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Seed Physiological Maturity in Dill (*Anethum graveolens* L.)

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ABSTRACT

Seed physiological maturity was studied to determine the optimum harvest time for dill seed production at the Faculty of Agriculture, Ubon Ratchathani University during October 2005 to March 2006. Seed reached physiological maturity at 35 days after anthesis with germination of 37.5%. At this stage seed moisture content was too high to harvest and germination percentage was low. The optimum time to commence harvesting should be after seed physiological maturity (45-70 days after anthesis) but before seed shedding. At these stages, seed color was dark brown with 9-12% seed moisture content. The highest seed germination (68.5%) was at 70 days after anthesis while seed started to shed.

Key words: germination, seed development, physiological maturity

INTRODUCTION

Herbs and spices, grown wildly in various regions of the world, have been used for several purposes since ancient times. Several uses of these plants are known for culinary purposes. Dill classified as a spice vegetable (Siemonsma and Piluek, 1994) is being applied more and more into modeling the flavor of numerous food products. It can be used as an ingredient in dried seasoning mixtures and in the production of cheeses, fish, and vegetarian dishes; as an admixture in "ready-to-eat" and more recently "do-it-for-me" dishes (Pszczola, 2001; Sloan, 2004).

Dill is a member of the plant family Umbelliferae and is mainly propagated by seed. Inflorescence has an indeterminate flowering habit (Rubatzky *et al.,* 1999). Lack of uniformity in flowering results in non-uniform seed maturation and creates difficulty in determining the optimum time of harvests. If harvest is too early, a high percentage of immature seeds may exist, while if it is too late, shattering can occur and field weathering may cause deterioration in mature seed. Keller and Kollmann (1999) reported that germination is a critical stage in the life cycle of weeds and crop plants, and often controls population dynamics, with major practical implications. To produce good quality seed, timely harvest is crucial to maximize seed viability and vigor.

Seed needs to be collected when mature, as immature seed has lower viability and poor storage life (Copeland and McDonald, 2001).

Visual indicators of physiological maturity (PM) have been used as an indicator of seed maturity. Seed shrinkage and loss of green color from the pod have been suggested as indicators of PM for okra (Demir, 1994). Some easily identifiable criteria to characterize seed maturity (the relation between visual indicators and PM) include formation of black layer in corn

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(Daynard and Duncan, 1969), seed moisture content in onion (Steiner and Akintobi, 1986) and seed color in brassica (Still and Bradford, 1998). Because quick field estimation of PM from physiological measurements such as seed dry weight or moisture content was somewhat difficult, methods for determining PM based on morphological indicators were needed.

Although several studies have been reported on others Umbelliferae seed production (George, 1999; Rubatzky *et al.,* 1999; Desai, 2004), the information about optimum harvest maturity of dill seed is none. A better understanding of optimum harvesting time for dill will further improve quality and quantity of seed produced. Such information is also important for planning of harvesting. Therefore, the objective of this paper was to determine the time when physiological maturity of dill seed is reached and how seed moisture, seed weight, germination percentage and seed color change during seed development and maturation.

MATERIALS AND METHODS

Experimental site and plant material

The experiment was conducted at the Faculty of Agriculture, Ubon Ratchathani University, Ubon Ratchathani Province, Thailand (15 °N, 104 °E; 130 m ASL). The site is on an upland sandy low humic soil (Roi-et soil series). Soil samples to 10 cm showed that the soil is acid (pH 4.8) and low in organic matter (0.9 %), N (0.05%), P (11.0 ppm) and K (18 ppm). Dill seeds, collected from Warinchamrap District, Ubon Ratchathani Province, were planted in peat media filled in plastic trays containing 104 inverted cone cells on October 1, 2005. Plants were transplanted on October 15, 2005 in a randomized complete block design with four replications. Plot size was 5.0 × 1.5 m^2 wide with 30 cm spacing in row and between rows. Prior to transplanting, one hundred and eighty seven kg ha^{-1} of 15-15-15 was applied to all well cultivated plots.

Sampling procedures

Once flowering began, daily field observations were carried out and sampling was conducted when the majority of the plants in the plot flowered. Umbels were deemed to have commenced anthesis when 50% of the florets were open. Forty plants from each replication were randomly chosen and tagged on the primary umbel for subsequent sampling. Three umbels from each replicate were randomly collected at 5-day intervals starting from 10 to 70 days after anthesis. The collected samples were immediately sealed in plastic bags and were taken to the laboratory. Harvested seeds from each replicate were thoroughly mixed and divided into two portions for seed moisture and germination determinations.

Dry weight and seed moisture content determination

Seed moisture content was measured by the hot-air oven method. Fresh weight (FW) of seed was recorded immediately after separation from inflorescences. Seed samples (four replicates of 100 seeds) were dried in oven at 103 °C for 17 hours and the dry weight (DW) was recorded to determine seed moisture content (SMC) in percentage on wet weight basis (ISTA, 2003).

Germination test

Seeds were hand threshed and dried in ambient conditions for 5 days. Seeds were then placed in an air-conditioned chamber (15^0C, 40% relative humidity) to minimize loss of SMC. When the seed lot weight remained constant (8% SMC), a germination test (four 100 seed samples) was carried out on two layers of germination paper in rectangular transparent plastic boxes (14 × 9 × 5 cm) and kept at 20/30 °C (16 hrs in the dark and 8 hrs in the light). First and final counts were taken at 7 and 21 days, respectively (ISTA, 2003).

Seed color comparison

Photographs of seed were taken at each harvest and a standard color chart, developed by the Royal Horticultural Society (RHS, 2001), was used to match seed color for each harvest. The closest color in the chart was used because the range of colors available in RHS color chart did not exactly match the seed colors.

Statistical analysis

The data on fresh weight, dry weight, seed moisture content, germination and fresh-ungerminated seed were analyzed using ANOVA. The treatment means were tested by the Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Fresh weight and dry weight

Fresh weight and dry weight were influenced by days after anthesis (Table 1). This indicates that there were increases in both fresh and dry weights within the seed during seed development. Thousand seed fresh weight increased from 4.0 g at 10 day after anthesis and reached the maximum value of 13.8 g at 35 days after anthesis. From 35 to 40 days after anthesis fresh weight decreased rapidly and thereafter slightly decreased. Maximum dry weight of dill seeds was reached 35 days after anthesis. The fresh weight developed ahead of the dry weight, reflecting the movement of water into the cell to drive cell expansion before dry weight gain occurs in the latter part of seed expansion (Egli, 1997). The greatest gain in dry weight occurred at 35 days after anthesis which meant that seed no longer had a functional connection to the vascular system of the mother plant and assimilate no longer moved into the seed. This indicates that dill seed reached PM 35 days after anthesis. A similar pattern had been reported in other species such as carrot (Nascimento *et al.*, 2003) and eryngo (Ekpong and Sukprakarn, 2006). However, there was a considerable decrease in dry weight in the last five harvests. This reduction possibly at the final stage of maturity was due to respiration by the seed might have exceeded the net import of sugar or other substrates resulting in loss of dry matter (Bewley and Black, 1994). Seed shedding commenced at 70 days after anthesis.

Seed moisture content

SMC changed significantly with time after anthesis (Table 1). At the very early stages of growth the moisture content of seeds was very high and decreased slowly to 35 days after anthesis and then decreased rapidly during 35 to 40 days after anthesis. The decrease in SMC at early developmental stages was a result of the increase in dry matter (Egli, 1997). The SMC at maximum dry weight was 67.0%. However, at this stage SMC was too high for direct harvesting or storage without further drying. Optimum harvest time should be after seed PM (10 days) but before seed shedding (70 days).

Seed color

The loss of the green colors of seed, along with change in seed texture are considered as practical and rapid field indicators for seed harvest (Demir, 1994; Elias and Copeland, 2001), which relate to seed dry weight and moisture content. Gradual change in seed color of dill was also observed with progressive development and maturity (Table 1). At the very early stages, seeds were green to yellowish-green up to 30 days after anthesis. With further development, the seeds turned to grayish-brown and then were brown when maximum dry weight was attained (40 days after anthesis). Thereafter, seed color became darker until seed started to shed. As seed color changed throughout the period of seed development and maturation, the seed dry matter also changed. Therefore, the change in seed color could be a dependable indicator of PM in dill. Visual indicators of PM have been suggested for

other Umbelliferae such as seed color in carrot (Rubatzky *et al*., 1999) and eryngo (Ekpong and Sukprakarn, 2006).

Germination

Seeds harvested at 10 and 15 days after anthesis contained immature seeds that did not germinate but some of those harvested on and after 15 days after anthesis were able to germinate (Figure 1). Only 4.5% germination was recorded for seed harvested at 20 days after anthesis and germination increased progressively to 29.5% at PM while fresh un-germinated (FUS) seed was at 60%. It indicates that dill exhibited forms of seed dormancy. Baskin and Baskin (2004) pointed out that abscisic acid (ABA), produced by embryo, induced dormancy during seed development. In most cases, ABA content reaches a maximum at about the time of maximum seed growth rate, then declines later in development to low levels at maturity (Kermode, 1995). In this case, germination reached maximum (68.5%) at 70 days after anthesis before seed shedding but was not completely free from or released from seed dormancy. These results which were consistent with other works, implies that many seeds become dormant during the mid-maturation phase, which prevents their germination until they are shed from the mother plant or required specific conditions are met before germination can occur (Welbaum, 1999; Samarah, *et al*., 2004; Hayati *et al*., 2006). Thus, further studies on the methods to overcome seed dormancy are needed.

CONCLUSION

This study demonstrated that mature dill seed could be safely harvested between 45-70 days after anthesis and when seed moisture content was between 9-12%. This corresponds to the time that fruits are fully dried but not shed. Color matching using a standard color chart against seed color can also be used as an instant seed maturity indicator by dill seed producers.

Table 1 Changes in fresh weight, dry weight, seed moisture content and seed color at differentstages during seed development.

Days after anthesis	FW [1] (g)	DW (g)	SMC (%)	Seed color
10	4.1e-g[1]	0.7h	81.9a	Green141B
15	6.8c	1.5g	78.2b	Yellowish-green144A
20	7.2c	2.2f	67.0cd	Yellowish-green144B
25	13.0b	3.8cd	70.7c	Yellowish-green144C
30	12.7b	4.1b	67.3de	Yellowish-green 152A
35	13.8a	4.5a	67.0e	Grayish-brown N199C
40	5.9d	4.8a	17.7f	Brown 200A
45	5.6d	4.6a	10.8gh	Brown 200A
50	4.5e	4.0bc	11.7gh	Brown N200A
55	4.4ef	3.9bc	10.7gh	Brown N200A
60	4.1e-g	3.7c-e	10.4gh	Brown N200A
65	3.9fg	3.5de	12.2gh	Brown N200A
70	3.8g	3.4e	9.0h	Brown N200A
C.V. (%)	4.5	2.9	4.0	

[1] Means followed by same letter within column are not significantly different at the 0.01 level according to the Duncan's Multiple Range Test.

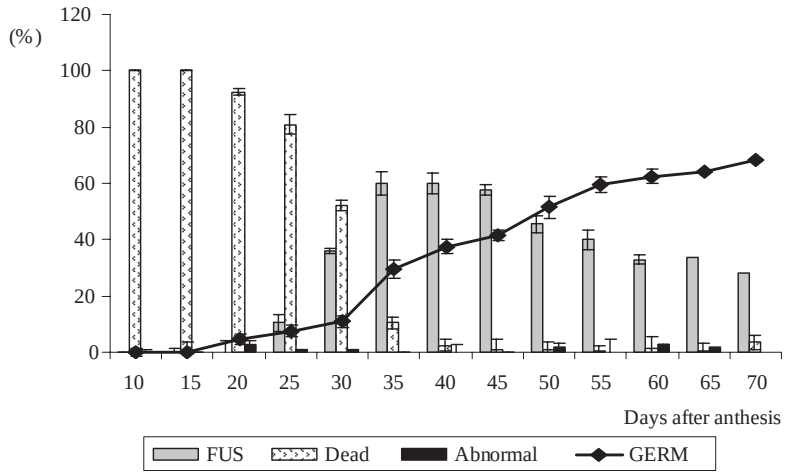

Figure 1 Changes in germination (GERM), fresh-ungerminated seed (FUS), dead seed and abnormal seedling during seed development. Error bars indicate the standard deviation from mean of the four tests at p = 0.01.

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