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Influence of Maize Seed Size/Shape, Planted at Different Depths and Temperatures on Seed Emergence and Seedling Vigor

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ABSTRACT

Variation in seed size and shape along the maize cob often raises this question that which one is better in terms of seed germination and seedling establishment. The widespread belief among farmers is that large and flat seeds germinate faster and produce larger seedlings than other sizes or shapes. Thus the current study was aimed to determine the influence of maize seed size/shape, planting depth and temperature on seed emergence and seedling vigor. For this purpose, a laboratory experiment was conducted during 2012 year at Seed Technology Research Unit in Mansoura, Dakahlia Governorate, Field Crops Research Institute, Agricultural Research Center, Egypt. The treatments comprised of six levels of seed size/shape (large round, large flat, medium round, medium flat, small round and small flat) of maize hybrid single cross 131 (SC131), three levels of planting depth (2, 4 and 6 cm) and three levels of temperature (20, 25 and 30°C). From the results, seed size/shape, planting depth and temperature showed significant effect on seed germination indexes such as seed emergence percentage, mean emergence time, shoot length, root length and seedling dry weight. For instance, germination indexed increased with increasing seed size, however; increase in planting depth significantly reduced the germination indexes. By contrast, the maximum values were obtained when seed germinate at 30°C. The interaction between seed size/shape, planting depth and temperature showed a significant effect on seed emergence percentage and seedling vigor, except for seedling dry weight. Although, the effect of seed size/shape was not significant on seed emergence percentage at a depth of 2 cm and 30°C, a significant effect was observed at the depth of 4 and 6 cm. The large seeds (whether flat or round) produced the best values through the different planting depths and temperatures. The lower in seed emergence and seedling vigor of round seed than flat one is evident in small and medium seed size, when planted at deeper depths and lower temperatures. The diversity of influences on maize seed quality between flat and round shapes is corresponding with unfavorable conditions.

Key words: Maize, planting depths, seed emergence, seed quality, seedling vigor, seed size/shape, temperatures

INTRODUCTION

Maize (*Zea mays* L.) seeds vary in shape and size in different kinds and varieties. The size and shape of the seeds which are formed on a cob are different based on the location of the constituting florets and also the filling length of each seed on the maize (Wych, 1988). Seeds come from the tip of the cob tend to be small round while from the bottom of the cob, tend to be large round but those from the middle tend to be flat. Stresses such as high temperature, low soil moisture, or low fertility can affect seed size (Burris *et al*., 1984). Although, maize seed industry has utilized of seed size/shape differences to grade seed of many hybrids and the graded seed was used initially to aid in precision field planting with plated planter. Either medium/flat or large/flat seed remains the first choice of many farmers, because of feeling that seed have higher quality and less susceptible to mechanical damage than the round grades (Graven and Carter, 1990; Tekrony *et al.*, 2005). Planting maize seed by hand is the most common method used by small farmers in Egypt. Presumably, seed (with different size/shape) cannot be placed at the correct depth by hand, particularly on a rough seedbed. In addition, the planting of those seed probably has been extended to unfavorable temperatures. This may induce a serious problem in seed emergence and seedling vigor.

Various studies have been done on the effect of the seed size/shape on seed quality of hybrid maize (Hampton, 1981; Shieh and McDonald, 1982; Graven and Carter, 1990; Bockstaller and Girardin, 1994; Peterson *et al.*, 1995; Varga *et al.*, 2012). They stated that seed size and shape had effect on seed quality and added that medium and small-round grades were lower in germination, seed and seedling vigor than flat one. Graven and Carter (1990) found that small/round seed was lower in germination in the field than small/flat under stressful conditions. Bigger seeds tend to germinate more successfully in the field and produce more vigorous seedlings (Hawkins and Cooper, 1979; Bockstaller and Girardin, 1994). Unlike, Lafond and Baker (1986) stated that smaller seeds germinate faster and their seedlings grow rather quickly than large seed and that is clear under stressful conditions (Muchena and Grogan, 1977). While, Martin *et al.* (1976) and Peterson *et al.* (1995) declared that round seed has more tendencies to mechanical damage than the flat one.

Planting depth is possibly one of the most important factors in maize production. The problem of low plant stands may be due to their planting method of covering seeds through ploughing. A depth of 2 cm under soil is considered shallow while 8 cm is considered deep (Sprague, 1977). Thus, achieve a good seedbed contact with more consistent moisture levels for immediately germination and establish a strong nodal root system depends on planting depth (Martin and Leonard, 1963). Depth of planting may be an important factor in seedling emergence (Martin *et al.*, 1976). While, Alessi and Power (1971) found that each 2.6 cm increase in planting depth faced by one day delayed in field emergence. Planting maize seed shallower (at least 5 cm), their crops will be healthier, more reliable and higher yields (Bockstaller and Girardin, 1994).

Temperature during germination is very important factor, it has effects both germination power and germination speed (Fortin, 1993; Esechie, 1994). It is fundamental to determine the optimum temperature for any plant. Maize maintains its growing at high temperatures. Ideally, maize plant needs 10-11°C temperature to start germination. Inglett (1970) and Bunting (1971) reported that most maize seed germinated slowly below 10°C. It needs a temperature parameter above 15°C (17-18°C) and 30°C for optimum and maximum temperature, respectively. If it reaches to 32°C, there would be a sudden decrease in stem and root growth (Bonner and Galston, 1952). If temperature is lower than 9°C, root growth well stops, too (Kirtok, 1998). Also, the germination rate and coleoptile length were affected at different temperatures (Idikut, 2013).

Thus, the purpose of this study was to evaluate the influence of maize seed size/shape, planted at different depths and temperatures, on seed emergence and seedling vigor.

MATERIALS AND METHODS

A laboratory experiment was carried out under the laboratory conditions of Seed Technology Research Unit in Mansoura, Dakahlia Governorate, Seed Technology Research Department, Field Crops Research Institute, Agricultural Research Center during 2012 year. The purpose of this

Table 1: Size/shape grade distribution of maize hybrid (Sc 131) seed sample by using hand round and slotted holes screens

Round-hole screen (mm)	Slotted-hole screen (shape) over/through (5.15 mm)	Size/shape grade
Over 8.7 mm	Over through	Large round large flat
Through 8.7 mm and over 7.5 mm	Over through	Medium round medium flat
Through 7.5 mm	Over through	Small round small flat

investigation was to examine the influence of maize seed size/shape, planted at different depths and temperatures, on seed emergence and seedling vigor. Sample of maize (*Zea mays* L.) hybrid Single Cross 131 (SC131) was obtained from Seed Testing Station in Mansoura, Dakahlia Governorate, Central Administration for Seed Certification, Giza, Egypt. The sample graded by using hand-screens. The separating was done from large to small size first and then by rounds and flats shape. This was accomplished by using round hole screens to separate the seed into small (<7.5 mm), medium (7.5-8.7 mm) and large (>8.7 mm), then used slotted screens (5.15 mm) to separate each of the small, medium and large into rounds and flats (Table 1).

Therefore, the studied treatments were as follow:

- Size/shape (small/round, small/flat, medium/round, medium/flat, large/round and large/flat)
- Planting depth (2, 4 and 6 cm)
- Temperature (20, 25 and 30°C)

Three replications of 50 seeds from each 6 graded maize seeds were prepared for every planting depth. The sterilized dry soil, composed of clay and sand (3:1), was leveled in plastic box (25×13×15 cm) at the required depth and after the graded seed were planted they were covered by dry soil to obtain the required depth (2, 4 and 6 cm). Boxes were watered after planting and then placed in germination room at 20°C, this procedure was done again two times in the same germination room under two temperature regimes (25 and 30°C). Every experiment was carried out in Factorial Randomized Complete Block Design. A 12 h photo period was maintained and boxes were watered every day after emergence. Laboratory evaluation of seed emergence and seedling vigor were conducted as follows:

- **Seed emergence percentage:** It was calculated by counting normal seedlings after 15 days from planting
- **Mean Emergence Time (MET):** It was calculated according to the equation of Ellis and Roberts, (1981)

$$MET = \Sigma\,(Dn)/\Sigma\,n$$

where, n is the number of emerged seed on day and D is the total number of days counted from the beginning of emergence.

- **Shoot length (cm):** After 15 days from planting the seedling biomass was gently washed to remove the soil and shoot length was measured of ten seedlings (cm)
- **Root length (cm):** The same 10 normal seedlings of shoot length evaluation test used to evaluate root length (cm)

- **Seedling dry weight (g):** After evaluating shoot and root lengths, 10 seedlings were dried in a forced air oven at 110°C for 17 h (Agrawal, 1986) to obtain seedlings dry weight and expressed as grams

Data was statistically analyzed according to the technique of the analysis of variance (ANOVA) for the factorial randomized complete block design and then combined analysis was done published by Gomez and Gomez (1984) by using means of “MSTAT-C” computer software package. The treatments and means were compared using the Least Significant Differences (LSD) method as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Differences in treatment main effects are shown in Table 2. The different temperature degrees during germination (30, 25, 20°C) had a significant effect on seed emergence percentage and seedling vigor (mean emergence time, shoot length, root length and seedling dry weight). The maximum values were obtained from planting at 30°C. While, the minimum values were obtained at 20°C. The temperature effect was the same for all studied characters. For example, the temperature 30°C recorded 95.6%, 25.13, 13.55 cm and 1.689 g with seed emergence percentage, shoot length, root length and seedling dry weight, respectively. In case of Mean Emergence Time (MET) the shorter (better quality) one (3.27 day) was obtained also, from 30°C while, the delayed one (7.84 day) was recorded with 20°C. This is similarly with Kirtok (1998) who reported that

Table 2: Seed emergence percentage, Mean Emergence Time (MET), shoot length, root length and seedlings dry weight as affected by temperature, size/shape and planting depth

Treatments	Emergence (%)	MET (day)	Shoot length (cm)	Root length (cm)	Seedlings dry weight (g)
Temperature effects (°C)					
30	95.6	3.27	25.13	13.55	1.689
25	93.9	4.14	22.88	11.29	1.342
20	90.3	7.84	16.77	9.44	1.150
LSD at 5%	0.4	0.05	0.45	0.28	0.012
Size/shape effects					
Small/round	90.1	5.41	17.70	8.77	1.304
Small/flat	90.8	5.27	18.33	9.44	1.312
Medium/round	92.9	5.28	21.03	11.44	1.384
Medium/flat	93.5	5.21	21.18	11.74	1.386
Large/round	96.0	4.70	25.48	13.44	1.491
Large/flat	96.2	4.65	25.85	13.74	1.486
LSD at 5%	0.3	0.06	0.39	0.26	0.010
Planting depth effects (cm)					
2	96.6	4.33	24.57	13.70	1.442
4	94.4	5.08	21.79	11.33	1.393
6	88.8	5.85	18.42	9.25	1.347
LSD at 5%	0.2	0.03	0.21	0.19	0.006
Interactions					
A×B	*	*	*	*	*
A×C	*	*	*	*	NS
B×C	*	*	*	*	NS
A×B×C	*	*	*	*	NS

*Significant, NS: Non Significant

temperature (10-30°C) had a linear effect on emergence, root and shoot growth. Idikut (2013) also reported that germination rate and coleoptile length were affected at different temperatures.

The size/shape of the seed which was under investigation has had significant differences on seed emergence and seedling vigor. The best values were obtained from large/flat seed while, the small/round seed recorded the lower seed quality. As seed size increased the seed quality (indicative by seed emergence percentage, mean emergence time, shoot length, root length and seedling dry weight) increased. As regard seed shape (flat, round), statistical analysis of data showed in almost all cases non significant differences between flat and round shapes except in small and medium size in emergence percentage, mean germination time and root length. Similarly, the significant differences were noted in root length of large size, whereas, the different sizes of flat seed precede the different sizes of round seed. For example, in emergence percentage of small size, small flat was 90.8% while, small round was 90.1%. Similarly, medium flat and medium round were 93.5 and 92.9%, respectively. These results are in conformity with Mugnisjah and Nakamura (1986) and Shirin *et al.* (2008) who reported seed size is one of the most important properties of a seed and it affects the emergence and seedling vigor. While, Hawkins and Cooper (1979) and Enayatgholizadeh *et al.* (2011) reported that larger seedling were produced from larger seed.

Planting depth influenced both seed emergence percentage and seedling vigor (Table 2). Seed emergence produced from planting at 2 cm depth was bigger than of that at 6 cm depth (96.6 and 88.8%, respectively). Also, at 15 days after planting, shoot and root lengths of seedlings produced from 2 cm depth (24.57 and 13.70 cm, respectively) differed significantly with those of 6 cm depth (18.42 and 9.25 cm, respectively). Generally, as planting depth increased, seed emergence and seedling vigor decreased. This implies that deeper planting is a part from reducing seedling emergence and seedling vigor. These results are in line with Alessi and Power (1971) who found that each 2.6 cm increase in planting depth face by one day delayed in field emergence. While, Bockstaller and Girardin (1994) reported that planting maize seed shallower (at least 5 cm) their plants will be healthier. Unlike, seed size does not have an effect on emergence and seedling vigour when planted at the depth of 5 and 10 cm but shows an adverse effect on emergence and seedling vigour when planted at 15 and 20 cm depth (Molatudi and Mariga, 2009).

The interaction among seed size/shape, planting depth and temperature, had a significant effect on seedling emergence and seedling vigor (Table 3 and 4).

Seed emergence percentage: The results in Table 3 showed no significant differences among all seed size/shape treatments on seed emergence percentage when planted at 2 cm depth at 30°C. But, planting at 4 or 6 cm depth, the differences among seed size/shape treatments significantly influenced seed emergence percentage. Increase round seed in size from small through medium and up to large at 4 cm planting depth produced increase in seed emergence percentage (94.6, 95.6 and 99.0%, respectively). Similarly, the flat seed increased 94.3, 96.6 and 99.3%, respectively. The trends were similar to those for 6 cm depth. It means that the large seed size (round or flat) is the best one but in case of shallower plant depth (2 cm) and optimum temperature (30°C), the differences in seed size/shape had no influence in seed emergence percentage.

As temperature decreased seed emergence percentage decreased for all seed size/shape treatments through the different planting depths (Table 3). When planting temperature decreased to 25°C similar trends were observed. However, at 2 cm depth, the large (flat and round) seed produced the maximum values followed by the medium (shapes) seed and then small (shapes) seed with significant differences among them. This is probably to the decrease in planting temperature

Table 3: Seed emergence percentage and Mean Emergence Time (MET), as affected by the interaction among size/shape, planting depth and temperature

	Temperature (°C)					
	Emergence (%)			MET (day)		
Size/shape and planting depth (cm)	30	25	20	30	25	20
Small/round						
2	98.6	96.0	92.6	2.83	3.40	6.70
4	94.6	92.3	88.6	3.60	4.33	7.90
6	87.0	83.3	78.3	4.60	5.70	9.70
Small/flat						
2	98.3	95.3	93.0	2.76	3.46	6.60
4	94.3	92.6	89.3	3.50	4.30	7.83
6	87.6	86.0	81.3	4.50	5.40	9.06
Medium/round						
2	98.6	97.6	93.3	2.80	3.63	7.50
4	95.6	94.6	92.0	3.30	4.33	8.23
6	91.6	88.6	84.3	3.93	4.83	9.00
Medium/flat						
2	98.6	97.0	93.6	2.73	3.60	7.46
4	96.6	95.6	92.6	3.23	4.26	8.16
6	91.6	89.6	86.0	3.86	4.76	8.80
Large/round						
2	99.3	98.3	96.0	2.60	3.33	6.36
4	99.0	97.3	93.6	2.93	3.73	7.66
6	95.3	94.6	90.6	3.23	4.33	8.13
Large/flat						
2	99.0	98.6	95.0	2.53	3.26	6.43
4	99.3	98.0	94.0	2.86	3.66	7.60
6	96.0	95.3	91.0	3.16	4.30	8.10
LSD at 5%	1.0			0.12		

from 30-25°C. Inglett (1970) and Bunting (1971) also reported that most maize seed germinate slowly at lower temperature. It is worth to mention that differences between the round and flat shape were observed when planting the small size of both shapes at 6 cm depth whereas the flat shape produced the higher seed emergence percentage (86.0%) compared to round shape (83.3%). These values indicated that small/ round seed is more susceptible to lower temperature and deeper planting than small/flat seed. These results are in line with Shieh and McDonald (1982), Graven and Carter (1990) and Peterson *et al.* (1995) who reported that there is evidence that round seeds have lower emergence percentage and seedling performance than flat seeds, particularly in the medium and small size seed under stressful conditions.

Planting at 20°C through the different planting depths resulted in significant differences among seed size/shape treatments on seed emergence percentage. The flat shape for all seed sizes surpassed the round shape, particularly small and medium sizes when planting at 6 cm depth which had a significant difference between the both shapes. Seed emergence percentage for small flat and small round was 81.3 and 78.3%, respectively. While, medium size was 86.0 and 84.3%, respectively. Similar results were obtained by Graven and Carter (1990) who reported that although small/round seed had low emergence percentage when differences due to seed size/shape

Table 4: Shoot and root lengths as affected by the interaction among size/shape, planting depth and temperature

	Temperature (°C)					
	Shoot length (cm)			Root length (cm)		
Size/shape and planting depth (cm)	30	25	20	30	25	20
Small/round						
2	25.66	22.66	15.00	13.00	11.00	8.33
4	22.33	19.33	12.33	11.33	9.00	6.33
6	19.00	15.66	7.33	9.00	7.00	4.00
Small/flat						
2	25.33	23.00	15.66	13.33	11.66	8.66
4	23.00	20.00	12.66	11.66	9.33	7.33
6	19.33	16.00	10.00	9.00	8.33	5.66
Medium/round						
2	27.33	24.66	19.33	15.66	13.33	12.00
4	25.00	22.33	16.66	13.00	11.66	10.00
6	21.66	18.66	13.66	11.00	10.00	6.33
Medium/flat						
2	27.66	25.00	20.00	16.00	13.00	12.33
4	24.33	22.66	17.00	13.33	11.33	10.33
6	21.33	19.33	13.33	11.00	10.33	8.00
Large/round						
2	30.33	30.00	24.66	18.00	16.00	14.66
4	28.33	26.66	21.66	16.00	12.33	11.00
6	26.00	24.00	17.66	14.00	10.00	9.00
Large/flat						
2	30.66	30.33	25.00	18.00	16.33	15.33
4	28.66	27.33	22.00	16.33	12.66	11.00
6	26.33	24.33	18.00	14.33	10.00	9.66
LSD at 5%	0.85			0.80		

occurred, in all environments small/flat seed had emergence percentage equal to, or greater than, the average values. It may be inferred from these results that seed shape effect are not apparent with large (flat or round) under optimum or stressful conditions compared to small or medium size seed. These results are supported by Hampton (1981), Shieh and McDonald (1982), Graven and Carter (1990), Bockstaller and Girardin (1994), Peterson *et al.* (1995) and Varga *et al.* (2012). They stated that seed size and shape have effect on seed quality and added that medium and small/round grades were lower in germination, seed and seedling vigor than flat one.

Mean Emergence Time (MET): A perusal of the transformed data regarding mean emergence time (Table 3) depicted that size/shape×planting depth×temperature was significant. However, the efficiency of a large seed size through planting depths at 30°C is reflected by its shortest MET (emerged more rapidly) than other sizes. Seed shape had insignificant effect. Accordingly, the MET of seed shapes in each size were similar. For example, flat and round of large size at 6 cm depth were 3.16 and 3.23 days, in medium were 3.86 and 3.93 days and in small were 4.50 and 4.60 days, respectively. The slow and prolonged emergence (high MET) in seed size/shape has often been associated with lower temperature and deeper planting depth. Thus, the shortest MET (best quality) was found in the shallowest depth (2 cm) with large flat seed at 30°C (2.53 days).

While, the slow and prolonged one (lower quality) was found with small/round seed in deeper depth at 20°C (9.70 day). As regard seed shapes effect, statistical analysis of data showed a significant difference between small flat and small round seed when planting at 6 cm depth at 25 or 20°C (5.40, 5.70 days and 9.06, 9.70 days, respectively). Also, the medium/flat seed precede the medium/round as given by MET at 6 cm depth and 20°C (8.80 and 9.00 days, respectively). Noteworthy, the significant differences between flat and round shape of seed sizes were also noted of seed emergence percentage under the same conditions. It means that MET is corresponding with final seed emergence percentage. For example, the longest MET (9.70 day) and the lower seed emergence percentage (78.3%) were obtained from planting small/round at 6 cm depth at 20°C. Contrary, the shortest MET and the highest seed emergence percentage at 6 cm depth under 20°C was produced with large/flat seed (8.10 and 95.3%, respectively). This may be due to the ability of coleoptiles of large/flat seed to penetrate the soil and grow up faster to develop normal seedling than small/round one. These findings are in conformity with Elmore and Abendroth (2005) they demonstrate that the amount energy stored in the endosperm in small size seed may be lower than the amount of energy needed under stressful conditions. Graven and Carter (1990) reported under those conditions field emergence of small/round seeds was 5-15% lower than small/flat seeds.

Shoot length: There was significant differences among seed size/shape treatments through planting depths under the different temperatures on shoot length (Table 4). Although, seed emergence percentage was not significant among the different seed size/shape treatments under the planting optimum conditions (30°C and 2 cm depth), shoot development showed significant differences at those conditions. The tallest shoot was obtained from large/flat seed (30.66 cm) while, the lowest one (25.66 cm) was obtained from small/round. Noticeable, the differences between round and flat shape in all seed sizes at the same planting depth were not significant, this seems to indicate that the differences in shoot length may be resulted from the differences seed size only. These results showed that different maize seed size can perform differently under normal conditions (30°C and 2 cm depth) while seed shape conducted evenly under those conditions Gholizadeh (2012) was also the opinion that the increase of seed size increased the seed emergence percentage and seedling vigor.

Similarly, at 25°C the large/flat and round seed produced the tallest shoot through the different depths. For example, planting at 6 cm depth shoot lengths of the large/flat and round seed were 24.33 and 24.00 cm, respectively. Meanwhile, the shortest one was produced from small/flat and round (16.00 and 15.66 cm, respectively).

Planting at the lower temperature (20°C) produced wide differences among seed size/shape treatments than of those occurred at 30 and 25°C. For example, the increase in shoot length of planting medium/round than small/round seed at 4 cm depth at 25°C was 3.0 cm while, the increase was 4.33 cm at 20°C. This indicated that ability of bigger seed size to produce tallest shoot than smaller seed size decrease with increase temperatures. Idikut (2013) was also the opinion that the germination rate and coleoptile growth were affected at different temperatures. As seedling emergence percentage was affected by seed shape in medium and small sizes at 20°C and planting at 6 cm depth, the flat shape, in small size, produced the taller shoot (10.0 cm) than the round (7.33 cm) one. This may be due to increased pericarp injury to the small/round (Graven and Carter, 1990) whereas, Martin *et al*. (1987) and Peterson *et al*. (1995) found increased in susceptibility to mechanical damage in round seed than flat shape one.

Root length: As the results are showed in Table 4, large seed size (flat or round) planted through different depths at temperature 30°C had a higher root length. Nevertheless, the lowest root length was obtained from small seed size (flat or round). Although, all seed size/shape treatments at 30°C demonstrated that the differences were related to seed size character only, the differences effect at 25°C between the two shapes (flat and round) of small seed on root length was significant at 6 cm depth (8.33 and 7.0 cm). Likewise, the medium/round seed at 20°C produced significantly the inferior root length (6.33 cm) compared to the medium/flat one (8.0 cm). Consequently, differences in effect of different shapes on root length through the same seed size were noted with small size seed at 4 and 6 cm depths whereas, the flat shape produced the highest values of root length through the both depths. The corresponding data were 7.33 and 5.66 cm, respectively. The stunted root produced by round shape seed comparing with flat one may be proved that the lower temperature and deeper planting demonstrate the diversity of seed shape effect of medium or small seed size or both. Our findings are in agreement with Hampton (1981), Shieh and McDonald (1982), Graven and Carter (1990), Bockstaller and Girardin (1994), Peterson *et al.* (1995) and Varga *et al.* (2012).

CONCLUSION

The summarization of the results of this experiment showed that, by increasing the seed size of maize, seed emergence and seedling vigor increased. The large seed size (whether flat or round) influence evenly compared to other sizes in seed emergence percentage when planting at shallower depth and optimum temperature but produced the best values of seed emergence and seedling vigor followed by medium and then small one at the deeper planting and lower temperatures. The lower in seed emergence and seedling vigor of round seed than flat one is evident in small and medium seed size, when planted at deeper depths and lower temperatures. The diversity of influences on maize seed quality between flat and round shapes is corresponding with unfavorable conditions.

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