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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effect of Cutting Treatment on Seed Yield and Seed Quality of Dill

Biçimin Dereotu Tohum Verimi ve Kalite Özellikleri Üzerine Etkisi

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Abstract

Dill, *Anethum graveolens* L., is grown in various regions of the world. It has been used as vegetable and medicinal plant since ancient times. Seed quality is important in dill cultivation and there is limited information on the effects of cutting treatment in this species. This research was carried out to find out the effect of cutting treatment on phenological traits, seed yield and quality of dill at Ege University, Izmir, during 2016-2018. The experiments were carried out in the randomized complete block design with three replications, comprising of cutting treatment for both spring and autumn seeding period. Significant differences were noted in the flowering period, seed yield and quality attributes with cutting treatment for both seeding period. The obtained results showed that the days from sowing to bolting initiation were increased with cutting treatment from 51 days to 65 days in spring seeding period and from 153 days to 184 days in autumn seeding period. The plant height, number of umbels per plant, seed weight per plant were lower in the cut plants in comparison to that of uncut plants for both seeding period. The uncut plants has produced significantly higher plant height (113 cm-spring seeding period; 133 cm-autumn seeding period), number of umbels/plant (8.4-spring seeding period; 10.1-autumn seeding period) and seed weight/plant (6.4 g-spring seeding period; 10.9 g-autumn seeding period). The cutting treatment decreased germination percentage by 9.27% in the spring seeding period and by 12.13% in the autumn seeding period compared to the control plant seeds. Lower mean germination time at 20/30°C (3.77 days-spring seeding period; 4.54 days-autumn seeding period) were also observed in uncut plants. Thus, it was concluded that cutting is not recommended in the vegetative stage in dill seed production as it provided lower seed yield and seed quality for both autumn and spring seed planting periods.

Keywords: *Anethum graveolens* L., Cutting, Phenological observations, Seed weight, Germination

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Öz

Dereotu, *Anethum graveolens* L., dünyanın çeşitli bölgelerinde yetiştirilmektedir. Antik çağlardan beri sebze ve tıbbi bitki olarak kullanılmaktadır. Dereotu yetiştiriciliğinde tohum kalitesi önemlidir ve bu türde biçimin etkileri konusunda sınırlı bilgi bulunmaktadır. Bu araştırma, dereotunun fenolojik özellikleri, tohum verimi ve kalite parametreleri üzerine biçimin etkisini belirlemek amacıyla, 2016-2018 yıllarında Ege Üniversitesi, İzmir'de yapılmıştır. Denemeler, ilkbahar ve sonbahar tohum ekim döneminde, tesadüf blokları deneme deseninde, üç tekerrürlü olarak kurulmuştur. Her iki ekim döneminde de biçim ile çiçeklenme dönemi, tohum verimi ve kalite özelliklerinde önemli farklılıklar kaydedilmiştir. Elde edilen sonuçlar, tohum ekim tarihinden generatif dönem başlangıcına kadar geçen sürenin biçim uygulaması ile ilkbahar tohum ekim döneminde 51 günden 65 güne; sonbahar tohum ekim döneminde 153 günden 184 güne çıktığını göstermiştir. Biçim yapılan bitkilerde bitki boyu, bitki başına şemsiye sayısı ve bitki başına tohum ağırlığı, her iki ekim döneminde de biçim yapılmamış bitkilere göre daha düşük bulunmuştur. Biçim yapılmayan bitkiler, daha yüksek bitki boyu (113 cm-ilkbahar ekim dönemi; 133 cm sonbahar ekim dönemi), bitki başına şemsiye sayısı (8.4-ilkbahar ekim dönemi; 10.1-sonbahar ekim dönemi) ve bitki başına tohum ağırlığı (6.4 g-ilkbahar ekim dönemi; 10.9 g-sonbahar ekim dönemi) meydana getirmiştir. Biçim uygulaması kontrol bitki tohumlarına göre çimlenme yüzdesini ilkbahar ekim döneminde %9.27, sonbahar ekim döneminde ise %12.13 oranında düşürmüştür. Biçim yapılmayan bitkilerde daha düşük ortalama çimlenme zamanı (3.77 gün-ilkbahar ekim dönemi; 4.54 gün sonbahar ekim dönemi) gözlenmiştir. Bu nedenle, dereotu tohumluk üretiminde, hem sonbahar hem de ilkbahar ekim döneminde daha düşük tohum verimi ve tohum kalitesini sağladığı için, vejetatif aşamada biçimin tavsiye edilmediği sonucuna varılmıştır.

Anahtar Kelimeler: *Anethum graveolens* L., Biçim, Fenolojik özellikler, Tohum ağırlığı, Çimlenme

1. Introduction

Dill which has been cultivated since ancient times is native to South West Asia or South East Europe and belongs to the *Apiaceae* (*Umbelliferae*) family. There are two cultivated species of dill in the world: European dill (*Anethum graveolens*) which grows in most parts of the World and Indian dill (*Anethum sowa*) which grows in and around India (Gupta et al., 2012). In addition to its leaves being used as vegetable, both its leaves and seeds are consumed as medicinal and aromatic plants due to the essential oils it contains by 2.5-4% (Carvon, Apiol, Dihydrocarvon, Limonen) and it is also used as a sedative, antispasmodic, diuretic and carminative in babies (Öztürk et al., 2004).

According to the recent statistics, the amount of dill production has increased in Turkey. The amount of production, which was 2.978 tons in 2010, reached to 8.267 tons with an increase of 194% in 2020. While 1.6% of this production is provided by greenhouse production, open field growing accounted for the remaining part of it (Anonymous 2019a). And organic production is carried out for approximately 50 tons of the specified production amount while conventional production is performed for the remaining amount (Anonymous, 2019b). Based on production area, it is observed that 56% of dill production in Turkey is provided by the Mediterranean region, followed by Marmara region by 23%, Aegean region by 9%, and Central Anatolia region by 7% (Yaldız et al., 2018).

Seeds for dill production is provided by various public and private sector institutions. Mostly open pollination varieties are used. Seeds are also provided by farmers who produce their own seeds.

Dill is marketed continuously throughout the year as a green vegetable and is grown both in open field conditions and under plastic tunnels (Yaldız et al., 2018). Single cut is performed when grown as a green vegetable but two cuts are recommended under good care conditions (Vural et al., 2000). For seed production, dill requires cool weather conditions in vegetative development periods and warm and dry weather conditions during seed formation and seed maturity. Thus, seeds can be planted in regions having temperate climatic conditions with relatively warm winters in early spring (February-March) or in autumn (September-October) seasons (Alan et al., 2022). In both seasons, high and low soil temperatures cause failure of field emergence or irregular emergence in this species that is grown by direct seeding and that has a long field emergence period, resulting in product loss (Zehtab-Salmasi et al., 2006; Ghassemi-Golezani et al., 2018). In addition, there have been reports about problems with the quality of the produced dill seeds, such as poor germination and slow and heterogeneous field emergence (Bukharov et al., 2021; Alan et al., 2022).

It was stated that, various production factors such as soil, cultural practices, harvest time, and climate conditions affect seed quality (Delouche, 1980; Balkan, 2019; Kadıoğlu, 2021). Especially climate conditions (maximum and minimum temperature, precipitation, humidity) in the period that starts with flower formation and continues with pollination, fertilization, and seed maturation affect seed quality and yield (Singh et al., 2013). It has also been shown that dill seed yield and quality was affected by some factors such as weather conditions, irrigation, seed harvest time (Zehtab-Salmasi et al., 2006; Ghassemi-Golezani et al., 2018; Alan et al., 2022), seed stalk architecture, disease and pests (Bralewski et al., 2005; Dorota and Bralewski, 2006; Holubowicz and Morozowska, 2011), umbel position (Bukharov et al., 2021). To the best of our knowledge there have been no studies to date investigating the effects of cutting on seed quality in dill, although it was reported that cutting decreased seed yield (Moustafa et al.,1990; Osman and El-Wahab, 2009).

In general, private companies and medicinal and aromatic plant breeders produce dill seed in both autumn and spring seeding seasons depending on years and regions. At the same time, it is noted that farmers who produce their own seeds get their supply of seeds from cut plants. Therefore, in this study we aimed to compare the effects of cutting on phenological traits, seed yield, and quality of dill seeds under temperate climate conditions for spring and autumn seeding period.

2. Materials and Methods

2.1. Plant material and cultural practices

The study was conducted at Ege University Odemiş Vocational Training School field (latitude 38°12’N, longitude 27°52’E, altitude 111 m a.s.l.) and laboratory, and Ege University Seed Technology Application and Research Center laboratory in 2016-2018 period.

Physical and chemical properties of soil of the trial field were given in *Table 1*, climate data were given in *Figure 1*. The soil of the field was clay-loam, neutral, without salt problems and had a low organic matter content.

Table 1. Some physical and chemical characteristics of experimental soil

	Soil Depth, cm	
Characteristics	**0-30**	**30-60**
Organic Matter, (%)	1.34	0.78
Total Nitrogen, (%)	0.081	0.047
Phosphorus, (ppm)	24	28.8
Potassium, (ppm)	210	300
pH	7.9	7.7
Saturation (%)	60.9 (clay-loam)	62.9 (clay-loam)
Electrical Conductivity (MOhms/cm)	0.08	0.17

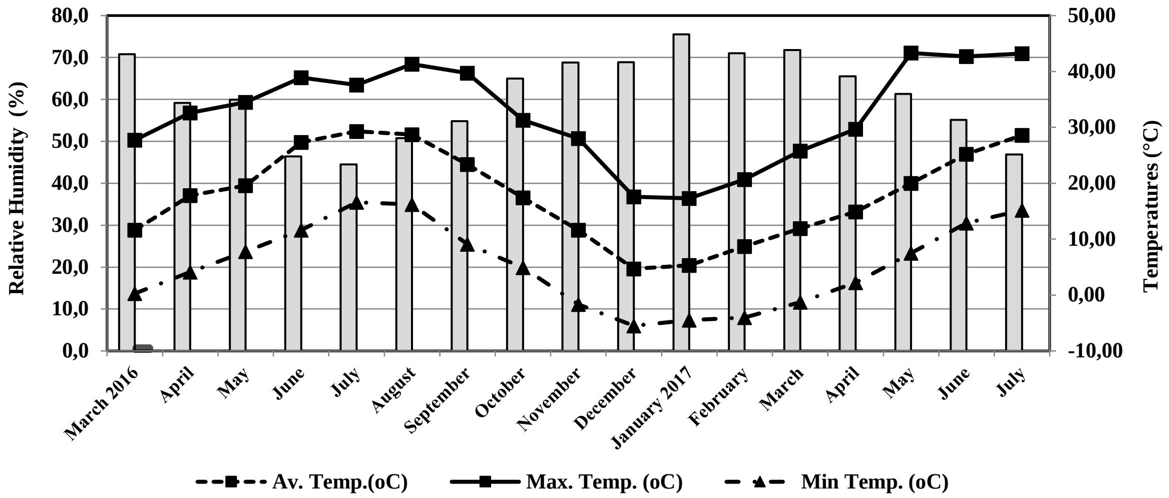

Figure 1. Mean monthly meteorological data of dill growing seasons from March 2016 to July 2017(Anonymous 2017)

For field tests a randomized block design was used with three replications in which 10 m x 1.50 m=15 m^2 plots contained two cutting treatment in both season. And experimental set up was randomized plot design for the seed quality parameters.

Dill seeds of cv. "Gönen" (from Kücükçiftlik Seed Company, Turkey) were sown with a spacing of 30 cm between plants within a row and 35 cm between the row on 20 March 2016 for the spring growing cycle and on 29 September 2016 for the autumn growing cycle. Same fertilization practices were performed in both season. Plants were fertilized with equivalent to 40 kg ha^{-1} nitrogen, 40 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O (Zehtab-Salmasi et al., 2006) based on the soil test results. Before sowing the soil was fertilized using about 13.3 kg 15:15:15 composite fertilizer per 0.24 acres. Thus potassium was completely added to the base. After removing the nitrogen and phosphorus provided from base dressing, all the remaining nitrogen and phosphorus were applied 30 days after sowing through fertigation as urea (3.5 kg / per acre) and MAP (monoammoniumphosphate; 3.3 kg / per acre). Weed control was conducted mechanically between plots and by hand in rows and drip irrigation method was applied as needed.

Cuttings were performed on May 11, 2016 for spring seeding period, on November 12, 2016 for autumn seeding period when plants reached 15-20 cm in height by cutting back to 3-5 cm above the soil level. In order to investigate the effects of cutting treatment, the following observations and seed yield and quality parameters were studied.

2.2. Phenological observations

When plants enter into generative stage, daily field observations were conducted to determine days to bolting initiation (the emergence of the elongated stalk on which flower buds develop), days to 50% bolting, days to the end of the bolting, days to flower initiation (5% open primary flowers) and days to 50% flower formation from date of sowing on the whole plot basis for both seeding period.

2.3. Seed yield parameters

Seed harvests were performed when seeds matured on main plant but not shed. This period was coincided with mid-July at cut and uncut plants in spring period (55 days after anthesis) and with the end of June at cut and uncut plants in autumn period (65 days after anthesis). During harvest period, 10 plants from the centre of each replicate were harvested randomly in the morning and plant height (cm) and number of umbels per plant were determined. Then the seeds were dried to 8% moisture content in room temperature and seed weight per plant (g) was determined. Subsequently, harvested seeds from each replicate were mixed then stored in sealed glass jars at 5 ± 1°C for three months.

2.4. Seed quality parameters

The seed quality tests were carried out in the laboratory of Ege University, Research and Technology Center for Seed Science. The germination tests were carried out using 8 × 50 seeds. Seeds were sown between moistened paper and kept at a temperature of 5 °C for seven days and then placed into an incubator at 20/30 °C- 16 hours in the dark and 8 hours in the light conditions for the standard germination (SG) test. A low temperature germination (LG) test was performed at 13 °C (ISTA, 2020). Normal seedling percentage were evaluated according to ISTA, (2020) after 21 days for SG test and 30 days for LG test. In addition, during both germination tests, the number of germinated seeds with a 2 mm radicle were counted every 24 h, to calculate mean germination time (MGT). MGT was calculated as Eq 1. (Ellis and Roberts, 1980);

$$\sum (nt)/ \sum n \qquad \text{(Eq.1).}$$

where n = number of seeds newly germinated (2 mm radicle) at time t;

t = days from when set to germinate

2.5. Statistical analysis

Analysis were conducted using TARİST statistical software (Açıkgöz et al., 1994) and least significant differences between means were calculated at *P=0.05*

3. Results and Discussion

3.1. Phenological observations

The effects of cutting on phenological characteristics of dills in both growing seasons are presented in *Table 2*. During spring seeding, significant differences were noted in the times from sowing to bolting initiation, 50% bolting, end of bolting and flower initiation ($P \leq 0.05$). Cutting treatment had no effect on the times from sowing to 50% flower formation. Bolting was initiated 51 days (May 12th) after seeds were sown in the uncut plants, while 65 days (May 25 th) after for the cut plants. Similar results were obtained for days to 50% bolting, end of bolting and days to flowering initiation where the span of reproductive phase was decreased. Although cutting had not statistically significant effect on the days to 50% flower formation, this period in cut plants was more extended compared to the uncut plants. It can also be seen that bolting was initiated on May 12th for uncut plants and on May 25th for cut plants while 50% flower formation took place at the end of May for both cut and uncut plants.

In autumn seeding period, cutting treatment had significant effect on bolting initiation ($P \leq 0.01$), 50% bolting, end of the bolting and flower initiation ($P \leq 0.05$), while it had no effect on the times from sowing to 50% flower formation (*Table 2*). Bolting was initiated 153 days (March 1st) after seeds were sown in the uncut plants, while 184 days (April 2nd) after for the cut plants. Also, cutting treatment increased the times from sowing to 50% bolting (from 166 days to 199 days), end of bolting (from 190 days to 206 days), flower initiation (from 173 days to 186 days) in this seeding period. It was also noted that the 50% flower formation took place by mid-April for both cut and uncut plants. This study showed that while the bolting and flowering were initiated in May for spring seeding cycle, they were initiated earlier (uncut plants-March, cutting plants-April) and were extended for a longer period in autumn seeding cycle (*Table 2*). While phenological properties varied according to genotypes, they can also change depending on cultural applications and climate characteristics. Because a certain vegetative growth is required ahead of bolting initiation, this period caused extension of bolting initiation and flower initiation in cut plants. Similarly, in *Trifolium alexandrinum* L. (Yadav et al., 2015) and *Medicago sativa* (Kowithayakorn and Hill, 1982) late bolting and flower initiation were reported in cut plants.

Table 2. The effect of cutting on bolting and flowering for spring and autumn seeding period in dill.

	Spring			Autumn		
	Uncut plants	Cut plants	*Significance*	Uncut plants	Cut plants	*Significance*
Days to bolting initiation (date)	51 (10 May)	65 (24 May)	*	153 (1 March)	184 (01 April)	**
Days to 50% bolting (date)	65 (24 May)	74 (02 June)	*	166 (14 March)	199 (16 April)	*
Days to the end of bolting (date)	72 (31 May)	81 (09 June)	*	190 (07 April)	206 (23 April)	*
Days to flowering initiation (date)	63 (22 May)	71 (30 May)	*	173 (21 March)	186 (03 April)	*
Days to 50% flower formation (date)	69 (28 May)	73 (01 June)	*ns*	195 (12 April)	200 (17 April)	*ns*

ns = not significant, * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$

3.2. Seed yield parameters

In spring seeding period, cutting had significant effect on plant height ($P \leq 0.01$), number of umbels per plant ($P \leq 0.05$), and seed yield per plant ($P \leq 0.05$) (*Table 3*). Cutting treatment decreased the plant height from 113 cm to 89 cm, the number of umbels per plant from 8.4 to 5.8 and the seed yield per plant from 6.4 g to 4.5 g.

In autumn seeding period, the cutting treatment had significant effect on plant height and seed yield per plant ($P \leq 0.01$) whereas it had no significant effect on the number of umbels per plant (*Table 3*). Plant height of cutting plants was taller by 9% (133 cm-uncut plant; 122 cm-cut plant). The seed yield was decreased by cutting treatments from 10.9 g seed/plant to 9.1 g seed/plant. Although there was no statistically significant difference in the number of umbels per plant in both treatments, the number of umbel per plant decreased by 0.4 with cutting.

Table 3. The effect of cutting on dill seed yield and yield parameters for spring and autumn seeding period

Seeding period		Plant height (cm)	Number of umbels/plant	Seed yield/plant (g)
Spring	Uncut plants	113±1.45	8.4±0.32	6.4±0.38
	Cut plants	89±1.45	5.8±0.32	4.5±0.38
Significance		**	*	*
Autumn	Uncut plants	133±0.73	10.1±0.32	10.9±0.15
	Cut plants	122±0.73	9.7±0.32	9.1±0.15
Significance		**	*ns*	**

ns = not significant, * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$
Data are expressed as mean ± standard error

In this study cutting back plants to 3-5 cm above the soil level when plants reached 15-20 cm in height lead to the decrease in plant height, in the number of umbels per plant and in seed yield per plant in both seeding period. Literature in relation to the effect of cutting treatment on the seed yield was varied. Moustafa et al., (1990) mentioned that first cutting of dill 75 days after seeding and second cutting 45 days after that increased seed yield compared to uncut plants. The increases in temperature along with the differences in total temperature values between the two cutting applications may have led to this result. On the other hand, Osman and El-Wahab (2009) argued that one or two cuts in dill and parsley resulted in decrease in seed yield and in components compared to uncut plants. Similar results of cutting treatment had been reported in *Setaria sphacelate* (Dwivedi et al., 1999), fenugreek (Gill et al., 2001), coriander (Datta et al., 2008), some grass plants (Bhatt et al., 2009), and sorghum (*Sorghum bicolor* (L.) Moench.) (Patil and Merwade, 2016). It was also noted in this study that the cutting treatment decreased the plant height by 21%, the number of umbel per plant by 31% and the seed yield per plant by 30% in spring seeding period but the treatment decreased all yield parameters by 8%, 4% and 16%, respectively in autumn seeding period. Thus, it can be stated that higher decrease on the yield and yield components in spring seeding period was due to the increase in maximum and minimum temperature (*Figure 1*) combined with day length causing bolting initiation in plants with insufficient vegetative growth in this growing period.

3.3. Seed quality parameters

As can be seen in *Table 4*, in spring seeding period the SG ($P \leq 0.01$), the LG ($P \leq 0.05$) and the MGT at 20/30 °C ($P \leq 0.05$) were affected significantly by cutting treatment, but treatment had no effect on the MGT at 13 °C. The SG was 86.3% in uncut plants and 78.3% with cutting treatment. The MGT was increased from 3.77 days to 4.38 days by cutting treatment. While LG were 83.5% in uncut plants, and it was decreased to 80.0% by cutting.

Table 4. The effect of cutting on seed quality of dill for spring and autumn seeding period

Seeding period		SG (%)	MGT at 20/30 °C (days)	LG (%)	MGT at 13 ºC (days)
Spring	Uncut plants	86.3±1.40	3.77±0.19	83.5±1.12	8.85±0.13
	Cut plants	78.3±1.40	4.38±0.19	80.0±1.12	8.60±0.13
Significance		**	*	*	*ns*
Autumn	Uncut plants	80.8±1.8	4.54±0.19	75.3±0.95	8.16±0.19
	Cut plants	71.0±1.8	5.15±0.19	59.0±0.95	10.69±0.19
Significance		**	*	**	**

ns = not significant, * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$
SG: standard germination; MGT: mean germination time; LG: low temperature germination.
Data are expressed as mean ± standard error

The effect of cutting on SG ($P \leq 0.01$), MGT (at 20/30 °C; $P \leq 0.05$), LG ($P \leq 0.01$), and MGT (at 13 °C; $P \leq 0.01$) in autumn seeding period was also found to be significant (*Table 4*). The cutting decreased SG from 80.8% to 71.0% and LG from 75.3% to 59%. The cutting treatment delayed germination from 4.54 days to 5.15 days at 20/30 °C; from 8.16 days to 10.69 days at 13 °C.

This study showed that higher SG and LG and lower MGT at both temperatures were found in cut plants. There are no data available on the effect of cutting on seed quality in dill. However, cutting treatment had adverse effect on seed quality compared to uncut grass plants in *Setaria sphacelat* (Dwivedi et al., 1999) and in sorghum (*Sorghum bicolor* (L.) Moench.) (Patil and Merwade, 2016). In this research, it was also determined that the cutting treatment decreased the SG by 9% and the LG by 4% in spring seeding period but the treatment decreased the SG and the LG by 12% and 22%, respectively in autumn seeding period. Particularly, the decrease in LG in autumn seeding might be due to the decrease in seed vigor by cutting.

In autumn seeding period, 50% flower initiation occurred in April and the seeds harvested in June. As shown in *Figure 1* minimum and maximum temperatures during seed development stages including pollination, fertilization, and seed maturation were recorded as 2 °C - 29.7 °C in April, as 7.5 °C - 43 °C in May, and as 12.9 °C - 42.7 °C in June, respectively. In spring seeding period, 50% flower initiation occurred in May and the seeds harvested in July. And minimum and maximum temperatures varied between 7.8 °C – 34.5 °C in May, 11.6 °C – 38.9 °C in June, and 16.6 °C – 37.6 °C in July, respectively. Therefore, it may be hypothesized that significant decrease in seed quality parameters in autumn period, particularly in cut plants, may result from extreme temperatures during pollination, fertilization, and seed maturation periods. Decreasing effect of high temperature conditions after flower initiation and thorough the fertilization and seed maturation periods in seed quality has also been reported in *Phaseolus vulgaris, Oriza sativa*, *Hordeum vulgare* L. and wheat (Siddique and Goodwin, 1980; Ellis et al., 1993¸ Ellis and Pieta Filho, 1992).

According to Bukharov et al. (2021) who studied the short-term (1-5 days) effect of high temperature (40°C) on the growth of the embryo and germination of dill seeds, the degree of development of the embryo determines seed germination. The reported results showed that the less developed embryos in seeds from secondary umbels are more sensitive to high temperatures during dill seed germination. It can be stated that the extreme temperatures during seed production can lead to less developed embryos in dill seeds.

4. Conclusions

We found that the days to bolting and to flower initiation in cut plants was shorter than in uncut plants but cutting had no effect on the days from sowing to 50% flower formation. Also, while the bolting and flowering initiated in May for spring seeding period, both phenological stages took place earlier (in March for uncut plants- and in April in cut plants-) and times for each stages were longer in autumn seeding period. Plant height, number of umbels per plant and seed weight per plant decreased with cutting treatment. The uncut plants had the highest seed yield and seed quality due to better attributing components. In addition cutting treatment decreased germination percentage at 20/30°C (SG) and at 13°C (LG), and increased mean germination time at 20/30°C. Thus it can be concluded that cutting treatment of dill at vegetative stage to market green leaves is not advisable for commercial seed production of dill.

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