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Seed Development and Maturation on Seed Quality of Upland Rice cv. Dawk Pa-yawm

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Abstract

Poor seed quality is a major problem of upland rice production in southern Thailand. The production of maximum quality seed should be harvested at physiological maturity. The objectives of this paper were to study the changes of morphological and physiological traits during seed development and maturation and to relate the color appearance to the physiological maturation of the upland rice cv. Dawk Pa-yawm. The experiment was conducted at the Department of Plant Science, Faculty of Natural Resources, Prince of Songkla University, Hat Yai campus, Hat Yai, Songkhla, Thailand from August 2014 to January 2015. Upland rice was planted in a field and the panicles were tagged to indicate the date of flowering. The panicles at 8, 12, 16, 20, 24, 28, 32, and 36 days after flowering were harvested to investigate seed quality. The results showed that upland rice seed reached physiological maturity at 28 days after flowering with a maximum dry weight, germination and vigor in terms of soil emergence, mean emergence time, seedling growth rate and the low electrical conductivity. The physiological maturity occurred when approximately 85 % of seeds in the panicle turned yellow. This characteristic can be used for physiological maturity to determine the optimum harvesting time of upland rice seed cv. Dawk Pa-yawm.

Keywords: Upland rice, seed quality, seed development, seed maturation, physiological maturity

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple foods for more than half of the world's population and influences the livelihoods and economics of several billion people [1]. Upland rice is grown under rain-fed conditions on both level and sloping fields with naturally well-drained soil and without surface water accumulation [2]. In Thailand, most upland rice is grown in northern and southern regions, which represent about 10 % of the total rice production area. It has been grown almost exclusively by small households for food security [3]. The southern part of Thailand has less lowland rice areas than the other parts of the country therefore, there is not enough rice for local consumption. Accordingly, upland rice is an alternative crop for household consumption or sale in local markets. However, one of the major problems of upland rice production in southern Thailand is seed quality [4] which is pivotal for their growth, uniformity, as well as yield [5].

Seed development refers to morphological and physiological changes of seeds since fertilization till maturation [6]. Seed maturation is one of the main factors of seed quality and a prerequisite for successful germination and emergence. Seed crops should be harvested when quality traits are at their maximum at physiological maturity [7]. This is defined as the time when seed attains its maximum dry weight, germination and vigor [8]. However, a quick estimation of physiological maturity in the field is quite difficult [9]. Physiological maturity can be determined by visual indicators, such as a black layer in the corn and pod color change in soybean [10]. Datta [11] reported that maturity of an individual rice seed occurs when the seed turned yellow and was free from any green tint. However, a visual indicator of physiological maturity on a whole panicle of upland rice has not been reported yet. The objectives of this paper were to study the changes of morphological and physiological traits during seed development and maturation and to relate the color appearance to the physiological maturation of the upland rice seed cv. Dawk Pa-yawm.

Materials and methods

Plant materials

Upland rice cv. Dawk Pa-yawm was planted in the field at the Department of Plant Science, Faculty of Natural Resources, Prince of Songkla University, Hat Yai campus, Hat Yai, Songkhla, Thailand, from August 2014 to January 2015. The experimental plot size was 10×20 m^2. The land was ploughed, disc hallowed and leveled before sowing the seeds. Five seeds of upland rice were sown per hole. The plants were thinned to 3 plants per hole at 10 days after emergence. Weeding was done by hand-hoeing twice at 20 and 40 days after emergence. The fertilizer 15N-15P-15K at a rate of 187.5 kg/ha was applied twice at 25 and 45 days after emergence. The panicles were tagged to indicate the date of flowering which were harvested at 8, 12, 16, 20, 24, 28, 32 and 36 days after flowering. Seeds were threshed gently by hand for separation from the panicle.

Determination of seed quality

A standard color chart (develop by the Royal of Horticultural Society, London) was used to match seed color for each harvesting age. The number of green (Yellow-green 144 C) and yellow (Yellow 14 C) seeds per panicle was recorded to determine the percentage. The good seeds were tested for their physical quality consisting of their dry weight and moisture content [12]. The seeds were soaked in water at 40 °C for 24 h for breaking dormancy before a physiological quality test [13]. Physiological seed quality tests consisted of standard germination, soil emergence, mean emergence time, root and shoot length, seedling dry weight and electrical conductivity [14].

Statistical analysis

A completely randomized design with four replications was used in this study. All data were analyzed using the analysis of variance and means separated by Duncan's multiple range test (DMRT) at a 5 % level of significance.

Results and discussion

Seed color

In the early stage of seed development, all seeds in panicles at 8 and 12 days after flowering were still green. Seeds at the tip of panicle began to turn to yellow with 30.67 % at 16 days after flowering (**Figure 1**). Then, the yellow seeds increased progressively to 85.30 % at 28 days after flowering and also increased until 36 days after flowering. All seeds in the panicles were yellow. These results are consistent with Pande [2] who reported that upland rice seed was ready for harvest when about 80 % of the panicle had a straw color and the seeds on the lower portion of the panicles were at the hard dough stage.

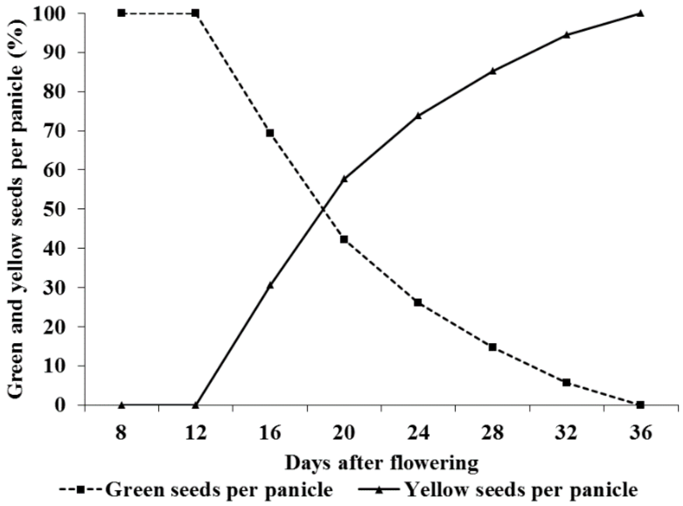

Figure 1 Changes in seed color during seed development and maturation of upland rice cv. Dawk Pa-yawm.

Seed dry weight

Seed dry weight increased rapidly from 6.07 mg/seed at 8 days after flowering to 18.00 mg/seed at 16 days after flowering (**Figure 2**). After that, dry matter accumulation increased slowly until 28 days after flowering that gave a maximum seed dry weight of 21.89 mg/seed. This result was consistent with Mutayakul [15] who found that upland rice seed var. Seiw Mae Jun reached a maximum dry weight at 28 days after flowering. The maximum seed dry weight 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 [16]. This indicated that upland rice seed cv. Dawk Pa-yawm reached physiological maturity at 28 days after flowering. After physiological maturity, seed dry weight decreased slowly due to there being no assimilates transmission to the seed and also increasing seed respiratory activities [7].

Moisture content

Initially, seed moisture content decreased rapidly from 57.81 % at 8 days after flowering to 33.23 % at 16 days after flowering and reached 24.35 % at 28 days after flowering (**Figure 2**). The decrease in seed moisture content at the early stage was a result of the increase in dry matter [9]. Seed moisture content also decreased after physiological maturity and reached a minimum of 18.28 % at 36 days after flowering. This result was consistent with Delouche [6] who reported that after physiological maturity, seed moisture content decreased until an equilibrium was established with the field environment at 12 to 18 % of moisture content.

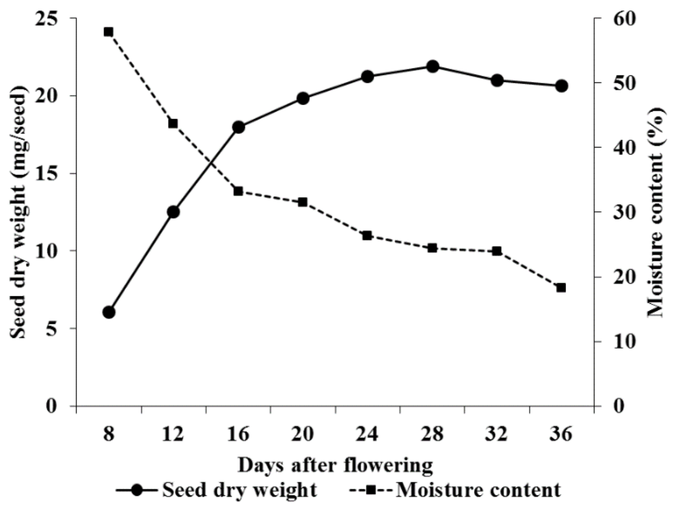

Figure 2 Changes in seed dry weight and moisture content during seed development and maturation of upland rice cv. Dawk Pa-yawm.

Germination

Upland rice seed was not able to germinate at 8 and 12 days after flowering. However, 55.50 % of seeds germinated at 16 days after flowering (**Figure 3**). This result was consistent with Delouche [6] who reported that seeds attained germination capability before they reached physiological maturity. Following 16 days after flowering, seed germination increased reaching a maximum of 97.00 % at 28 days after flowering and decreased slowly thereafter. The maximum value of germination and seed dry weight of upland rice was attained at same time. Similar results have been found in maize cv. DC-370, SC-500, OSSK-602 and SC-604 where the highest seed germination was achieved at mass maturity or the end of seed filling phase [17].

Soil emergence and mean emergence time

Seed vigor in term of soil emergence followed the same trend as germination. Soil emergence increased from 54.50 % at 16 days after flowering to a maximum of 96.50 % at 28 days after flowering (**Figure 3**) and decreased slowly thereafter. On the other hand, mean emergence time decreased rapidly from 8.05 days at 16 days after flowering to 6.01 days at 20 days after flowering. Following 20 days after flowering, mean emergence time decreased slowly until reached the minimum of 5.44 days at 28 days after flowering and increased slowly thereafter.

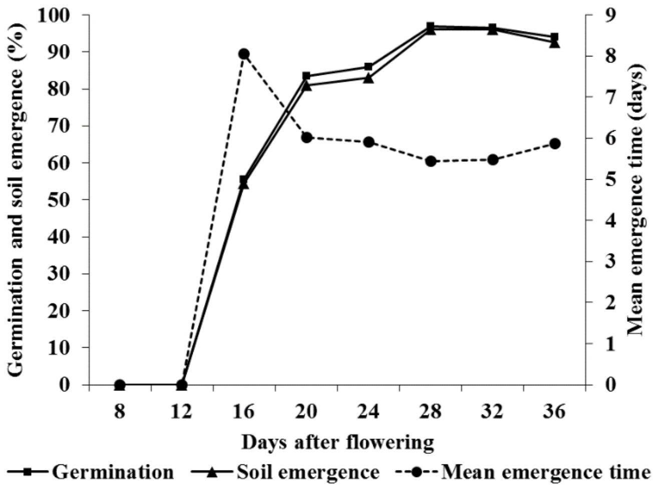

Figure 3 Changes in germination percentage, soil emergence and mean emergence time during seed development and maturation of upland rice cv. Dawk Pa-yawm.

Seedling growth rate

Seedling growth rate of upland rice seed was low at the early stage of seed development. Upland rice seed gave root and shoot lengths of 10.92 and 4.71 cm, respectively at 16 days after flowering (**Figure 4**). Then, seedling growth rate increased until 28 days after flowering that gave the longest root and shoot lengths of 13.30 and 7.92 cm, respectively. After physiological maturity, root and shoot length decreased rapidly. The pattern of seedling dry weight was similar to root and shoot length that increased from 4.68 mg/seedling at 16 days after flowering to a maximum of 7.51 mg/seedling at 28 days after flowering and decreased rapidly thereafter.

The maximum seed vigor in terms of soil emergence, mean emergence time and seedling growth rate was obtained at 28 days after flowering. This result was consistent with Delouche [6] who reported that the maximum seed vigor or seedling vigor was attained at approximately the same time as the maximum dry weight or physiological maturity. Similar results were found in sorghum var. CO 24, CO 25, CO 26 and JH 35 that gave the highest field emergence, vigor index and seedling growth at physiological maturity [18].

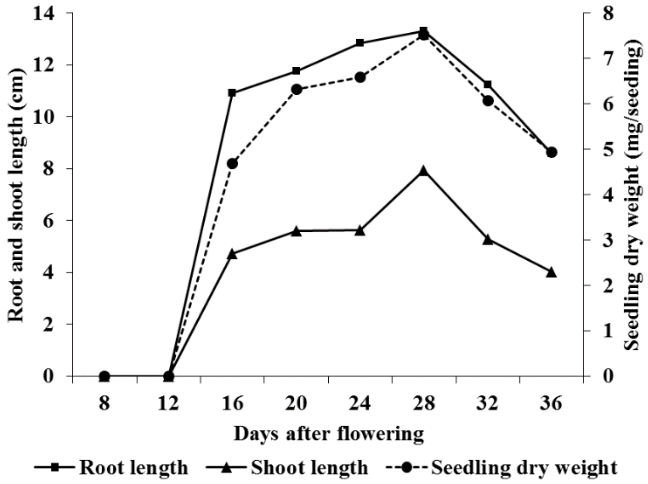

Figure 4 Changes in seedling growth rate during seed development and maturation of upland rice cv. Dawk Pa-yawm.

Electrical conductivity

The electrical conductivity of seed leakage is an indirect measure of membrane integrity [19]. Electrical conductivity was high in the early stage of seed development being 13.84 µS/cm/g at 8 days after flowering due to immaturity of seed formation (**Figure 5**). Then, electrical conductivity decreased to a minimum of 8.05 µS/cm/g at 28 days after flowering. This result indicated that there was an increase of cell membrane integrity and subsequent reduction in electrolytes leakage [20]. After physiological maturity, electrical conductivity increased rapidly to 14.43 µS/cm/g at 36 days after flowering because of seed aging and the beginning the deterioration processes. The weakening of the cell membrane in poor vigor seeds caused leakage of water soluble compounds like sugars, amino acids and electrolytes etc. when immersed in water [7].

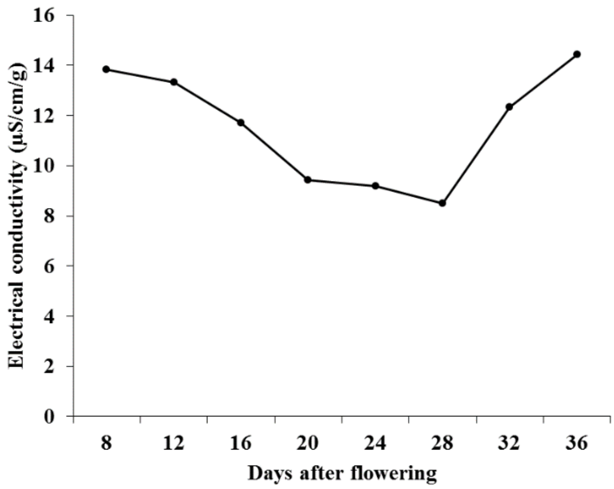

Figure 5 Changes in electrical conductivity of seed leachates during seed development and maturation of upland rice cv. Dawk Pa-yawm.

Conclusions

Upland rice seed cv. Dawk Pa-yawm reached physiological maturity at 28 days after flowering with a maximum seed dry weight, germination and vigor in terms of soil emergence, mean emergence time, seedling growth rate and low electrical conductivity. At this time, seed moisture content was 24.35 %. Physiological maturity was attained when approximately 85 % of the seeds in the panicle turned yellow. Thus, this characteristic can be used as a visual indicator for physiological maturity to determine the optimum harvesting time of the upland rice seed cv. Dawk Pa-yawm.

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