Potential Role of Cutting Date in Lodging and Yield of Three Oat Cultivars

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Abstract. This study aimed to investigate the role of cutting at different growth stages according to the Zadoks scale and the possibility of reducing plant height and lodging at the end of the season. Moreover, it aimed to study the effect of cutting on some growth and yield traits of oat cultivars introduced into Iraq. A field experiment was carried out in an agricultural area on the left bank of the Euphrates River in the city of Ramadi during the winter season of 2020-2021. In this experiment, a randomized complete block design (RCBD), factorial arrangement, with three replications was used. The experiment included two factors: the first factor included three cutting dates according to the Zadoks scale: “Main stem and one tiller (GS21), main stem and four tillers (GS24), Main stem and seven tillers (GS27)”, in addition to the control without cutting. The second factor included three oat cultivars: Carrolup, Genzania, and Shafa. The most important results are summarized as follows: Cutting at all growth stages delayed ripening and reduced plant height, cutting at GS24 and GS27 reduced lodging, and cutting at GS27 reduced the grains per panicle, 1000 grain weight, grain yield, and total dry matter. Genzania cultivar was superior in grain yield and total dry matter. The cultivars showed similar responses to cutting dates in the terms of lodging and yield. It can be concluded from this study that cutting at GS24 is beneficial in reducing lodging without a negative impact on yield quantity.

1. Introduction
Oat (Avena sativa L.) is one of the world's major cereal crops, cultivated for use as human food or animal feed [1]. Despite the importance of the oat crop globally, its cultivation in Iraq is not known at the strategic production level. When Oat cultivars were introduced to new regions, adaptation to the new environment and production should be studied then introduced to the local farmers and highlight their importance in terms of high productivity and its nutritional and health benefits. The cultivars under study were noted as cultivars suffering from lodging because of their excessive shoots elongation. Lodging is one of the phenomena that negatively affects the quantity and quality of the yield [2,3]. To ensure high productivity and good quality of oat yield, efficient oat cultivars are recommended to reduce lodging negative effects [4,5]. Cutting oat plants at certain growth stages may reduce plant height, which leads to reduced lodging. [6] and [7] found that short plants are more resistant to lodging. Cutting may affect some other traits of growth and yield. Based on the previous information, this study aimed to investigate the effectiveness of cutting in reducing plant height, controlling lodging, and affecting some growth and yield traits of some oat cultivars newly introduced for cultivation in Iraq.
2. Materials and Methods
A field experiment was carried out in an agricultural area on the left bank of the Euphrates River in the city of Ramadi, 110 km west of Baghdad at a longitude 31, -16 and 43°, and latitude = 24, -26 and 33°, during the winter season of 2020-2021. A sample of field soil was taken before planting and analyzed in the laboratories of the Department of Soil Sciences and Water Resources (Table 1).

| Analysis type | Results       |
|---------------|--------------|
| Sand          | 316 g kg⁻¹   |
| Clay          | 30 g kg⁻¹    |
| Silt          | 654 g kg⁻¹   |
| Texture       | Silt Loam    |
| pH            | 7.90         |
| EC            | 1.55 dS m⁻¹  |
| Bulk density  | 1.3 g cm⁻³   |
| Total N       | 119 mg kg⁻¹  |
| Available P   | 6.9 mg kg⁻¹  |
| Available K   | 120 mg kg⁻¹  |

The experiment was laid out as factorial arrangement in randomized complete block design (RCBD) with three replications. The experiment included two factors: the first factor included three cutting times at tillering stage according to Zadoks scale [8]: “Main stem and one tiller (GS21), main stem and four tillers (GS24), Main stem and seven tillers (GS27)”, in addition to the control without cutting. The second factor included three cultivars of oat (Carrolup, Genzania, and Shafa).

The planting took place on October 25, 2020, in experimental units consisting of panels with dimensions (3 m * 3 m). The planting was carried out at a seeding rate of 80 kg ha⁻¹, swarming in lines, the distance between one line and the other is 25 cm. The experiment was irrigated as often as needed depending on soil moisture and plant status. The weeds were controlled manually throughout the season. The cutting was applied by hand at 3 cm stubble height when 50% of the plants reached the mentioned growth stages for each experimental unit. After completing the cutting treatments, the plants were left until growth was completed and the final yield was given after cutting.

The following traits were studied: Days from sowing to 50% physiological maturity identified by the yellowing 75% of the stalks [9], plant height (cm) from the soil surface to base of the panicle [10] in 10 random plants from the guarded middle lines in the center square meter, then the average of the 10 plants were taken. Lodging index was calculated in the center square meter in experimental units after maturity, an indicator whose value ranges from 0 to 100 to calculate the rate of deviation of all stems from the vertical axis at all angles from 0° to 90°, where the angle 0° is the vertical axis and the angle 90° is the horizontal axis. The method described by [6] was used by calculating the percentage of the number of stems within each angle range (0° to 15°, 15° to 30°, 30° to 45°, 45° to 60°, 60° to 75°, 75° to 90°), and then using the equation next:

Lodging Index = (1/6(% at 0°-15°) + 2/6(% at 15°-30°) + 3/6(% at 30°-45°) + 4/6(% at 45°-60°) + 5/6(% at 60°-75°) + (% at 75°-90°)).

The number of panicles per meter (Panicles m⁻²), was in the center square meter. The number of grains per panicle (grains panicle⁻¹) was calculated from randomly twenty panicles in the central square meter. 1000 grains weight (gm), from the total grain yield per square meter guarded, was dried at 65° C for 72 hours. Grain yield (kg ha⁻¹) was taken from the center square meter after harvesting and drying naturally by the sun's rays, then the grains were mulched and dried in the drying oven at a
temperature of 65° for 72 hours. Total dry matter (kg ha⁻¹) was taken from the center square meter after harvesting and drying naturally by sun's rays, then drying at a temperature of 65° for 72 hours.

The data were analyzed statistically according to analysis of variance (ANOVA), based on the experimental design used (RCBD) using the GenStat software, and the significantly differed averages were marked by least significant difference test (L.S.D) at 0.05 probability [11].

3. Results and Discussion
3.1. Days from sowing to 50% physiological maturity
The results presented in Table 2 indicated that cutting of plants led, on average, to a significant delay in ripening by 12, 15, and 16 days for cutting at GS21, GS24, and GS27 respectively, in comparison with the non-cutting control which took the least period to reach maturity, which averaged 133 days. The cutting treatments did not differ among themselves significantly. The reason for the delay in the maturation of plants that have been cut maybe due to the fact that they needed a longer time to regrow after cutting and to reach the stage of flowering and maturity. Similar results were found by [12] who confirmed that heading in wheat was delayed by the cutting effect.

Table 2. Effect of cutting date on the days from sowing to 50% physiological maturity of three oat cultivars

| Cutting       | Cultivars | Cutting mean |
|---------------|-----------|--------------|
| Control       | Carrolup  | 133          |
| Cutting at GS21| Genzania  | 134          |
| Cutting at GS24| Shafa     | 131          |
| Cutting at GS27| Carrolup  | 150          |
| Cutting mean  |           |              |
| Cutting at GS27| Genzania  | 143          |
| Cutting at GS27| Shafa     | 141          |
| Cutting mean  |           | 153          |
| Cultivars mean| Carrolup  | 150          |
| Cutting 7.0   | Genzania  | 154          |
| Cutting 7.0   | Shafa     | 139          |
| LSD 0.05      |           |              |
| Cutting × Cultivars | NS |               |

The results of the aforementioned table also indicated that the cultivars differed significantly from each other in the period from sowing to physiological maturity, where the two cultivars Carrolup and Genzania took the longest period 146 days for both and were significantly different from the Shafa cultivar, which took the least period 139 days. The reason for the different cultivars in the period from sowing to physiological maturity may be attributed to the difference in their genetic backgrounds, which led to the variation of cultivars in the period of reaching the stage of maturity. The results were inconsistent with what was found by [13] and [14] in the difference in the duration from planting to maturity among genotypes. The results showed that there is no significant effect of the interaction between the cutting and cultivars on days from sowing to 50% physiological maturity.

3.2. Plant height (cm)
Table 3 showed that the plant height was significantly decreased by the cutting effect at GS21, GS24, and GS27 by 7.4%, 12.3%, and 17.3%, respectively, compared to control (without cutting), which recorded the highest height (81 cm). The reason for the decrease in plant height due to cutting may be due to the depletion of the nutrients needed for growth and development, as well as the period from regrowth until the stage of the panicles formation at which growth stops was not sufficient for the cut plants to reach the height of the plants that were not cut. This goes in agreement with what was found by [15].
### Table 3. Effect of cutting date on the plant height (cm) of three oat cultivars

| Cutting          | Carrolup | Genzania | Shafa | Cutting mean |
|------------------|----------|----------|-------|--------------|
| Control          | 77       | 89       | 75    | 81           |
| Cutting at GS21  | 74       | 77       | 74    | 75           |
| Cutting at GS24  | 71       | 75       | 68    | 71           |
| Cutting at GS27  | 70       | 64       | 67    | 67           |
| Cultivars mean   | 73       | 76       | 71    |              |

LSD 0.05 Cutting 4.6 Cultivars 3.9 Cutting × Cultivars NS

It is clear from table 3 that the Genzania cultivar recorded the highest average of plant height (76 cm) and did not differ significantly from the Carrolup cultivar, but it significantly differed from the Shafa cultivar which recorded the lowest average of plant height (71 cm). The differences among cultivars in plant height might be due to the different genotypes, which led to a difference in the extent of utilization of the available nutrients, which was reflected in the increase of vegetative growth including plant height. These results are in agreement with the results obtained by [16] and [17] where they found significant differences in plant height of oat cultivars. The same table showed that there was no significant effect of the interaction between cutting and cultivars on plant height.

#### 3.3. Lodging index

It is evidenced from the results presented in Table 4 that the Lodging index significantly decreased due to the cutting at GS24 and GS27 compared to the control by 40% and 41.5%, respectively. The control treatment recorded the highest average of the Lodging index (13.5) and did not differ significantly from the cutting at GS21. The reduction of lodging by cutting might be due to the reduction of plant height (Table 3), where [18] found that short plants were more resistant to lodging in comparison with tall plants.

### Table 4. Effect of cutting date on the lodging index of three oat cultivars

| Cutting          | Carrolup | Genzania | Shafa | Cutting mean |
|------------------|----------|----------|-------|--------------|
| Control          | 13.4     | 15.9     | 11.2  | 13.5         |
| Cutting at GS21  | 14.0     | 11.4     | 12.1  | 12.5         |
| Cutting at GS24  | 6.5      | 9.1      | 8.6   | 8.1          |
| Cutting at GS27  | 7.4      | 8.8      | 7.5   | 7.9          |
| Cultivars mean   | 10.3     | 11.3     | 9.9   |              |

LSD 0.05 Cutting 1.82 Cultivars NS Cutting × Cultivars NS

The results of table 4 also showed that there were no significant differences among the cultivars in the lodging index. The same table indicated that there was no significant effect of the interaction between cutting and cultivars on this trait.

#### 3.4. The number of panicles (Panicles m⁻²)

Table 5 indicated that the cutting did not have a significant effect on the number of panicles per square meter, while the data showed that the cultivars differed significantly among themselves in this trait. Shafa cultivar recorded the highest average of 348 panicles m⁻², which is significantly superior to Carrolup and Genzania cultivars. Genzania cultivar recorded the lowest average number of panicles, which was 295 panicles m⁻², and it did not significantly differ from Carrolup cultivar.
Table 5. Effect of cutting date on the number of panicles (panicles m⁻²) of three oat cultivars

| Cutting        | Carrolup | Genzania | Shafa | Cutting mean |
|----------------|----------|----------|-------|--------------|
| Control        | 347      | 303      | 299   | 316          |
| Cutting at GS21| 297      | 297      | 371   | 322          |
| Cutting at GS24| 308      | 284      | 383   | 325          |
| Cutting at GS27| 254      | 296      | 339   | 296          |
| Cultivars mean | 301      | 295      | 348   |              |

LSD 0.05 Cutting NS Cultivars 25.6 Cutting × Cultivars 51.3

The difference among cultivars in the number of panicles per unit area might be due to the differences in genetic background, which led to a difference in the ability of the plant to form additional tillers that complete their growth until the flowering and maturation stages. These results are in line with the results found by [19] and [17] in oat cultivars that differed in the number of active tillers per unit area.

The results also showed that the interaction between the cutting dates and the cultivars had a significant effect on the number of panicles per square meter (Table 5), as the Shafa cultivar recorded the highest number of panicles which amounted to 383 panicles m⁻² when it was cut at GS24, while the Carrolup cultivar recorded the lowest number of panicles of 254 panicles m⁻² when it was cut at GS27.

Also, it is noted that the Shafa cultivar differed in the extent and direction of its response to cutting, as it was characterized by a clear increase in the number of panicles when cutting, while cutting did not lead to an increase in the number of panicles in Genzania and Carrolup.

3.5. Grains per panicle (Grains panicle⁻¹)

The results presented in table 6 showed that the number of grains per panicle was significantly decreased by the effect of cutting at GS27 by 13.6% compared to the control that recorded the highest number of grains per panicle amounting to 38.9 grains panicle⁻¹, while cutting at GS21 and GS24 had no significant effect on this trait. The reason for the decrease in the number of grains per panicle when cutting in the late growth stage might be due to the short period from the cutting to flowering and maturity. This result agreed with what was found by [15] and [12] that the number of grains per spike of wheat decreased by cutting.

Table 6. Effect of cutting date on the grains per panicle (Grains panicle⁻¹) of three oat cultivars

| Cutting        | Carrolup | Genzania | Shafa | Cutting mean |
|----------------|----------|----------|-------|--------------|
| Control        | 29.4     | 50.7     | 36.5  | 38.9         |
| Cutting at GS21| 29.3     | 50.9     | 27.9  | 36.0         |
| Cutting at GS24| 28.1     | 51.0     | 28.4  | 35.8         |
| Cutting at GS27| 29.4     | 48.7     | 22.9  | 33.6         |
| Cultivars mean | 29.0     | 50.3     | 28.9  |              |

LSD 0.05 Cutting 3.46 Cultivars 3.00 Cutting × Cultivars NS

The results indicated that the Genzania cultivar recorded the highest average number of grains per panicle, which was 50.3 grains panicle⁻¹, and significantly outperformed the two cultivars Carrolup and Shafa, which did not differ significantly. The Shafa cultivar recorded the lowest average of the number of grains per panicle which was 28.9 grains panicle⁻¹ (Table 6). These results were in line with the results of [20] and [21] where they indicated differences among oats genotypes in the number of
grains per panicle. It was also noted from the aforementioned table that the number of grains per panicle was not affected by the interaction between cutting and cultivars treatments.

3.6. 1000 grains weight (gm)

The results presented in table 7 showed that the cutting of oat plants caused a decrease in the weight of 1000 grains, as cutting at GS27 recorded the lowest average 25.9 g and significantly differed from the control, which recorded the highest average of 29.2 g. The reason for the decrease in the weight of the grain due to the effect of cutting at GS27 might be due to reducing the materials needed to fill the grain. [12] concluded that the weight of 1000 grains decreased as a result of cutting wheat plants in late growth stages.

The results also indicated that the Shafa cultivar recorded the highest average weight of 1000 grains which reached 31.7 g and did not significantly differ from the Carrolup cultivar, which also outperformed the Genzania cultivar which recorded the lowest average 1000 grains weight of 23.0 g. In a previous study, similar results were obtained about the difference in grain weight depending on the genotype [22].

Table 7. Effect of cutting date on 1000 grains weight (g) of three oat cultivars

| Cutting          | Cultivars | Cutting mean |
|------------------|-----------|--------------|
| Control          | Carrolup  | 30.1         |
|                  | Genzania  | 25.9         |
|                  | Shafa     | 31.6         |
| Cutting at GS21  | Carrolup  | 28.1         |
|                  | Genzania  | 24.4         |
|                  | Shafa     | 34.7         |
| Cutting at GS24  | Carrolup  | 29.8         |
|                  | Genzania  | 20.9         |
|                  | Shafa     | 32.6         |
| Cutting at GS27  | Carrolup  | 29.0         |
|                  | Genzania  | 20.6         |
|                  | Shafa     | 27.9         |
| Cultivars mean   | Carrolup  | 29.2         |
|                  | Genzania  | 23.0         |
|                  | Shafa     | 31.7         |

LSD 0.05 Cutting 2.96 Cultivars 2.56 Cutting × Cultivars NS

The results in the table 7 showed that there are no significant differences by the effect of the interaction between cutting and cultivars on the 1000 grains weight.

3.7. Grain yield (kg ha⁻¹)

The results presented in table 8 showed that cutting oats plants at the last growth stage (GS27) led to a significant decrease in grain yield by 29.9% compared to the control that recorded the highest average of grain yield (3326 kg ha⁻¹), and cutting at growth stages GS21 and GS24 recorded non-significant decrease. The decrease in grain yield when cutting plants in the late growth stage (GS27) was due to a decrease in the number of grains per panicle (Table 6) and 1000 grains weight (Table 7).

Table 8. Effect of cutting date on the grain yield (kg ha⁻¹) of three oat cultivars

| Cutting          | Cultivars | Cutting mean |
|------------------|-----------|--------------|
| Control          | Carrolup  | 2824         |
|                  | Genzania  | 3887         |
|                  | Shafa     | 3266         |
| Cutting at GS21  | Carrolup  | 2295         |
|                  | Genzania  | 3578         |
|                  | Shafa     | 3472         |
| Cutting at GS24  | Carrolup  | 2524         |
|                  | Genzania  | 2970         |
|                  | Shafa     | 3387         |
| Cutting at GS27  | Carrolup  | 2099         |
|                  | Genzania  | 2804         |
|                  | Shafa     | 2090         |
| Cultivars mean   | Carrolup  | 2435         |
|                  | Genzania  | 3310         |
|                  | Shafa     | 3054         |

LSD 0.05 Cutting 389.8 Cultivars 337.5 Cutting × Cultivars NS

The results indicate that the Genzania cultivar record the highest rate of grain yield 3310 kg ha⁻¹ and was significantly superior to the Carrolup cultivar, which recorded the lowest rate 2435 kg ha⁻¹ (Table 8). The superiority of the Genzania cultivar in grain yield was due to its superiority in the
number of grains per panicle (Table 6). A previous study [22] found that oat cultivars differed in grain yield. It is noted from the results in the previous table that there was no significant interaction between cutting and cultivars on the grain yield.

3.8. Total dry matter (kg ha⁻¹)

The results presented in Table 9 indicated that the control treatment recorded the highest average of total dry matter (12920 kg ha⁻¹), and cutting at GS27 led to a significant decrease in total dry matter 29.5% less than the control. The decreased total dry matter when cutting plants at GS27 might be due to the short period of dry matter accumulation after cutting to maturity [15], which led to a decrease in plant height (Table 3) and grain yield (Table 8) thus, the total dry matter was reduced.

It was evidenced from the results presented in table 9 that oat cultivars significantly differed in total dry matter, as Genzania recorded the highest rate of 12459 kg ha⁻¹ which significantly outperformed the Carrolup cultivar, which recorded the lowest average (9804 kg ha⁻¹). The superiority of the Genzania cultivar might be due to its genetic background, which made it form the highest plant height (Table 3). Similar results were reached by [20] in terms of cultivar difference in total dry matter.

Table 9. Effect of cutting date on the total dry matter (kg ha⁻¹) of three oat cultivars

| Cutting       | Carrolup | Genzania | Shafa | Cutting mean |
|---------------|----------|----------|-------|--------------|
| Control       | 11564    | 15269    | 11928 | 12920        |
| Cutting at GS21| 9796     | 12297    | 12891 | 11662        |
| Cutting at GS24 | 9370     | 12248    | 12520 | 11379        |
| Cutting at GS27 | 8485     | 10022    | 8799  | 9102         |
| Cultivars mean | 9804     | 12459    | 11535 |              |

LSD 0.05  Cutting 1345.9 Cultivars 1165.6 Cutting × Cultivars NS

The results in table 9 showed that there was no significant effect of the interaction between cutting treatments and oat cultivars on the total dry matter.

4. Conclusion

It can be concluded that cutting at the middle of the tillering stage might be useful to reduce lodging without negatively affecting the yield quantity for the cultivars studied. It also can be concluded that the use of Genzania cultivar is suitable for cultivation for grain and dry matter production.

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