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Research Article

Management of Early Harvesting Time and Drying Temperature on Maize (*Zea mays* L.) Seeds Storability and Seeds Vigor

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Abstract

Background and Objective: Maize seed production systems are nowadays used to try to conduct early harvests and thereafter submitted for seed processing and marketing within a short period of time. Thus, the experiment was aimed to evaluate the effect of harvesting time and drying management on maize storability and seed vigor after early harvested. **Materials and Methods:** The experimental design was arranged in 2×4 factorial in Randomized Complete Block Design (RCBD) with four replications. The effect of two different harvesting times were H_1: 100 Day after emergence (DAE, R5), H_2: 110 DAE (R6) and four drying temperatures (T_1: 30°C, T_2: 35°C, T_3: 40°C, T_4: 45°C) were observed. Then, seed qualities and vigor were tested. **Results:** The H_2 had the highest speed of germination. At 0 month, the highest germination percentage, speed of Germination, shoot length, Root Length (RL), Seedling Dry Weight (SDW) and seedling growth rate were obtained at 45°C. At 6th month of storage, the highest germination percentage, AA-test, RL and SDW were obtained at 35°C. **Conclusion:** The experiment could be concluded that seed drying at 45°C can be used for immediate use of seeds without storage. For storability, the anticipation of harvest and seeds drying at temperatures of 35°C result in maize seeds that have the ability to grow into normal seedlings in field conditions.

Key words: Maize, harvesting time, drying management, seed vigor, storage

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The maize demand in Thailand has been continuously increasing and has reached approximately 7.41 M ton. Thailand had a total yield of about 4.62 M tons. As is evident from the statistics, maize production is not enough to meet the country's demand. So, the research on increasing the yield and season of maize produce was crucial and has become a new area of interest. High seed quality production is one of the major factors for successful crop production[1]. Furthermore, maize seed production systems currently operate by conducting early harvests then produce is submitted for seed processing and then marketed within a short period. In some cases, improper environmental incidents force the need for early harvests and these incidents include heavy rain, flooding, drought and damage due to diseases and other pests. For these reasons, it is impossible to wait for the harvest period. Unfortunately, high moisture content in the seeds occurs as a result of these premature harvests. Harvesting time is an important factor since both seed immaturity and drying seed moisture content could reduce seed quality[2]. Ingle *et al.*[3] reported that seed development and maturation studies are important in order to ensure good yield associated with viability, vigor and field performance. Moisture content of harvested crops also affects seed quality. Harvesting with high moisture content in the crops increases of mycofloral infection on seeds, while harvesting at low moisture content increases mechanical damage to seeds. One of the first considerations during harvesting is the effect of the stage of maturity or moisture content of the seeds on their ability to germinate and produce normal plants. Immaturity at harvest and increasing of drying temperature could decrease seed quality[4]. Differences were observed between seeds that were over dried at higher temperatures and maintained in that condition and seeds that were over dried at the same temperatures and subsequently equilibrated. These differences could be due to injuries resulting from an abnormally rapid uptake of water and lesion formation associated with the water uptake[5].

In addition to being dried to a safe storage level, seeds must also endure the drying process with as little loss of seed quality as possible. Therefore, seed drying management become a very vital process[4]. Storability of seeds is influenced by pre-storage history of the seeds, seed maturation and environmental factors during pre and post-harvest[6]. Thus, the experiment was aimed to study the effects of harvesting time and drying management on maize seed vigor during storage.

MATERIALS AND METHODS

Study area: The experiment was conducted at Crop Physiology and Renewable Energy Crops Laboratory, Seed laboratory, Department of Agronomy, Faculty of Agriculture, Kasetsart University (KU), farmer field at U-Thong district, Suphan Buri province, Thailand and Georg-August University of Gottingen, Germany during December, 2018 to July, 2020.

Seed production management and plant samples: The experiment was supported by Syngenta Seed (Thailand) Co. Ltd. In both of research place and plant materials. The experimental field was conducted under farmer field condition at U-Thong district, Suphan Buri province, Thailand. Duration December, 2018 to July, 2020 (dry seasons).

Plant materials and seed samples were collected from parental hybrid lines for F_1 maize hybrid seeds production. Plants were grown by 20×40 cm of crop spacing. Compound fertilizer amount 60 and 40 kg h^{-1} after 3-5 days of germination, 20 kg h^{-1} after 40 days of germination was applied for topping fertilizer when single fertilizer was applied as basal fertilizer amount 50 to 30 kg h^{-1} at 20 days after emergence and 15 kg h^{-1} after 40 days after emergence. Droplet micro-irrigation was applied once a week. Weeds were controlled spraying herbicides (2.4-D, glufosinate1.0 L h^{-1} + fluroxypyr 0.3 L h^{-1}).

The experimental design was arranged in 2×4 factorial in Randomized Complete Block Design (RCBD) with four replications. The effect of two different harvesting time (H_1: 100 Day after emergence (DAE (R5)), H_2: 110 DAE (R6)) and four drying temperature (T_1: 30°C, T_2: 35°C, T_3: 40°C, T_4: 45°C) were the experimental treatments. After each harvest, samples containing 10 ears were placed in paper bags and then taken to a hot air oven for drying at 30, 35, 40 and 45°C. The drying was performed until the seeds reached approximately 12% of moisture content. Seeds were stored in plastic sealed bag in 25°C. Then, seeds were sampling for seed qualities and vigor were tested at 0 and 6th month. Seed qualities were tested following:

Determination of moisture content: The moisture content of seed samples was determined according to ISTA[7]. Ground (100 seeds) seed samples of each harvesting time were taken into moisture cup and put into a pre-heated oven at temperature of 130±2°C, for 4 hrs 103±2°C for one hour according to ISTA[7]. Four replicates were taken. After cooling, the weight of the container with its cover and contents were taken. The seed samples were cooled in desiccators and weighed to work out the percent moisture content of the grains. The seed moisture content was determined by dry weight basis and was calculated by the following formula:

$$\frac{M2\text{-}M3}{M2\text{-}M1}\times 100$$

where, M1is the weight in grams of the container and its cover, M2 is the weight in grams of the container, its cover and its contents before drying and M3 is the weight in grams of the container, its cover and contents after drying.

Determination of germination percentage: Germinations were carried out according to ISTA[7]. For each treatment, 100 seeds were put into paper bags. Four replicates were used. The samples were put up on a laboratory table at room temperature (25±2°C). After four and seven days, normal, abnormal and diseased seeds were counted.

Measurement of root and shoot length: After seven days, five plants were randomly selected for study, taking from each replicate of each treatment. The seedlings were cut into root and shoot parts and their lengths were measured (cm).

Determination of fresh and dry weight of seedling: After measuring the root and shoot length as described above, fresh weight of seedlings was recorded. Then the root and shoot were put into paper packet separately and placed into the preheated oven (70°C) for 48 hrs. After cooling in desiccators, the dry weight was taken.

Determination of seed vigor: Seedling vigor was calculated based on the following formulae: Accelerated Aging (AA) test[7], speed of radicle emergence test[7], seedling growth rate[7], seedling dry weight[7] and shoot-root ratio[7].

Statistical analysis: The data were submitted to the analysis of variance (ANOVA), using a 2×4 factorial in Randomized Complete Block Design (RCBD) with four replications and mean comparisons were accomplished using a Least significant different test at the 5% level.

RESULTS AND DISCUSSION

Harvesting time at H_1 had the highest time of drying followed by H_2 (Table 1). According to the drying temperature, the highest recorded drying time was at 30°C followed by 35, 40 and 45°C, respectively (Table 1). In the effect of harvest time on the maize seed quality at 0 and 6th month of storage, H_2 had the highest speed of germination (Table 2). The results for the effect of drying temperature on the maize seed quality at 0 and 6th month of storage showed that at 0 month the highest germination percentage, speed of Germination, shoot length, root length, seedling dry weight and seedling growth rate were obtained at 45°C. At 6th month of storage, the highest germination percentage, AA-test, root length and seedling dry weight were obtained at 35°C (Table 3). From the experiment, the seed can be used immediately without storage by drying temperature at 45°C. Whereas for storage, it can used seeds drying temperature at 35°C, the result in maize seeds had the potential to grow to normal seedlings in the field condition.

From the results of the effect of harvest time and drying temperature on the time of drying maize seeds it has been found that the harvesting time at R6 (physiological maturity stage) used less drying time than the harvesting time at R5 (dent stage). This is because the moisture content in seeds remains high in the harvesting time before R6 which causes the water in the seeds in the R5 stage to take a longer time to evaporate. The seed drying temperature at 45°C used the least time because temperature is one of the factors that affect the evaporation of water. At high temperatures liquids evaporate faster as opposed to low temperatures where

Table 1: Effect of harvest time and drying temperature on the time of drying maize seed

Harvesting time	Time of drying (h)
H_1	449.44[a]
H_2	383.51[b]
$LSD_{0.05}$	0.2619
Temperature (°C)	**Time of drying (h)**
30	455.56[a]
35	437.22[b]
40	408.11[c]
45	365.02[d]
$LSD_{0.05}$	0.3703

H_1: 100 (R5) DAE, H_2: 110 (R6) DAE and a, b compared with LSD (p<0.05)

Table 2: Effect of harvest time on the maize seed quality at 0 and 6th month of storage

0 month		
Harvesting time	Germination (%)	Speed of germination
H_1	66.000[b]	13.042[b]
H_2	86.625[a]	16.366[a]
$LSD_{0.05}$	6.3684	1.2946
6th month		
Harvesting time	Root length (cm)	Speed of germination
H_1	6.5881[a]	12.475[b]
H_2	7.3242[a]	14.516[a]
$LSD_{0.05}$	0.5520	0.8495

H_1: 100 (R5) DAE, H_2: 110 (R6) DAE and a, b compared with LSD (p<0.05)

Table 3: Effect of drying temperature on the maize seed quality at 0 and 6th month of storage

0 month

Temperature (°C)	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling growth rate (g seedling^{-1})	Seedling dry weight (g)	Speed of germination	AA-test (%)
30	40.000^{b}	6.300^{c}	2.7450^{b}	0.0138^{a}	0.3394^{c}	7.420^{c}	59.000^{c}
35	93.750^{a}	8.992^{b}	5.6250^{a}	0.0105^{b}	0.3469^{bc}	19.071^{a}	92.000^{a}
40	80.000^{a}	9.145^{ab}	4.9550^{a}	0.0107^{b}	0.3769^{ab}	15.103^{b}	74.500^{b}
45	91.500^{a}	10.303^{a}	4.8450^{a}	0.0115^{ab}	0.3822^{a}	17.223^{ab}	66.750^{bc}
$LSD_{0.05}$	9.007	0.6236	0.7315	0.001215	0.0156	1.8309	6.1292

6th month

Temperature (°C)	Germination (%)	Root length (cm)	Seedling dry weight (g)	AA-test (%)
30	59.000^{c}	7.2008^{ab}	1.1202^{a}	74.500^{ab}
35	92.000^{a}	7.8050^{a}	1.0928^{a}	92.000^{a}
40	74.500^{b}	7.1762^{ab}	1.1347^{a}	87.500^{a}
45	66.750^{bc}	5.6425^{b}	1.0779^{a}	64.500^{b}
$LSD_{0.05}$	6.1292	0.7806	0.0355	8.9619

a, b, c compared with LSD ($p<0.05$). AA: Accelerated aging vigour test

liquids are less volatile. Therefore, evaporation of water will be faster in high temperatures compared to low[8].

The results of the effect of harvest time on the maize seed quality at 0 and 6th month showed that the germination speed was higher in H_2 compared to H_1. This was observed because at the R5 stage the produce was harvested before the physiological maturity stage which causes damage and subsequently low yields and poor seed quality. Moreover, the seeds have high moisture content which in turn causes seeds to be easily destroyed by disease and therefore it is not possible to reduce seed moisture content to a safe level in time[9]. Early harvested seeds recorded lesser viability and vigor potentials due to more number of immature seeds with relatively low degree of embryo development, high moisture content and as such will have poor storage compared to seeds harvest at physiological maturity[9,10]. At physiological maturity seeds will have maximum viability and vigor. Attainment of physiological maturity is a genotypic character which is influenced by environmental factors[11,6]. Harvesting time of any crop for seed quality depends on its maturity time and on physiological maturity. Harvesting of seeds at optimum stage of maturity helps to obtain better quality seeds. Harvesting stage influences the quality of seeds in relation to germination, vigor, viability and also storability[12].

From the results of the effect of drying temperature on the maize seed quality at 0 and 6th month it was seen that at 0 month, the highest germination percentage, speed of Germination, SL, RL, SDW and seedling growth rate were obtained at 45°C. In addition, at 6th month the highest germination percentage, AA-test, RL and SDW were obtained at 35°C. This means that if the seeds are dried at 35°C, the seeds will still have the potential to revert to normal growth to seedling after 6 months. Seeds dried at the temperature of 45°C can be used immediately without storage. Sadjad and Minaei[13] reported that an increase in drying temperature and moisture gradient, created internal tensions, cracks, breakages and fractures in the seed. Therefore, the mechanical properties could change. Burris and Navratil[14] reported that a possible relationship between dryer-induced injury has been attributed to faulty membrane reorganization. The expression of dryer injury may be a consequence of permanent membrane damage. Tuite and Foster[6] reported that storability of seeds is mainly a genetic character and is influenced by pre-storage history of seeds, seed maturation and environmental factors during pre and post-harvest.

CONCLUSION

Maize seed production systems are currently being used to conduct early harvest followed by submitting the seeds for seed processing and then taken to market within a short period of time. In some cases, improper environmental incidents lead to early harvest, factors such as heavy rain, flooding, drought, damage due to diseases and other pests. As a result it impossible to wait for the harvest period. Seed drying at 45°C can be used for immediate use of seeds without storage. For storability, the anticipation of harvest and seeds drying at temperatures of 35°C result in maize seeds that have the ability to grow into normal seedlings in field conditions.

SIGNIFICANCE STATEMENT

This study discovered the management of harvesting time and drying on maize seeds storability and seeds vigor that can be beneficial for maize seed production systems are nowadays used to try to conduct early harvests and thereafter submitted for seed processing and marketing within a short period of time. Consequently, seed drying management becomes a very important process to decrease seed moisture content down to a desired level that could maintain seed quality. This study will help the researchers to uncover the critical areas of the management of harvesting time and drying on maize seeds storability and seeds vigor that many researchers were not able to explore. Thus a new theory on the management of harvesting time and drying on maize seeds storability and seeds vigor may be arrived at.

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