SABRAO Journal of Breeding and Genetics
55 (1) 90-96, 2023
http://doi.org/10.54910/sabrao2023.55.1.8
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

ECOLOGICAL VARIETAL EVALUATION OF CUCUMBER (*CUCUMIS SATIVUS* L.) UNDER FIELD CONDITIONS

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SUMMARY

Strengthening agriculture involves various approaches to developing high-yielding new cultivars, optimization of soil composition, rational use of fertilizers, and pre-sowing treatment of seeds and seedlings. The safest and most environmentally friendly approach is to develop new genotypes, combining the most suitable characteristics in the existing growing area and environmental conditions. In this regard, the completed study aimed to breed various cucumber (*Cucumis sativus* L.) cultivars during the years 2020–2021 under the environmental conditions of Aktobe region, Kazakhstan. Cucumber cultivars 584, 577, 427, 294, and 264 gained selection from the nursery based on a complex of economically valuable traits, laying of seed fruits, and individual selection from F_2 to F_8 populations, using the hybrid cultivar 'Ular' as the standard of comparison. Recorded phenological observations on growth stages, morphometrics, types of flowering, disease resistance, production, and biochemical traits of the fruits received analysis. Cucumber samples came from the Kazakh Research Institute of Potato and Vegetable Growing (KazNIIKO), Kazakhstan. The hybrid was a derivative of the L-1 maternal line and the Phoenix 640 paternal line. The research result on the above-recorded parameters characterized six promising domestic cultivars of cucumber, namely, 264, 294, 427, 524, 577, and standard hybrid 'Ular.' Based on the complex of economically valuable features, the most predominant *C. sativus* L. cultivar was 294.

Keywords: Vegetable crops, cucumber (*C. sativus* L.), varietal testing, field conditions, production and biochemical traits, Kazakhstan

Key findings: With six promising domestic cultivars of cucumbers (*C. sativus* L.), the varietal testing happened during 2020–2021 under the environmental conditions of the Aktobe region of Western Kazakhstan. Based on the complex of economically valuable features, the cucumber cultivar 294 showed superior and most promising.

Communicating Editor: Prof. Naqib Ullah Khan

Manuscript received: December 22, 2022; Accepted: January 21, 2023.

Citation: Bazargaliyeva A, Utarbayeva N, Nussupova A, Admanova G, Yechshanova G, Kuanbay Z, Sarzhigitova A, Baubekova A (2023). Ecological varietal evaluation of cucumber (*Cucumis sativus* L.) under field conditions. *SABRAO J. Breed. Genet.* 55(1): 90-96. http://doi.org/10.54910/sabrao2023.55.1.8.

INTRODUCTION

In the present era, it seemed hard to enhance and improve the commodity resources of vegetable crops without its industry intensification as a whole. Strengthening of need-based agriculture provides the introduction and development of modern high-yielding cultivars and hybrids, the use of resource-saving technologies for the production of vegetable crops, differentiation of placement and compliance with the optimal structure of their land, soil fertility ecologization, rational application of agrochemicals that allows to master ecologically balanced farming systems and several other measures aimed at the use of bioclimatic potential and production resources (Vysochin *et al.*, 2018; Kalashnikov *et al.*, 2022; Nasiyev *et al.*, 2022).

The plant breeding contribution in enhancing the potential yield of the most critical crops over the past decade is estimated at 30%–70%, while the vital role of production intensification factors will also constantly increase. It is due to the general trend of biologization and ecologization of agricultural production, which significantly increased the possibilities of breeding in managing the genotypic variability in the cultivated species.

Breeders should pay special attention to creating cultivars with greater agroecological targeting and enhanced production, environment-improving, and resource-reproducing capabilities (Pratami *et al*., 2020; Ivanov *et al.*, 2021). The correct choice of cultivars is of greater importance to obtain the maximum possible and stable yield of vegetable crops. In each soil-climatic zone, there is a need for a set of cultivars of different maturity groups with varied responses to high and low agrophone. A new cultivar/hybrid is the most vital, accessible, and centralized means of using soil-climatic, weather, artificial, labor, financial, and other resources (Blinova, 2018; Vysochin *et al.*, 2018). Currently, intensive late-ripe crop cultivars predominate in the crops. However, with climate change, the planting time has been shifted by one to two weeks and even more. Therefore, it is necessary to strengthen the selection for early maturity and drought resistance.

Improving intensive cultivars that played a significant role in enhancing yields focused on the use of higher doses of mineral fertilizers, pesticides, and irrigation, for the cultivars to realize their productivity potential in comfortable conditions of plant growth and development (Lawal *et al.*, 2019; Omotade and Babalola, 2019; An *et al.*, 2021). However, paying little attention to the fact that the costs of non-replenished energy are often not spent productively forming the non-economical significant organs, hence, the non-use of the vegetative mass growth in the future. It led to several negative consequences, i.e., a) the widespread distribution of cultivars and hybrids with a long growing season without taking into account the climatic characteristics of cultivation, b) the duration of the frost-free period, c) the amount of solar insolation, d) the sum of active temperatures, and e) a sharp decrease in the resistance of many intensive cultivars to biotic and abiotic stresses, which led to a high dependence of crop quality on soil and climatic conditions. The conditions of the zone include a sharp deterioration in the quality of products since breeding programs focused on gross indicators, a sharp decrease in the level of adaptation of cultivars and hybrids to growing conditions, and an increase in energy costs for production and environmental pollution.

Given the cucumber production dependency on the natural and climatic resources of the cultivation zone, the greening of vegetables compels particular importance (Paris *et al*., 2016). The main way of ecologization is the creation of cucumber cultivars adapted to the growing zone, yielding a sufficiently high produce with a low level of security, natural and climatic factors that do not require synthetic effects on crop plants during their cultivation, harvesting, and storage, having high consumer properties throughout their use. In light of the above discussion, the recent research work evaluated promising cultivars of cucumber (*C. sativus* L.) for economically valuable traits under the environmental conditions of the Aktobe region of Western Kazakhstan.

MATERIALS AND METHODS

Place of study

The research work on cucumber (*C. sativus* L.) proceeded in 2020–2021 at the Aktobe Regional University territory, Aktobe, Kazakhstan. Aktobe city location at 50.2797 N latitude and 57.2072 E longitude at an altitude of 209 masl. The city situates in the northern part of the Aktobe region, on both banks of the left tributary of the Urals — the Ilek River, where the Kargaly River flows into it; in the central part of the Poduralsky plateau, a plain with a height of 250–400 m. A characteristic feature of the Poduralsky plateau is that a Cretaceous mineral substrate lies under the soils (overlain by Paleogene clays in depressions), which are white-colored chalk deposits exposed in places of destroyed soil layer due to erosion. The qualitative indicator analysis ensued in the laboratory of mass analyses of KazNIIPO LLP, the Regional Branch, Kainar, Almaty, Kazakhstan. During the study conditions, the temperature regime was optimal for the growth and development of the cucumber plant, having the night and daytime temperatures maintained at 12 °C and 27 °C, respectively (Table 1). Temperature measurement used a standard mercury thermometer with a high degree of accuracy. Temperature plays a critical role in obtaining a high yield of cucumber greens.

Table 1. Temperature regimes of the growing season 2020.

Weather conditions	May	June	July	August	September	Mean values
Daytime temperature (°C)	+25.5	+27.5	+31.5	+27	+23.5	+27
Night temperature (°C)	+12	+13.5	+13	+13.5	+6.5	+11.7
Humidity (%)	54	41	43	53	52	48,6
Rain (mm)	13	33	27	35	10	23,6

Plant material

A phenological observation of the growth stages took place to conduct a comparative analysis of morphometric, productivity, and biochemical traits in the cucumbers (*C. sativus* L.). Promising cultivars 584, 577, 427, 294, and 264 underwent ecological cultivar testing. The basis for selecting the cucumber cultivars from a nursery resulted from a distinct complex of economically valuable characteristics (productivity, resistance to major diseases, and biochemical qualities of green), the laying of seed fruits, and individual selection from F_2 to F_8 populations. The F_1 hybrid 'Ular' served as the standard cultivar, originating from the Kazakh Research Institute of Potato and Vegetable Growing (KazNIIKO), Kazakhstan (http://fvri.kz/). The hybrid came from the crossing of maternal line L-1 and the paternal line Phoenix 640 (Figure 1). The average number of hybrids from mass seedlings to the period of the first fruit harvest was 58–61 days. The growing season took 125–129 days, with the fruiting period at 63–70 days, having a total yield of 22.80–26.07 kg m^2. Resistance to powdery mildew and peronosporosis resulted relatively better, with fruit marketability high at 85%–90% and good transportability.

Figure 1. Phoenix 640 – a paternal line of *C. sativus* L.

Research methodology

The experiment proceeded in the augmented design with complete randomization as the environmental design. The augmented design continued in a population with a limited number of seeds and consisted of four blocks. The selection of fruits for analysis used the "Methodology of the state cultivar testing of crops" (Method, 1975). The method of sowing was by seeds in the open field. Noted timings of the onset and passage of phenological phases focused on a) the phase of the appearance of single and mass shoots, b) the phase of the beginning of flowering, c) the date of fruit formation, and d) the date of the first and last harvest. The harvest was early and generally, according to the experience options. Each line and standard cucumber cultivar sown had plots the size of 60 m^2. Yield determination happened by harvesting fruits from 12 bushes in each of the four plots (https://gossortrf.ru/wp-content/uploads/ 2019/08/metodica_1.pdf).

Biochemical analysis for the content of dry substances, vitamin C, total sugars in fruits, and determination of acidity took place in the laboratory of chemical analysis of the regional branch, Kainar, according to the experimental methods in vegetable and melon growing (Methodological Guidelines, 1985), ascorbic acid (Ermakov, 1987), sugar (State Standard, 1991), acidity – titration of 0.1 N with alkali (NaOH) (State Standard, 1999), and dry matter by drying according to State Standard (2012). Damage to plants by powdery mildew and *Peronospora* assessment went on a 3-point scale according to the "Guidelines for breeding and seed production of vegetable crops cultivated in protected soil" as follows, i.e., 0 points – no disease: leaf surface damage 0%; 1 point – single spots on single leaves: leaf surface damage 12.5%–25%; 2 points – single spots on many leaves: 25%–50% of leaves affected; 3 points – spots on many leaves: 50%–75% of leaves affected (Methodology, 1970; Korottseva and Belov, 2019).

Statistical analysis

The presented data served as a mean ± error of the mean. The statistical analysis used the Student's parametric criterion. Checking the normality of the distribution followed the Shapiro-Wilk criterion (Akhylbekova *et al.*, 2022).

RESULTS

The cucumber (*C. sativus* L.) cultivar seeds began to germinate at a temperature of 15 °C–16 °C in the first two to three days after sowing the seeds. Cucumbers began to grow well with maintained temperatures around the clock at 25 °C–26 °C. Daytime temperature above 30 °C for a long time also negatively affects fruit formation.

The cucumber fruit is a false berry with three to five seed chambers. The shape and size of fruits of different cultivars and hybrids vary from 5–7 to 25–30 cm or more. In addition, the spikes on the peel can be white, brown, or black. In the seed fruits of cucumber (biological ripeness), the number of seeds ranges from 100 to 400 or even more. The fruits were large-sized, elongated, flat, and ovoid, with sharp edges and white-yellowish color. The 1000-seed weight was 16–35 g, where one gram contained 40–50 pieces. The length of the seeds ranged from 7 to 16 mm. Cotyledon leaves were oblong, oval, and light green; however, the real leaves differed in shape and size. The hypocotyl develops between the root and cotyledon leaves, while the epicotyl develops between cotyledons and real leaves. The edge of the real leaves was rough, light green, and flat, with the tip of the leaf, pointed.

Morphological structure of the leaf

The leaves were large, green, and/or dark green, with rounded and pentagonal shapes and strongly pubescent and slightly wrinkled. The stem reaches 4 cm, the third leaf's length reaching an initial 4–5 cm, with the width of the flattest leaf at 3–4 cm. During growing conditions, the plant reaches a length of 17–18 cm, a leaf length of 7–8 cm, and a width of 9–10 cm. Therefore, if the shoot length is excessive, the width also increases. The total length of the cucumber plant during the three-leaf period was 12–13 cm. Morphometric parameters of the cucumber cultivars, viz., 584, 577, 427, 294, and 264, were higher than the control F_1 hybrid 'Ular.'

During the growing season, evaluation of six promising domestic cultivars of cucumber (264, 294, 427, 524, 577, and the check and standard hybrid – 'Ular') ensued according to a complex of economically valuable characteristics (productivity, type of flowering, resistance to a complex of diseases, taste qualities of green). Based on the results

Table 2. The main indicators of the duration of the growing season.

Cultivars and hybrids	Since shoots		Fruiting period (days)
	Till the appearance of female flowers (days)	Till fruiting (days)	
584	36	46	48
427	34	46	51
294	33	45	51
264	34	47	46
577	34	49	45
Hybrid 'Ular'	33	48	48

Table 3. Productivity of cucumber (*C. sativus* L.) cultivars.

No.	Cultivars and hybrids	Yield in one month fruit (kg)		Yield from the plot during the growing season (kg)		Yield increase (%) over standard	
		Total	Trade	Total	trade	total	trade
1	584	5.83	5.44	8.9	7.9	-	-
2	427	7.91	7.50	11.5	10.6	39	37
3	294	7.92	7.46	12.6	11.4	42	39
4	264	4.48	4.32	6.3	5.6	-	-
5	577	3.76	3.76	5.7	4.1	-	-
6	Hybrid 'Ular'	5.34	5.14	9.2	8.5	-	-

Table 4. Biochemical parameters, taste qualities, and degree of damage by peronosporosis of cucumber (*C. sativus* L.) cultivars.

No.	Cultivars and hybrids	Dry matter (%)	Total sugar (%)	Vitamin C mg (%)	Nitrates (mg kg^{-1} - MAC-150)	Taste qualities (score)	Damage by peronosporosis (score)
1	584	4.24	3.15	2.9	73.4	4.5	1
2	427	3.4	3.0	3.2	89.8	4.4	2
3	294	4.1	4.46	3.1	86.8	4.9	0
4	264	3.10	3.24	2.7	89.4	4.9	2
5	577	4.04	3.3	3.2	86.0	4.5	2
6	Hybrid 'Ular'	3.26	2.34	3.0	76.2	4.9	0

of phenological observations, all the cultivars reached the level of the stage of germination to the flowering of female flowers, on average, 33–36 days (Table 2). Harvesting occurred for the cucumber lines 294, 584 and 427, genotype 264, and line 577 on the 45th, 46th, 47th, and 49th days, respectively. However, harvesting for the standard F_1 hybrid 'Ular' was beyond 48 days.

The growth and fruiting periods for all the cucumber cultivars ranged from 45 to 49 days. On the 45th day from the sowing date, the cucumber cultivar 294 had fruits three days earlier than the check hybrid 'Ular.' However, among all the cultivars, the fruiting period ranged from 45 to 51 days. As for productivity data of cultivars, the highest early productivity appeared in two cultivars, i.e., 427 (7.91 kg) and 294 (7.92 kg), compared with the standard hybrid cultivar 'Ular' (5.3 kg) (Table 3). The total productivity of these cultivars was also higher, amounting to 11.5 and 12.6 kg from the plot, compared with the check hybrid 'Ular' (9.2 kg). In testing cucumber genotypes, the increase in yield against the standard was 39%–42% in total and 37%–39% in commodity, respectively. Promising cultivars, viz., 427 and 294, proved distinct by a complex of economically valuable features, showing themselves as the most adaptive under the agro-ecological conditions of the Aktobe region, Kazakhstan.

According to Table 4, the largest amount of dry matter (4.24%) falls in cucumber cultivars 584 and 547. In terms of the total sugar content, cultivar 294 stood out, amounting to 4.46%. For vitamin C content, all the evaluated cultivars were at the standard level, with the nitrate content of all tested genotypes within the permissible limit of the concentration. For the taste test, the highest score resulted from the cucumber cultivars 294, 264, and the standard hybrid cultivar 'Ular.' However, cultivars 427, 264, and 577 showed the maximum susceptibility to peronosporosis.

DISCUSSION

A pumpkin family is a large group of crops, numbering more than 800 species known worldwide. Vegetables of this family served as food for centuries, as well as for their medicinal value. The most characterized and vital crops in this family are pumpkin and cucumber, grown and consumed in many parts of the world. Pumpkin plants are rich in carotenoids, terpenoids, saponins, and phytochemicals. Vegetables from the pumpkin family have a beneficial effect on human health, having antioxidant, antidiabetic, anti-inflammatory, and laxative properties (Rolnik and Olas, 2020). Cucumber is an economically viable vegetable crop that is cultivated all over the world. Compared with the wild ancestor bearing tiny, bitter, and sluggish fruits, domesticated cucumbers show significant differences in their appearance, size, and taste of fruits (Che and Zhang, 2019).

In the presented research work, the cultivation of cucumbers at optimal temperatures and humidity and in the open field transpired. This regime made it possible to avoid negative factors that occur in greenhouse cultivation conditions (Amin *et al.*, 2021). The studied set of parameters that the cucumber cultivars underwent evaluation was limited (dry matter, sugar, vitamin C, nitrates, taste qualities, and resistance to *Pseudoperonospora cubensis*); however, it allowed to identify the best performing and most promising cultivars.

It is imperative to determine the influence of other factors on yield, i.e., the biological characteristics of cucumber plants and the suitability of their cultivation in various cultivation facilities. Firstly, it is necessary to choose the right cultivar adapted to the climate of Kazakhstan and a cultivar that is suitable for growing in the closed ground and artificial agro-phytocenosis. This is especially important for areas with a pronounced continental climate, such as the Aktobe region of Kazakhstan. Secondly, the problem of irrigation following time requirements is very critical, and current investigations confirmed that even minimal concentrations of bisphenol-A in water inhibit photosynthesis in crop plants (Yu-Ting *et al*., 2018). It is particularly relevant in light of past results on the influence of chemicals in ultra-low doses (Ratushnyak *et al.*, 2005). The third significant point was the introduction of mineral fertilizers and trace elements necessary for the growth and development of vegetative plants (Eryashev and Eryashev, 2022). In obtaining a good yield, the quality of greenhouses, heating, temperature stability, and illumination played an essential role. Therefore, it is also necessary to consider the allelopathic relationship among the vegetables.

Throughout the study, the timely application of plant protection measures proved crucial in the fight against diseases and pests. The use of light substrates under greenhouse conditions has also shown a significant improvement in the cultivation of cucumber plants. Thus, identifying the variants of cucumbers most adapted and valuable in nutritional and commercial terms requires a more detailed analysis of the totality of various factors, including molecular genetic approaches (Lin *et al.*, 2022). This work is especially relevant in light of the influential role of Kazakhstan as a leading producer of agricultural products in the Central Asian region (Bespalyy, 2021; Grigoruk *et al.*, 2021; Nurmanbetova *et al.*, 2021).

CONCLUSIONS

Ecological cultivar testing occurred on six promising and domestic cucumber cultivars, i.e., 264, 294, 427, 524, 577, and the check hybrid 'Ular' under the environmental conditions of the Aktobe region of Western Kazakhstan. A complex of economically valuable characteristics (productivity, type of flowering, resistance to a complex of diseases, taste qualities of green) had shown in the genotypes of *C. sativus* L. The largest harvest collection came from cultivar 294, which was 39% higher than the standard hybrid 'Ular.' Ecological cultivar testing of the promising and domestic cucumber cultivars, viz., 584, 577, 427, 294, 264, and the check hybrid 'Ular' made it possible to get a good harvest of greens. Notably, also, per economically valuable features, the cucumber cultivar 294 proved superior.

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