

# STUDYING AND UTILIZATION OF PLANT GENETIC RESOURCES

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## Effects of seed size on seed germination, plant growth, and yield of kok-saghyz

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**Background.** Kok-saghyz is an emerging promising natural rubber crop plant, but there is still no economical and convenient seed-quality grading or screening method for production.

**Materials and methods.** We took accession k-445 of kok-saghyz from Russia as the study object, using four sieves with different meshes to screen its seeds into four grades, and studied the effects of seed size on seed germination, plant growth, and yield. The study was carried out in 2020–2022 under the conditions of a field experiment at the experiment station in Harbin (45.592729°N, 126.581668°E).

**Results.** It was established that sieves No. 28 and No. 30 with mesh sizes of 0.83 mm and 0.60 mm retained about 90% of the total seed mass. The germination capacity of seeds selected with sieves No. 28 and No. 30 was significantly higher compared to seeds selected with sieves No. 32 and No. 35 with mesh sizes of 0.50 mm and 0.43 mm. No significant differences in germination energy or germination uniformity were found among seeds of different fractions. The duration of growth stages of kok-saghyz plants sorted with sieves having different mesh sizes generally increased as the seed size decreased (with increasing sieve number) and was prolonged by one to four days. With an increase in the sieve number, rubber yield in kok-saghyz plants gradually decreased.

**Conclusions.** Thus, in production practice, sieves No. 30 and No. 35 can be directly used to improve operational efficiency by separating kok-saghyz seeds into two fractions. The use of sieves No. 30 and No. 35 for two-fraction seed sorting is a convenient and cost-effective method for grading and selecting kok-saghyz seeds according to quality.

**Keywords:** *Taraxacum kok-saghyz*, natural rubber plant, seed grading, rubber yield, rubber content

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## ИЗУЧЕНИЕ И ИСПОЛЬЗОВАНИЕ ГЕНЕТИЧЕСКИХ РЕСУРСОВ РАСТЕНИЙ

Научная статья

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### Влияние размеров семян на прорастание, рост растений и урожайность кок-сагыза

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**Актуальность.** Кок-сагыз является перспективным растением – источником натурального каучука, однако в настоящее время для его производства по-прежнему отсутствует экономичный и удобный метод градации и отбора семян по качеству.

**Материалы и методы.** В качестве объекта исследования использовали образец кок-сагыза k-445 из России. Семена с помощью четырех сит с различным размером ячеек были разделены на четыре фракции, после чего изучали влияние размера семян на их всхожесть, рост растений и урожайность. Исследования проводились в 2020–2022 гг. в условиях полевого эксперимента на опытной станции в Харбине (45,592729° с. ш., 126,581668° в. д.).

**Результаты.** Установлено, что сита № 28 и № 30 с размером ячеек 0,83 мм и 0,60 мм задерживали около 90% общей массы семян. Всхожесть семян, отобранных ситами № 28 и № 30, была достоверно выше по сравнению с семенами, отобранными ситами № 32 и № 35 с размером ячеек 0,50 мм и 0,43 мм. Существенных различий по энергии прорастания и равномерности прорастания между семенами различных фракций не выявлено. Продолжительность фаз роста растений кок-сагыза, отсортированных ситами с различным размером ячеек, в целом увеличивалась с уменьшением размера семян (увеличением номера сита) и удлинялась на 1–4 дня. С увеличением номера сита урожай каучука у растений кок-сагыза постепенно снижался.

**Заключение.** Таким образом, в производственной практике для повышения эффективности работ можно непосредственно использовать сита № 30 и № 35 для разделения семян кок-сагыза на две фракции. Применение сит № 30 и № 35 для двухфракционной сортировки семян является удобным и экономичным способом градации и отбора семян кок-сагыза по качеству.

**Ключевые слова:** *Taraxacum kok-saghyz*, источник природного каучука, сортировка семян, урожайность каучука, содержание каучука

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Прозрачность финансовой деятельности: авторы не имеют финансовой заинтересованности в представленных материалах или методах. Авторы благодарят рецензентов за их вклад в экспертную оценку этой работы. Мнение журнала нейтрально к изложенным материалам, авторам и их месту работы.

## Introduction

Seed quality plays a vital role in the progress of crop production, as it ensures the purity of seeds, provides the desired plant stand, and contributes to uniform growth and maturation. High seed quality enhances the crop's ability to withstand adverse conditions, respond well to fertilizer and other inputs, produce vigorous, fast-growing seedlings that can endure pest and disease incidence to a certain extent, and establish a well-developed root system that will make the uptake of nutrients more efficient (Singh, 2011).

Seed quality includes physical quality, genetic purity, physiological quality, and seed health. Seeds with good physical quality should have uniform size, weight, and color, and are expected to be free from undesired materials like stones, debris, dust, etc. (Dadlani, Yadava, 2023). Seed size, as an aspect of seed physical quality characterizing each plant species, is central to the regeneration and establishment of seeds (Sharma et al., 2013), and also is one of the most important components that determine final yield and quality during crop production (Kavita, Yogeesh, 2022). As a rule, seed-grading sieves are used to differentiate among different seed sizes in order to obtain high-quality seeds.

Kok-saghyz, or Russian dandelion (*Taraxacum kok-saghyz* Rodin), belongs to the Asteraceae family. Kok-saghyz seeds are small, with one seed basket (achene head) producing from 50 to 100 seeds. The absolute weight of 1000 seeds is 0.40–0.45 grams, meaning that there are between 2,000 and 2,500 seeds in a single gram (Vakhrusheva, 1992). Kok-saghyz roots contain 2.89–27.89% (Whaley, Bowen, 1947; Luo, 1951; Arias et al., 2016; Ramirez et al., 2017) of natural rubber, making this crop one of the best natural rubber plants in the world. Due to its advantages of being harvestable in the same year, easiness for mechanized harvesting, and high rubber quality, it is favored by major rubber tire companies and has attracted substantial investment to promote its industrialization (Polhamus, 1962; Ramirez et al., 2017) around the world.

Since kok-saghyz is an emerging crop, there is no economical and convenient seed-quality grading and screening method for production. In order to improve the performance of field seedlings and rubber yield of kok-saghyz, we used ordinary sieves to screen and grade its seeds, and then studied the effects of sieve-screened seeds on germination indicators, plant growth, and yield, so as to provide a convenient and practical seed-screening and grading method for kok-saghyz production.

## Materials and methods

The seeds of a kok-saghyz accession (k-445 of Ukrainian origin) from Russia served as the material for this study. We weighed 2.5 g of seeds randomly as one sample and repeated this procedure three times for each experiment. Seed sorting was performed using sieves with different aperture sizes: No. 28 (0.83 mm), No. 30 (0.60 mm), No. 32 (0.50 mm), and No. 35 (0.43 mm). The seeds were sifted sequentially; 2.5 g of seeds were sifted first through sieve No. 28, then No. 30, then No. 32, and finally No. 35. The material that fell out of sieve No. 35 was an impurity consisting of empty seed shells. With four sieves of different diameters, the seeds were divided into four size grades (seeds detained by sieves were studied). Each grade was weighed separately, so that the specific weight and thousand-seed weight were determined for each grade. We randomly selected 30 seeds from each grade, measured the length and width of the seeds, and analyzed whether the differences between them were significant. Next, we ran-

domly selected 30 seeds from each grade for germination tests to analyze the differences in germination percentage, germination rate, and germination consistency among them. Finally, 100 seeds were randomly selected from each grade to produce seedlings, which were transplanted to the field, and the differences in the phenological period and yield among them were analyzed.

Index calculation method:

Germination percentage: germinated seeds/total number of seeds  $\times 100\%$ ;

Germination rate:  $\text{CVG} = (\sum_{i=1}^K f_i / x_i) 100$ , where  $f_i$  is the number of seeds germinated on day  $i$ ,  $x_i$  is the number of days from the start of seed germination, and  $K$  is the number of days when the seeds finished germination;

Germination consistency:  $\text{CVt} = (\text{St} / \bar{t}) 100$ ,  $\text{St}$  is the standard deviation of germination time,  $\bar{t}$  is the average germination time –  $\sum_{i=1}^K n_i t_i / \sum_{i=1}^K n_i$

where  $t_i$  is the time from the start of the experiment to the count on the  $i$ -th day,  $n_i$  is the number of seeds germinated on the  $i$ -th day, and  $K$  is the end of the experiment.

The number of germinating seeds was recorded at a fixed time every day.

Growth period:

Seedling stage: from the appearance of real leaves to 6–7 leaves;

Leaf expansion stage: from 6–7 leaves to the beginning of flowering;

Beginning of flowering: from flowering to 10% of flowers blooming;

Full flowering stage: from 15% of flowers blooming to 50% of flowers blooming;

Fruit stage: from the ripening of the first fruit to the last fruit.

Thirty plants were randomly selected from each grade to observe the phenological period. When about 10% of the plants reached the standard of a certain phenological period, it was defined as the beginning of this phenological period; when more than 50% of the plants reached the standard, it was defined as the peak period; when more than 80% of the plants reached the standard, it was defined as the end period.

The climatic conditions of the year were favorable for the growth and development of plants. The experiment station where the research was conducted is characterized by a temperate continental monsoon climate, with a short and cool summer, and a long cold winter. The average annual precipitation ranges from 494 to 651 mm, with most rainfall occurring in July and August. The soils at the experiment are dark-brown, with relatively high humus content. The mean summer temperature from June to August was  $+22^\circ\text{C}$ . The hottest month was July, with the mean minimum temperature of  $+23^\circ\text{C}$ , and the mean maximum temperature of  $+29^\circ\text{C}$ . The highest average amount of precipitation was recorded in July – 110.7 mm, and in August – 89.4 mm. Sowing was carried out on April 20 using the seedling method. The distance between rows was 30–40 cm, and the distance between plants was 25 cm. To study the rubber content in the dried roots of kok-saghyz, the method of root extraction with a hot alkaline solution of NaOH was applied. This method is used to produce purified rubber (Ramirez Cavidad et al., 2022).

For the data analysis, we used single-factor (sieve diameter) multivariate (germination percentage, and germination rate) variance analysis with post-hoc comparison by the Tukey criterion, and applied the *pwr* software package in the R language to determine the minimum number required for variance analysis (<https://www.r-project.org>).

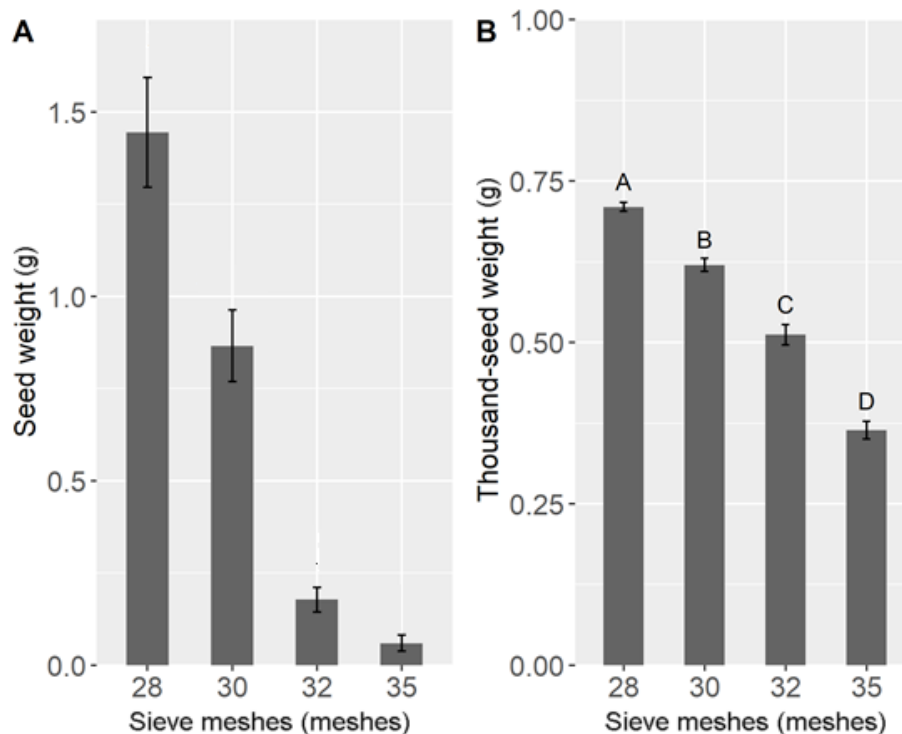
## Results and discussion

### Weight comparison of seeds screened through sieves with different meshes

Kok-saghyz seeds were separated into fractions using sieves No. 28, No. 30, No. 32, and No. 35. The proportion of seeds retained on the sieves increased as the aperture size decreased. Sieve No. 28, with an aperture diameter of 0.83 mm, retained the largest proportion of seeds, accounting for more than half of the total mass – 1.45 g (56.6%). This was followed by the fraction retained on sieve No. 30, with an aperture diameter of 0.60 mm, which accounted for 0.85 g (33.9%). Seeds retained on sieve No. 32 comprised 0.18 g (7.0%), while the smallest fraction was obtained using sieve No. 35, accounting for only 0.06 g (2.4%) of the total seed mass (Fig. 1).

clustering within the top statistical significance fraction ( $P \leq 0.01$ ). A pronounced decline in viability was observed in the smaller physical fractions, culminating in the lowest germination rate for seeds of No. 35.

In stark contrast to overall viability, neither germination speed ( $F = 0.14$ ,  $P = 0.931$ ) nor germination uniformity ( $F = 0.21$ ,  $P = 0.884$ ) were significantly affected by seed grading. Irrespective of their physical dimensions, viable seeds across all cohorts exhibited a consistent germination speed and a highly uniform temporal spread. This divergence suggests that while smaller seed fractions contain a substantially higher proportion of nonviable seeds, the functionally viable subpopulation within those smaller fractions possesses normative germination vigor equivalent to that of the largest seeds. The differences in seed germination rate and germination consistency across all sieves were not significant (Fig. 2, Fig. 3).



**Fig. 1.** Seed specific weight and 1000-seed weight of kok-saghyz seeds after screening, g: **A** – seed specific weight of kok-saghyz seeds after screening; **B** – 1000-seed weight (different capital letters above the bars indicate statistically significant differences ( $P \leq 0.01$ ) based on the analysis of variance)

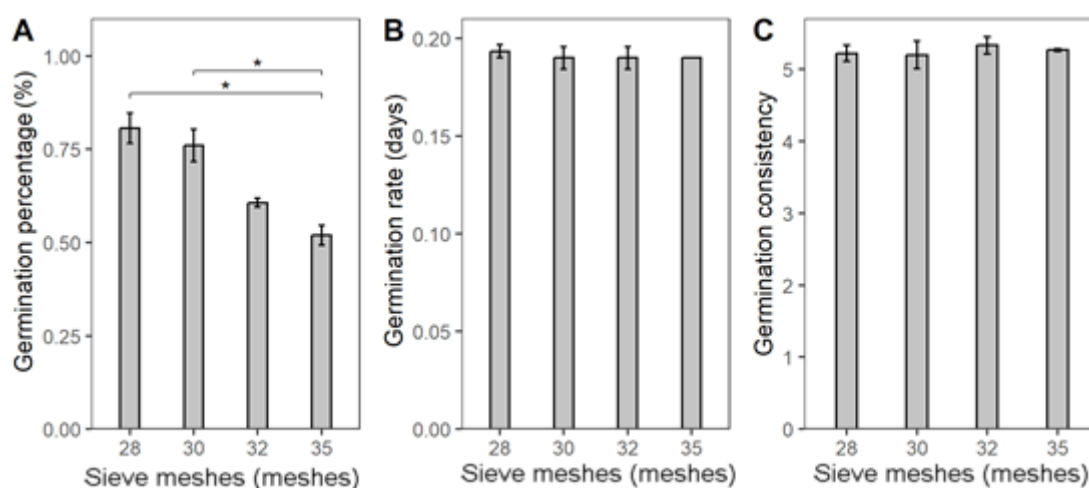
**Рис. 1.** Удельный вес семян и масса 1000 семян кок-сагыза после калибровки, г: **A** – удельный вес семян кок-сагыза после калибровки; **B** – Масса 1000 семян (различные заглавные буквы над столбцами указывают на статистически значимые различия ( $P \leq 0,01$ ) по результатам дисперсионного анализа)

### Seed germination index after screening through sieves with different meshes

The germination of seeds screened through sieves with different meshes showed that the seed germination percentage of sieves No. 28 and No. 30 was significantly different from that of No. 35 ( $\alpha = 0.05$ ) (Fig. 2A), and there was no significant difference among the other sieves. The physiological viability of kok-saghyz seeds was heavily dependent on physical dimensions, whereas germination kinetics remained completely conserved across all size classes. Sieve size demonstrated a highly significant effect on total germination percentage ( $F = 16.18$ ,  $P < 0.001$ ,  $\eta^2 = 85.9\%$ ). The larger seed fractions (No. 28 and No. 30) maintained the highest viability,

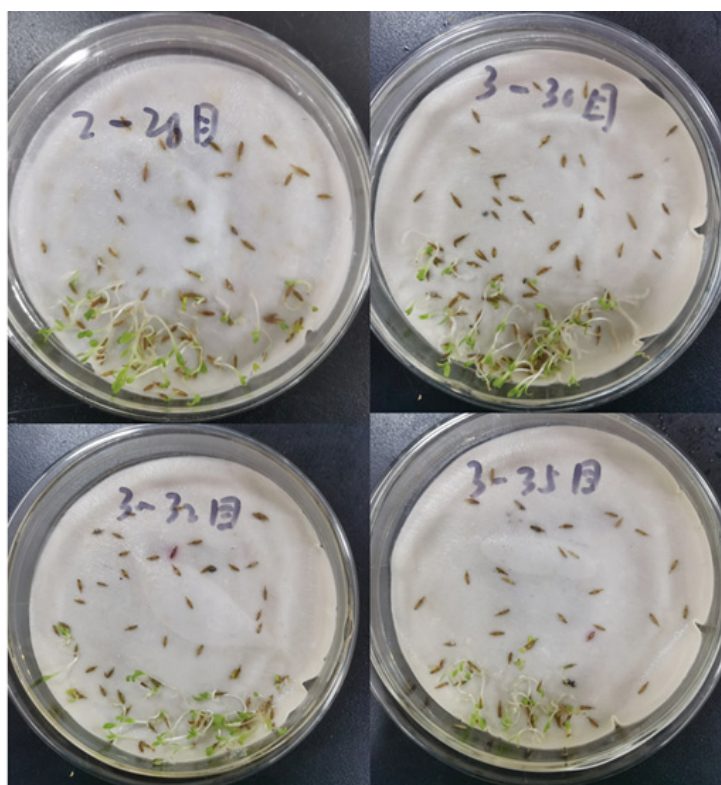
### Comparison of the growth period of seeds screened through sieves with different meshes

During the seedling stage, no statistically significant differences in plant growth periods were observed among seeds screened through sieves with different mesh sizes. However, the following trends were noted: during the leaf expansion stage, the larger the mesh size of the sieve, the later the plant growth was delayed by 1–2 days; during the initial flowering stage, except for sieve No. 35, the growth period of plants screened through other sieves was delayed by 2–3 days; during the peak flowering stage, the larger the mesh size of the sieve, the later the plant growth period was delayed by 2–4 days; during the fruiting stage, the larger the mesh size of



**Fig. 2.** Differences in the germination index of seeds screened through sieves with different meshes ( $\alpha = 0.05$ )

**Рис. 2.** Различия в индексе всхожести семян, отсортированных с использованием сит с разным размером ячеек ( $\alpha = 0,05$ )



**Fig. 3.** Experiment on seed germination after screened through sieves with different meshes

**Рис. 3.** Определение всхожести семян, калиброванных на ситах с разным размером ячеек

the sieve, the later the plant growth period was delayed by 1–4 days (Table).

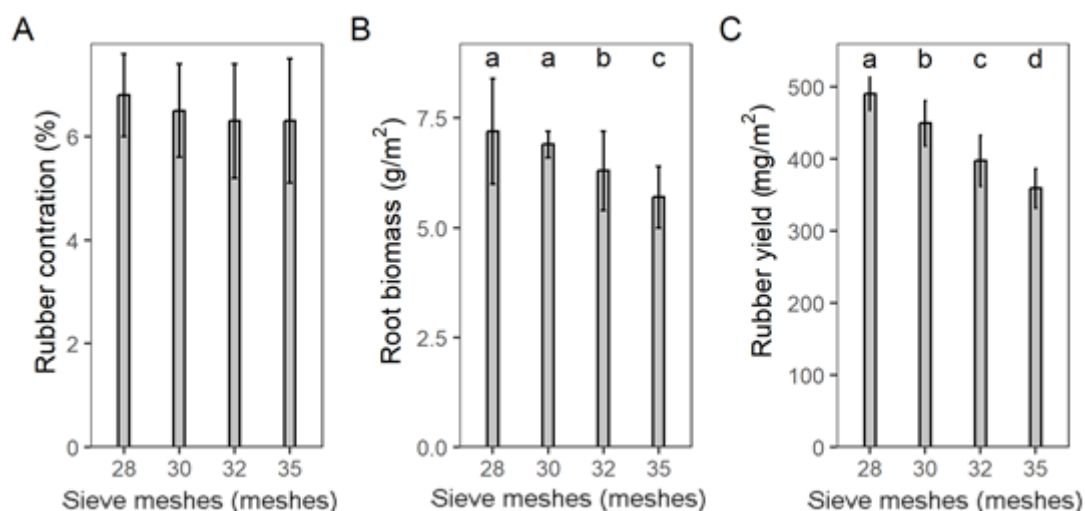
#### **Plant yield of seeds screened through sieves with different meshes**

The differences in rubber concentration in kok-saghyz plants grown from seeds screened through sieves with different meshes were not significant, with an average between 6.3% and 6.8% (Fig. 4, A); however, the root biomass of kok-saghyz plants grown from seeds screened through sieves with different meshes was significantly different. Among the

No. 28 and No. 30 groups, there was no significant difference in root biomass, but there were significant differences between these groups and the other mesh sizes. The highest root biomass of kok-saghyz plants screened with sieve No. 28 was 7.2 g/m<sup>2</sup>. As the sieve mesh number increased, the root biomass gradually decreased, and the root biomass of plants screened with No. 35 was the lowest at 5.7 g/m<sup>2</sup> (Fig. 4, B; Fig. 5). There were significant differences in rubber yield of kok-saghyz plants screened by sieves with different meshes. As the mesh number of the sieve increased, the pore size reduced, and the rubber yield of kok-saghyz gradually decreased, with the highest rubber yield of sieve No. 28 plants

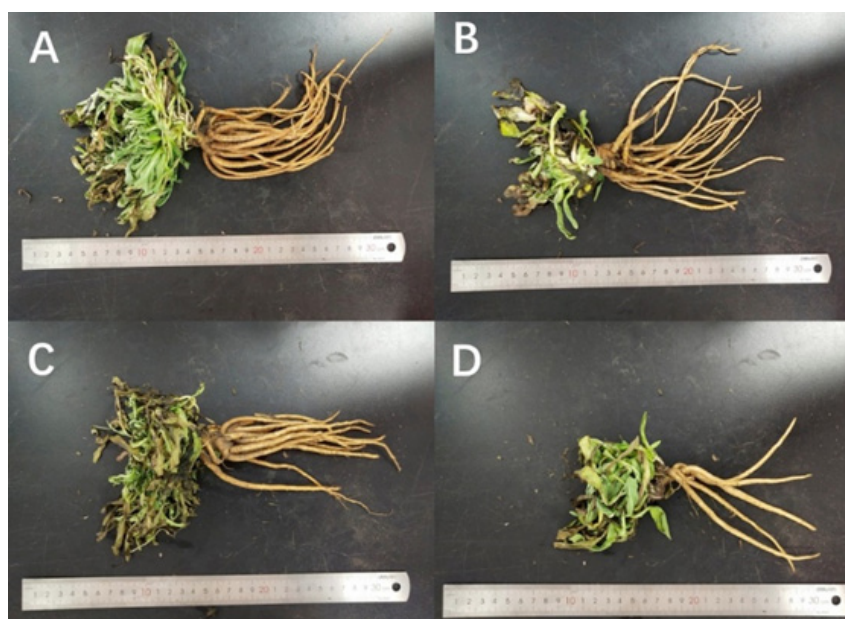
**Table.** Growth period of kok-saghyz plants grown from seeds screened through sieves with different meshes  
**Таблица.** Продолжительность фаз развития растений кок-сагыза, выращенных из семян, отсортированных ситами с разным размером ячеек

| Sieve sizes | Seedling stage    | Leaf stage      | First flowering stage | Blooming stage    | Fruiting stage     |
|-------------|-------------------|-----------------|-----------------------|-------------------|--------------------|
| 28 meshes   | April 20 – May 11 | May 12 – May 27 | May 25 – June 12      | June 13 – June 28 | June 16 – Sept. 28 |
| 30 meshes   | April 20 – May 12 | May 13 – May 29 | May 27 – June 14      | June 15 – July 2  | June 19 – Sept. 29 |
| 32 meshes   | April 20 – May 11 | May 12 – June 3 | June 2 – June 17      | June 18 – July 4  | June 21 – Oct. 3   |
| 35 meshes   | April 20 – May 13 | May 14 – June 4 | June 3 – June 15      | June 16 – July 16 | June 20 – Oct. 2   |



**Fig. 4.** Comparisons of rubber concentration, root biomass, and rubber yield of kok-saghyz plants grown from seeds screened through sieves with different meshes (A – rubber concentration; B – root biomass; C – rubber yield)

**Рис. 4.** Сравнение концентрации каучука, биомассы корней и выхода каучука у растений кок-сагыза, полученных из семян, отсортированных ситами с разным размером ячеек (А – концентрация каучука; В – биомасса корней; С – выход каучука)



**Fig. 5.** External appearance of the roots of plants obtained from seeds of different fractions (A – 28 meshes; B – 30 meshes; C – 32 meshes; D – 35 meshes)

**Рис. 5.** Внешний вид корней растений, полученных из семян разных фракций (А – фракция сита № 28; В – № 30; С – № 32; D – № 35)

being 490 mg/m<sup>2</sup>, and the lowest rubber yield of sieve No. 35 plants being 359 mg/m<sup>2</sup> (Fig. 4, C).

After kok-saghyz seeds were screened, seeds of different sizes were obtained. Large seeds had a higher germination rate, larger root biomass, and greater rubber yield. Therefore, screening and grading of kok-saghyz seeds proved an effective way to increase the crop's rubber yield. Previous studies also showed that seed size was one of the physical indicators of seed quality. Generally, large seeds performed better than small seeds in the field (Ambika et al., 2014). Large wheat seeds grew more vigorously and had higher biomass and yield (Moussavi Nik et al., 2011; Aboye, 2021). For example, wheat seed size was positively correlated with seed vitality, and large seeds were more likely to produce strong seedlings (Ries, Everson, 1973); the seed germination rate and seedling vitality index of rice were positively correlated with seed size (Roy et al., 1996); peanuts exhibited a high germination percentage in large and medium-sized seeds, and their yield increased with seed size (Trivedi, Bhatt, 1994; Sibuga, Nsenga, 2003); the germination rate, seedling length, seedling vitality, and dry weight of large sunflower seeds were positively correlated with seed size (Nagaraju, 2001); large soybean seeds in tropical regions had higher yields (Adebisi et al., 2012); plants with large seeds of elite maize lines also demonstrated higher seed quality and yield (Adejare, 2010). Other germination indicators of large kok-saghyz seeds, such as germination rate and germination consistency, did not differ from those of small seeds.

The kok-saghyz seeds screened through sieves No. 28 and No. 30 accounted for about 90% of the total weight, and there was no difference in the germination rate of seeds screened through sieves No. 32 and No. 35. Sieve No. 30 could simultaneously screen the seeds retained by No. 28, and No. 35 can simultaneously screen the seeds retained by the 32-mesh sieve. Therefore, in production practice, sieves No. 30 and No. 35 can be used directly to divide kok-saghyz seeds into two grades to improve work efficiency.

### Conclusion

In this study, a method for sorting and grading the quality of kok-saghyz seeds using four sieves (Nos. 28, 30, 32, and 35, with different aperture sizes of 0.83, 0.60, 0.50, and 0.43 mm, respectively) was established. Among the sieved groups, based on weight, sieve No. 28 retained 56.6% of the seeds, No. 30 retained 33.9%, No. 32 retained 7.0%, and No. 35 retained 2.4%. The germination percentages of kok-saghyz seeds retained by sieves No. 28 and No. 30 were significantly different from those retained by No. 35 ( $\alpha = 0.05$ ). The differences in germination percentage among the other mesh sizes were not significant; the germination rates and germination consistency across all sieves were not significantly different as well.

The growth period of kok-saghyz plants grown from seeds screened through sieves with different mesh sizes generally increased as the mesh number increased, and the growth period was delayed by 1 to 4 days.

There were significant differences in the rubber yield of kok-saghyz plants grown from seeds screened through sieves with different mesh numbers. As the mesh number increased (i.e., as the pore size reduced), the rubber yield of kok-saghyz plants gradually decreased. The highest rubber yield, obtained from plants grown from seeds retained by sieve No. 28, was 490 mg/m<sup>2</sup>, while the lowest rubber yield, obtained with sieve No. 35, was 359 mg/m<sup>2</sup>.

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