Influence of the evenness of seeding using a disk-cell seeding mechanism on the productivity of scarlet amaranth

Evgeny I. Artamonov, *Sergey N.* Zhiltsov, *Maxim P.* Erzamaev*, *Dmitry S.* Sazonov, *Maxim S.* Prikazcnikov, and *Nikolai A.* Cherkashin

Samara State Agrarian University, 2, Uchebnaya St., Kinel, 446442, Russian Federation

Abstract. The paper presents the results of a field study of the effect of the evenness of seeding using a disk-cell seeding mechanism on the fresh yield and Scarlet amaranth grain of Kinelsky 254 variety. The problem of the amaranth evenness of seeding was solved by developing an experimental seeder of precision sowing for small-seeded crops. Field experiments were carried out on the fields of the Volga Research Institute of Selection and Seed Production named after P. N. Konstantinovin 2019-2021. To control the qualitative parameters of sowing, amaranth was sown with ballast (blind seeds) with a VS-4.2 vegetable seeder. The study revealed that the evenness of seed distribution in a row during sowing with an experimental seeder was 22%, for plants – 24.6%, control – 24.6 and 72.1%, respectively. The use of an experimental seeder made it possible to sow in accordance with agrotechnical requirements and create the best conditions for plant nutrition, which led to an increase in the fresh yield of Scarlet amaranthof Kinelsky 254 variety by 2.6 times, grain – by 1.6 times.

1 Introduction

The intensive development of animal husbandry associated with active import substitution in the whole country and in the Volga region in particular sharply raise the question of the need to increase the production and use of highly efficient feed [1, 2, 3]. One of the promising, unconventional forage crops with high yield and nutritional value is the Scarlet amaranth, the interest in which has grown in recent years [2, 3]. The Volga Research Institute of Selection and Seed Production named after P. N. Konstantinov(VRISSP named after P. N. Konstantinov) licensed the Kinelsky 254 amaranth and conducts the selection studies on its reproduction and creation of new varieties of fodder and grain [2, 3].

Scarlet amaranth belongs to the Amaranth family [4, 5, 6] – in most cases it is an annual large herbaceous plant with a dense spike-panicledinflorescence and small flowers. In different agricultural regions of Russia the plant can reach a height of up to 2.5 m, has a straight or branched stem, leafy to the base, a wide fleshy leaf. The weight of one plant can reach 8 kg, and the stem in the root part – 5 cm.

The nutritional value of Scarlet amaranth, in comparison with traditional legumes and cereal crops, is characterized by higher protein content and a well-balanced amino acid composition. Some basic valuable indicators of this culture are given in Tables 1 and 2 [4].

Table 1. Chemical composition of amaranth in the early flowering phase.

Indicator	In %of the dry weight	
	Varieties	
	Stere	Scarlet amaranth
Drymatter	13.5…20.2	17.1…19.0
Nitrogen-freeextractivesubstances	44.8…46.7	36.1…43.4
Protein	16.4…17.7	17.7…19.6
Cellulose	26.6…27.4	27.2…27.3
Ash	10.3…10.8	13.7…13.9
Sugar	4.7…6.5	5.3…7.9
Ascorbicacid, mg, %	30.8…36.2	28.3…28.7

* Corresponding author: erzamaev_mp@mail.ru

It is known that the green crop of amaranth can be used to prepare silage both in admixture with other crops, for example corn, and in pure form for the feed of cattle and pigs [4, 5]. The selection studies of V.F. Kazarin describe that one of the main conditions for obtaining the highest yield of amaranth, depending on the production purposes for which the sowing is carried out, is the optimal dotted distribution of seeds along the row. So, when cultivating the green crop of amaranth the distance between seeds should be 20–22 mm, and for grain cultivation – 40–45 mm respectively [2, 3]. The purpose of sowing amaranth determines the number of plants in a row per meter run, and it, in turn, is directly related to the sowing rate, germination of seeds and the chosen sowing method. Due to its agrobiological characteristics, the culture is very demanding on the food area, which sets high requirements for an even longitudinal distribution of seeds and plants in a row during sowing. The analysis of the domestic practice of cultivating Scarlet amaranth, as well as the structures of sowing devices and seeders, showed that due to a number of technical and technological limitations, it is not possible to fulfill the agronomic requirements for the longitudinal evenness of seeds in a row, which is caused by the low sowing rate, size, shape and low friction properties of seeds [7].

Table 2. Amaranth yield in comparison with leguminous crops and its nutritional value.

Indicator	Crop				
	Wheat	Corn	Rice	Beans	Amaranth
Biologicalyield, t/hha					
Freshyield, t/ha	–	32.0	–	–	56.4
Grainyield, t/ha	1.2–2.5	1.7	–	–	2.3
Substancecontent, %					
Protein	13.00	7.68	7.60	21.48	15.54-29
Fat	1.70	5.00	2.20	1.96	7.31
Cellulose	2.90	2.46	6.40	5.70	5.2
Ash	1.50	165	3.40	4.61	3.61
Copper	28.00	7.00	7.00	8.00	6.00
Sodium	0.01	0.01	0.01	0.02	0.12
Potassium	0.40	0.48	0.12	1.30	0.57
Phosphorus	0.41	0.27	0.18	0.41	0.54
Aminoacids, mg %					
Arginine	3.80	4.20	6.90	6.20	10.00
Lysine	1.20	0.70	3.80	0.00	8.00
Leucine	7.70	12.50	8.20	8.20	5.70

The studies revealed that the seeding rate may reach 0.1...0.9 kg/ha and depends on the established width of rows, while the depth of seeding may be 1...1.5 cm. For accurate or dotted seeding, seed germination should be at least 92% [2, 3, 6].

Amaranth is sown in the farms of Samara region by grain and vegetable seeders, and it is necessary to use some filler: calibrated river sand, blind amaranth seeds or seeds of other crops, granulated mineral fertilizers in a proportional ratio of 1:10, which significantly complicates and increases the cost of crop cultivation technology, and most importantly reduces the yield directly related to sowing quality indicators [3, 6, 7].

Such domestic grain seeders as SZT-3.6 equipped with a special device for sowing clover, melilot, rapeseed, SP-6 – for sowing rapeseed seeds, SLT-3.6 – for sowing in meadows and pastures, SZL-3.6 – grain seeder, to one degree or anotherperform the seeding of Scarlet amaranth in various ways: wide-row planting, row sowing and others. Seed dosing devices in most of these seeders are equipped with coils that do ensure small seeding rates on small-seeded crops, since they form a seed flow in portions of several pieces and throw them out simultaneously at certain intervals. This does not result in precise placement of seeds at the bottom of the furrow at the same inter-seed intervals, but in thickened continuous sowing. Besides, these seeders and their modern modernizations have quite large structural leakages along the entire route of seed movement from the bunker to the bottom of the furrow, where only on small seeds there is a phenomenon of “leakage” through gaps of seed material and, as a result, an increase in the seeding rate, thickening of crops, a decrease in grain yield and fresh yield [1].

In most grass and grain seeders their seeding and dispensing devices are equipped with dampers that are closed on the sowing of amaranth with a wide-row seeding method, however, the listed disadvantages are not eliminated by this operation [1].

The use of seeders by foreign manufacturers, such as: Monocenter– Germany, Unisem– France, Siklow-500– USA and many others, do not allow withstanding the agrotechnical requirements for sowing amaranth due to the fact that the pneumatic transportation of seed material leads to an increase in dispersion along the bottom of a furrow and along its walls and even in cases with pneumatic sowing of amaranth seeds – beyond the furrow, which is explained by the low weight of seeds (weight of 1000 seeds – 0.8 g) and high requirements for air flow pressure evenness. The engineering service specialists of Samara agricultural enterprises use various sealants and gasket material to prevent "leakage" of seed material through the gaps between the parts of the seeders in the dispensing devices and the transportation system. Additional operations to increase seeder tightness affect the seeding agro-termsand increase pre-seeding costs.

Besides, vegetable seeders VS-5.4 and VS-4.2 were also used to cultivate amaranth. Their main advantage is the creation of a compacted bed of the bottom of a furrow, a semi-shaped ploughshare, which allows improving the germination of seeds.

The main disadvantages of considered the seeders include the inability to ensure a small seeding rate in accordance with agricultural demands and to ensure longitudinal evenness of seeds in a row.

Based on the above-mentioned material it can be concluded that when Scarlet amaranth is cultivated for seeds and fresh yield, the best yield can be achieved at minimum sowing rates thus ensuring the even longitudinal distribution of seeds in a row and a wide-row sowing method. Today, the weaknessof the Scarlet amaranth sowing technology is the longitudinal evenness of the distribution of inter-seed intervals.

To study the effect of the evenness of sowing of Scarlet amaranth of Kinelsky 254 on grain and fresh yield.

2 Materials and methods

As a result of close scientific cooperation between the scientists of the Department of Technical Service of Samara State Autonomous University and VRISSP named after P. N. Konstantinov, the problem of even sowing of amaranth was solved by developing an experimental precision seeder for small-seeded crops (Figure 1).

Fig. 1. Experimental seeder (left) and seeding section (right).

The beet seeder SST-12B served the basis for the experimental seeder of precision seeding. For sowing seeds of Kinelsky 254 Scarlet amaranth, the units of the SST-12B seeder equipped with a disk-cell seeding mechanism were designed and manufactured [patent for the invention "seeding device" No. 2347349] with optimal design parameters of working organs justified during preliminary laboratory studies [8, 9].

The experiments to study the effect of the longitudinal evenness of the distribution of seeds and plants of Kinelsky 254 Scarlet amaranth in a row in terms offreshand grain yield were carried out on the fields of preliminary and main variety multiplication of the VRISSP named after P. N. Konstantinov from 2019 to 2021. Amaranth seeding with ballast was used to control the quality of seeding using the vegetable seeder VS-4.2. Blind seeds of the same culture were used as ballast. Seed material was used with a germination rate of 94% [10].

According to the established test method [11], the distribution of seeds during sowing was determined by the seedlings in three accounting sections of 2 m long and the width equal to the width of the seeder grip. A 2-meter ruler with single-centimeter divisions was applied at these sites, and the distance between individual seeds was measured on a cumulative basis (Figure 2) (the first seed was taken as zero).

Fig. 2. Evenness of distribution of amaranth seeds along the row using an experimental seeder.

Similarly, the distribution of plants along the row was determined after the complete emergence of seedlings at each of the three selected sites (Figure 3).

Fig. 3. Evenness of plant distribution along the row; using the experimental seeder VS-4.2.

The evenness of the distribution of seeds and plants was evaluated by the variation coefficient ν.

3 Results and discussion

As a result of processing the obtained data to determine the longitudinal evenness, variation curves of the distribution of intervals between seeded seeds (Figure 4) and the obtained plant seedlings were built (Figure 5).

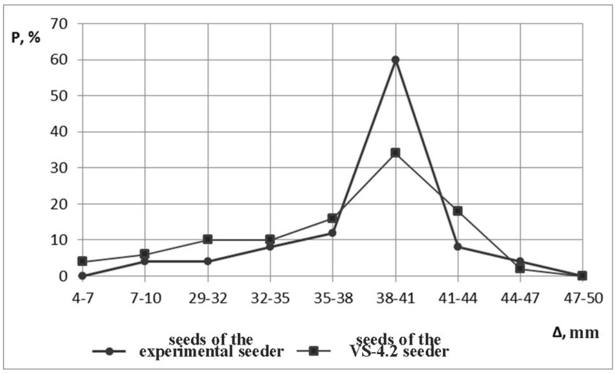

Fig. 4. Distribution of intervals between amaranth seeds in a row.

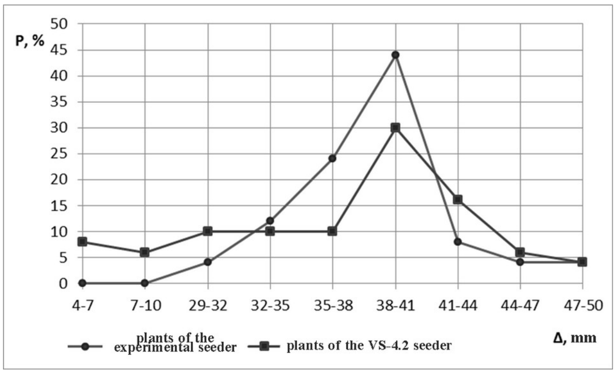

Fig. 5. Distribution of intervals between amaranth seedlings in a row.

The best indicators of the evenness of the distribution of seeds in a row were obtained during sowing with an experimental seeder. The variation coefficient of the intervals between the seeds was ν = 22% for the crops planted with the experimental seeder and ν = 65% for the crops planted by the seeder with a roller seeding mechanism.

The analysis of the variation curves (Figure 5) of the distribution of intervals between plants shows that when sowing with an experimental seeder, the variation coefficient of was ν = 24.6%, and with a control seeder – ν = 72.1%. A significant difference in evenness is explained by the fact that the seeding mechanismVS-4.2 supplies a mixture of seeds and ballast in portions. Besides, there is additional sowing of the furrow edges from the leakages of the seed transporting system, which leads to an additional increase in the seeding rate and significant thickening of crops. Intraspecific control in tall crops significantly reduces yields.

The uniform distribution of seeds when sowing amaranth using the experimental seeder made it possible to directly affect the crop yield. This is explained by high requirements for the food area of plants due to its size and high growth. The use of the experimental seeder at the VRISSP named after P. N. Konstantinov made it possible toincrease the grain yield on average by 1.6 times over the past three years, and the fresh yield increased 2.6 times compared to the crops planted with by the VS-4.2 (Table 3).

Table 3. Productivity of Kinelsky 254 amaranth using experimental seeder and control seeder VS-4.2(according to VRISSP named after P. N. Konstantinov).

Yield, t/ha	2019		2020		2021		Average	
	Experimental seeder	VS-4.2	Experimental seeder	VS-4.2	Experimental seeder	CO-4,2	Experimental seeder	VS-4.2
Fresh yield	30.0	11.5	55.0	21.2	84.4	32.4	56.3	21.7
Grain	0.9	0.6	1.2	0.75	2.7	1.6	1.6	0.98
Dry matter	7.2	2.7	13.2	5.1	19.4	7.6	13.3	5.1
Protein	0.8	0.56	1.5	0.7	2.2	1.49	1.5	0.92

Due to the best conditions for the evenness of sowing close to the agrotechnical requirements the sowing of Kinelsky 254 amaranth variety with an experimental seeder allowed achieving the maximum indicators for the fresh and grain yields, which had not previously been obtained in divisional selected cultivation or in preliminary reproduction. This made it possible to license the variety with the best indicators.

4 Conclusion

The field studies aimed at evaluating the effect of the evenness of longitudinal placement of seeds and plants of Scarlet amaranth in a row showed that the evenness of the distribution of seeds in a row during sowing with an experimental seeder was 22%, for plants – 24.6%, for control – 24.6% and 72.1%, respectively. This made it possible to perform sowing in accordance with agrotechnical requirements and create the best conditions for plant nutrition, which led to an increase in fresh yield by 2.6, and grain – by 1.6 times.

Thus, the scientific and industrial experiment of cultivating amaranth in Samara region allows recommending agricultural producers to use a wide-row sowing method with dotted placement of seeds to cultivate amaranth for various purposes.

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