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Effect of Harvesting Time on the Seed Quality of Hybrid Maize (*Zea mays* L.) COHM 8

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ABSTRACT

Background: The present study was aimed to identify the optimum harvest time in hybrid Maize COHM 8 for better seed yield and quality. Seed ability to produce vigorous seedlings is a significant characteristic of any productive crop. The ideal harvest time is one of the factors that contribute to high seed vigor.

Methods: In this proposed study hybrid maize crop was raised at Agricultural Research Station, Veppanthattai, Perambalur District, Tamil Nadu during 2021-22 and seeds were harvested at five days intervals starting from 40 days after tasseling and evaluated for its vigour through cold test, accelerated aging test, seed leachate test etc in addition to germination test.

Result: The seed moisture content was optimum in the seeds harvested at 50 days after tasseling. In the cold test, seeds harvested at 50 days after tasseling performed better (germination of 90%) than other days of harvest, whereas seeds harvested at 40 days after tasseling (germination of 50%) resulted least compared to other days of harvest. The vigour test and accelerated aging test revealed that seeds harvested at 50 days after tasseling reached germination of 90%, the required minimum germination as per the Indian minimum seed certification standards (IMSCS) on the 3rd day of accelerated aging against germination of 48% with seeds harvested after 40 days. Hence it can be concluded that seeds could be harvested between 50-55 days for the maize hybrid COHM 8.

Key words: Accelerated aging test, Cold test, Harvesting intervals, Seed vigour.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops grown across the globe due to its widespread adaptability and is called the 'Queen of Cereals'. In 2022, over 1.2 billion metric tons of maize was produced globally. The cultivation of hybrid maize accounts for more than 95% of all maize production. The economic benefit of seed producers depends heavily on producing high-quality hybrid maize seeds. Due to its versatility and contribution to other cereals around the world, it is widely grown in various soil and climatic conditions.

Numerous studies have been conducted in recent years to investigate the physiological responses of seed germination and seedlings to chilling and osmotic stress. Despite this though, there is a lack of scientific knowledge about the ecological impact of extended growing seasons. In order to meet the growing demand for high quality food to feed the growing global population, fast and uniform field emergence is crucial. The plant has naturally evolved a variety of adaptations in order to cope with harsh environments. There is no doubt that these adaptation measure cause a change in the physiology and biochemistry of the plant in order to improve its performance.

Harvesting at the proper time is a key factor that contributes to obtaining high-vigor seeds in seed production. Harvesting too early may result in immature seeds that have poor vigor. On the other hand, the delayed harvest of seeds increases the potential damages from insects and microorganisms that may accelerate the seed deterioration process. During seed post-harvest processes, a delay in harvest may also increase the potential for environmental damage. Therefore, determining the stage of maturity and ideal harvest time (IHT) for hybrid maize seed harvest will ensure maximum seed yield and vigor in hybrid maize seed programmes.

The quality of the seed is generally reflected in the vigor of the seed. In essence, this term refers to the totality of seed properties, including the ability of seeds to germinate in a variety of environments and the ability of seeds to survive in storage environments. There are three most widely used parameters regarding seed vigor: standard germination (SG), cold test (CT), and accelerated aging test (AAT).

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Germination of seeds under favorable conditions is called seed germination (SG), which is often overestimated in conditions of suboptimal germination. Among seed vigor indexes, CT and AAT are most commonly used to determine the vigour of seeds when they reach physiological maturity (PM). In this context, an experiment was conducted in order to investigate the impact of harvest dates on the seed vigor of a maize hybrid var. COHM 8.

MATERIALS AND METHODS

As part of the field experiment conducted at Agricultural Research Station, Veppanthattai, Perambalur District, Tamil Nadu (located at 11032′N latitude and 78083′longitude) during 2021-22, the seeds were harvested over a period of five days at intervals starting as early as 40 days after tasseling and ending at 60 days after tasseling. The harvested seeds were taken to Department of Seed Science and Technology, Agricultural College and Research Institute, Madurai during 2022 for laboratory studies and dried to 12% moisture and graded using wire mesh sieves of 16 $\frac{3}{2}$ 16. The experimental details are as follows:

Harvesting intervals

Treatments	Day after tasseling (DAT)
H_1	40 DAT
H_2	45 DAT
H_3	50 DAT
H_4	55 DAT
H_5	60 DAT

The following parameters were evaluated using the processed seeds.

Moisture content (ISTA, 2010)

Moisture content was estimated immediately after harvest to evaluate the moisture content of cob and seeds at the time of harvest by low constant oven method at 103±1°C for 16±1 h. After drying, the samples were placed in desiccators containing calcium chloride for 30 min and weighed. The per cent of moisture content was calculated using the following formula.

$$\text{Moisture content (\%)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M_1= Weight of the empty moisture bottle along with the lid (g).

M_2= Weight of the moisture bottle along with the sample before drying (g).

M_3= Weight of the moisture bottle along with the sample after drying (g).

Hundred seed weight

Five cobs from each treatment were randomly selected and shelled on wet basis. From this, a representative sample of 100 seeds were picked out and weighed using an electronic balance and expressed in grams.

Germination test

The germination study was performed with 400 seeds in paper medium. In the germination room, test conditions of 25+2°C temperature and 95+3 percent relative humidity were maintained. At the end of seventh day, the number of normal seedlings (ISTA, 2013) was evaluated and the mean was reported in percentage.

Cold test

Cold tests were conducted with soil taken from the top 5 cm of a maize field. A 5 mm sieve was used to screen the soil, and the dried soil was placed in a metal tray. The metal trays were filled with dry soil and 50 seeds were planted in each of four replications of each treatment. In order to achieve 70% of water holding capacity, prechilled distilled water was added as a calculated amount. Incubation was carried out for seven days under darkness at 5°C. The containers were then moved to a 25°C growth chamber with an altered light source for 4 days and the normal seedlings were evaluated as per ISTA rules after seven days.

Accelerated aging test

Seeds from different harvests were sealed in perforated butter paper and kept under an accelerated ageing chamber by subjecting the seeds to 40±1°C temperature and 95±5 per cent relative humidity for a period of 3 days. The seeds were shuffled daily and allowed for moisture stabilization in a desiccator containing calcium chloride.

Samples were collected under accelerated ageing conditions on the first, second and third days and analyzed for physiological parameters. Seed samples that recorded high germination were considered more vigorous and expected to maintain high viability during storage.

Electrical conductivity (dSm^{-1})

Twenty five seeds, each from different dates of harvest were drawn and soaked in 25 ml of double distilled water for 16h at room temperature, decanted and leachate thus obtained was used to estimate the electrical conductivity with digital conductivity meter and the conductivity of leachate was expressed as dSm^{-1}.

Statistical analysis

An experiment was conducted using Randomized Block Design (RBD) with four replications. All management practices were followed meticulously to maintain superior crop standards. Several physical and physiological parameters, *viz*, cob and seed moisture content, 100 seed weight, electrical conductivity, germination test, cold test for germination and accelerated aging test related to seed vigour were evaluated on five randomly selected plants from each entry in all replications. Data were analyzed statistically in OPSTAT for the purpose of evaluating the linear regression among the harvesting intervals and physical and physiological traits.

Regression is the average relationship between dependent and independent variables. The regression equation for all the models is given by:

$$Y= \acute{\alpha}+\beta X$$

Where

Y= Harvesting intervals.

ά= Regression constant.

β= Regression coefficients for seed quality parameter variables.

X= Seed quality parameter variable.

RESULTS AND DISCUSSION

Seed quality and harvest time have a strong relationship with seed viability and vigor. Despite being a genetic characteristic, seed storability is strongly influenced by the pre-storage history of the seed, by seed maturation, and by environmental factors during the pre- and post-harvest stages. Physiological maturity occurs when a seed reaches its maximum dry weight with minimal seed moisture. Therefore, it is the most appropriate time to harvest the seeds to ensure their germination and viability. With regard to genotypes, ambient temperatures prevailing during harvest and other factors, seed quality between physiological maturity (PM) and harvest maturity (HM) varies significantly. Thus, it is vital to harvest seed crops at the optimal stage of seed maturation in order to produce the highest quality seeds.

Harvesting the seeds within the correct range of seed/cob moisture will maximize seed yield and quality and minimize mechanical injuries during processing. Swift changes occur in both the dry matter and moisture content of the maize cob during the period of seed maturation. Loss of moisture from the cob beyond physiological maturity determines seed moisture at harvest. Physiological maturity is always defined as the time at which seeds reach their maximum dry weight. The increase in dry weight during seed maturation more than compensates for the net loss of moisture from the cob. Cob moisture reduced from 50.76 % to 25.11% from 40 DAT to 60 DAT (Fig 1). Here the loss in

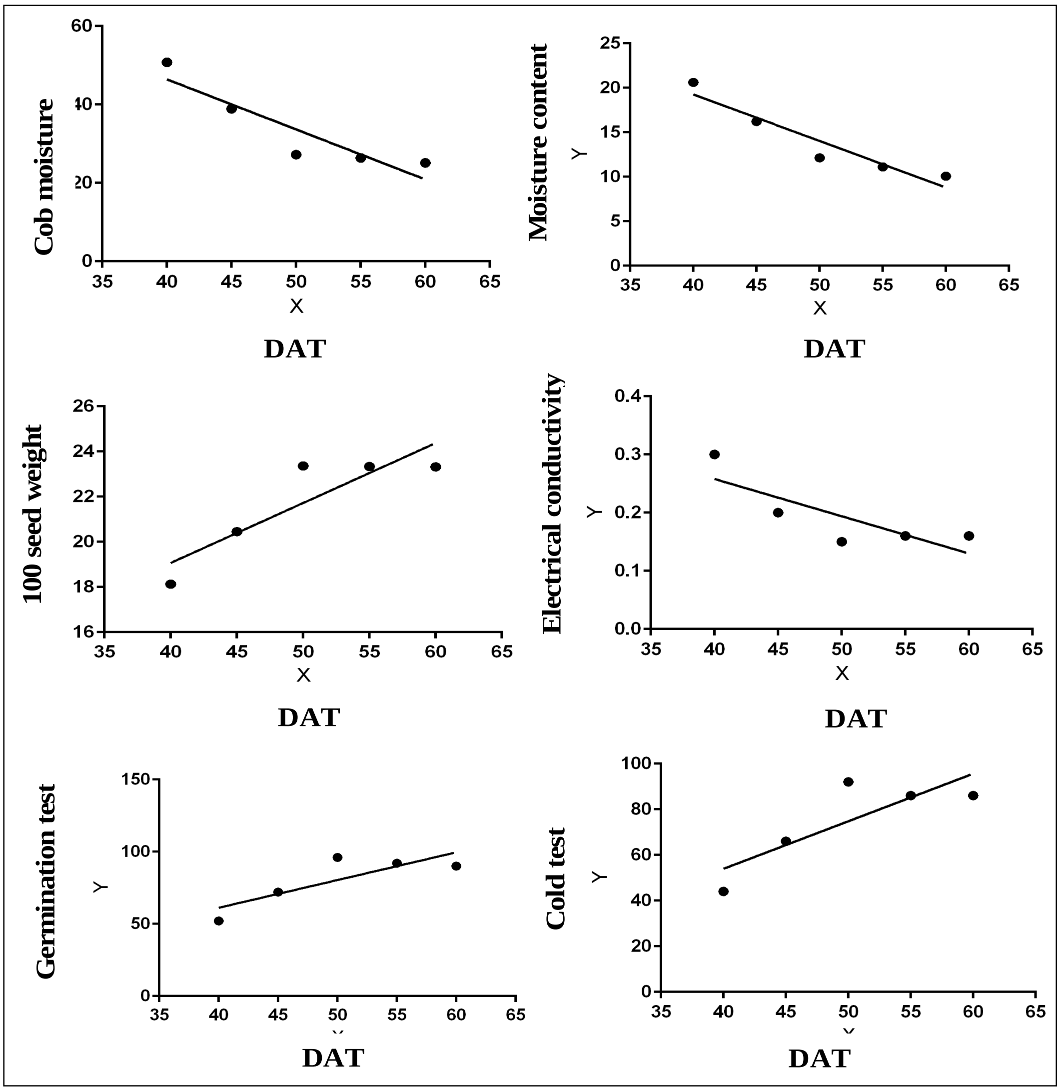

Fig 1: Relationship between harvesting intervals on seed quality parameters.

moisture was 46.39% during seed maturation (40-50 DAT) as against 7.72% loss during physiological maturity to harvestable maturity (50-60 DAT). In the early stages of seed development, seed moisture remains high, and dehydration is a slow process. However, it accelerates when the seed reaches its maximum dry weight and continues to decrease until hygroscopic equilibrium is reached. That is the stage where the dry weight of seeds starts declining along with moisture and indicates the maturation of seeds. A similar pattern was observed in the development of maize seeds, where seed moisture decreased from 20.62 to 16.21 (40 - 45 DAT) and thereafter to 10.08% at 60 DAT (Fig 1). Prevailing temperature during seed maturation may also have its impact on loss of seed moisture. There is growing evidence supporting the claim that chickpea seeds harvested 29 days after anthesis (DAA) showed the highest moisture content percentage, while chickpea seeds harvested 45 days after anthesis (DAA) showed the lowest moisture content percentage (Mehta *et al*., 1993). The moisture content is high during early harvesting, which has a direct impact on the dry weight, which was lower during early harvesting. The highest moisture content was found when seeds were collected at 30 days after flowering (DAF) and the lowest moisture content was found when seeds were collected at 40 days after flowering (DAF) (Mahesha *et al*., 2001).

Dehydration and seed filling occur simultaneously during seed maturation. It was found that seed moisture content decreased simultaneously with an increase in test weight, which was reflected in the germination percentage at 50 DAT (Shete *et al*., 1992). In agreement with the previous reports the increase in maize seed moisture at 40 and 50 DAT concurrently resulted in accumulation of dry matter content which was evident from the hundred seed weight where the increase was 22.38% up to 50 DAT (Fig 1) indicating the progressing seed development and after 50 DAT the increase in dry mass was stagnant showing the attainment of seed maturity. The development of seeds begins with fertilization and continues until they reach physiological maturity. Seed maturation increases as time passes. As seed maturity approaches physiological maturity, its level of maturity increases (Purnomo D and Sitompul S M 2006). As determined by the weight of 100 seeds, seed harvested from 50 DAT tends to be more vigorous than seed harvested at late harvest.

A seed's dry weight is believed to be an accurate indicator of the seedling's vigor since it gives an accurate estimate of the amount of stored reserves in the seed. Dry weights of seeds were significantly different between early harvests and delayed harvests. It may be due to low dry matter accumulation at early harvests and deterioration in seeds caused by physical factors at later harvests. The accumulation of dry matter content was evident from the hundred seed weight where the increase was 18.13 to 23.36 g (Fig 1) indicating the progressing seed development and after H3 the increase in dry mass was stagnant showing the attainment of seed maturity. A characteristic of mature seeds is their maximum dry weight, which identifies them as having reached physiological maturity.

The amount of dry matter accumulated in seeds is one physical indicator of seed maturity, while other non-physical or physiological indicators include the viability and vigor of the seed. Physiologically mature seeds are highly vigorous and can be stored for longer periods of time. Due to lack of development and maturation, lower germination rates of 52% and 72% were observed in H1 and H2. After physiological maturity *i.e*., at 50 DAT higher germination of 96% was noticed in H3. The same trend was observed in speed of germination (Fig 2). During early harvest, the germination rate and speed of germination were significantly lower than those observed in later harvests. Germination percentages also tend to decline after physiological maturity is reached. The low germination rate of early harvested seeds may be due to the presence of a greater number of immature seeds. Despite the fact that the crop had been harvested earlier, the seed quality of the crop was poor due to immaturity

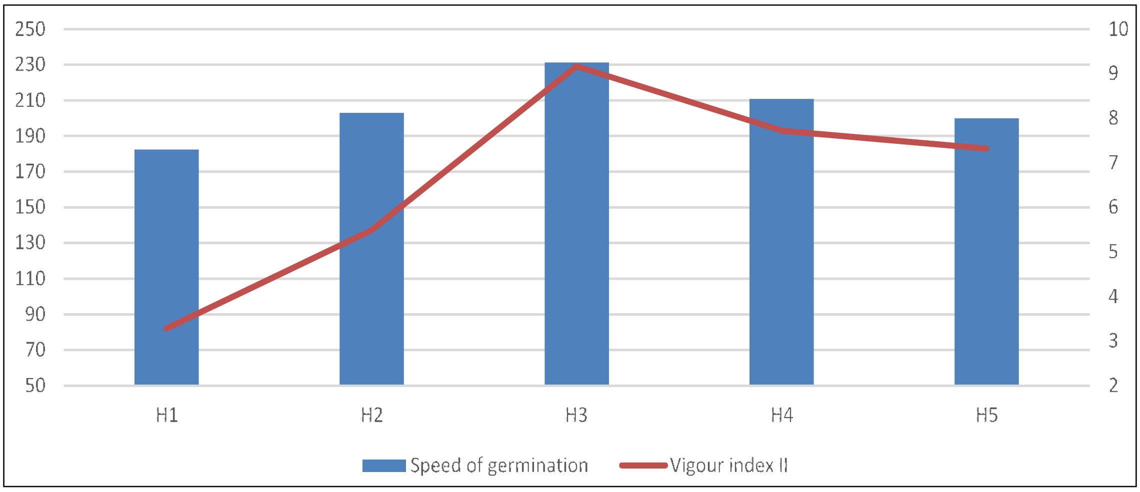

Fig 2: Effect of harvesting intervals on speed of germination and vigour index II.

(Jayaraj and Karivaratharaju, 1992). Mehta *et al*. (1993) reported that seeds harvested before 33 DAA exhibited a drastically reduced germination percentage and significant differences were also noted in germination due to harvesting. Generally, germination percentages were highest in the H2 stage, *i.e*. seeds collected at 35 days after flowering (DAF), and the lowest in the H1 stage, *i.e*. seeds collected at 30 days after flowering (DAF) (Mahesha *et al*., 2001). In addition to decreasing seed moisture content, seed germination percentage increased with the advancement of harvesting dates (Shete *et al*., 1992). Delaying of harvest after seed maturity may be the result of the onset of ageing biochemical processes after physiological maturation (Bewley and Black, 1985; Powell, 1988) and germination was only 90% at 60DAT as against 96% when harvested during 50DAT.

The highest vigour index I and II was observed in H3 (3755 and 229) and the lowest vigour index is observed in H1 (1274 and 82) and H2 (2433 and 137) (Fig 2 and 3). It is possible that increased seed vigor index is related to seeds maturing in the H3 stage resulting in better germination percentages and seedling lengths.

Conductivity testing of seeds usually involves cellular membrane integrity or its manifestation determined by potentiometric measurements on hydrated seeds or on seed steeped in water and the association of such measurements with seed quality involving vigour and viability. A highly negative correlation was observed between EC and germination rate (Fig 3). Seed germination was negatively correlated with EC, which indicated that a greater amount of leachate was escaping from a low quality seed *i.e*., immatured or developing seeds. High EC of seed (0.30) at 40DAT is assumed due to membrane deterioration during the imbibition period of lower quality seeds. Decrease in electrical conductivity was not significant after H3, which indicates the attainment of seed maturity. There is a pattern of variation in electrical conductivity values recorded during the maturation process of seeds, as reported by Powell (1986), which has been associated with the development of cellular membranes and their structural organization associated with the maturation process of seeds. As seed maturity increases, Styer and Cantliffe (1983) found that seed leachate conductivity generally decreases. A high correlation has been found between leachate conductivity and field emergence (Waters and Blanchette, 1983). The higher membrane permeability and the broken pericarps may be responsible for the greater leakage of metabolites during imbibition of seeds, even though germinability may be normal. It has been reported that EC tests performed on soybean seeds have shown a high degree of accuracy to indicate the seed performance to establish a stand under a variety of field conditions (Vieira *et al*., 2004).

Tests of vigour, both AAT and cold germination, confirmed the results of the germination test. During the cold germination test, differences in the vigour of maize seeds were identified, which might have an impact on the emergence of the seeds in the field. Due to decreased metabolism and inactivation of enzymes that are essential for germination, seed harvests before maturity stages are of poor quality and cannot withstand a cold test. This was evident from this study where poor germination of 44% and 66% was seen in H1 and H2 during the cold germination test. In the cold germination test, seeds harvested when they are physiologically mature performed better, resulting in a germination rate of 92% (Fig 3). The seeds from the harvest after 50 DAT were better compared to earlier harvests. Cold germination testing not only measures the percentage of viable seeds in a sample, it also reflects the ability of those seeds to produce normal seedlings under less than optimum growing conditions like those that may occur in the field. Seeds harvested at physiological maturity

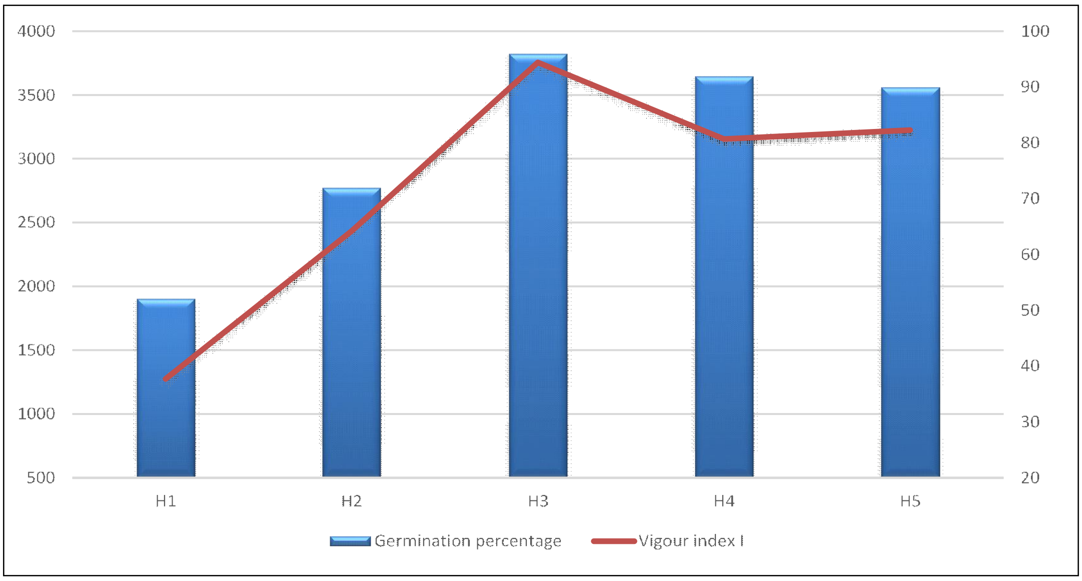

Fig 3: Effect of harvesting intervals on germination and vigour index I.

register proper field emergence and produce normal and uniform seedlings (Yadav *et al.,* 2020).

Accelerated aging, another vigour test, also showed the progressive decline in viability and vigor in seeds of maize, when the seeds were harvested early. AAT always mimics natural aging and hence reflects the fate of seeds during storage. Artificially aged seeds from different early dates of harvest registered not only poor germination but also decreased seedling vigor (Fig 4 and 5).

A possible explanation for this reduction is the lowering of biochemical activities in seeds. An aging process of immature or low-quality seeds can damage the enzymes that convert reserve food in the embryo into usable forms, resulting in substandard seed quality. The germination rate for seeds taken from H3 was 94% (Fig 4) on the first day of ageing; this rate gradually decreased and reached 90% (Fig 4) after 3 days of aging, the minimum required germination per cent for hybrid maize seed certification fixed

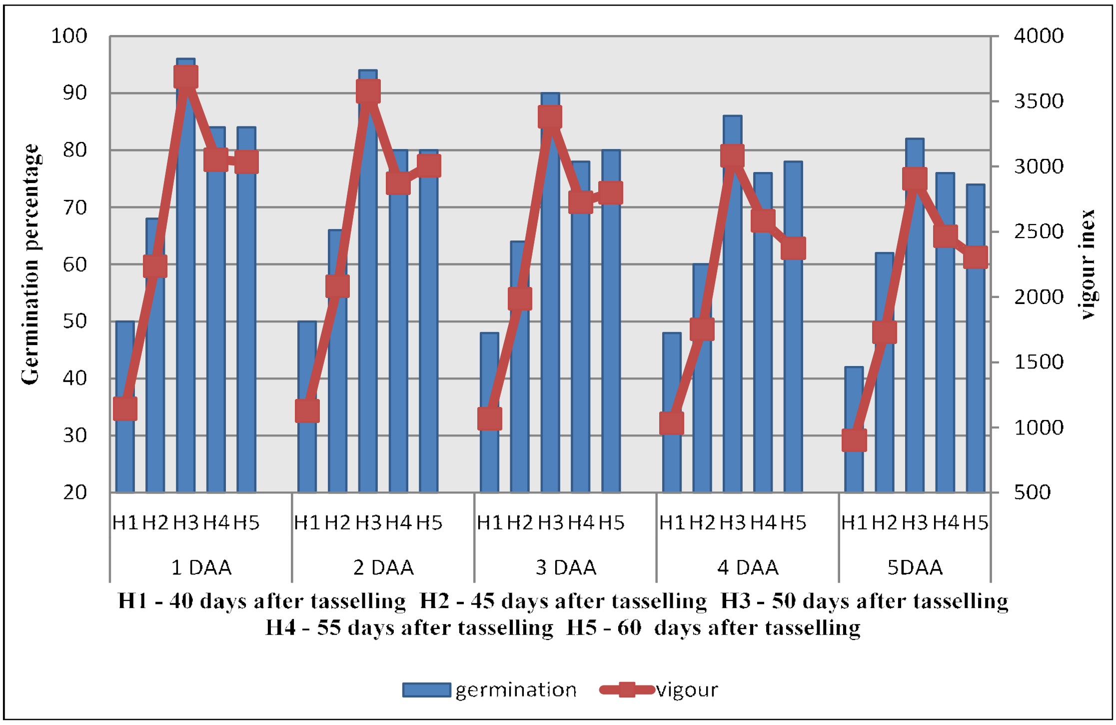

Fig 4: Accelerated aging test on germination and vigour index.

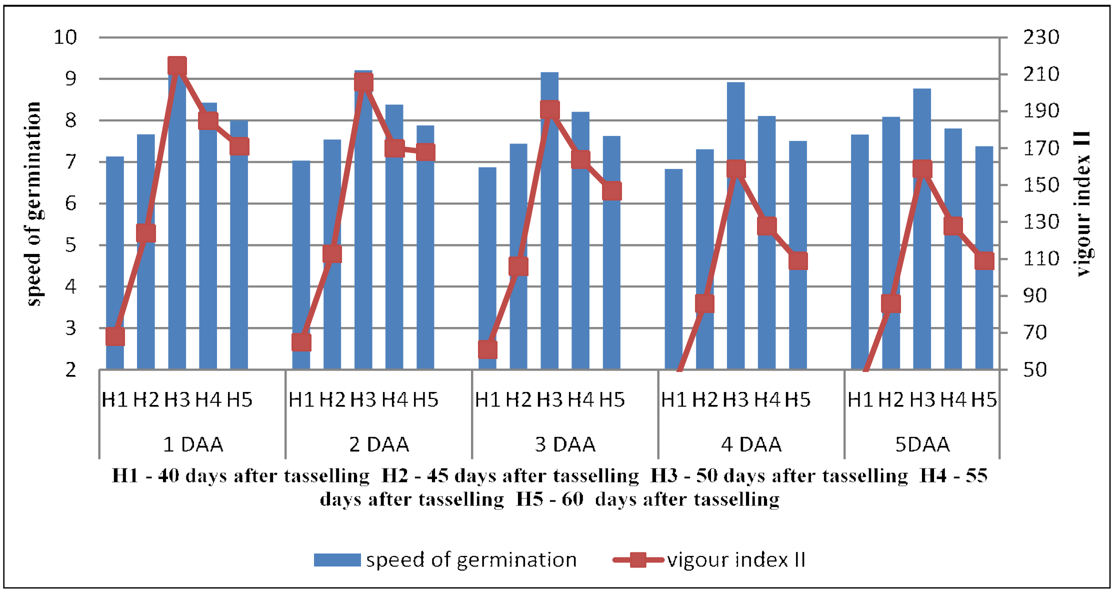

Fig 5: Accelerated aging test on speed of germination and vigour index II.

Table 1: Multiple linear regression equations fitted to explain the influence of harvesting intervals on seed quality parameters.

Dependent variable vs independent variable	R square	Equation
DAT vs cob moisture	0.73	Y= 97.53-1.277*X
DAT vs moisture content	0.90	Y= 40.21-0.5236*X
DAT vs 100 seed weight	0.88	Y= 8.450+0.2654*X
DAT vs electrical conductivity	0.65	Y= 0.5140-0.0064*X
DAT vs germination test	0.68	Y= -15.60+1.920*X
DAT vs cold test	0.68	Y= -29.20+2.080*X

as per Indian minimum seed certification standards (IMSCS). The seeds harvested from H3 maintained above 90% of germination upto three day of aging, but in four and five days of aging, we observed germination and vigour loss in H3. The reduction in germination might be due to the degradation of mitochondrial membrane leading to reduction in energy supply necessary for germination. The seeds that attain the physiological maturity (PM) were able to tolerate the exposed aging conditions of high temperature and high relative humidity, deteriorate at a slower rate and have high germination following aging, compared to earlier harvested seed lots.

Elias and Copeland (1997) also observed that seeds harvested earlier to PM resulted with germination of 19 and 25 % during accelerated aging test of two cultivars, whereas they were 64 and 72% for the standard germination test for the same cultivars. This may be because of seeds level of maturity, which makes them sensitive to any stress such as high temperature and relative humidity in accelerated aging test. Seeds that recorded high germination are considered as more vigorous and expected to maintain superior viability during storage.

In the multiple linear regression analysis, it indicates the influence of harvesting intervals on seed quality, where the R^2 value ranges from 0.6 to 0.98 (Table 1) and had positive significant relationship between different days of harvest and seed quality parameters such as hundred seed weight, electrical conductivity, germination percentage, accelerated aging, seed and cob moisture content and cold germination test.

As per Table 1, the multiple linear regression equation resulted in negative variables with respect to cob moisture, seed moisture content and electrical conductivity (- 1.277, -0.5236 and-0.0064), this demonstrates how changes in electrical conductivity and moisture content have a direct impact on seed quality. As a result, the positive variables of 0.2654, 1.920, and 2.080 resulted in a positive factor in multiple linear regression, which indicates that seed quality has improved as a result of an increase in seed weight, germination %, and cold germination test results.

R square value in multiple linear regression analysis (Table 1), seed moisture content and 100 seed weight cause 93%and 88% change in seed quality, which shows that moisture content and 100 seed weight directly influence seed quality.

CONCLUSION

It has been concluded from the above results and discussion of the present study that germinating properties such as hundred seed weight, electrical conductivity, germination percentage, accelerated aging test, seed and cob moisture content and cold germination test may be used potentially for the evaluation of seed quality. Across different harvesting intervals we found that seeds harvested at 40 and 45 DAT resulted poor seed quality, whereas seeds harvested at 50 DAT performed well and said to be the ideal harvest time. In future research for sustainable maize production in a changing climate, the techniques of the present study can be helpful in estimating and evaluating seed vigour by evaluating germination properties.

Conflict of interest: None.

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