Influence of seed rate and row spacing across on two different maturity groups of sorghum grain yield and quality characteristics

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Abstract. The goal of this resesrch is to develop cultivation practices that optimize the economical cultivation of sorghum, taking into account current environmental factors., by determining the optimal seeding rate and row spacing for two different maturity groups of sorghum hybrids, RGT Icebergg (early) and RGT Huggo (mid-early). In this context, we examine the maximum achievable yield and quality characteristics. The experiment involved different plant densities: 210,000, 240,000, 270,000, and 300,000 plants/ha, and three different row spacings: 25, 45, and 76 cm. Through conducted experiments, significant differences have been observed in harvest moisture content, hectoliter weight, protein content, head size, and plant height. Significant differences were observed in the average number of head per square meter. Although similar average protein levels were measured for different genotypes, there were differences in their stability. Increasing row spacing decreased hectoliter weight, while increasing seeding rates increased it. Harvest moisture content was significantly higher with wider row spacings, while increasing plant density resulted in a slight decrease in moisture content. Looking at the average of the tested hybrids, the row spacing of 45 cm and the number of seed of 300,000 plants/ha are the most ideal combination to achieve the yield.

1 Introduction

The productive area available for plants is one of the most important factors in the intensity of plant development and the amount of yield [1- 3]. Therefore, the number of plants and row spacing play a role as determining factors in the success of crop production. The yield of sorghum (*Sorghum bicolor* L.), just like that of maize, is highly responsive to changes in plant density [4-6].

The correct determination of the number of plants and row spacing is influenced by several factors, such as the genotype, maturity, the amount of available irrigation or rainfall (water supply), the available plant nutrients (the ability of the soil to supply nutrients and nutrient supply) and the time of sowing [7-14]. An excessively low number of seedlings usually ensures higher weed pressure, which ultimately leads to less yield. On the other hand, the plant increases the competition for natural resources beyond the limit of the population reaching the optimal area, which can strengthen weaker plants and severe leaning [8], [15-19].

The use of the correct row spacing provides a better microclimate for the plants and allows more light and CO_2 uptake, which has a favourable effect in order to increase the yield and internal quality content [24-25]. Determining the optimal number of plants and row spacing is essential for place of production recommendations and for achieving maximum yield [26-27]. The aim of the experiment is to determine the maximum seed yield and internal quality content parameters (protein, hectoliter weight) in relation to the row spacing of two hybrids of RGT Icebergg and RGT Huggo of two different ripening groups (early and mid-early) that match the current climatic conditions.

2 Materials and methods

We conducted this study in the location of Töltéstava in Győr-Moson-Sopron County, Hungary, in the year 2023. The experiment was carried out in a randomized complete block design. The row spacings examined were 25, 45, and 76 cm, while the seeding rates investigated were 210.000, 240.000, 270.000 and 300.000 plants/ha. Results from three replicates of plots sized 3 m x 7.5 m with an intermediate 1.5 m x 7.5 m (11.25 m^2) were averaged. The experiment was sown on May 11th using a plot seeder. In the study year, 45-45-45 NPK kg/ha fertilizer was applied. Chemical weed control was performed on May 13th, using 4 l/ha of Gardoprim Gold (terbuthylazine + s-metolachlor), and on June 22th, with 0.3 l/ha of Banvel 480 S (480 g/l dicamba) herbicide, along with physical weed control. The area was free from pests. The year 2023 was generally rainy, with a measurable precipitation of 588.9 mm during the growing season. The sorghum development was optimal. Data on plant height, head size, number of heads per square meter, hectoliter weight, protein content, protein yield, harvest moisture content, and grain yield per hectare were recorded in the study. Data from the three replicates were averaged, and statistically analyzed. Differences among treatment means were compared using Student-Newman-Keuls (LSD) test at a probability level of P=0.10 using the ARM program.

3 Results and discussion

Significant differences were found between row spacing and seed quantity in moisture content, hectoliter weight, protein content, head size, plant height and number of heads per square meter (Tables 1-2). Plant height increased with increasing seed quantity and decreasing row spacing. Gondal et al. (2017) also reported the effect of seeding rate on plant height in their study, according to which, in addition to decreasing plant spacing, higher seeding rate stimulated plant height due to the elongation of internodes [28].

The data also showed that plant height decreased with increasing row spacing and decreasing seed rate, possibly due to competition between plants for light. The highest plant height (156.33 cm) was achieved with the early genotype with a row spacing of 25 cm and a number of plants of 300,000 plants/ha. The plants already started a drastic competition for the 270,000 plants/ha, so considerable flexibility was shown. On the other hand, the mid-early maturing hybrid showed a wide tolerance to changing the number of seeds and row spacing, during which we could observe determinism. During the investigation, it was revealed that there was an average difference of 7.03 cm between the plant heights of the two hybrids. Row spacing and seeding quantity had different effects in the case of the two hybrids. Similar results of row spacing on plant height have been reported by others [28-30].

The average number of heads per square meter in the rows also showed significant differences. It was unanimously true for the two hybrids that, on average, the highest seed quantity had the most heads, which decreased as the seed quantity decreased. Depending on the rows, the row spacing of 25 and 45 cm represented almost the same average. Gondal et

al. (2017) study row denisty (30 cm) sowing and yielded the highest number of heads [28]. This result was explained by better utilization of the given area. In the case of the early hybrid, row spacing had only a minor effect on the head. However, in the case of mid-early ripening, we can see much more significant differences. In this hybrid, the narrow row spacing and the high number of plants clearly resulted in the highest number of heads per square meter. However, we found no correlation between the number of heads and the yield, this behavior is also supported by the studies of Mascagni and Bell (2005) [31].

Table 1. Results of harvest moisture (14%), net yield and plant height.

Maturity group	Row distance	Density	Harvest moisture		Net yield (14 %)		Plant height	
	cm	1000/ha	%		t/ha		cm	
Mid-early	25	210	14.00	*a-f	10.53	-	151.13	*ab
Early	25	210	12.90	*c-g	9.91	-	145.00	*bc
Mid-early	25	240	13.77	*a-g	10.26	-	144.33	*bc
Early	25	240	13.50	*a-g	10.00	-	141.00	*bc
Mid-early	25	270	13.73	*a-g	11.88	-	143.67	*bc
Early	25	270	12.53	*fg	10.66	-	151.67	*ab
Mid-early	25	300	14.07	*a-f	11.12	-	151.00	*ab
Early	25	300	12.37	*g	10.33	-	156.33	*a
Mid-early	45	210	13.80	*a-g	10.97	-	142.00	*bc
Early	45	210	12.90	*c-g	10.99	-	141.00	*bc
Mid-early	45	240	13.27	*b-g	11.16	-	147.67	*ab
Early	45	240	13.23	*c-g	10.08	-	128.00	*de
Mid-early	45	270	14.10	*a-f	10.84	-	151.17	*ab
Early	45	270	12.67	*efg	10.06	-	129.67	*de
Mid-early	45	300	13.37	*a-g	11.63	-	151.67	*ab
Early	45	300	12.83	*d-g	10.84	-	135.33	*cd
Mid-early	76	210	14.93	*a	10.07	-	150.00	*ab
Early	76	210	15.43	*a	10.45	-	141.33	*bc
Mid-early	76	240	14.87	*ab	10.89	-	146.33	*ab
Early	76	240	14.00	*a-f	11.12	-	135.67	*cd
Mid-early	76	270	14.23	*a-e	10.07	-	141.00	*bc
Early	76	270	13.77	*a-g	10.13	-	125.00	*e
Mid-early	76	300	14.53	*abc	10.44	-	124.33	*e
Early	76	300	14.40	*a-d	10.09	-	130.00	*de
LSD=0.10			0.82		1.20		5.90	
CV			4.37		8.23		3.03	

*Homogeneous groups: a-g (a – strongest group, g-weakest group)

The protein content ranged from 11.8 to 12.62 %, and the average of the experiment was 12.30 %. Singh et al. (2005), in which they investigated the possibilities of increasing the protein content of corn, that compared to the 5.7-11% protein content of corn, sorghum can produce an average of 3.86 % higher protein content [32]. Although similar average proteins were measured for both genotypes. Different reactions to row spacing and seeding quantity

were observed. At the early hybrid level, it yielded a stably high protein content for all row spacing and sowing rates.

Table 2. Results of quality content, number of head per square meter, and head size.

Maturity group	Row distance	Density	Hectoliter weight		Protein		Head size		Head/ m^2	
	cm	1000/ha	kg/hl		%		cm		piece	
Mid-early	25	210	74.37	*ab	12.03	*bc	30.00	*ab	25.54	*a
Early	25	210	74.97	*ab	12.61	*a	25.87	*d-g	24.16	*abc
Mid-early	25	240	74.93	*ab	12.51	*ab	29.67	*abc	18.10	*i
Early	25	240	74.97	*ab	12.30	*ab	28.00	*b-e	21.73	*ef
Mid-early	25	270	75.50	*ab	12.05	*bc	30.00	*ab	24.50	*ab
Early	25	270	75.60	*a	12.51	*ab	28.67	*a-d	20.00	*gh
Mid-early	25	300	75.13	*ab	12.22	*abc	28.07	*b-e	25.28	*a
Early	25	300	75.70	*a	12.49	*ab	24.73	*f-i	22.60	*b-e
Mid-early	45	210	74.53	*ab	12.28	*ab	27.03	*c-f	22.12	*def
Early	45	210	74.93	*ab	12.11	*abc	24.40	*f-i	24.50	*ab
Mid-early	45	240	75.40	*ab	12.62	*a	26.00	*d-g	23.25	*b-e
Early	45	240	75.23	*ab	12.43	*ab	22.50	*i	22.77	*b-e
Mid-early	45	270	73.83	*ab	12.31	*ab	28.07	*b-e	22.68	*b-e
Early	45	270	75.13	*ab	12.19	*abc	23.00	*hi	21.56	*ef
Mid-early	45	300	75.37	*ab	12.26	*abc	26.53	*def	24.33	*ab
Early	45	300	74.67	*ab	12.12	*abc	25.33	*e-h	21.60	*ef
Mid-early	76	210	73.63	*ab	12.31	*ab	28.50	*a-d	18.15	*i
Early	76	210	73.10	*c	12.46	*ab	24.70	*f-i	18.93	*hi
Mid-early	76	240	73.77	*ab	12.47	*ab	27.00	*c-f	19.68	*gh
Early	76	240	73.97	*ab	11.81	*c	23.67	*ghi	22.42	*cde
Mid-early	76	270	75.03	*ab	12.33	*ab	30.90	*a	20.49	*fg
Early	76	270	74.37	*ab	12.42	*ab	28.00	*b-e	23.92	*a-d
Mid-early	76	300	74.67	*ab	12.05	*bc	27.60	*b-e	23.78	*a-d
Early	76	300	73.43	*b	12.32	*ab	23.67	*ghi	21.39	*ef
LSD=0.10			1.02		0.26		1.51		1.06	
CV			0.99		1.52		4.13		3.47	

*Homogeneous groups: a-i (a – strongest group, i-weakest group)

It produced the highest protein content (12.61%) with the number of plants of 210,000 plants/ha and the narrow row spacing of 25 cm. The mid-early hybrid already behaved in a much more limited manner for each treatment. Here, the widely spaced row spacing of 45 and 76 cm proved to be better, and the best results came from the sowing rate of 240,000 plants/ha. Its highest achieved protein content, which was also the best of the results in the experiment, was 12.62% on the 45 cm row span. Increasing the row spacing shows a decreasing trend for the hectoliter weight. On the other hand, by increasing the number of seeds, it had the opposite effect, whereby an intense increase was observed. The highest hectoliter weight (75.70 kg/hl) is found in the sowing of 25 cm row spacing and 300,000 plants/ha of the early maturing hybrid.

The moisture contents at the time of harvest were the highest in the row spacing of 76 cm for both hybrids, which were 0.75-1.58 % higher than in the narrower row spacing. In the case of increasing the seeding amount, a slight decrease in water content was observed. The highest net grain yield was 11.88 t/ha calculated back to a water content of 14 percent, which was achieved with a row spacing of 25 cm. The second highest yield result was with a row spacing of 45 cm and a setting of 300,000 plants/ha. In the average row spacing, we measured the highest average yield with 10.82 t/ha in the row spacing of 45 cm. This was followed by the 25 cm row spacing with 10.59 t/ha and the lowest average with 10.41 t/ha by the 76 cm

wide row spacing. A similar response to row spacing was reported in previous studies, where a higher yield was achieved with similar row spacing [23], [28], [33].

However, the response of the hybrids to changes in row spacing was different. While in the case of the mid-early hybrid, the wide row spacing of 76 cm proved to be significantly weaker compared to the narrower row spacing, in the case of the early hybrid, the 76 cm row spacing was hardly weaker compared to the 45 cm row spacing. In the case of early, the row spacing of 25 cm proved to be the weakest, but at the same time it did not show as much yield depression as in the mid-early hybrid. In our study, considering the average of the two hybrids, by increasing the sowing amount, an additional yield was realized. In the case of the middle-early hybrid, the increase in the number of plants brought a clear linear increase in yield, while in the case of the early hybrid, on the other hand, a decreasing trend was observed. Snider et al. (2012) reported a significant decrease in yield with an increase in the number of seeds between 218,000 and 393,000 plants/ha; however, the number of seeds between 116,000 and 291,000 plants/ha did not significantly affect crop yields [34-35]. According to the current tests, depending on the changes in the examined seed quantities and row spacing, the row spacing of 45 cm and 300,000 plants/ha can achieve the highest yield potential. RGT Icebergg produced its best results on the 45 cm row spacing and 210,000 seedlings, while RGT Huggo was able to maximize its performance on the same row spacing with 300,000 seedlings.

4 Conclusions

The development of sorghum is influenced by many factors, among which row spacing and seed quantity are prominent. Based on the tests carried out, we found significant differences in the moisture content, hectoliter weight, protein content, head size, plant height and number of heads per square meter. In general, it can be said that seed quantities higher than 210,000 plants/ha resulted in a slight yield increase in the average of the two hybrids. In the case of the mid-early hybrid, the increase in the number of plants showed a linear increase in yield, while a slight decreasing trend was observed in the case of the early hybrid. Broken down by genotype, the early RGT Icebergg achieved its best performance at the 45 cm row spacing and 210,000 seedlings, while the mid-early RGT Huggo achieved its maximum at the same row spacing and 300,000 seedlings.

So, the 45 cm distance expressed the most optimal agronomic characteristics, even if its effect on the yield was not statistically significant, it still proved to be optimal from the point of view of the arrangement. Currently, in large-scale technologies, sorghum is generally sown at 76 cm, simply because there is technological equipment for this, but the experiment also shows that the 76 cm row spacing is not the most ideal for sorghum. At 76 cm, the distance between the plants is probably small, and there may already be competition between the plants. At 45 cm, the stem distance is larger, and we could observe the positive effects of this in our experiment. The 25 cm did not bring the expected results, even though in principle the row and plant spacing arrangement is even more ideal there.

Among the advantages of the row spacing of 76 and 45 cm, it should be mentioned that seed drills are available for these technologies, which have already been proven in practice. The access of seed drills to the 25 or 24 cm row spacing is still limited, and for now it can be considered a special procedure, so we can say that farmers will not invest in such special machines for sowing sorghum. That is why row spacings of 45 and 76 cm can definitely have a bigger future at the moment. In addition, it is important to emphasize that in the case of 45 cm row spacing, there is a good opportunity to use effective row cultivation. For sorghum, where the possibility of chemical weed control is limited, this can be particularly important. Cultivators equipped with row control optics have a large area capacity and good efficiency [36-38].

Looking at the average of the examined hybrids, the row spacing of 45 cm and the seed quantity of 300,000 plants/ha is the most ideal combination to achieve the highest yield, however, the quality parameters, such as protein content and hectoliter weight, proved to be better in the number of plants of 240,000 plants/ha. Nevertheless, with the improvement of the quality parameters, the quantity can result in a lower yield difference of about 5.44%, with which the protein yield per hectare proved to be 40 kg/ha higher at the sowing of 300,000 plants/ha.

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