Turk J Agric For
30 (2006) 281-286

Effect of Sowing Date and Limited Irrigation on the Seed Yield and Quality of Dill (*Anethum graveolens* L.)

Saeid ZEHTAB-SALMASI[1,*], Kazem GHASSEMI-GOLEZANI[1], Sajad MOGHBELI[2]

[1]Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Tabriz, Tabriz, IRAN

[2]Agricultural Offices of Salmas, Salmas, West Azarbaijan, IRAN

Received: 12.12.2005

Abstract: Field and laboratory experiments were carried out in order to investigate the influence of 3 sowing dates and 4 irrigation disruption treatments at different growth stages on the seed yield and quality of dill (*Anethum graveolens* L.). The results showed that for successful seed production dill must be sown in early spring (3 to 18 April), since there was no significant difference in seed yield between the sowing dates of 3 April (S_1) and 18 April (S_2). Seeds from S1 sowing had a higher percentage of germination after accelerated ageing (AA), a faster germination rate and a heavier seedling dry weight (SDW), compared to S_2 and S_3 (4 May). Irrigation disruption during stem elongation (I_1) and umbel appearance (I_2) had no significant effect on mean seed weight, AA germination, mean germination time (MGT) or SDW of harvested seeds. However, water deficit during seed filling (I_3) reduced seed vigour significantly. Although irrigation disruption at this stage (I_3) had no considerable effect on the seed yield of dill, it reduced seed quality and vigour, especially at later sowings (S_2 and S_3). Therefore, it was recommended that for producing high quality dill seeds it is necessary to provide sufficient water during seed filling.

Key Words: *Anethum graveolen*s, dill, sowing date, limited irrigation, seed quality, seed yield

Introduction

Dill (*Anethum graveolens* L.) is an annual and sometimes biennial herb of the family *Apiaceae*, which is native to south-west Asia or south-east Europe, and has been cultivated since ancient times (Bailer et al., 2001). It is used as a vegetable, a carminative, an aromatic and an antispasmodic (Hornok, 1992; Sharma, 2004), and as an inhibitor of sprouting in stored potatoes (Score et al., 1997).

Dill seed is usually sown in early spring for seed production, although sowing in cold soils may give rise to poor emergence, and a weak crop that has little chance of producing a high quality yield at harvest (Hornok, 1992). While time of sowing can influence crop establishment, it also dictates the environment experienced during seed development, both within and above the crop canopy (Castillo et al., 1994). The effects of sowing date and its interaction with the environment on dill seed quality are not well understood, although it is known that high temperatures during seed development can give lower seed quality in other crops (Halligan, 1986; Castillo et al., 1994; Greven et al., 2004). Low quality seed lots may affect yields in 2 ways: first because emergence from the seedbed may be less than expected, and then plant population density may be sub-optimal, and second because the growth rate of those plants that do emerge may be less than those grown from high quality seeds (Roberts and Osei-Bonsu, 1988). In a large part of the agricultural areas in the world, water is an important factor limiting growth and productivity. An efficient use of scarcely available water and good productivity under poor water supply are desirable for crops in west Asia (Boogaard, 1995). Moisture stress during seed development is another factor that can affect seed vigour (Delouche, 1980). Since water resources in north-west Iran are limited at the later stages of dill growth and development, this research aimed to investigate the influence of sowing date and disruption of irrigation at different stages of growth on the seed quality and yield of dill.

* Correspondence to: szehtabi@yahoo.com and s-zehtab@tabrizu.ac.ir

Materials and Methods

Experiment layout

A field experiment was conducted during 2003 at the Salmas Research Farm (Lat. 38°, 11'; Long. 44°, 48' and elevation 1385 m) on dill (*Anethum graveolens* L. var. Mammoth). Salmas is located in the north-west of Iran and has a mean annual temperature of 11.5 °C and average rainfall of 270 mm. The soil was a sandy-loam with EC of 0.63 ds m^{-1}, pH of 7.6, field capacity of 19 (% w/w) and permanent wilting point of 12(% w/w). Some climate data from sowing to harvest of dill are presented in Table 1.

The research area was ploughed in October 2002 and again in March 2003. Then, after the application of 40 kg ha^{-1} nitrogen, 40 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O, the site was harrowed to prepare the seed bed.

In this experiment 4 irrigation treatments were used: I_1 = irrigation was skipped during stem elongation (2 weeks), I_2 = irrigation was skipped during umbel appearance (2 weeks), I_3 = irrigation was skipped during the seed filling period (3 weeks), and I_4 = weekly irrigation (control). These treatments were applied to plots established on 3 sowing dates (S_1 = 3 April, S_2 = 18 April and S_3 = 4 May) in a factorial experiment. Plots of 5 rows, 0.25 m wide and 3 m long were arranged in a randomised complete block design (RCBD) with 3 replications. Seeds were sown 3 cm apart at about 2 cm depth.

Plants grown under S_1, S_2 and S_3 were hand-harvested from 1.5 m^2 in the centre of each plot on 8, 17 and 25 July 2003, respectively. Immediately after harvest, seeds were detached from the umbels by hand. Subsequently, seeds were ambient air dried for about a week and transferred into a laboratory for quality tests.

Germination and seed vigour tests

Germination tests were carried out using 4 replicates of 25 seeds for each treatment. Seeds were sterilised with 2.5 g l^{-1} thiram for about 1 min, before testing. Seeds were placed on top of two 30 x 30 cm wetted germination papers (Whatman), which were then placed in plastic bags to prevent water loss. The seeds were germinated at 20 °C for 10 days in the dark, after which the numbers of normal and abnormal seedlings and remaining seeds were counted (ISTA, 2005). In addition, the numbers of germinated seeds with a 2 mm radicle were counted every 24 h, to estimate mean germination time (MGT) as described by Ellis and Roberts (1980). Mean seedling dry weight (SDW) was determined at the end of germination test, after drying the normal seedlings at 70 °C for 48 h.

For accelerated ageing (AA) a slight modification of the method described by Hampton and TeKrony (1995) was used. From each treatment, 10 g of seeds with seed moisture content of 13% (± 1) was placed in a single layer on plastic netting suspended 4 cm above 50 ml of water in a plastic container. The seeds were kept at a constant 45 °C (± 0.5 °C) for 48 h. The germination test after AA followed the same protocol as for standard germination, in order to determine the percentage of normal seedlings for seeds of each treatment.

Data given in percentages were subjected to arcsine transformation before statistical analysis. The MSTAT-C software package was used to analyse all the data and to calculate correlation coefficients between quality parameters (MSTAT-C, 1993).

Table 1. Some climate changes during growing season of dill in 2003 at Salmas.

Months	Temperature °C			Precipitation mm	Relative Humidity %
	Min.	Max.	Mean		
April	2.3	17.3	9.1	30.2	70.8
May	7.2	24.2	13.3	42.5	73.2
June	10.2	30.8	18.7	10.2	64.3
July	15.8	32.2	23.1	5.7	61.7

Results

Sowing date and irrigation disruption had a significant effect on seed yield (Figure 1), thousand seed weight (TSW), AA germination and seedling dry weight (SDW). Mean germination time of the harvested seeds was also significantly affected by sowing date, but not by irrigation treatments. Neither sowing date nor irrigation disruption had a significant effect on germination percentage. Interactions between sowing date and irrigation treatments were not significant for TSW, AA germination or SDW, but were significant for seed yield, germination percentage and MGT (Table 2).

Mean seed yield of dill ranged from 430 to 850 kg ha^{-1} (Figure 1). Plants sown on 3 and 18 April (S_1 and S_2) had greater seed yield than those sown on 4 May (S_3). Average seed yield was reduced significantly by

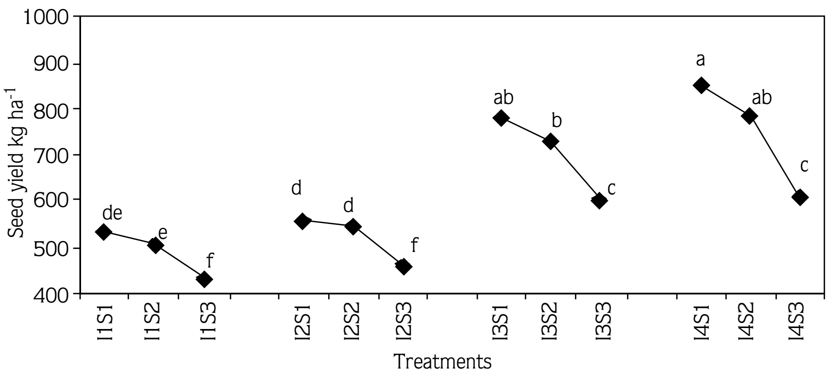

Figure 1. Mean seed yield of dill as affected by water limitation at different sowing dates. S_1 = 3 April, S_2 = 18 April, S_3 = 4 May, I_1 = Irrigation disruption during stem elongation, I_2 = Irrigation disruption during umbel appearance, I_3 = Irrigation disruption during seed filling and I4 = weekly irrigation (control). Different letters indicate significant difference at P < 0.05.

Table 2. Effects of sowing date and irrigation disruption on vigour parameters of harvested dill seeds.

Treatments	TSW+ (g)	Germination (%)	AA+ germination (%)	MGT+ (day)	SDW+ (g)
Sowing date (S)					
3 April (S_1)	1.44	92	66	2.11	0.018
18 April (S_2)	1.31	93	60	2.67	0.014
4 May (S_3)	1.15	91	57	2.85	0.011
$LSD_{0.05}$	0.09	NS	2.7	0.51	0.002
Irrigation disruption (I)					
Stem elongation (I_1)	1.37	92	66	2.52	0.021
Umbel appearance (I_2)	1.41	93	67	2.31	0.022
Seed filling (I_3)	1.20	92	61	2.81	0.019
Control (I_4)	1.42	94	68	2.35	0.014
$LSD_{0.05}$	0.11	NS	3.2	NS	0.004
Interactions (S x I)	NS	**	NS	**	NS

+ TSW = thousand seed weight, AA = accelerated ageing, MGT = mean germination time, SDW = seedling dry weight ** = significant at P < 0.01 and NS = not significant.

irrigation disruption during stem elongation (I_1) and umbel appearance (I_2). However, water deficit during the seed filling period (I_3) did not affect seed yield (Figure 1).

The first sowing (3 April) produced the largest seeds, with a thousand seed weight (TSW) of 1.44 g, which was 0.13 g and 0.29 g heavier than seeds from 18 April and 4 May sowings, respectively. Only irrigation disruption during the seed filling period reduced TSW (Table 2). At S_2 and S_3 sowings, germination percentage of the seeds from the I_2 and I_3 treatments was reduced significantly, but at the S_1 sowing irrigation disruption had no significant effect on the germination percentage of harvested seeds (Figure 2).

Germination percentage after AA decreased significantly for seeds of S_2 and S_3 sowings (Table 2). AA germination was significantly higher for S_1 seeds (66%) than for S_2 (60%) and S_3 (57%) seeds (Table 2). There was no significant difference in AA germination for seeds produced under I_1, I_2 and I_4 irrigation treatments. However, seeds from I_3 (water deficit during the seed filling period) had significantly lower AA germination. Mean germination time (MGT) was longer for S_2 and S_3 seeds than for S_1 seeds, showing that the seeds from S_1 sowing germinated faster. Water deficit had no significant effect on the MGT of harvested seeds (Table 2). However, there was a significant interaction between sowing date and irrigation treatments (Figure 3).

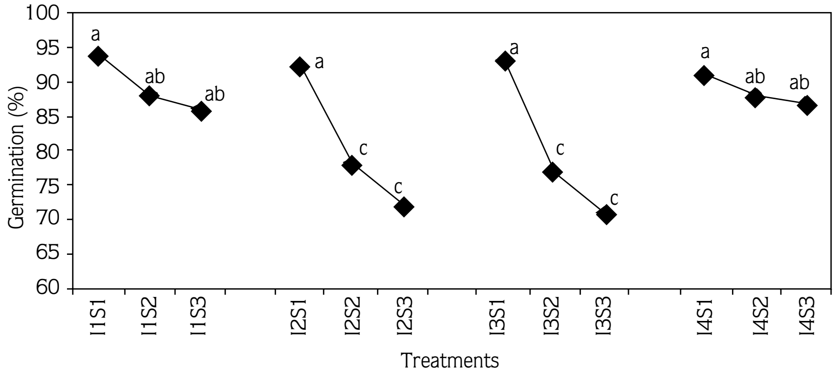

Figure 2. The effect of sowing date and water deficit on germination percentage of harvested dill seed. S_1 = 3 April, S_2 = 18 April, S_3 = 4 May, I_1 = Irrigation disruption during stem elongation, I_2 = Irrigation disruption during umbel appearance, I_3 = Irrigation disruption during seed filling and I4 = weekly irrigation (control). Different letters indicate significant difference at $P < 0.05$.

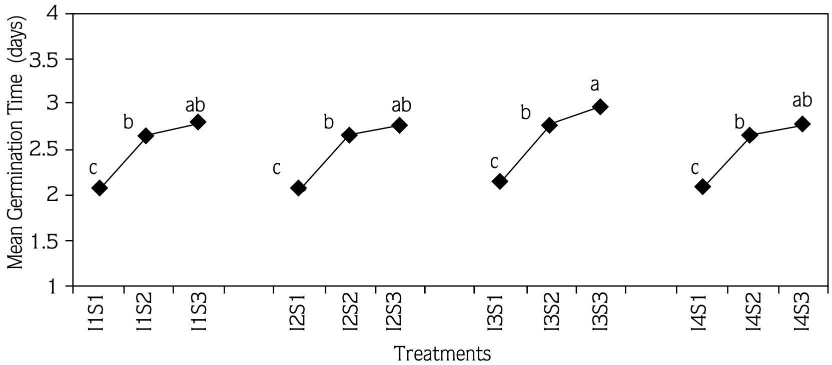

Figure 3. Mean germination time (MGT) of dill seeds as affected by sowing date and water deficit. S_1 = 3 April, S2 = 18 April, S_3 = 4 May, I_1 = Irrigation disruption during stem elongation, I_2 = Irrigation disruption during umbel appearance, I_3 = Irrigation disruption during seed filling and I4 = weekly irrigation (control). Different letters indicate significant difference at $P < 0.05$.

The average seedling dry weight (SDW) of harvested seeds was decreased significantly by delaying the sowing date (Table 2). Seeds from I_3 irrigation had the lowest SDW among the irrigation treatments, but SDW of seeds from I_1 and I_2 did not decrease significantly, compared to I_4 (Table 2).

Discussion

Sowing date

The environment during seed development is a major determinant of seed quality, particularly seed vigour (Castillo et al., 1994). For successful seed production at this site, dill must be sown in early spring (3 to 18 April), as delaying sowing until early May reduced seed yield (Figure 1). While sowing date had no significant effect on germination percentage of the harvested seeds (Table 2), vigour differences among these seeds were significant ($P < 0.05$). Seeds from S_1 showed higher vigour as measured by AA germination, mean germination time and seedling dry weight (Table 2). Greven et al. (1997) suggested that a lower air temperature during seed maturation increases the duration of seed growth, which enabled seeds to be better organised at the cellular level. Therefore, the lower quality of seeds produced from S_2 and especially S_3 sowings (Table 2) could be due to higher temperatures, which occurred during the seed filling period (Table 1). Adam et al. (1980) demonstrated the effect that time of sowing can have on soybean seed quality, when they found that hotter environmental conditions were associated with lower quality of harvested seeds. Our results showed that for dill seed production sowing in early April is preferable in north-west Iran.

Irrigation disruption

Water deficit during stem elongation (I_1) and umbel appearance (I_2), when plants grow fast, can reduce seed yield (Hornok, 1992; Sharma, 2004). However, plants grow more slowly during the seed filling period. Consequently, disrupting irrigation at this stage had no significant effect on dill seed yield.

In this study, germination percentage of the seeds from different irrigation treatments did not differ significantly (Table 2), but their interaction with sowing date was significant. Germination reductions of the seeds produced under I_2 and I_3 for S_2 and S_3, were probably due to early maturity and seed ageing on the mother plant. AA germination, MGT, SDW and TSW of the seeds from I_1 and I_2 were similar to I_4 (control). In comparison, the vigour of the seeds produced under I_3 was significantly lower than that of the other irrigation treatments (Table 2). Although abundant information demonstrates an association between parameters of maturity such as seed size (and weight) and seed vigour, the environment during seed maturation has an indirect effect on its potential vigour (Hoy and Gamble, 1985). This study also proved that there is a positive correlation between seed weight and vigour as measured by AA ($r = 0.923$) and MGT ($r = -0.913$). The results contradict the view that larger seeds are better quality, and are similar to those reported by Pieta Filho and Ellis (1991), in which the seed production environment that provided heavier seeds also provided maximum seed quality. Moreover, the demonstration here that irrigation can substantially affect seed quality development is not only of practical interest to commercial seed producers, but is also of relevance to the elucidation of those factors responsible for seed quality.

In general, it can be concluded that for producing high quality dill seeds it is necessary to provide sufficient water for plants during seed filling, especially for delayed sowings.

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