Short communication

DIOECIOUS HEMP SEED YIELD UNDER THE INFLUENCE OF CROP MANAGEMENT

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SUMMARY

In order to define the most optimal technique for field trials that would allow broader exploration of the interaction of G × E × M (G – genotype, E – environmental conditions, M – crop management) in hemp seed production, one-year trials were set up with the typically dioecious hemp variety Marina. The trials included three different crop densities (20, 150, and 300 plants m^{-2}) and the control unpinched variant which was compared with the apical bud removal treatment (pinching) at a plant height of 60 cm. The results showed that with pinching in all crop densities, a decrease in plant height and an increase in seed yield are achieved. The highest seed yields of over 1200 kg ha^{-1} were achieved in the pinched crop with 20 and 150 plants m^{-2}, which can be considered the optimal method for determining the yield potential of the genotype. The obtained results of the preliminary research will serve as a basis for recommendations for commercial hemp seeds production, as well as for defining the method for testing the wider germplasm in the hemp breeding programs.

KEYWORDS: dioecious hemp, grain yield, pinching, plant height

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INTRODUCTION

The fruit of hemp is a small achene containing a single seed surrounded by a thin pericarp. Although in other crops the mercantile product is called grain, in hemp the term seed is used in the case of commercial products as well as when dealing with reproductive material. In our work for the final commercial product, we will use the term 'hemp seed'.

Hemp as an industrial crop is primarily grown for the stem with a significant content of high-quality fiber, and for the seed. The stem is a raw material for several industries, which are based on the processing of fibers or hurds (Duque Schumacher et al., 2020). Hemp seeds are a source of vegetable fats and proteins for human and animal nutrition (Leizer et al., 2000; Aluko, 2017), as well as for further reproduction as seed material.

In times when hemp cultivation was limited to mainly biomass production, the reproductive material was obtained from individual plants grown in low densities. Such plants were robust, with more long, productive branches, and obtaining seeds required a lot of manual work (Berenji et al., 2013), Picture 1.

With hemp seed increased demand, mechanized harvesting methods were developed (Burczyk et al., 2005; Leonte et al.,

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2016) by which seed production was made possible in larger areas. Production is rationalized by using an axial flow harvester, but it has disadvantages due to seed shattering in the harvest. Cutting the stem during harvesting with a combine harvester can be

Picture 1. Traditional manual harvest, drying and manual threshing of hemp for seed production

technically performed at a limited height. If the plants are high, part of the seeds shatters before the material reaches the harvesting mechanism within the machine (Picture 2).

This can be overcome by breeding the assortment specialized for seed production or by adapting the existing assortment to plants of appropriate proportions that would allow an unhindered harvest with minimal losses (Sikora et al., 2022).

Based on one-year experiments on the example of one dioecious hemp variety, the main objective of the short communication is to evaluate more complex research related to the development of varietal technology for wider dioecious as well as monoecious assortments for hemp seed production in specific conditions.

MATERIAL AND METHODS

Trials with different crop densities of dioecious hemp variety Marina were conducted in 2022 at the Department for Vegetable and Alternative Plant Species of the Institute of Field and Vegetable Crops Novi Sad in Bački Petrovac (N 50°21'; E 39°56'). Hemp was grown as a rainfed crop without irrigation, as is traditional for the region, and the typical production system for commercial production of hemp in Middle and Southern Europe was applied. Hemp was seeded with a small grain planter on 21 April 2022. After the sprouting of the plants, manual thinning was performed, which resulted in three variants of sowing spacing 12.5 cm, 25 cm, and 50 cm row space, i.e. 300, 150, and 20 plants m^{-2} were obtained. The crop density is also related to the sowing rate, which was 3-4 kg ha^{-1}, 20-25 kg ha^{-1}, and 40-50 kg ha^{-1} for the densest sowing, respectively. When the plants were approximately 60 cm high, on half of the elementary plot was performed manual cutting (pinching) at a height of 40 cm. The experimental design was completely randomized with three replicates, with the size of the experimental plots being 15 m^2. On each plot, branches with seeds from 5 m^2 were manually removed on October 5th. Removed branches from each treatment were dried in a tobacco dryer under ambient conditions, after which the seeds and green parts were

Picture 2. Harvesting hemp with an axial flow harvester

separated from the branches manually. After sieve separation, the seeds of each treatment were weighed with an analytical scale.

The significance of differences in seed yield and plant height between treatments was tested using Duncan's test.

RESULTS AND DISCUSSION

Hemp is one of the rare dioecious plant species with pronounced sexual dimorphism caused by genes in sex chromosomes. The male -to-female ratio in dioecious hemp is 1:1, but in the populations, there are about 0.1% of monoecious plants with flowers of both sexes (Berenji et al., 2013). By counting the plants in the experiments, it was established that sowing densities and pinching do not significantly affect the sex ratio (Table 1), which makes Marina a typically dioecious variety. Compared to female plants, male plants mature earlier and at the time of physiological grain maturity, they have completed their vegetation and dried up. The presence of such plants can be an obstacle during the mechanized harvesting of seeds, due to their winding on the rotating parts of the harvester. As a dual-purpose (seed and stalk) alternative, Baldini et al. (2018) state the use of monoecious varieties.

The average plant height in all treatments in the trial was 249.2 cm (Table 1). The height of the plants is correlated with the size of the vegetation area of the individual plants. Average plant height (300.2 cm) was achieved by non-pinched plants with the lowest growth density of 20 plants m^{-2}, sowing rate of 3-4 kg ha^{-1}, and interrow distance of 50 cm. With an increase in the sowing rate and crop density, the height of the plants decreases by 10 - 15% to 271.2 cm at 150 plants m^{-2} (sowing rate 20-25 kg ha^{-1}) or 254.1 cm at 300 plants m^{-2} (sowing rate 40-50 kg ha^{-1}). Variants in which the terminal tips were not removed were taller in all densities compared to pinched plants. To obtain high yields of textile hemp with stems up to 8 mm in diameter, Berenji et al. (2013) recommend sowing 350 seeds m^{-2}, i.e. over 250 plants m^{-2} in the harvest.

Ačko et al. (2019) in experiments with five varieties of hemp (monoecious and dioecious) with apical bud removal obtained shorter plants by an average of 18.3% and seed yield increased by 15-30%. Leonte et al. (2016) describe the application of the so-called 'Secuieni method' of monoecious hemp defoliation that includes two cutbacks. Plants are cut for the first time when they have 5-6 floors with opposite leaves, and after 15-20 days the second time 15-20 cm above the first cutback. The results indicate that by applying this method, the plant size can be reduced with a reduced sowing rate without a significant impact on the seed yield. Apart from the influence of defoliation, these studies emphasize the importance of variety and the external environment in achieving the genetic potential for hemp seed yield.

In the experiments, seed removal was done manually, where care was taken to collect all the seeds from the plants with minimal losses. Considering that, we can assume that the

Table 1. The proportion of female plants, average plants height and seed yield in different densities of hemp crop

Plant density (plants m^{-2})	Treatment	Female plants		Average plant height (cm)	Seed yield (kg ha^{-1})
		(m^2)	(%)		
20	pinching	9±1	45±5	257.5^b	1219^a
	non-pinching	10±1	48±3	300.2^a	933^c
150	pinching	75±8	50±6	212.7^c	1263^a
	non-pinchihg	82±2	54±1	271.2^b	1006^b
300	pinching	146±14	49±5	199.1^c	1017^b
	non-pinching	138±11	46±4	254.1^b	968^c

Within each column: means followed by the same letter are not significantly different at $P < 0.05$

genetic potential for seed yield has been reached for the Marina variety in the agroecological conditions that prevailed in the region in 2022.

In a previous study, Amaducci et al. (2015) reported that the hemp seed yield of 20 varieties, harvested at different times, varied from 27 to 149 g m^{-2}.

The lowest seed yield of 933 kg ha^{-1} was achieved in the unpinched treatment in the least dense sowing, and the highest of 1263 kg ha^{-1} in the pinched treatment in the sowing of 150 plants m^{-2}, i.e. sowing rate of 20-25 kg ha^{-1}. The average seed yield in the trial is 1068 kg ha^{-1} (Table 1). In hemp seed production, yields above 1000 kg ha^{-1} are considered economically profitable, so it can be concluded that the Marina variety has exceptional seed yield potential.

At all plant densities, the yield was higher for the pinched compared to the non-pinched variant, which justifies this treatment for targeted hemp seed production. Without apical bud removal, the height of the plants exceeds 250 cm and the seed yielded below 1000 kg ha^{-1}, while in pinched treatments the plants were 200-250 cm tall and the grain yields exceed 1000 kg ha^{-1}.

The assertion of Baldini et al. (2018) that hemp seed and oil yield were influenced by climate and cultivar, but not by their interaction, can be a starting point for examining the stability and adaptability of the wider genetic basis within breeding and agronomic research.

CONCLUSION

The current European assortment of hemp includes a wide range of varieties for different purposes. Considering the available genetic resources and the variability of quantitative properties within them, it is realistic to expect that in the breeding process, a certain small shift in terms of yield and quality can be achieved. On the other hand, the economic effect of production is significantly influenced by the environment and management. To optimize the entire process of hemp seed production, a methodology was defined that enables the most rational understanding of G × E × M interaction.

The highest seed yields of 1263 kg ha^{-1} and 1219 kg ha^{-1} were achieved with pinched variants at a lower crop density of 20 and 150 plants m^{-2}, respectively. Crop pinching reduces plant height and increases seed yield.

The data obtained from the preliminary one-year research will be applied when recommending the technological process of hemp seed production on a commercial scale, in breeding programs to determine the genetic potential for seed yield and in the production of certified seeds of various categories. The results also provide a basis for more extensive investigations of G × E × M interactions on seed yield in breeding programs on a wider genetic basis.

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SAŽETAK

PRINOS SEMENA DVODOME KONOPLJE POD UTICAJEM UPRAVLJANJA USEVOM

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Da bi se definisala najoptimalnija tehnika za poljska ispitivanja koja bi omogućila šire istraživanje interakcije G E M (G – genotip, E – uslovi životne sredine, M – upravljanje usevom) u proizvodnji semena konoplje, postavljena su jednogodišnji ogledi sa tipično dvodomom sortom konoplje Marina. Ispitivanja su uključivala tri različite gustine useva (20, 150 i 300 biljaka m^{-2}) i kontrolnu varijantu bez pinciranja koja je upoređena sa tretmanom uklanjanja apikalnih pupoljaka (pinciranjem) na visini biljke od 60 cm. Rezultati su pokazali da se pinciranjem u svim gustinama useva postiže smanjenje visine biljaka i povećanje prinosa semena. Najveći prinosi semena od preko 1200 kg ha^{-1} ostvareni su pri pinciranju useva sa 20 i 150 biljaka m^{-2}, što se može smatrati optimalnom metodom za određivanje potencijala prinosa genotipa. Dobijeni rezultati preliminarnih istraživanja poslužiće kao osnova za preporuke za komercijalnu proizvodnju semena, kao i za definisanje metode za ispitivanje šire germplazme u programima oplemenjivanja konoplje.

Ključne reči: dvodoma konoplja, pinciranje, prinos zrna, visina biljke

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