Germination Characteristics of SC701 Maize Hybrid According to Size and Shape at Different Temperature Regimes

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Abstract: The aim of this study was to determine the effect of seed size and shape on germination characteristics of SC701 maize at different temperature regimes. Seeds were grouped according to shape and size and germinated using constant (30ºC and 20ºC), and two alternating (30/20 and 15/20ºC; 12/12 hrs) temperatures. A factorial experiment arranged in completely randomized design with three replications was used. Highly significant differences ($P < 0.001$) were observed for daily germination percentage, germination rate, mean germination time, germination velocity index and vigor index. Germination rate, and germination velocity index showed that flat seeds germinated faster than round seeds at constant temperatures while, small seeds germinated faster than large seeds. A similar trend was observed for vigor index which was higher in the small and flat seeds having a higher vigor index than large and round seeds. However, the vigor index was higher at the alternating temperature (20/30ºC) than at constant temperatures in all seed groups. Highly significant differences ($P < 0.001$) were observed in the root: shoot ratio, seedling dry mass and fresh mass. Small seeds had higher germination speed than large seeds. Higher temperatures (30ºC constant and 20/30ºC) were associated with better germination. It is concluded that the temperature regime has a major influence on seed morphology and its seed quality parameters. These findings are useful for selection of seed size and determination of soil temperature conditions to grow maize under field conditions.

Key words: Germination, Maize, Seed grouping, Temperature, Vigor.

Farmers plant their maize at different times ranging from early to late planting. The earlier planted crop is often sown in a dry cold seedbed, while optimum and late plantings usually occur during summer when the soil is often warm and wet. Under these conditions, temperature may prove to be an impediment to successful stand establishment. Therefore, testing the germination characteristics of seed at different temperatures is important.

Seed quality is determined by viability and vigor. While seed viability is responsible for germination, seed vigor influences the rate of germination and seedling establishment. Uniform seedling emergence and their vigorous establishment can ensure good plant population and final yield (Copeland and McDonald, 2001; Tekrony et al., 2005; Shirin et al., 2008). This is important because it influences field emergence, seedling establishment and subsequent performance of the resulting plant (Moreno-Martinez et al., 1998; Abbasian et al., 2013). Germination is an indication of viability, defined as the property of the seed that allows it to germinate under optimum conditions (Baldwin et al., 2006). Germination of seed may vary with the temperature regime (Bosci and Kovacs, 1990). This is because temperature is a modifying factor in germination since it can influence available soil water and nutrient supply necessary for maize growth and development (Bosci and Kovacs, 1990; Keeling and Greaves, 1990). The minimum temperature response for maize development is 10ºC while the optimum temperature is 30ºC (Bosci and Kovacs, 1990; Birch et al., 2003). According to Idikut (2013), the optimum temperature for maximum seed germination was 30ºC, and ranging from 17ºC to 30ºC produced high crop stand or seed germination and emergence. In KwaZulu-Natal, South Africa the mean monthly temperature ranges from 25 to 33ºC during the summer planting season and from 11ºC to 23ºC during the winter season (Smith, 2006). In the bioclimatic area where the study site was located, maize is usually planted in late spring or early summer when soil temperatures are low (10 – 11ºC) and it normally takes 138 – 150 days after planting to maturation. However, farmers and researchers worldwide have noticed a strong, negative relationship between low temperatures and seedling emergence which
in turn affects yield (Keeling and Greaves, 1990; Kirtok, 1998; Birch et al., 2003; Idikut, 2013).

Seed size and shape are also important characteristics that affect growth of maize hybrid (Shashdhara et al., 1988; Mazur and Feranec, 1994; Copeland and McDonald, 2001; Enayat Gholizadeh, 2012). Maize seed size and shape vary considerably due to genetics, and environmental conditions during growth and development, especially during the grain filling stage (Hussaini et al., 1984). The location of seed on the ear also plays an important role in deciding seed size (Graven and Carter, 1990). Conventionally, maize seed is categorized by size and shape. While some local small-scale farmers do not differentiate the shapes and sizes of seeds, previous studies have shown that germination and vigor of maize are significantly affected by seed size and shape.

Rammana (1967) found that the emergence rate was higher in the large seeds than in the medium and small seeds. Halim et al. (1969) studied the plants grown from seeds collected from the apical, middle and basal portions of the maize ear. They found that the seeds from the middle portion of the ear recorded highest seedling emergence. Hunter and Kannerberg (1972) found no difference in the germination percentage of maize in relation to seed size and shape. Recently, Tekrony et al. (2005) reported that germination rate and vigor indices were lower in round than flat seeds.

Among the maize hybrids in Southern Africa, SC701 is one of the most popular hybrids among small-scale farmers who still depend on rain fed agriculture. The SC701 hybrid is a high yielding variety with fairly good drought tolerance, and hence an optional variety under rain fed farming. This variety has a large ear size which is an important selection criteria for green mealies production (Corke and Kannenberg, 1989). Seed quality of SC701 hybrid has been obtained by the standard germination test (Mabhaudhi and Modi, 2010), but the germination according to seed size and shape under different temperatures has not been reported. The present study investigated the interactive effect of seed size and shape on the germination characteristics of SC701 hybrid under different temperature regimes. The results of the present study are expected to be beneficial to the farmers elsewhere and the information obtained could be useful for other maize hybrids.

**Materials and Methods**

1. **Planting material**

The standard large seed of SC701 was obtained from McDonalds Seed Company, Pietermaritzburg, South Africa. These seeds were grouped into small seeds with a weight of 4.0 to 4.5 g (0.4 to 0.45 g/seed) and large seeds with a 5.0 to 6.5 g (0.5 to 0.65 g/seed), using 10 seeds for each measurement. The seeds were further grouped according to shape giving four groups: round-large, round-small, flat-large and flat-small (Fig. 1). The 100 grain mass of these four ‘seed groups’ was then determined.

2. **Standard germination test**

A factorial experiment consisting of four temperature regimes, [30ºC and 20ºC constant and two alternating temperatures, 30/20ºC and 15/20ºC (12/12hrs)], seed shape (round and flat) and seed size (large and small) was laid out in a completely randomised design with three replications. The standard germination test was conducted by germinating four replicates of 25 seeds from each ‘seed group’ between double-layered paper towels (AOSA, 1992). The rolled paper towels were put in sealed plastic bags to avoid moisture loss and incubated in four different Labcon growth chambers (Labcon laboratory Equipment Germany L.T.I.E) with temperature set at 20ºC, 30ºC, 15/20ºC and 30/20ºC for 8 days. Daily count of germination was based on defining germination as radicle protrusion of 2 mm. Observations for final germination percentage, on day 8, were made according to AOSA (1992) guidelines. Upon termination of the experiment, 10 seedlings from each seed group were randomly selected and used to determine root length and shoot length, root: shoot ratios, fresh mass and dry mass. Seedling dry mass was determined by oven-drying at 70ºC for 72 hours and weighing them afterwards.

Germination rate (GR) was calculated according to Krishnasamy and Seshu (1990):

\[
GR (\%) = \frac{Number\ of\ seed\ germinated\ at\ 48hrs}{Number\ of\ seed\ germinated\ at\ 120hrs} \times 100
\]

Germination velocity index (GVI) which measures the speed of seedling germination was calculated according to Maguire (1962) formulae:

\[
GVI = \frac{G1}{N1} + \frac{G2}{N2} + \cdots + \frac{Gn}{Nn}
\]
where: GVI = germination velocity index,
\( G_1, G_2, \ldots G_n \) = number of germinated seeds in the first, second... last count, and
\( N_1, N_2, \ldots N_n \) = number of days after sowing at the first, second... last count.

Mean time to germination was calculated according to Bewley and Black (1994):

\[
MGT = \frac{\sum f x}{\sum f}
\]

where: MGT = mean germination time,
\( f \) = the number of seed completing germination on day \( x \), and
\( x \) = number of days counted from the beginning of germination.

The seed vigor index was calculated according to the formula by (Abdul-Baki and Anderson, 1973):

\[
Seed\ Vigor\ Index = \text{shoot length} \times \text{germination percentage}
\]

### Results and Discussion

The aim of this study was to determine the interactive effect of seed size and shape on germination characteristics (viability and vigor) of SC701 maize hybrid under different temperature regimes. Seed germination is an important characteristic and is critical to successful crop establishment in maize (Begna et al., 2001). On the other hand, seed quality can be inferred from germination characteristics. In terms of viability, the results showed that final germination for all the seed groups (seed size and shape) responded similarly to different temperature regimes. All seed groups had attained 100% germination by the eighth day and radicle protrusion was evident on the fourth day. Highly significant differences \((P < 0.001)\) were observed for daily germination percentage among seed groups, temperatures and their interaction, except temperature - seed size interaction (Fig. 2).

There were significant differences \((P < 0.001)\) in all the seed germination parameters except dry mass at different temperature regimes (Table 1). Similarly, significant differences were observed for germination velocity index, germination rate, mean germination time, root length, shoot length and fresh mass for both seed shape (flat and
round), whereas only mean germination time, fresh mass and dry mass were significant for seed size. This study observed better germination at 30ºC (constant) and 20/30ºC (alternating night/day) temperatures which was in accordance with Idikut (2013). Most studies showed that temperature is fundamental to germination, seedling emergence and vigor, which occur at a defined range (Carvalho and Nakagawa, 2000).

The interaction between temperature and seed size showed significant differences (P < 0.05) for vigor index, root : shoot ratio and fresh mass while temperature and shape interaction had significant differences for germination velocity index, germination rate and root length, which indicated their importance in determining seedling vigor. When considering the interaction between seed size and shape, the results showed significant differences (P < 0.001) for germination rate, germination velocity index, mean germination time, fresh mass, dry mass, and root : shoot ratio (Table 1) which agreed with previous studies by Harper et al. (1970) who suggested that seed shape and size affected seedling germinability and vigor.

However, when the interaction of the seed shape and size with the temperature was taken into consideration there were significant differences (P < 0.001) at germination velocity index, germination mean time, germination rate, vigor index, fresh mass, dry mass and shoot length (Table 1). The results of this study showed that an alternating temperature of 20/30ºC produces seedlings with the highest value in mean germination time, vigor index, root length, shoot length and fresh mass (Table 2). This could be attributed to a warmer alternating temperature at 20/30ºC which enhances germination better than at constant temperature regimes. According to Idikut (2013), the optimum temperature for maximum seed germination was 30ºC.

The interaction between seed size and temperature showed that, small seeds at 20/30ºC had a higher vigor index and R: S, than large seeds, while small seeds had a smaller fresh mass at the same temperature regimes (Table 2). This could be attributed to a warmer alternating temperature at 20/30ºC which enhances germination better than at constant temperature regimes. According to Idikut (2013), the optimum temperature for maximum seed germination was 30ºC.

### Table 1. Analysis of variance for interactive effect of temperature and seed group on seedling germination performance.

| S.O.V                        | df | Mean square          |
|------------------------------|----|----------------------|
|                              |    | GVI      | GR       | MGT      | VI        | RS       | RL       | SL       | FM       | DM       |
| Temperature regime           | 3  | 93.881** | 9833.22**| 0.0184** | 352501**  | 11.18218**| 130.067**| 47.81**  | 1.614**  | 0.0035ns |
| Seed shape                   | 1  | 408.33*  | 85.65**  | 0.98**   | ns        | ns        | 14.17*   | 3.63*    | 0.29*    | ns       |
| Seed size                    | 1  | ns       | ns       | 0.743**  | ns        | ns        | ns       | 0.65*    | 0.10**   | ns       |
| Seed group(size × shape)     | 3  | 32.860** | 211.00*  | 0.811284**| 0.03902*  | ns        | ns       | 0.34**   | 0.054**  | ns       |
| Temperature × seed size      | ns | ns       | ns       | 139543** | 0.054*    | ns        | ns       | 0.18*    | ns       | ns       |
| Temperature × seed shape     | 3  | 408.33** | 35.88**  | ns       | 79567ns   | ns        | 10.68*   | 1.4ns     | ns       | ns       |
| Temperature × seed group     | 9  | 14.998** | 168.33** | 0.018681*| 97507**   | ns        | ns       | 1.713*   | 0.081**  | 0.0079** |
| error                        | 30 | 2.082    | 55.04    | 0.001443 | 87.5      | 0.01075  | 3.701    | 0.679    | 0.013    | 0.0013   |

ns=non significant. *, ** indicate significant difference at probability levels of 5% and 1%, respectively. GR= germination rate; GVI=germination velocity index; MGT= mean germination time; VI = vigor index, RS= Root : Shoot; RL= root length; SL= shoot length; FM= fresh mass and DM= dry mass.

### Table 2. Mean value of temperature regimes on seed germination and seedling performance.

| Temperature | GR (%) | GVI | MGT (days) | VI   | RS   | RL(cm) | SL(cm) | FM(g) | DM(g) |
|-------------|--------|-----|------------|------|------|--------|--------|-------|-------|
| 20/30       | 0.00 a | 11.86 a | 3.60 a     | 771.6 b | 2.33 c | 17.97 d  | 7.77 c  | 2.19 d | 0.39 a |
| 15/20       | 17.42 b | 14.57 b | 3.51 a     | 402.7 a   | 0.33 a  | 10.34 a   | 3.45 a   | 1.37 a | 0.43 a |
| 30          | 58.67 d | 22.40 c | 3.54 a     | 461.2 a   | 0.48 b  | 15.30 c   | 7.30 c   | 2.00 c | 0.40 a |
| 20          | 34.33 c | 27.14 d | 3.58 a     | 657.9 b   | 0.48 ab | 12.68 b   | 5.18 b   | 1.63 b | 0.40 a |

LSD(P= 0.05) 8.670 2.187 ns 135.10 0.100 1.686 0.818 0.185 ns

Means in the same column followed by the same letters are not significantly different at 5% level of significance according to Duncan’s Multiple Range Test, ns=non significant. GR = germination rate; GVI = germination velocity index; MGT = mean germination time; VI = vigor index; RS = Root : Shoot, RL = root length; SL = shoot length; FM = fresh mass and DM = dry mass.
seeds absorb water faster than large seeds. Souza and Fagundes (2014) studied the correlation of seed size with seed germinability and seedling performance in *Copaifera langsdorffii* and reported that small seeds have a higher germination percentage and germinate faster. Germination may be different from that controlling the vigor of emerging seedlings.

Alternating temperatures generally gave the lowest germination rate and germination velocity index across the temperature regimes. However, flat seeds showed higher germination rate, germination velocity index and root length than round seed (Table 4). Germination rate was higher at constant temperatures compared to alternating temperatures. This was consistent with the report by Brevedan et al. (2013) that the germination rate was higher than 50% at constant (30 or 35ºC) than at alternating (10/30 or 10/35ºC) temperatures.

The only distinct trend observed with respect to seed size and shape interaction was that flat-small seed had the lowest mean germination time, fresh mass and dry mass, while round-large had the highest fresh mass and dry mass (Table 5).

Interestingly, small seeds had a higher germination rate than large seeds at a constant temperature among the seed groups (Table 6). This may be due to the fact that small seeds absorb water faster than large seeds. Souza and Fagundes (2014) studied the correlation of seed size with seed germinability and seedling performance in *Copaifera langsdorffii* and reported that small seeds have a higher germination percentage and germinate faster.
The lowest germination velocity index (10.81) was obtained in round-large seeds at alternating temperature of 20/30ºC while the highest germination velocity index (28.00) was obtained in flat-small seeds at the constant temperature of 30ºC (Table 6). This showed that the speed of germination was faster in small and flat seeds than in large and round seeds contrary to the report by Nik et al. (2011) that, in wheat, large seeds have superior performance to small seeds. Mabhaudhi and Modi (2010) observed that germination velocity index is a better indicator of germination speed than germination rate. Therefore, this study relies more on the germination velocity index than germination rate as an indicator of germination speed. This suggested that seed shape influences the speed of germination. Flat seeds have a larger surface area than round seeds. Therefore, flat seeds have a higher water uptake rate than round seeds. Batistella-Filho et al. (2002) also reported that seed shape showed a significant effect on seed germination, seed emergence, and speed of germination. In the present study, seed size had no effect on germination but had impact on seedling vigor. According to Evans and Bhatt (1977), the threshold level for growth activation in small seeds may be reached faster when the quantity of food reserves and metabolites in grain is smaller. Other studies revealed that germination was significantly slower at alternating temperatures than when the temperature was constant (Bosci and Kovacs, 1990; Birch et al., 2003; Idikut, 2013). In the present study, a high germination rate observed at a constant temperature of 30ºC might be due to rapid hydrolysis and mobilization of seed reserves through higher alpha–amylase activity at higher temperatures (Bewley and Black, 1994).

All seed groups showed a decreasing trend in vigor index as temperature increased from 20ºC to 30ºC. At 20ºC, the vigor index was 495 – 733, while at 30ºC, the vigor index was 267 – 533 (Table 6). All seed groups had the highest vigor index at 20/30ºC, flat-small seeds showed the highest vigor index at 20/30ºC while round-large (231.7) and flat-large (250) seeds had the lowest vigor index at 15/20ºC. Seed vigor index which is an attribute of vigour test complement the standard germination test (Abbasian et al., 2013). Sulewska et al. (2014) reported lower amylase activity in large seedlings than small seedlings. The seedling vigor which is important in germination also decreases in large seeds under a low temperature. Therefore, flat-small seeds are likely to perform better under field conditions due to their high vigor index (Shirin et al., 2008).

At alternating temperatures (15/20 and 20/30ºC), all seed groups showed similar germination rates. However, the mean germination time was faster in smaller seeds of both shapes. The mean germination time in flat-large and flat-small seeds was the lowest at different temperature regimes, which means that the flat seeds of SC701 germinated faster than the round seeds at different temperatures.

### Table 6. Effects of temperature and seed size on the mean values of seedling germination performance.

| Seed group    | Temperature | GR(%)   | GVI     | MGT (days) | VI  | RS     | RL(cm) | SL(cm) | FM(g) | DM(g) |
|---------------|-------------|---------|---------|------------|-----|--------|--------|--------|-------|-------|
| Round-large   | 20          | 17.33 ab| 26.47 f | 3.41 ab    | 733.30 fg | 0.42 abc| 12.12 abcd | 5.10 b | 1.79 e | 0.52 f |
|               | 30          | 53.33 d | 26.47 f | 3.45 ab    | 510.00 cd | 0.49 c  | 15.31 def  | 7.33 de | 2.11 fg | 0.48 ef |
|               | 15/20       | 0.00 a  | 14.06 cd| 3.48 b    | 231.70 a  | 0.42 abc| 12.12 abcd | 5.10 b  | 1.79 e  | 0.52 f  |
|               | 20/30       | 0.00 a  | 10.81 a | 3.47 ab    | 793.30 fg | 2.49 c  | 19.72 h   | 7.93 de | 2.45 h  | 0.49 ef |
| Round-small   | 20          | 28.00 bc| 20.61 e | 4.09 e    | 495.00 bc | 0.42 abc| 11.90 abcd | 4.95 b  | 1.55 d  | 0.37 bcd|
|               | 30          | 64.00 d | 27.69 f | 3.86 d    | 266.70 a  | 0.46 bc | 17.13 fg  | 7.80 de | 2.03 f  | 0.39 cd |
|               | 15/20       | 0.00 a  | 13.60 bc| 3.77 c    | 774.30 fg | 0.29 ab | 9.32 a    | 2.67 a  | 1.21 ab | 0.41 d  |
|               | 20/30       | 0.00 a  | 11.02 ab| 4.05 e    | 769.10 fg | 2.22 d  | 19.32 gh  | 8.70 c  | 2.07 f  | 0.34 abc|
| Flat-large    | 20          | 45.33 cd| 26.47 f | 3.40 a    | 718.30 fg | 0.395 ab| 13.45 cde | 5.33 bc | 1.78 e  | 0.40 d  |
|               | 30          | 53.33 d | 26.25 f | 3.40 a    | 553.30 cde| 0.51 c  | 14.45 def | 7.18 de | 1.77 c  | 0.32 ab |
|               | 15/20       | 0.00 a  | 14.51 cd| 3.40 a    | 250.00 a  | 0.26 a  | 9.78 ab   | 2.50 a  | 1.35 bc | 0.47 ef |
|               | 20/30       | 0.00 a  | 13.25 abc| 3.45 ab   | 665.00 def| 2.47 c  | 15.95 egf | 6.65 cd | 2.29 gh | 0.43 de |
| Flat-small    | 20          | 46.67 cd| 25.97 f | 3.41 ab   | 685.00 ef | 0.40 abc| 13.27 bcde| 5.35 bc | 1.41 cd | 0.30 a  |
|               | 30          | 64.00 d | 28.14 f | 3.43 ab   | 555.00 cde| 0.47 bc | 14.45 def | 6.85 d  | 2.09 fg | 0.43 de |
|               | 15/20       | 0.00 a  | 16.51 d | 3.40 a    | 355.00 ab | 0.35 abc| 10.15 abc | 3.55 a  | 1.14 a  | 0.33 abc|
|               | 20/30       | 0.00 a  | 12.35 abc| 3.43 ab   | 858.90 g  | 2.17 d  | 16.88 egf | 7.80 de | 1.94 ef | 0.32 ab |

LSD ($P = 0.05$) 12.37 2.41 0.05 153.20 0.17 3.27 1.42 0.19 3.27

Means in the same column followed by the same letters are not significantly different at 5% level of significance according to Duncan’s Multiple Range Test. MGT= mean germination time; VI = vigor index; RS= Root : Shoot; RL= root length; SL= shoot length; FM= fresh mass and DM= dry mass.
temperature regimes. Moreover, Moreno-Martinez et al. (1998) compared the effect of seed shape and size on seed viability of flat and round seeds of maize hybrid and found that flat-large maize seed maintained a higher viability during storage than round-small seeds. This was attributed to the fact that flat seeds not only germinated faster, but also their seedlings were established more quickly. In the experiment conducted by Popp and Brumm (2003) on five hybrids of maize graded as flat and round seeds, they observed that germination and vigor of round seed declined faster than flat seeds which was attributed to lower vigor of round seeds as compared to flat seeds.

Similarly, at 20/30°C, all seed groups had longer shoots at 20/30°C than at 15/20°C (Table 6). The shoot length was the shortest at 15/20°C (2.50 cm) and highest at 20/30°C (7.80 cm). Shoot length in maize increases with increase in optimum temperature. The present findings were in agreement with the studies conducted by (Li et al., 2014) in wheat and maize varieties who reported that maize seedlings had weaker resistance to low temperature which inhibited the seedlings length (root and shoot lengths).

Although, the fresh mass was statistically significant, increasing trends were observed with increasing temperatures among the seed groups. The fresh mass values were lowest at 15/20°C among the seed groups (1.14 – 1.79 cm). This could be attributed to the low rate of metabolic activity in the seed due to low temperature. Dry mass was also smaller in small seeds (0.30 – 0.39 cm) than in large seeds (0.32 – 0.52 cm) among the seed groups at different temperature regimes except flat-small (0.43 cm) at 30°C constant (Table 6). This was possibly due to variation in storage nutrients in large seeds compared with the small ones (Shirin et al., 2008). Contrary to the findings of Lehtilä and Ehrlén, (2005), this study suggested that seed size is a good indicator of seed quality in maize.

Conclusions

The findings of the present study showed that both seed size and shape affect the germination performance of SC701 white maize cultivar. Flat-small maize seeds had a high germination and seedling establishment potential compared with round-large seeds. Although the study was laboratory based, the findings showed that optimum germination occurred at 20/30°C (night/day) and 30°C (constant), were comparable to the optimum temperatures for growing maize in the tropical and sub-tropical areas of the world. The effect is better understood in the context of interaction between germination temperature and seed morphology and is less obvious when single factors are observed. Therefore, depending on the temperature conditions, the speed of germination is important for uniform seedling establishment. Further studies are required on the performance of the maize hybrid seeds in terms of shape and size at different temperature regimes under a wide range of field conditions.

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