	420± 35.7	471.3± 28.2	533± 34.3	406.1± 22.7	423± 23.6	302± 26
Tuber number*	3.5± 0.3	2.8± 0.2	3.5± 0.3	**3.7± 0.4**	2.8± 0.2	3.6± 0.4	2.6± 0.3
Yield t/ha**	**31.2± 2.4**	17.4± 1.4	19.5± 1.1	22.1± 1.4	16.7± 0.9	17.5± 0.9	12.5± 1

*The mean difference is significant at the p ≤ 0.05 level
***41667 plants/ha*

Table 3 – Quantitative analysis of vitamin C and carbohydrate in sweetpotato varieties

Cultivars	Vitamin C mg/100 g		Sucrose g/100 g		Glucose g/100 g		Fructose g/100 g	
	2018	2019	2018	2019	2018	2019	2018	2019
'Rizi0603'	5.7	4.1	**6.8**	9.2	0.8	4.9	0.6	0.4
'Beauregard'	1.1	6.0	5.3	5.7	0.6	4.7	0.5	0.3
'Tainong 71'	3.7	**6.7**	5.2	6.8	0.8	4.8	0.9	0.3
'Xushu 28'	1.0	5.6	5.4	5.5	**1.0**	5.7	0.6	**0.9**
'Xushu 25'	5.3	4.4	5.2	**10.1**	0.8	**5.7**	0.5	0.3
'Sinzami'	**5.9**	4.8	6.1	6.7	0.6	4.5	1.2	0.4
'A1'	5.8	4.5	5.5	7.6	0.7	4.3	**1.3**	0.1

Discussions

It should be noted that in 2018 after 10 days after seedlings were planted, atypical negative temperatures were recorded (avg. -5°C). Plants survived the cold shock but some of the plant leaves were necrotised. As can be seen in Fig. 2, in 2018 cold shock influenced the formation of tuberous roots, and in particular, increased their number, but the yield decreased in tested cultivars except for 'Beauregard'. This could explain the difference in quantitative data between years.

According to the literature on sweetpotato cultivation in Turkey, the yield variability per plant ranged from 210 to 620 g [19]. In a study by Uwah et al., Nigeria showed a similar result (380~460 g) [20]. Conversely, Maria and Soare in the southwest of Romania achieved greater yield of tuberous roots per plant (1000~1600 g) similar to Slosar et al. (1185~1455 g) in the southern Slovak Republic [21, 22].

In the report by the FAOSTAT in Asia, China leads in sweetpotato yields with 22.2 t per ha, followed by the Republic of Korea with 14.5 t per ha, and Vietnam and India with 11 t per ha [23]. The US reached 25 t per ha and Europe harvested 26.8 t per ha. On average, the yield of sweetpotato is 11.4 t per ha. The obtained results are comparable to the world indicators.

The contents of vitamin C in this study showed 1.0~6.7 mg/100 g depending on cultivars during two years of 2018 and 2019, which corresponds with previous reports [8]. Picha investigated the carbohydrate content of sweetpotato before and after long dry weight storage. After 8 months (30 weeks) of storage in the 'Whitestar' cultivar with a white flesh, glucose, fructose and sucrose showed 0.40, 0.43 and 3.09 g/100 g, respectively [24]. In the 'Jewel' cultivar with an orange flesh, glucose and fructose and sucrose reached 1.32, 1.32 and 5.01 g/100 g, respectively. The sucrose data we obtained are comparable to Adu-Kwarteng et al., which ranged from 4.10~10.82 g/100 g but well above Namutebi et al. (1.47 to 5.74 g/100 g) [25, 26].

Nevertheless, it is possible to significantly increase the qualitative and quantitative indicators of sweetpotato with the application of various agricultural methods including fertilizers and vinyl mulching [22]. Using black or coloured plastic mulch in relatively cool climates is advisable, because of increased soil temperatures [27]. According to the literature comparing to uncovered soil, a significantly higher yield of marketable roots was obtained with black plastic film mulch [28]. In addition, using genetic engineering methods it is possible to improve the resistance to abiotic and biotic stresses in the sweetpotato, which will lead to better adaptation to adverse environmental conditions including low temperature and increase yield [29, 30, 31].

Potentially the results on the content of carbohydrates and vitamin C in the sweetpotato cultivars studied were influenced by several factors. Both high intra-genotypic variability and the climatic conditions of the year of cultivation could have contributed to differences between varieties. In addition to vitamin C, increase of many antioxidants such as vitamin E, polyphenols including anthocyanin, and β-carotene (provitamin A) are also very useful for plant and human health [32].

Conclusion

The results obtained in the experiment show that quantitative indicators of sweetpotato growth in southeast Kazakhstan are significantly dependent on cultivar and climatic conditions of cultivation. Taken together, 'A1', 'Beauregard' and 'Tainong 71' cultivars may be good candidates for the mass cultivation of sweetpotato in the Almaty region. Therefore, sweetpotatoes can be successfully cultivated in Kazakhstan to expand the range of crops for healthy nutrition. The best cultivation practices using the best sweetpotato cultivars remain to be studied to increase yield for commercial production in Kazakhstan. The research will continue on the search for optimal sweetpotato varieties with an increase in the spectrum of sweetpotato cultivars for use in food and technical industries, as well as to improve cultivation technologies using vinyl mulching and fertilizers to increase yield in Kazakhstan. In addition, molecular breeding of selected sweetpotato cultivars will be useful to increase the increase of sweetpotato yields and high value-added components in the face of climate crisis [7, 33, 34].

Conflict of interest

All authors have read and are familiar with the content of the article and have no conflicts of interest.

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