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Investigating the potential for dual-purpose use in winter oats

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SUMMARY

Dual-purpose usage is not a common technology for oats in Hungary, which is not surprising, as the area sown to our main crop is also very low. Yet the crop has a lot of untapped potential, not to mention its excellent nutritional parameters. In our experiment we investigated how much biomass can be expected after mowing winter oats at different phenological stages and whether we can expect a valuable grain yield after this process. Mowing was carried out at one-week intervals on a total of 4 occasions with 2 cutting heights. Plant height and NDVI values of the vegetation in the plots were measured during the experiment. After the harvest of the fully ripened grains, the yield and the thousand kernel weight (TKW) were determined. Our results show that with a lower cutting height (6 cm), a higher biomass yield can be achieved. The cutting height had no statistically verifiable effect on either NDVI or plant height. Droughty weather conditions during subsequent mowing significantly reduced the regeneration capacity of the plants, which was strongly reflected in the measured parameters. Furthermore, a higher grain yield was measured at a cutting height of 9 cm, which decreased gradually with the mowing time. Neither the cutting height nor the mowing time had any effect on the TKW.

Keywords: *winter oat; biomass yield, grain yield; cutting height; mowing time*

INTRODUCTION

Oat (*Avena sativa* L.) is a highly valuable crop, both for human consumption and livestock feed, as it has excellent nutritional parameters. It is a rich source of protein, phosphorus, iron and other minerals and can be grown effectively on a wide range of soil types with little inputs (Kelling and Fixen, 1992). Its popularity is also due to the fact that it is easier to protect compared to other common cereals (e.g. barley, triticale), as it is less affected by diseases (Deen et al., 2019). Although oats are grown primarily for their grain in Hungary, they are produced worldwide as winter cereal fodder. It ranks 5th among cereals in terms of volume of production and is also a popular and widespread companion crop, providing excellent support for some leguminous crops (Dost, 1997).

A considerable amount of literature is available on the grain yield, but much less on the mowing of oats, despite the fact that they are also grown worldwide as a bulk feed (Stevens et al., 2004). It can be fed green, hayed or silaged after it was wilted, and according to Armstrong and colleagues (2002), it is usually possible to mow several times in a growing season due to its excellent regeneration skills, which we have also observed in our previous works. In developing countries, for example, higher biomass oat varieties have contributed greatly to the shift from grazing to confined, shed-based livestock production.

In the United States of America, spring oats are more widely used for grain feed, but in the southern regions, autumn oats are more popular, not only for bulk feed or grain, but also for dual-purpose (Kim et al., 2014). Autumn-sown crops are also needed because in many places, it is during the winter and early spring period that the greatest demand for both quantity and quality of crops for the animal husbandry occurs, while low light intensity limits the growth of food crops (Xu et al., 2021; Ahmad et al., 2014).

With regard to the preparation of silage, it should be mentioned that oat, as a member of the *Poaceae* plant family, contains significant amounts of cellulose and hemicellulose (Fenja and Qendrim, 2021). These fibers provide an excellent basis for fermentation processes. Cellulases, produced by fungi, bacteria and protozoa, are able to catalyse the hydrolysis of cellulose (Barbosa et al., 2020). The products of this cellulase-catalysed reaction, such as monosaccharides and oligosaccharides, are a direct source of nutrients for bacteria. It is also worth mentioning that there are huge differences between genotypes to silage yields, crude ash, neutral detergent fiber, acid detergent fiber, crude protein, dry matter and silage pH and many other parameters affecting the quality of silage (Kaplan et al., 2024).

The method and timing of mowing is crucial for optimizing forage quality and yield, especially in regions where climatic conditions are less optimal for this plant. Abood et al. (2023) found that forage yield, as well as soluble carbohydrate content and relative fodder value and quality, were significantly influenced by the length of different mowing periods, as the effect of cultivar and mowing period on yield and forage quality was significant or extremely significant. An experiment by Favre and colleagues (2019) showed that for spring oats, mowing at the boot stage maximizes forage quality, as this stage is associated with higher nutrient values and digestibility indices, which are of paramount importance for animal nutrition. In their experiments, Vologzhanina and Batalova (2022) found a positive relationship between plant height and yield ($r=0.72$, $p>0.95$) and a moderately positive relationship between biomass and plant height ($r=0.59$). The optimal mowing time also

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depends largely on the variety itself, which may vary both in terms of biomass yield and quality (Chen et al., 2022). Yahya and Abood (2023) explained in their paper that mowing dates have a significant effect on certain features, with the highest average plant height and green forage yield measured at the 60th day of mowing after sowing.

The frequency of mowing also affects forage yield and quality, which also varied by variety in the study by Gao-Lin and colleagues (2010). They further found that double mowing improves forage quality. Zhang and his colleagues (2024) also confirmed that the choice of genotype itself has a significant influence on yield and quality parameters (crude protein, neutral detergent fiber, acid detergent fiber, crude ash and relative feed value), as well as the interaction of environment and the parameters studied.

The choice of the cutting height is also important; harvesting at the height of about 5 cm from the ground prevents damage of the growing points, resulting better regrowth and higher yields (Shoaib et al., 2018).

The timing of harvesting for the biomass is crucial too; oats are usually harvested at the dough stage to optimize the nutrient quality and quantity in the silo (David et al., 2010). This stage provides the balance between dry matter content and nutrient availability that is essential for the efficient fermentation. Our objective is to find out whether it is economically feasible to produce winter oat biomass under our climatic conditions and whether a valuable amount of grain can be obtained after mowing. In addition, whether these properties are affected by different mowing dates and cutting heights.

MATERIALS AND METHODS

Experimental setup

The experiment was located in Hungary, at the Experimental Garden of the University of Debrecen. The research project was set up in small plot conditions (3 m x 4 m = 12 m^2), with three independent repetitions.

The preceding crop was bean, so no NPK fertilizers were used, as oats are prone to lodging and the soil of the Experimental Garden is enrichted in potassium and phosphorus. The soil type is chernozem, with a good humus content. The main soil parameters are shown in *Table 1*.

Table 1. **The main soil parameters in different soil layers (Debrecen, 2024)**

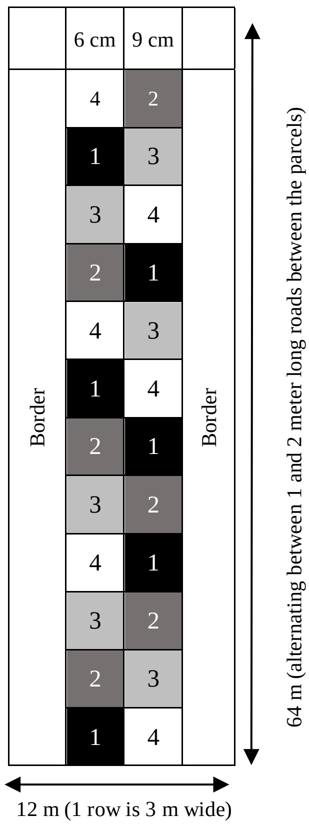
	Soil layer (cm)				
	0–20	**20–40**	**40–60**	**60–80**	**80–100**
pH (KCl)	6.93	7.46	7.51	7.56	7.55
KA	45	52	52	53	53
$CaCO_3$ (%)	0.52	1.45	1.97	2.07	1.86
Humus (%)	2.89	2.87	2.63	2.44	2.37
NO_3 (KCl) (mg kg^{-1})	82.2	53.4	48.5	36.5	31.6
P_2O_5 (AL) (mg kg^{-1})	1538	1149	1020	390	321
K_2O (AL) (mg kg^{-1})	638	586	366	315	103

Note: first published by Kutasy et al. (2022)

We used a Hungarian-bred winter oat variety called ‘Mv. Hópehely’, which –based on preliminary experience – has shown outstanding performance in terms of both grain yield and biomass production. Sowing was performed on October 3, 2023, with a seeding rate of 600 seeds per square meter at a depth of 5 cm.

Four different mowing dates with a one-week interval between them were examined. At each mowing time two cutting heights (6 cm and 9 cm) were tested in three repetitions. The first mowing took place on April 30, 2024, followed by the second on May 6, 2024, and the third and fourth on May 13 and May 21, 2024, respectively. The phenological stages of the plants developed as follows, in accordance with the timing of the mowing: April 30: BBCH37, May 6: BBCH48, May 13: BBCH51, May 21: BBCH59. The map of the experiment is shown in *Figure 1*. We had to apply chemical protections, against cereal leaf beetle (*Oulema melanopus*). The applied pesticide active substance was lambda-cihalotrin, the date of the application was at April 10, 2024 (BBCH32), and May 15, 2024 (BBCH47-55). After mowing, a significant infestation of oat crown rust (*Puccinia coronata*) was observed, but we did not controlled. It is assumed that its appearance has had an impact on grain yields.

Figure 1. **The map of the experiment (Debrecen, 2024)**



Note: The meaning of the numbers: 1: first mowing date (April 30), 2: second mowing date (May 6), 3: third mowing date (May 13), 4: fourth mowing date (May 21). A cutting height of 6 cm was used in the first plot strip and 9 cm in the second.

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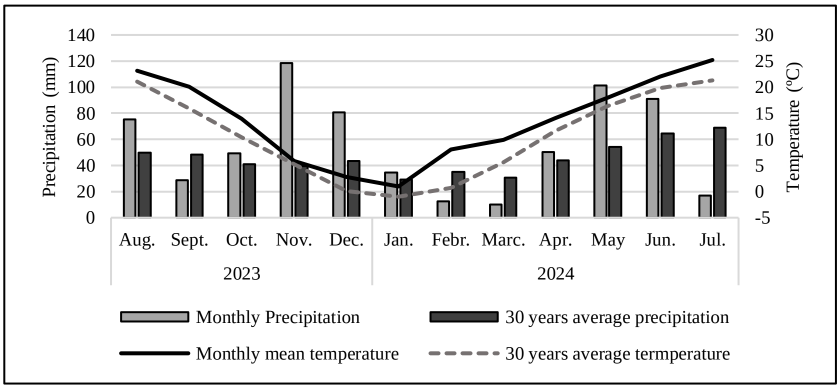
Weather conditions of the growing season

Figure 2 shows the monthly average temperature and precipitation conditions during the growing season of winter oats. Autumn weather was ideal for winter oats in terms of both rainfall and temperature. The winter, in particular the month of February, where the monthly temperatures were more than 4.6 ºC warmer than the 30-year average, was mild. After the winter period, it can be seen that the monthly temperatures exceeded the 30-year average in all months, but the temperatures in the spring period were within the optimum range for cereals, particularly in April and May. This allowed a very favorable vegetative development of the oat plants. From the second decade of June onwards, a drought period began, which tested the abiotic stress tolerance of plants and affected their development. The autumn, winter, and spring periods were also considered adequate in terms of precipitation; with the exception of September, February, and March, monthly precipitation amounts exceeded the 30-year monthly averages. In the month of November, for instance, nearly three times more precipitation was recorded (118.5 mm) compared to the long-term monthly average (39.7 mm), which can be regarded as significant in terms of winter recharge precipitation. From June onward, however, the distribution of precipitation became highly unfavorable, ultimately leading to the development of drought conditions.

Figure 2. **The weather conditions of the growing season of the winter oat (Debrecen, 2024)**



Source: data from the measurement program of the DE-MÉK PNK Agrometeorological Observatory

Method of measurements

To accurately determine the biomass, the mass of the cuttings from each plot was measured and the moisture content of the samples was determined in a drying cabinet. The values were then corrected to 60% moisture content.

To determining the plants height, we used a telescopic height pole. Three plants in a given plot were measured which were evenly located from each other and from the edges of the parcels. The values we obtained were averaged, this number was used to represent the plot average. Due to the small plot experiment, there vegetation was homogenous within a given plot. We measured the heights of the plants weekly from the date of 31th of May.

For the NDVI values, we used the Trimble GreenSeeker handheld instrument to determine the NDVI values of the vegetation in each plot. We measured the NDVI values weekly from the date of 3rd of June. In the case of NDVI, the third measurement was not possible due to the drying up of plants.

After harvesting, the total weight of the oat grains per plot was measured and its moisture content was determined in a drying cabinet. The values obtained were then corrected to 14% moisture. To determine the thousand kernel weight (TKW), 200 oat grains were counted from the samples and – after we obtained the moisture content values – the corrected result was multiplied by 5.

The experiment was harvested at 27th of July.

Statistical analysis

Data analysis and evaluation were performed using the IBM SPSS Statistics 22.0. software. We used the univariate general linear model to compare examined parameters, the results based on the one-way ANOVA tests. LSD post-hoc test was used for pairwise comparisons of the means. The alpha (significance level) was p=0.05. The significance and the standard errors was showed on the diagrams: the letters (a-c) on the graphs shows the significant differences at α=5%.

RESULTS AND DISCUSSION

Biomass

In terms of biomass, the use of a 6 cm cutting height resulted in a higher average yield (21.10 t ha^{-1}) compared to the 9 cm cutting height (17.37 t ha^{-1}), representing an 18% difference. Biomass increased with the progression of mowing dates for both cutting heights, which can be attributed to the vegetative growth of the plants. However, the rate of increase significantly slowed between May 13 and May 21, due to increasingly drought weather and the fact that during these phenological stages (BBCH51 – BBCH59), the plants begin prioritizing the development of generative growth over vegetative growth. The highest biomass was measured with the combination of the 6 cm cutting height and the latest mowing dates (May 21).

At the 6 cm cutting height, a statistically significant difference was observed between the first and fourth

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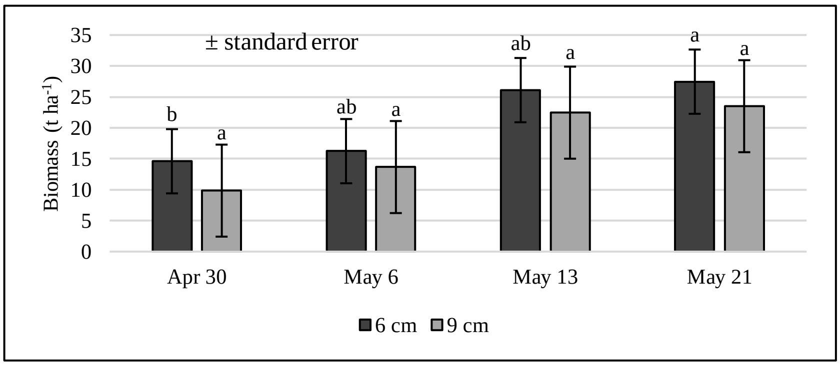
mowing dates. However, at the 9 cm cutting height, no statistically verifiable differences were found between the cutting dates. It can be concluded that at every cutting date, the 6 cm height produced higher biomass compared to the higher cutting height. The greatest difference was observed at the first mowing date, with the 6 cm height yielding 48.14% more biomass. At the subsequent mowing dates, this difference was notably smaller (second cutting date: 18.81%, third: 16.23%, fourth: 16.86%). The results can be seen in *Figure 3*.

Chen and his colleagues (2022) tested 4 oat cultivars, which were evaluated at several phenological stages. It was found that there were significant differences between genotypes, and that some genotypes had the highest biomass when mowed at different stages of development, so that the optimal mowing date also depends on the genetic background of the plants. For the varieties studied, biomass was the highest during the heading stage or during the filling period. For us, such a late mowing would compromise the potential for the development of grain, and due to our climatic conditions, plant regeneration would be slowed down and no significant increase in biomass is expected. All this is, of course, strongly influenced by the weather.

Figure 3. **The amount of biomass in different mowing time and cutting height (Debrecen, 2024)**



Note: *The different lowercase letters (a-b) indicate the significant differences ($p<0.05$) between mowing dates depending on the cutting height.
** The dates on the chart represent the mowing dates (from the first to the fourth)
*** ± standard error of means. 3 replicates.

Plant height

HASAN said (2010), that the forage yield is mostly depended on the plant height, number of leaves and the area of the leaves. Plant height was measured in the plots 31, 38 and 45 days after mowing to investigate the regeneration ability of the plants.

Although cutting height did not significantly affect plant height at any of the measurement time after mowing, with a few exceptions (e.g., results from the May 6 mowing), higher plant heights were generally recorded in plots with a cutting height of 9 cm. The largest difference between the two cutting heights was observed at the first mowing date (April 30), with an average of 7.67 cm. By the last mowing date, the height difference was minimal, averaging 1.89 cm – differences of this magnitude may result from measurement inaccuracies. However, in terms of the mowing dates, significant differences were found for both cutting heights across all three measurement weeks between the four mowing dates. In all cases, the highest values were measured at the first mowing date and the lowest at the last. The values are shown in *Table 2*.

Table 2. **Plant height values at different measurement times depending on the number of days since mowing (Debrecen, 2024)**

		Mowing date			
Measurement date	Cutting height	**Apr 30**	**May 6**	**May 13**	**May 21**
A (31 days after cutting)	6 cm	62.22	62.00	54.22	49.22
	9 cm	68.44	56.11	50.00	49.78
B (38 days after cutting)	6 cm	72.11	67.22	59.67	48.56
	9 cm	80.00	67.67f	63.67	49.33
C (45 days after cutting)	6 cm	81.22	73.67	60.33	48.11
	9 cm	90.11	70.78	69.11	52.44

Note: * The dates in the table represent the mowing dates (from the first to the fourth)
** The capital letters indicate the time of each measurement. The letter "A" refers to the values measured on the 31st day after mowing, "B" to the 38th day and "C" to the 45th day after mowing.

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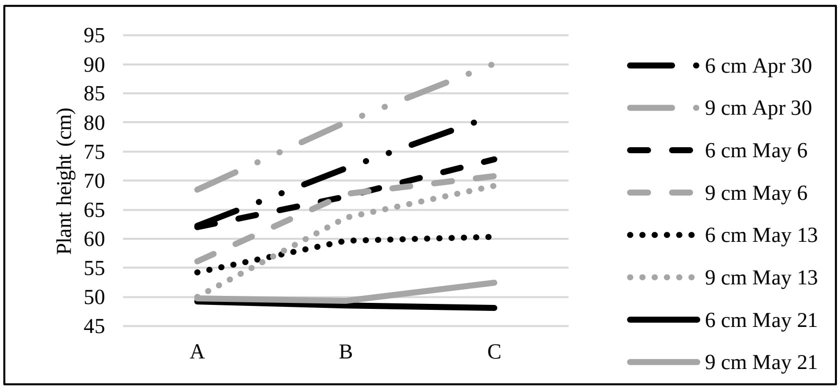
The intensive growth of plant height slowed down drastically by the end of June, mostly because the region was already experiencing significant drought conditions at that time. Regarding the mowing dates, plant growth was most intensive in the earlier mown plots and gradually decreased with later mowing dates.

Figure 4 supposed to illustrates the plants' regeneration capacity depending on the mowing date and cutting height, which was strongly influenced by weather conditions (drought, hail). At the latest mowing date, no notable change in plant height was observed over time for either cutting height, with values averaging around 50 cm. It can be seen that later mowing negatively affected the growth intensity of the plants.

Figure 4. **Growth dynamics of plant height after mowing (Debrecen, 2024)**



Note: * The dates on the chart represent the mowing dates (from the first to the fourth)

** The capital letters indicate the time of each measurement. The letter "A" refers to the values measured on the 31st day after mowing, "B" to the 38th day and "C" to the 45th day after mowing.

Normalized difference vegetation index (NDVI)

NDVI values were also evaluated based on the number of days after mowing, similarly to plant height. Values marked with the letter “A” represent NDVI measurements taken on the 34th day after mowing, while “B” corresponds to measurements taken on the 41st day (*Table 3*).

No significant differences were found regarding cutting height. Furthermore, cutting height had less influence on NDVI values compared to plant height. However, in terms of mowing date, significantly higher NDVI values were recorded during the first mowing week compared to the others, across both measurement weeks and both cutting heights.

Table 3. **Values of the different NDVI measurements dates based on cutting height (Debrecen, 2024)**

		Mowing date			
Measurement date	Cutting height	**Apr 30**	**May 6**	**May 13**	**May 21**
A	6 cm	58.00	54.33	42.00	30.67
(34 days after cutting)	9 cm	57.67	45.33	40.00	33.67
B	6 cm	61.00	45.00	26.00	31.67
(41 days after cutting)	9 cm	60.33	39.33	23.33	23.67

Note: * The dates in the table represent the mowing dates (from the first to the fourth)

** The capital letters indicate the time of each measurement. The letter "A" refers to the values measured on the 34st day after mowing, and "B" refers to the values measured to the 41th day after mowing.

Figure 5 illustrates the dynamics of changes in NDVI values. In early mowing, plants showed a 4.5–5% increase in NDVI values. However, after later mowing dates, a decline was observed, with average values on the second measurement week being 17–42% lower depending on mowing date and cutting height. An exception to this trend was observed at the latest mowing (May 21) date with a 6 cm cutting height, where NDVI values were 3% higher on the 41st day after mowing.

The combination of the NDVI and plant height results allows us to observe the dynamics of plant development after mowing.

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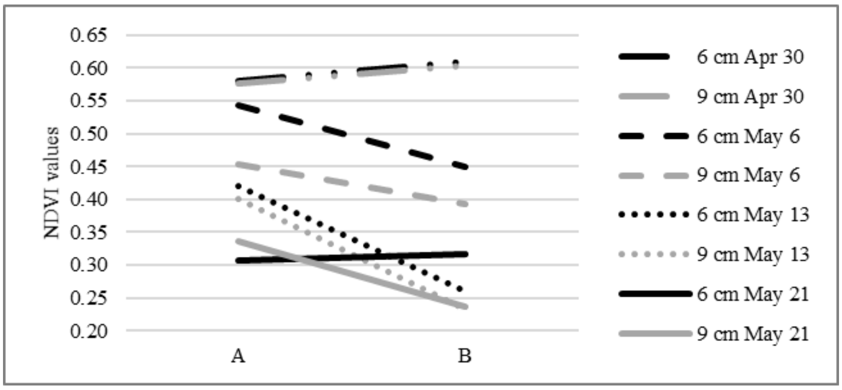
Figure 5. **Mean values of the NDVI at different time period due to the mowing time (Debrecen, 2024)**



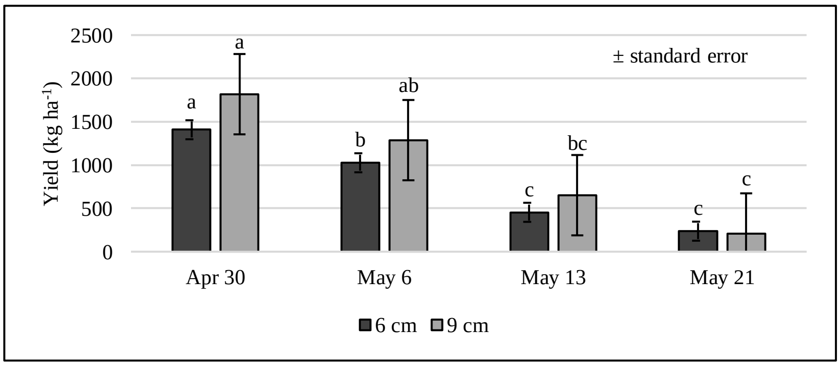
Note: * The dates on the chart represent the mowing dates (from the first to the fourth)
** The capital letters indicate the time of each measurement. The letter "A" refers to the values measured on the 34st day after mowing, and "B" refers to the values measured to the 41th day after mowing.

Yield

Francia and colleagues (2006) in their research found out, that dual-purpose use had a drastic effect on grain yield and the related traits. Based on our experiment, we can confirm this trend. At a 9 cm cutting height, the average yield was higher (991.69 kg ha^{-1}) compared to the 6 cm cutting height (781.04 kg ha^{-1}). The results are illustrated in *Figure 6*. As the mowing dates going forward, the yield decreased at both cutting heights. The most striking decline was observed at the 9 cm cutting height on the last mowing date, where the yield dropped by nearly 68% compared to the previous, third mowing date (from 651.89 kg ha^{-1} to 209.76 kg ha^{-1}). It can be stated that starting from the second mowing date, the yield roughly halves with each passing week. Between the first and second mowing dates, a 30% decrease in yield was observed for both cutting heights. Similar to the biomass results, this yield reduction is primarily attributed to increasingly dry weather conditions, despite oat's excellent regenerative capacity.

In addition, there was a high incidence of the oat crown rust (*Puccinia coronata*), which also significantly impacted yield. The difference between the two cutting heights never exceeded 30% at any mowing date. While the first, second, and third mowing dates all showed higher yields at the 9 cm cutting height, at the fourth mowing date, the 6 cm cutting height resulted a slightly higher yield – approximately 30 kg ha^{-1} more. The differences between mowing dates were statistically significant.

Figure 6. **Yield influenced by the different mowing dates and cutting height (Debrecen, 2024)**



Note: *the different lowercase letters (a-c) indicate the significant differences ($p<0.05$) between mowing dates depending on the cutting height.
** The dates on the chart represent the mowing dates (from the first to the fourth)
*** ± standard error of means. 3 replicates.

Thousand kernel weight (TKW)

No significant difference was found in the Thousand kernel weight between mowing dates or between the two cutting heights. In this latest case, the differences were minimal in terms of the mean value (6 cm: 32.61 g, 9 cm: 32.67 g). Although the differences are not great, with the exception of the 3rd mowing date (May 13), higher values were measured for the 9 cm cutting height compared to the 6 cm cutting height. However, at mowing date 3., TKW was nearly 4 grams less compared to 6 cm (*Figure 7*).

The reason for this cannot be explained at the moment, but it is possible that it is a measurement error, especially in view of the fact that the moisture content

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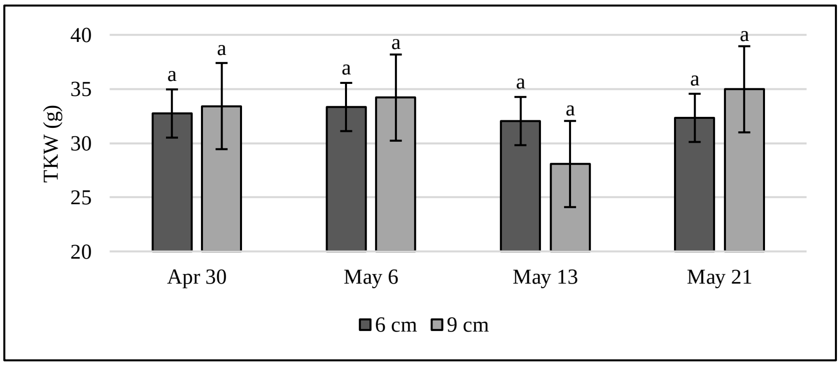
of the samples ranges between 12.18% and 12.68% for all 4 dates.

The TKW of some winter oat genotypes have been previously examined in the experimental area. In the year of 2021, in similar weather conditions, the average TKW value of oat plants of the Mv Hópehely variety from untreated plots was 35 g (I would like to emphasize that the TKW value of the treated plots was lower, the experimental average value for the Mv Hópehely variety alone was 33.92 g) (Kutasy et al., 2022). In our current experiment, we measured an average TKW of 32.64 g. It is assumed that after mowing, biomass development is significant mainly until ideal temperature and precipitation conditions are maintained, after which the development of generative organs takes priority.

Figure 7. **Thousand kernel weight influenced by the different mowing dates and cutting height (Debrecen, 2024)**



Note: *the different lowercase letters (a-b) indicate the significant differences ($p<0.05$) between mowing dates depending on the cutting height.
** The dates on the chart represent the mowing dates (from the first to the fourth)
*** ± standard error of means. 3 replicates.

CONCLUSIONS

The result is that we can expect higher biomass at lower cutting heights. It is interesting though that the difference was 3,73 t ha^{-1} between the two heights in average of the 4 mowing dates. The later the mowing, the higher the biomass, of course. The highest value were obtained at the mowing at the end of the booting stage (25.48 t ha^{-1}), but the difference was not significant compared to mowing at the beginning of the booting stage (which was one week earlier) (24.28 t ha^{-1}). However, considering the grain yield, it is preferable to mow at the beginning of the booting stage, as in our experiment it resulted in a higher yield of 248%.

In the case of dual-purpose use, it is always worth considering which product to focus on and adjusting the timing of mowing accordingly. Early mowing gives a relatively low biomass, but a valuable grain yield. Later mowing gives a significant green mass, but in this case the grain yield is almost negligible and presumably of poorer quality. We are only speculating about the lower quality, as we do not currently have the test results for the quality parameters, but this could be the subject of a forthcoming article.

Dual-purpose provides flexibility to the farmers from a feed point of view and also contributes to increasing sustainability (by maximizing productivity) in the case of winter crops. It is therefore worthwhile from an economic point of view to carry out an analysis if you are considering dual-purpose use. However, it can also contribute to a more stable ecological base by diversifying income sources. Among others, Francia and colleagues (2006) mentioned that under optimal conditions, dual-purpose farming can be profitable for livestock farmers.

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