

To Cite: Enişte, A.T. & Temel, S. (2026). The Effect of different harvesting periods and intra-row spacings on some seed yield and quality characteristics in mountain Spinach. *Journal of the Institute of Science and Technology*, 16(2), 819-831

The Effect of Different Harvesting Periods and Intra-Row Spacings on Some Seed Yield and Quality Characteristics in Mountain Spinach

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Highlights:

- Intra-row distances were determined
- Harvesting periods were determined for seed production
- Seed and stem yield and quality parameters were determined

Keywords:

- *Atriplex nitens*
- Plant density
- Phenological stages
- Seed yield
- Quality values

ABSTRACT:

This study was conducted to determine the effects of different intra-row spacings (10 cm, 20 cm, 30 cm and 40 cm) and seed harvest periods (1st harvest period; 100% ripening, 2nd harvest period; 50% ripening) on seed yield and quality in Mountain spinach. The research was established in 2023 according to factorial arrangement in randomized blocks in the dry experimental field of İğdır University Agricultural Application and Research Center Directorate. The effects of row spacing and harvest periods on the examined parameters showed statistical differences. In terms of row distance, plant height was found to be important; 2.71-2.91 m, stem thickness was found to be 14.10-17.13 mm, seed yield was found to be 390-1055 kg/da, stem yield was found to be 1311-2717 kg/da, biological yield was found to be 1701-3772 kg/da, harvest index was found to be 23.13-28.12%, ripening time was found to be 188.33-196.00 days and seed crude protein ratio was found to be 16.26-17.13%. In terms of harvest periods, plant height was found to be 2.77-2.87 m, stem thickness was found to be 14.28-16.70 mm, seed yield was found to be 508-811 kg/da, stem yield was found to be 1757-2044 kg/da, harvest index was found to be 19.07-31.41%, thousand-grain weight was found to be 5.05-6.63 g, the ripening period was found to be 182.92-201.42 days, seed crude protein ratio was found to be 16.51-16.99%, seed NDF ratio was found to be 33.07-37.51%, seed ADF ratio was found to be 20.43-23.88% and stem ADF ratio was found to be 49.56-51.49%. As a result of the research, it was revealed that the highest seed yield and quality values were obtained from applications sown with narrow row spacing (except seed crude protein ratio) and harvested at 50% maturity.

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This study is derived from Ali Tolgahan ENİŞTE's Master's thesis.

INTRODUCTION

One of the important problems of animal husbandry in our country is the inability to provide sufficient amounts of quality roughage production (Temel & Şahin, 2011; Tan, 2018; Okçu, 2020; Tan & Yolcu, 2021). The reasons for this have been presented many times by expert researchers, but the desired results have not been achieved. For this reason, in order to meet the need for quality roughage, scientists and producers have focused on alternative species that can be used for feed purposes other than known forage plant species, especially those that can grow in marginal areas and produce feed material in the desired quantity and quality from a unit area, and they have reached important findings (Acar & Güncan, 2002; Kara & Yüksel, 2014; Oktay & Temel, 2015; Temel et al., 2015; Temel, 2018; Demiroğlu Topçu & Özkan, 2019; Kuşvuran et al., 2019; Temel, 2019; Tan & Temel, 2020; Temel & Tan, 2020; Pirasteh-Anosheh et al., 2021; Pirasteh-Anosheh et al., 2023). One of these species is *Atriplex nitens* (Mountain spinach), which is in the *Atriplex* genus of the *Chenopodiaceae* subfamily.

Mountain spinach is an annual herbaceous species with a therophyte life form. The plant grows upright over 2 meters, with branching starting from the base. The flowers are unisexual and form sparse clusters. While the plant develops and grows rapidly during the vegetative stage, it exhibits slower growth during the generative stage (Acar & Güncan, 2002; Kurgan & Temel, 2024). The vegetative and generative parts of the plant are consumed both as vegetables in human nutrition and as a feed source in livestock. On the other hand, the plant has a high adaptability and can easily grow in extreme climate and soil conditions (Acar et al., 2017; Doudova et al., 2017; Dursun & Acar, 2015; Keskin and Temel, 2022; Temel & Keskin, 2022a; 2022b; Keskin et al., 2023). Indeed, studies have shown that the plant can grow in high salinity and severe drought conditions (Kurgan & Temel, 2024). While it varies according to the sowing and harvesting periods, it was determined that high amounts of herbage (6837.0 -7382.9 kg/da green herbage and 2336.12568.8 kg/da dry herbage) and seed yields (2597.3 kg/da) were obtained from the unit area without any fertilizer and irrigation application. It has also been reported that the resulting herbage and seeds have a high nutritional content (Keskin & Temel, 2022; Temel & Keskin, 2022a; 2022b; Temel et al., 2022a; 2022b; Keskin et al., 2023; Temel et al., 2024a). Due to these features, demand for the plant has increased in recent years, and agronomic studies on the plant have been intensified. A large part of these agronomic studies have focused on determining herbage yield and quality parameters. While the effects of inter-row spacing and sowing times (in irrigated and dry conditions) on seed yield and quality have been determined, studies on seed production have been found to be insufficient.

Agronomic practices such as fertilization, irrigation, inter-row and intra-row distance, sowing depth, cutting height, and sowing and harvesting periods are crucial for species cultivated as forage sources. Within these cultural practices, knowledge of harvest time is essential to ensure high-quality and high-quantity seed production. This is particularly crucial for forage species with inhomogeneous generative maturation. Because seed losses can be high in species where budding, flowering and seed formation periods are not synchronized. Indeed, studies on various species used as forage sources have reported significant effects of harvest periods on seed yield and quality (Temel & Tan, 2002; Temel & Tufur Öztürk, 2020; Keskin & Önkür, 2019). A similar situation also applies to Mountain spinach plant. The flower cluster of Mountain spinach plant is a bunch and shows a bunch with many branches. As a result, budding, flowering, and therefore seed formation and maturation on the same plant are not synchronous. This causes losses in seed yield due to shedding during late harvests. Early harvests can also lead to problems with seed viability and quality due to incomplete seed formation and maturation.

However, there are no previous studies on determining harvest periods for seed production in Mountain spinach plant. Another important cultural practice in seed production is the sowing norm (inter-row and intra-row distance). Although plant densities vary according to the ecological, physiological and morphological characteristics of plants, previous studies have shown that seed production in many forage crop species should be sown at lower sowing norms or wider inter-row and intra-row distance compared to herbage production (Tan, 2018). However, it has been determined that seed yields are higher in narrow inter-row distances for Mountain spinach (Temel et al., 2024b).

For these reasons, the current study aimed to test how seed yield and yield components would change in Mountain spinach plant sown at different intra-row distances. The aim was also to determine the appropriate harvest period(s) for high seed production. For this purpose, plants were planted in four different row spacings and harvested at two different seed maturation stages.

MATERIALS AND METHODS

The research was carried out in the experimental field of Iğdır University Agricultural Application and Research Center Directorate in 2023. Some climate values for the experimental region for long-term and 2023 are presented in Table 1 (Anonymous, 2023). According to these data, total precipitation, average temperature, and relative humidity were found to be higher than the long-term averages in the experimental year. Following the parcellation process, soil samples (0-30 cm deep) were taken from at least three different locations to represent the experimental area, and soil analyses were conducted through outsourcing. According to the analysis results, it was determined that the soil of the experimental field had a clayey-loamy (Saturation 69.00%), medium calcareous (5.62%), non-saline (EC: 2.58 dS m⁻¹) and slightly alkaline (pH: 8.11) structure, medium available potassium content (25.01 kg K₂O/da), available phosphorus content (3.17 kg P₂O₅/da), and low organic matter content (1.37%) (Ülgen & Yurtsever, 1995; Saraçoğlu et al., 2014).

Table 1. Some climate values of the experiment area for 2023 and long-term (1978-2022) averages

Months	Mean Temperature (°C)		Total Precipitation (mm)		Mean Relative Humidity (%)	
	2023	LTA*	2023	LTA	2023	LTA
March	11.7	6.9	27.2	21.5	55.4	49.9
April	13.7	13.4	51.2	37.9	60.1	49
May	18.1	17.6	43.2	48.9	53.8	51.1
June	23	22.3	48.3	33.2	52.6	45.7
July	26.5	26.2	10.5	14.7	42.2	43.3
August	28.3	25.6	1.0	9.8	39.8	44.5
September	22	20.7	7.6	10.3	50.1	48.9
October	15.2	13.3	29.5	28.1	64.3	62.3
Mean/Total	19.8	18.3	218.5	204.4	52.3	49.3

* Long-Term Average

The experiment was established according to Factorial Arrangement in Randomized Blocks with three replications under rainfall conditions. Intra-row spacing (10 cm, 20 cm, 30 cm, and 40 cm) and seed harvest times (100% maturation: when all the fruits on the whole plant turn yellow, and 50% maturation: when the fruits on the clusters at the ends of the main stem and lateral branches turn yellow) were used as factors. In the present study, each plot area was planned as 12.15 m² (3.6 m x 3.375 m). Additionally, 3 m space was left between blocks and 2 m between plots, resulting in a total experimental area of 606.8 m² (41.0 m x 4.8 m). Seeds were sown in plots with 67.5 cm inter-row spacing and in 5 rows (with 10 cm, 20 cm, 30 cm and 40 cm intra-row distance). When sown in 40 cm intra-rows, there were 9 plants in each row, 12 plants when sown in 30 cm intra-rows, 18 plants when sown in 20 cm intra-rows, and 36 plants when sown in 10 cm intra-rows. Sowing was done in the last week of March (22.03.2023), when the soil was tempered and, when the highest yields were obtained

in a previous study conducted in the Iğdır region. Considering the results of previous fertilization and soil analysis, only 15 kg of pure phosphorus (39-41% Triple Super Phosphate) fertilizer was used per decare before sowing as fertilizer material (Temel & Şahin, 2022). Seeds were sown 3-4 cm deep using the hole method. Weeds that emerged in the experimental area during and after the seedling period were removed manually and by hoeing. When the plants reached 50% (between 20 September and 1 October, depending on the intra-row distances) and 100% (between 10 October and 17 October, depending on the intra-row distances) harvest periods, one row from the edges of the plot and 50 cm sections from the tops were mowed and discarded as edge effect, and sampling was carried out in the remaining area.

In each harvest period, the distance from the soil surface to the top of 10 plants selected at random within the area left was measured with a ruler, and the average plant height was determined in meters (m). The thickness of the main stem at 7.5-10.0 cm above the soil surface of 10 plants selected for plant height was measured with a digital caliper, and the main stem thickness of the plants was determined in mm. The average maturation time was determined by calculating the time elapsed between the day the plants were sown and the day the seeds were harvested in both harvest periods. The stems and clusters of the plants harvested from a 1 m² area were separated and dried first in the open air for 4-5 days, and then in a drying oven set at 40 °C for 24 hours. The stems removed from the oven were then weighed, and the stem yields and clusters were threshed, and seed yields were determined in kg per decare. Then, the stem + seed yields of the plants were collected and the biological yield per decare was calculated, and the harvest index (%) was calculated by proportioning the seed yield to the biological yield. For thousand-grain weight, 4x100 seeds from each plot were counted and weighed on a precision balance. The average of the obtained values was multiplied by 10 to calculate 1000-grain weight in grams. Using dried and ground (to pass through a 2 mm diameter sieve) seed and stem samples, first the % nitrogen ratios of the seeds and stems were determined according to the Micro Kjeldahl method, and then the % crude protein content was determined by multiplying these ratios by a coefficient of 6.25 (AOAC, 1997). The NDF (neutral detergent fiber) and ADF (acid detergent fiber) contents of the seeds and stems were determined using the ANKOM fiber analyzer following the method recommended by Van Soest et al. (1991).

The results obtained in the study were subjected to variance analysis according to Factorial Arrangement in Randomized Blocks in the JMP (5.0.1.) statistical package program and the grouping of significant means was done according to the LSD_(0.05) test.

RESULTS AND DISCUSSION

Evaluation of Seed Yield Characteristics in Terms of Intra-Row and Development Periods

According to the results of variance analysis, in terms of development stages, while stem thickness, thousand grain weight, stem yield, seed yield, harvest index and ripening time were found to be significant at $P \leq 0.01$ and plant height at $P \leq 0.05$ levels, stem thickness, stem yield, seed yield, biological yield and ripening time were found to be significant at $P \leq 0.01$ and plant height and harvest index at $P \leq 0.05$ levels in terms of intra-row distance. When evaluated in terms of harvest period x intra-row interaction, only thousand grain weight (at $P \leq 0.01$) and ripening time (at $P \leq 0.05$) were found to be statistically significant (Table 2).

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Table 2. F values of the examined seed yield traits according to intra-row spacings and development stages

Sources of Variation	df	Plant Height	Stem Thickness	Thousand Grain Weight	Stem Yield	Seed Yield	Biological Yield	Harvest Index	Maturation Time
Replication	2	0.65 ns.	1.14 ns.	1.35 ns.	0.84 ns.	0.08 ns.	0.74 ns.	0.28 ns.	1.17 ns.
HP	1	5.02*	97.67**	52.58**	9.78 **	99.78**	0.03 ns.	116.33**	3593.625**
IR	3	3.34*	28.34**	2.40 ns.	45.56 **	92.17**	87.44**	3.49*	115.31**
HP x IR	3	0.25 ns.	2.80 ns.	5.30**	0.49 ns.	1.21 ns.	0.67 ns.	0.81 ns.	3.99*
Error	14	0.65 ns.	1.14 ns.	1.355 ns.	0.84 ns.	0.07 ns.	0.74 ns.	0.28 ns.	1.17 ns.
General	23	5.022*	97.670**	52.58**	9.78 **	99.78**	0.03 ns.	116.33**	3593.62**

** and * are significant at $P \leq 0.01$ and $P \leq 0.05$, respectively, and ns is non-significant. df: Degrees of freedom, HP: Harvesting Period, IR: Intra-Row

Plant height (m), Stem thickness (mm) and Thousand grain weight (g)

When evaluated in terms of intra-row distance, it was determined that the highest plant height and stem thickness were obtained from plants sown with 40 cm intra-row spacing (Table 3). These results showed that plant height and stem thickness increased with increasing intra-row distance. This may be due to the greater number of plants per unit area in plots sown with narrow intra-row spacing, resulting in greater competition between plants and environmental conditions (light, humidity, fertilizer, etc.). Indeed, in narrow rows, plants compete more intensely with environmental conditions, and as a result, they tend to develop more thinly (Li et al., 2023). There is no previous study testing different intra-row spacings on the height and stem thickness of Mountain spinach. However, it was determined that plant height and stem thickness increased with increasing inter-row spacing in *Atriplex nitens* grown for seed production without fertilizer and under rainfall conditions (Temel et al., 2024b). It has been stated that plant height increases with increasing inter-row spacing in the quinoa plant, which is also in the same family and grown for seeds (Spehar & da Silva Rocha, 2009; Geren et al., 2015; Keskin & Önkür, 2019).

Table 3. Average plant height, stem thickness and thousand grain weight of Mountain spinach according to intra-row and development stages

Intra-Row Distance	Plant Height (m)			Stem Thickness (mm)			Thousand Grain Weight (g)		
	Harvest Periods		Mean	Harvest Periods		Mean	Harvest Periods		Mean
	50%	100%		50%	100%		50%	100%	
10 cm	2.66	2.77	2.71 b*	13.41	14.78	14.10 d**	5.79	5.26	5.53
20 cm	2.71	2.88	2.80 ab	13.74	16.02	14.88 c	6.16	5.09	5.63
30 cm	2.82	2.87	2.85 ab	14.48	17.23	15.86 b	6.86	4.96	5.91
40 cm	2.87	2.95	2.91 a	15.47	18.79	17.13 a	7.70	4.86	6.28
Mean	2.77 b*	2.87 a		14.28 b**	16.70 a		6.63 a**	5.04 b	
LSD Value	HP: 0.10., IR: 0.14			HP: 0.53, IR: 0.75			HP: 0.47, IR: 0.66		

** Means indicated with different letters in the same column and row are statistically different according to the LSD test at $P \leq 0.01$, * Means indicated with different letters in the same column and row are statistically different within the error limits of $P \leq 0.05$. HP: Harvest period, IR: Intra-row

When Table 3 was evaluated, it was determined that the highest plant height and stem thickness were obtained from plants harvested at 100% maturity. This may be due to the fact that plants at 100% maturity have a longer vegetation period compared to 50% maturity and therefore benefit more from environmental conditions. In the literature search, no study was found testing the seed harvest periods of Mountain Spinach. However, it was determined that delaying the harvest periods in Mountain Spinach harvested at different maturity periods for hay production increased plant height and stem thickness (Keskin & Temel, 2022; Temel & Keskin, 2022a). It was also revealed that plant height increased in late harvests of Common vetch (*Vicia sativa* L.) grown for seed production (Temel & Tan, 2002). When evaluated in terms of thousand grain weight, thousand grain weight (6.63 g) of seeds obtained at 50% maturity period was determined to be higher than those at 100% maturity period. This may be due to the fact that the seeds, especially the large ones, that matured at 100% harvest were

shed, leaving smaller seeds on the plant. Indeed, Temel et al. (2024b) reported that seeds with fuller and larger fruits (seeds) had higher thousand-seed weights.

When Figure 1 was examined, thousand-grain weight increases linearly with increasing intra-row spacing at 50% maturity, while it initially decreases at 100% maturity, remaining constant at subsequent intra-row spacings, as this decrease rate is not statistically significant. The difference in thousand grain weight according to the changing intra-row and harvest periods may have caused the harvest period x intra-row interaction to be significant.

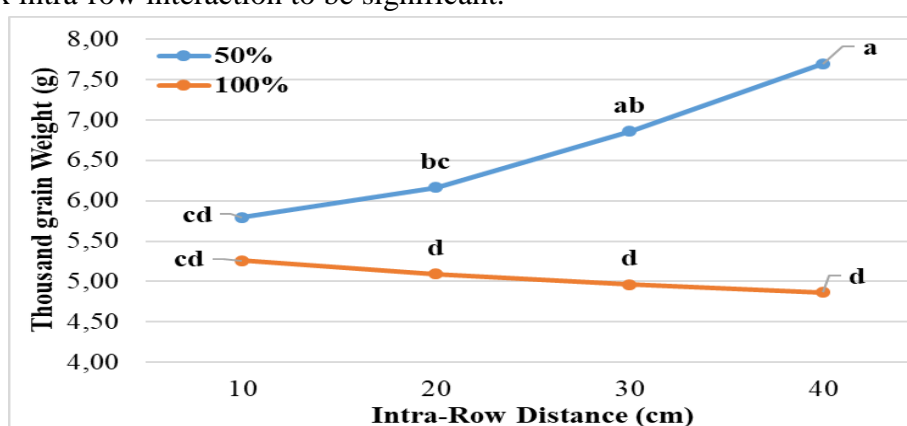


Figure 1. Effect of harvest period x intra-row interaction on thousand grain weight

Stem yield (kg/da), Seed yield (kg/da) and Biological yield (kg/da)

When Table 4 was evaluated, it was seen that as the intra-row distances decreased, the stem, seed and biological yields obtained from unit area increased. The increase in stem and seed yields may have been due to the higher number of plants per unit area in plots grown with narrow intra-row distance. Furthermore, less seed shedding due to wind in plots grown with narrow intra-row distance may have contributed to the higher seed yields. On the other hand, observations made under field conditions showed that the upper parts (side branches) of the plant were more densely intertwined in plots grown with narrow intra-row spacing compared to plots grown with wide intra-row spacing, and the physical friction effect caused by the wind and therefore seed shedding was less. In fact, Osmond et al. (1980) reported that wind-induced seed shedding occurs in most *Atriplex* species, and that this shedding is due to the slightly papery bracteoles of the seeds. Furthermore, the higher stem and seed yields in plots sown with narrow intra-row spacing may have contributed to the higher biological yield. Indeed, biological yield is the sum of stem yield and seed yield. There is no previous study testing different intra-row spacings on stem, seed, and biological yield components of Mountain Spinach plant. However, in Mountain Spinach plant sown at different inter-row spacings (22.5 cm, 45.0 cm and 67.5 cm), they reported that the highest stem, seed and biological yields were obtained from the plants sown at 22.5 cm inter-row spacing, where the highest number of plants per unit area was found (Temel et al., 2024b). Similarly, they reported that the highest stem, seed, and biological yields were obtained from plants sown with narrow inter-row spacings in quinoa, which is in the same family and exhibits similar plant characteristics (Keskin & Önkür, 2019). In addition, it has been reported that biological yields increased with increasing planting density in amaranth plant (Yarnia et al., 2010).

When evaluated in terms of harvest periods, plants harvested at 100% maturity had higher stem yield and lower seed yield compared to those at 50% maturity (Table 4). The increase in stem yield may be due to the longer vegetation period of plants at 100% maturity compared to those at 50% maturity, allowing them to benefit more from environmental conditions. This is because plants achieve greater growth and dry matter accumulation with increased growth (Taiz & Zeiger, 2008). Indeed,

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Temel & Tan (2002) reported that stem yield increased with late harvests. The decrease in seed yield may have been due to the shedding of most seeds formed on the plant during the late harvest period due to wind gusts. In other words, since most seeds formed on the plant during the early harvest period were not fully yellowed and mature, natural shedding (abscission) or shedding due to wind force occurred to a lesser extent. It has been determined that delaying the harvest period causes seed shedding in different species (Caballero et al., 1996; Temel & Tan, 2002).

Table 4. Average stem, seed and biological yields of Mountain spinach according to intra-row and development stages

Intra-Row Distance	Stem Yield (kg/da)			Seed Yield (kg/da)			Biological Yield (kg/da)		
	Harvest Periods		Mean	Harvest Periods		Mean	Harvest Periods		Mean
	50%	100%		50%	100%		50%	100%	
10 cm	2488.9	2945.3	2717.1 a**	1210.6	898.4	1054.5 a**	3699.5	3843.8	3771.6 a**
20 cm	1907.8	2137.4	2022.6 b	873.7	507.5	690.6 b	2781.5	2644.9	2713.2 b
30 cm	1471.2	1627.8	1549.5 c	663.9	338.7	501.3 c	2135.1	1966.5	2050.8 c
40 cm	1158.2	1463.9	1311.0 c	494.5	285.4	389.9 d	1652.6	1749.3	1701.0 d
Mean	1756.5 b**	2043.6 a		810.7 a**	507.5 b		2567.2	2551.1	
LSD Value	HP: 197, IR: 278			HP: 65 IR: 92			HP: 209, IR: 295		

** Means indicated with different letters in the same column and row are statistically different within the $P \leq 0.01$ error limits according to the LSD test. HP: Harvest period, IR: Intra-row

Harvest index (%) and maturation time (day)

The highest harvest index was obtained in plots sown with 10 cm intra-row spacing, and it was observed that the harvest index decreased as the intra-row spacing increased (Table 5). This may be due to the higher seed yield in plants sown at 10 cm intra-row spacing compared to other intra-row spacings. In a related study conducted on quinoa, although the effect of intra-row spacing on the harvest index was found to be statistically insignificant, it was found that the harvest index was higher in plants sown with narrow intra-row spacing (Keskin & Önkür, 2019). Taş (2010) also reported that increasing intra-row spacing in Zea mays decreased the harvest index, and vice versa, increased it. On the other hand, it was observed that the maturity period of the plants shortened as the intra-row spacing decreased (Table 5). Accordingly, the shortest maturity period occurred at 10 cm intra-row spacing (198.33 days), and the longest maturity period occurred at 40 cm intra-row spacing (204.67 days). This may be due to the fact that plants sown at wider intra-row distances benefited more from environmental conditions and reached maturity later. Indeed, Temel & Keskin (2022b) reported that Mountain Spinach, which benefited more from environmental conditions, reached harvest maturity later. In addition, in a study testing different inter-row spacings, it was revealed that maturation times in Mountain Spinach plant increased with increasing inter-row spacing. (Temel et al., 2024b).

Table 5. Mean harvest index and maturation time of Mountain spinach according to intra-row and development stages

Intra-Row Distance	Harvest Index (%)			Maturation Time (day)		
	Harvest Periods		Mean	Harvest Periods		Mean
	50%	100%		50%	100%	
10 cm	32.82	23.42	28.12 a*	178.3	198.3	188.3 d**
20 cm	31.67	19.20	25.44 ab	181.3	200.3	190.8 c
30 cm	31.24	17.30	24.27 b	184.7	202.3	193.5 b
40 cm	29.91	16.34	23.13 b	187.3	204.7	196.0 a
Mean	31.41 a**	19.07 b		182.9 b**	201.4 a	
LSD Value	HP: 2.46, IR: 3.47			HP: 0.66, IR: 0.94		

** Means indicated with different letters in the same column and row are statistically different according to the LSD test at $P \leq 0.01$, *) Means indicated with different letters in the same column are statistically different within the error limits of $P \leq 0.05$. HP: Harvest period, IR: Intra-row

When evaluated in terms of harvest periods, it was determined that the harvest index was higher at 50% maturity compared to 100% maturity (Table 5). This may be due to the higher ratio of seed

yield to total biomass in plants harvested at 50% maturity. Because the harvest index is calculated by dividing the seed yield by the biological (total) yield. As a matter of fact, previous studies conducted with different species have shown that harvest indices were also high in applications where seed yield was high within the total yield (Temel & Tufur Öztürk, 2020; Temel & Keskin, 2022b; Keskin et al., 2023). When Table 5 was examined, it was determined that the longest average maturation time was in plants harvested at 100% maturity. This is an expected result. Because plants remain in the field longer in late harvests compared to early harvests, they benefit more from environmental conditions, and as a result, they can continue their growth and development for a longer period. As a matter of fact, Temel & Keskin (2022b) reported that seed harvests and therefore maturation times were extended in Mountain Spinach plant that remained in field conditions for a longer time.

When Figure 2 was examined, it was seen that the ripening time increased linearly in both ripening periods as the intra-row distances increased. However, the increase in ripening time at 30 cm intra-row spacing compared to 20 cm was slightly greater in the 50% ripening period (1.84%) than in the 100% ripening period (1.00%). This may have caused the harvest period x intra-row interaction to be significant.

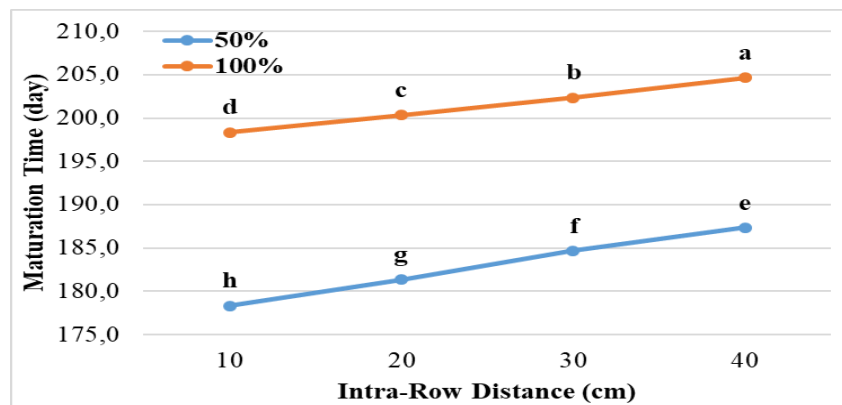


Figure 2. Effect of harvest period x intra-row interaction on maturation time

Evaluation of seed and stem quality characteristics in terms of intra-row and development periods

Seed and stem quality characteristics of Mountain Spinach grown at different intra-row spacings and harvested at seed maturation were subjected to statistical analysis. According to the analysis results, the effect of harvest period on seed NDF and ADF ratio was found to be significant at $P \leq 0.01$ level, and on seed crude protein and stem ADF ratio at $P \leq 0.05$ level. The effects of intra-row (except seed crude protein ratio) and binary interactions on other examined parameters were found to be insignificant (Table 6).

Table 6. F values of the examined seed and stem quality characteristics according to intra-row spacings and development stages

Sources of Variation	df	Plant Height	Stem Thickness	Thousand Grain Weight	Stem Yield	Seed Yield	Biological Yield
Replication	2	0.261 ns.	2.007 ns.	1.430 ns.	0.554 ns.	0.435 ns.	0.378 ns.
HP	1	6.114*	33.250**	17.694**	2.697 ns.	3.908 ns.	7.444 *
IR	3	3.969*	1.471 ns.	1.292 ns.	1.234 ns.	0.588 ns.	1.327 ns.
HP x IR	3	0.303 ns.	0.356 ns.	0.048 ns.	0.227 ns.	0.021 ns.	0.088 ns.
Error	14						
General	23						

** and * are significant at $P \leq 0.01$ and $P \leq 0.05$, respectively, and ns is non-significant. df: Degrees of freedom, HP: Harvesting Period, IR: Intra-Row, CPR: Crude protein ratio, NDF: Neutral detergent fiber, ADF: Acid detergent fiber

Seed crude protein, NDF ve ADF contents (%)

When Table 7 was examined, it was determined that the highest seed crude protein values were obtained from plants sown with 30 and 40 cm intra-row spacings, which are in the same statistical group. This may be since plants sown with wider intra-row spacings produced bigger seeds (fruits). Bigger seeds can have higher thousand-seed weights and therefore more nutritional structure (Yağdı, 2004). Indeed, in the current study, although thousand-seed weight was found to be statistically insignificant in terms of row spacing, it was determined that thousand-seed weight increased as the intra-row spacing increased. Furthermore, it was noted that seed crude protein content increased with increasing inter-row spacing in Mountain Spinach plant sown with different row spacings, and the highest seed crude protein content was obtained from plants sown with 67.5 cm inter-row spacing (Temel et al., 2024a). When evaluated in terms of harvest periods, it was determined that the highest seed crude protein content was obtained from plants harvested at 50%, and seed NDF and ADF contents were obtained from plants harvested at 100% development (Table 7).

Table 7. Average seed crude protein, NDF and ADF contents of Mountain spinach according to intra-row and development stages

Intra-Row Distance	Seed Crude Protein Ratio (%)			Seed NDF Ratio (%)			Seed ADF Ratio (%)		
	Harvest Periods		Mean	Harvest Periods		Mean	Harvest Periods		Mean
	50%	100%		50%	100%		50%	100%	
10 cm	16.62	15.91	16.26 b*	31.50	36.84	34.17	19.53	22.48	21.01
20 cm	16.92	16.29	16.61 ab	32.47	37.50	34.99	20.15	23.62	21.89
30 cm	17.14	16.88	17.01 a	33.61	37.67	35.64	20.63	24.43	22.53
40 cm	17.30	16.95	17.13 a	34.70	38.03	36.36	21.39	25.00	23.20
Mean	16.99 a*	16.51 b		33.07 b**	37.51 a		20.43 b**	23.88 a	
LSD Value	HP: 0.42, IR: 0.60			HP: 1.65, IR: 2.34			HP: 1.76, IR: 2.49		

** Means indicated with different letters in the same row are statistically different according to the LSD test at $P \leq 0.01$, (*) Means indicated with different letters in the same column and row are statistically different within the error limits of $P \leq 0.05$. HP: Harvest period, IR: Intra-row, NDF: Neutral detergent fiber, ADF: Acid detergent fiber

This may be due to the high prevalence of undersized seeds with lower nutritional tissue content as a result of the shedding of big seeds (fruits) during the late harvest period. Because small seeds may have lower nutritional value and higher pericarp content than bigger seeds (Yağdı, 2004). Indeed, pericarps are richer in cell wall materials (Zhao et al., 2015; Han and Hendek Ertop, 2022). It may also be due to the fact that the bracteoles (pericarps) surrounding the seeds in seeds harvested at 50% harvest period were less yellowed (ripened) compared to those harvested at 100% harvest. In studies conducted on different species on the subject, it has been stated that the crude protein content of the seeds increased as the 1000-grain weight increased (Tan and Temel, 2019; Hicks et al., 2002).

Stem crude protein, NDF ve ADF contents (%):

In the current study, only the stem ADF content was found to be statistically significant. When Table 8 was evaluated, it was determined that the highest average stem ADF ratios were in plants harvested at 100% maturity. This may have been due to the yellowing of leaves on the plant during late developmental stages and the shedding of a large portion of them. This may have led to an increase in structural carbohydrate (lignin, cellulose, hemi-cellulose) ratios. It was reported that stems of Mountain Spinach contain more extracellular matter than leaves and therefore have a higher ADF ratio (Temel et al., 2022a). It has also been reported that the ADF ratios of the herb obtained from Mountain Spinach were higher in late harvests (Temel et al., 2022b).

Table 8. Average stem crude protein, NDF and ADF contents of Mountain spinach according to intra-row and development stages

Intra-Row Distance	Stem Crude Protein Ratio (%)			Stem NDF Ratio (%)			Stem ADF Ratio (%)		
	Harvest Periods		Mean	Harvest Periods		Mean	Harvest Periods		Mean
	50%	100%		50%	100%		50%	100%	
10 cm	4.91	4.36	4.64	74.32	76.43	75.37	48.50	50.50	49.50
20 cm	4.81	4.15	4.48	75.20	77.47	76.34	49.34	51.29	50.32
30 cm	4.49	4.05	4.27	75.86	78.38	77.12	50.17	51.55	50.86
40 cm	4.00	3.92	3.96	76.08	79.00	77.54	50.22	52.62	51.42
Mean	4.55	4.12		75.36	77.82		49.56 b*	51.49 a	
LSD Value	HP: 0.56, IR: 0.80			HP: 0.10, IR: 0.14			HP: 1.52, IR: 0.14		

* Means indicated with different letters in the same row are statistically different within the $P \leq 0.05$ error limits according to the LSD test. HP: Harvest period, IR: Intra-row, NDF: Neutral detergent fiber, ADF: Acid detergent fiber

CONCLUSION

In this study where different intra-row distances and seed harvest times were tested in *Atriplex nitens* (Mountain Spinach), it was determined that the highest plant height (2.99 m), stem thickness (17.13 mm), maturation period (196 days) and seed crude protein content (17.13%) were obtained from plants sown with 40 cm intra-row distance, while seed yield (1055 kg/da), stem yield (2717 kg/da), biological yield (3772 kg/da) and harvest index (28.12%) values were obtained from plants sown with 10 cm intra-row distance. When evaluated in terms of harvest period, the highest plant height (2.87 m), stem thickness (16.70 mm), stem yield (2044 kg/da), seed NDF (37.51%), seed ADF (23.88%) and stem ADF (51.49%) rates were obtained from plants harvested at 100% maturity stage, while seed yield (811 kg/da), harvest index (31.41%) and thousand grain weight (6.63 g) were obtained from plants harvested at 50% maturity stage. These values showed that seed yield performances were better in plants sown with narrow intra-row spacing and harvested at 50% maturity stage.

ACKNOWLEDGEMENTS

This project was supported by the Iğdır University Scientific Research Projects Unit with the code number ZİF0424Y08.

Conflict of Interest

The authors of this article declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

REFERENCES

- Acar, R. & Günçan, A. (2002). Kaba yem olarak değerlendirilebilecek bazı yabancı ot karakterindeki bitkilerin morfolojik özellikleri ve ham protein oranlarının belirlenmesi. *Selcuk Journal of Agriculture and Food Sciences*, 16(29), 79-83.
- Acar, R., Özköse, A. & Koç, N. (2017). Selvi sirkenin (*Atriplex nitens* Schkuhr) alternatif kullanım potansiyelinin araştırılması. *Bahri Dağdaş Bitkisel Araştırma Dergisi*, 6(2), 18-22.
- Anonymous. (2023). Turkish State Meteorological Service. Ankara, Turkey.
- AOAC. (1997). Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists AOAC Intl., Gaithersburg, MD.
- Caballero, R., Barro, R., Rebole, C., Arauzo, M. & Hernaiz, P. J. (1996). Yield components and forage quality of common vetch during pod filling. *Agronomy Journal*, 88: 797-800. <https://doi.org/10.2134/agronj1996.00021962008800050018x>

- Demiroğlu Topcu, G. & Özkan, Ş. S. (2019). Akdeniz ekolojik koşulları için alternatif bir bitki: *Crotalaria juncea* L. (Krotalarya). *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, 22(2), 339-345. <https://doi.org/10.18016/ksutarimdog.vi.485713>
- Doudova, J., Douda, J. & Mandak, B. (2017). The complexity underlying invasiveness precludes the identification of invasive traits: a comparative study of invasive and non-invasive heterocarpic *Atriplex congener*s. *Plos ONE*, 12(4), E0176455. <https://doi.org/10.1371/journal.pone.0176455>
- Dursun, Ş. & Acar, R. (2015). Effect of different lead (Pb(NO₃)₂) dose applied on *Atriplex nitens* Schkuhr. seedling growth. *International Journal of Ecosystems and Ecology Sciences*, 5(4), 491-494.
- Geren, H., Kavut, Y. T. & Altınbaş, M. (2015). Bornova ekolojik koşullarında farklı sıra arası uzaklıkların kinoa (*Chenopodium quinoa* Willd.)’da tane verimi ve bazı verim özellikleri üzerine etkisi. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 52, 69-78. <https://doi.org/10.20289/euzfd.64719>
- Han, Ş. & Hendek Ertop, M. (2022). Kastamonu’da üretilen siyez buğdayının (*Triticum monococcum*) bazı kimyasal ve fiziksel özellikleri. *Academic Food*, 20(1), 63-70. <https://doi.org/10.24323/akademik-gida.1097846>
- Hicks, C., Tuinstra, M. R., Pedersen, J. F., Dowell, F. E. & Kofoid, K. D. (2002). Genetic analysis of feed quality and seed weight of sorghum inbred lines and hybrids using analytical methods and NIRS. *Euphytica*, 127, 31-40.
- Kara, N. & Yüksel, O. (2014). Karabuğdayı Hayvan Yemi Olarak Kullanabilir miyiz? *Türk Tarım ve Doğa Bilimleri Dergisi*, 1(3), 295-300.
- Keskin, B. & Önkür, H. (2019). Kinoa (*Chenopodium quinoa* Willd.)’nın tohum verimi ve bazı bitkisel özellikleri üzerine sıra üzeri ve sıra arası mesafelerinin etkileri. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, 22, 51-59. <https://doi.org/10.18016/ksutarimdog.vi.536580>
- Keskin, B. & Temel, S. (2022). Kuru şartlarda yetiştirilen selvi sirken (*Atriplex nitens*)’in ot verimi ve bazı verim öğeleri üzerine farklı ekim ve hasat dönemlerinin etkileri. *Türk Tarım ve Doğa Bilimleri Dergisi*, 9(2), 340-349. <https://doi.org/10.30910/turkjans.1060028>
- Keskin, B., Temel, S. & Akbay Tohumcu, S. (2023). Kıraç şartlarda yetiştirilen selvi sirken’in tohum verimi ve bazı verim unsurları üzerine farklı ekim zamanlarının etkileri. *Journal of the Institute of Science and Technology*, 13(2), 1394-1404. <https://doi.org/10.21597/jist.1243402>
- Kurgan, L. & Temel, S. (2024). Determination of germination characteristics and salinity and drought tolerances of Mountain Swan (*Atriplex nitens* Schkuhr). *Mediterranean Agricultural Sciences*, 37(1), 33-39. <https://doi.org/10.29136/mediterranean.1387536>
- Kuşvuran, A., Uysal Can, Ü. & Boğa, M. (2019). Farklı gelişme dönemlerinde biçilen Guar (*Cyamopsis tetragonoloba* (L.) Taub.)’ın yem verimi ve kalitesi. *Türk Doğa ve Fen Dergisi*, 8(1), 1-7.
- Li, Y., Qi, W. & Zhang, Y. (2023). Plant spacing effects on stem development and secondary growth in *Nicotiana tabacum*. *Agronomy*, 13(8), 2142. <https://doi.org/10.3390/agronomy13082142>
- Okcu, M. (2020). Türkiye ve Doğu Anadolu Bölgesi çayır-mer’a alanları, hayvan varlığı ve yem bitkileri tarımının mevcut durumu. *Atatürk Üniversitesi Ziraat Fakültesi Dergisi*, 51(3), 321-330. <https://doi.org/10.17097/ataunizfd.708884>
- Oktay, G. & Temel, S. (2015). Ebu cehil (*Calligonum polygonoides* L. ssp. *Comosum* L’Her) çalısının yıllık yem değerinin belirlenmesi. *Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, 32(1), 30-36. <https://doi.org/10.13002/jafag770>
- Osmond, C. B., Björkman, O. & Anderson, D.J. (1980). *Physiological Processes in Plant Ecology: Toward a Synthesis with Atriplex*. 1st edition, Vol. 36, Springer Verlag, Berlin.
- Pirasteh-Anosheh, H., Mirhosseini, A., Akram, N. A. & Hasanuzzaman, M. (2021). Forage potential of *Salsola* species in arid-saline rangelands. *Turkish Journal of Botany*, 45(3), 203–215. <https://doi.org/10.3906/bot-2010-36>

- Pirasteh-Anosheh, H., Ranjbar, G., Akram, N. A., Ghafar, M. A. & Panico, A. (2023). Forage potential of several halophytic species grown on saline soil in arid environments. *Environmental Research*, 219(2023), 114954. <https://doi.org/10.1016/j.envres.2022.114954>
- Saraçoğlu, M., Sürücü, A., Koşar, İ., Taş, M. A., Aydoğdu, M. & Kara, H. (2014). Şanlıurfa İli Halfeti İlçesi topraklarının bazı özellikleri ve bitki besin elementi kapsamalarının belirlenmesi. *Toprak Bilimi ve Bitki Besleme Dergisi*, 2(2), 38-45.
- Spehar, C. R. & Da Silva Rocha, J. E. (2009). Effect of sowing density on plant growth and development of quinoa, genotype 4.5, in the Brazilian savannah highlands. *Bioscience Journal*, 5(4), 53-58.
- Taiz, L. & Zeiger, E. (2008). *Bitki Fizyolojisi*. (Çev. Türkan, İ). Palme Yayıncılık, Ankara, ISBN: 978994434161.
- Tan, M. & Temel, S. (2019). *Quinoa in Every Aspect: Importance, Use and Cultivation*. IKSAD Publishing House, 183 p, Ankara, Turkey. ISBN: 978-605-7875-88-4.
- Tan, M. & Temel, S. (2020). Doğu Anadolu'nun kuru şartlarında farklı kinoa (*Chenopodium quinoa* Willd.) çeşitlerinin kaba yem üretimlerinin belirlenmesi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi (UTYHBD)*, 6(3), 554-561. <https://doi.org/10.24180/ijaws.741652>
- Tan, M. & Yolcu, H. (2021). Current status of forage crops cultivation and strategies for the future in Turkey: A Review. *Journal of Agricultural Sciences (Tarım Bilimleri Dergisi)*. 27(2), 114-121. <https://doi.org/10.15832/ankutbd.903732>
- Tan, M. (2018). *Baklagil ve Buğdaygil Yem Bitkileri*. Erzurum: Erzurum Atatürk Üniversitesi Ziraat Fakültesi Ders Yayınları. No: 256, Erzurum.
- Taş, T. (2010). *Harran Ovası Koşullarında Farklı Ekim Sıklıklarında Yetiştirilen Mısırdaki (Zea mays L. indentata) Değişik Büyüme Dönemlerinde Yapılan Hasadın Silaj ve Tane Verimine Etkisi*. Yüksek Lisans Tezi, Çukurova Üniversitesi.
- Temel, I., Keskin, B. & Temel, S., (2022b). Kıraç şartlarda yetiştirilen selvi sirken (*Atriplex nitens*)'in otunun kalitesi üzerine farklı ekim zamanları ve biçim dönemlerinin etkileri. *Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 12(3), 1831-1842. <https://doi.org/10.21597/jist.1133553>
- Temel, S. & Keskin, B. (2022a). Alternatif yem kaynağı olarak selvi sirken bitkisinde farklı ekim ve hasat dönemlerinin ot verim ve bazı verim bileşenlerine etkisi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 8(1), 92-107. <https://doi.org/10.24180/ijaws.1059666>
- Temel, S. & Keskin, B. (2022b). Farklı ekim zamanlarının selvi sirken bitkisinin tohum verimi ve bazı verim unsurları üzerine etkisi. *Çanakkale Onsekizmart Üniversitesi Ziraat Fakültesi Dergisi*, 10(2), 405-417. <https://doi.org/10.33202/comuagri.1184970>
- Temel, S. & Şahin, C. (2022). *Atriplex nitens* Schkuhr'in ot verim ve kalite özelliklerine farklı azot ve fosforlu gübre dozlarının etkisi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 8(3), 491-501. <https://doi.org/10.24180/ijaws.1174766>
- Temel, S. & Şahin, K. (2011). Iğdır ilinde yem bitkilerinin mevcut durumu, sorunları ve çözüm önerileri. *Yuzuncu Yıl University Journal of Agricultural Sciences*, 21(1), 64-72.
- Temel, S. & Tan, M. (2002). Erzurum şartlarında adi fiğ (*Vicia sativa* L.)'in ekim ve hasat zamanlarının belirlenmesi üzerine bir araştırma. *Atatürk Üniversitesi Ziraat Fakültesi Dergisi*, 33(4), 363-368.
- Temel, S. & Tan, M. (2020). Kuru koşullarda yetiştirilen farklı kinoa çeşitlerinin kaba yem kalite özellikleri açısından değerlendirilmesi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 6(2), 347-354. <https://doi.org/10.24180/ijaws.735557>
- Temel, S. & Tufur Öztürk, A. (2020). Kinoaada yüksek tohum üretimi için uygun ekim zamanı ve çeşitlerin belirlenmesi. *Journal of the Institute of Science and Technology*, 10(4), 3095-3108. <https://doi.org/10.21597/jist.794312>
- Temel, S. (2018). Tuzlu-alkali meralarda yaygın olarak yetişen çorak çimi (*Puccinellia distans*) ve sahil ayrığı (*Aeluropus litoralis*) bitkilerinin farklı gelişme dönemlerindeki besin içeriklerinin belirlenmesi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 4(2), 237-246.

- Temel, S. (2019). Yem kaynađı olarak deđerlendirilen *Noaea mucronata*'nın aktif gelişme süresince besin kompozisyonundaki deđişimler. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 5(1), 117-123. <https://doi.org/10.24180/ijaws.487284>
- Temel, S., Keskin, B. & Akbay Tohumcu, S. (2024a). The nutritional and chemical content of *Atriplex nitens* seeds grown under water and nutrient stress. *Turkish Journal of Field Crops*, 29(1), 1-8. <https://doi.org/10.17557/tjfc.1409610>
- Temel, S., Keskin, B. & Akbay Tohumcu, S. (2024b). Gübresiz ve yağış koşulları altında yetiştirilen *Atriplex nitens*'de farklı sıra aralıklarının tohum verim ve verim özelliklerine etkisi. *Journal of the Institute of Science and Technology*, 14(1), 458-469. <https://doi.org/10.21597/jist.1387892>
- Temel, S., Keskin, B. & Güner, Z. (2022a). Change in forage quality of whole plant, leaf and stem according to sowing and harvesting periods in *Atriplex nitens* Schkuhr grown without fertilizer. *Turkish Journal of Field Crops*. 27(2), 208-216. <https://doi.org/10.17557/tjfc.1105275>
- Temel, S., Sürmen, M. & Tan, M. (2015). Effects of growth stages on the nutritive value of specific halophyte species in saline grasslands. *Journal of Animal and Plant Sciences*, 25(5), 1419-1428.
- Ülgen, N. & Yurtsever, N. (1995). *Türkiye Gübre ve Gübreleme Rehberi*. Toprak ve Gübre Araştırma Enstitüsü Teknik Yayın No: 28, Ankara.
- Van Soest, P. J., Robertson, J. D. & Lewis, B. A. (1991). Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animals nutrition. *Journal of Dairy Science*, 74, 3583-3597. [https://doi.org/10.3168/jds.S0022-0302\(91\)78551-2](https://doi.org/10.3168/jds.S0022-0302(91)78551-2)
- Yađdı, K. (2004). Bursa koşullarında geliştirilen ekmeçlik buđday (*Triticum aestivum* L.) hatlarının bazı kalite özelliklerinin araştırılması. *Bursa Uludađ Üniversitesi Ziraat Fakültesi Dergisi*, 18(1), 11-23.
- Yarnia, M., Benam, M. B. K. & Tabrizi, E. F. M. (2010). Sowing dates and density evaluation of Amaranth (cv. Koniz) as a new crop. *Journal of Food Agriculture and Environment*, 8(2), 445-448.
- Zhao, Y. L., Yan, S. M., He, Z., Anele, U. C., Swift, M. L., Mcallister, T. & Yang, W. (2015). Effects of volume weight, processing method and processing index of barley grain on in situ digestibility of dry matter and starch in beef heifers. *Animal Feed Science and Technology*, 199, 93-103. <https://doi.org/10.1016/j.anifeedsci.2014.11.005>.