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Effects of Planting Date on Seedling Emergence and Vigor of Okra [*Abelmoschus esculentus* (L.) Moench.] in Swaziland

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Abstract: Vegetables such as okra [*Abelmoschus esculentus* (L.) Moench.] are nutritious but might have poor seedling emergence and vigor. The objective of this study was to determine the best planting dates for okra in Swaziland. The experimental design was a randomized complete block design with eight treatments, each replicated three times. The treatments were: T_1, seeds planted in the third week of September; T_2, seeds planted on the fourth week of September; T_3 seeds planted on the first week of October; T_4, seeds planted on the second week of October; T_5, seeds planted on the third week of October; T_6, seeds planted on the fourth week of October; T_7, planted on the first week of November; and T_8, planted on the second week of November. Results showed that seeds sown in the fourth week of September showed significant ($p < 0.05$) slow emergence rate than seeds sown at other times. Soil temperature was significantly ($p < 0.01$) higher at 5-cm depth (23.4-36.7°C) than soil temperature at 10-cm depth (20.4-32.4°C). Stem diameter was positively and not significantly ($p > 0.01$) correlated to dry mass of plants ($r = 0.181$; $n = 24$); the coefficient of determination ($R^2 = 0.033$), implied that 3.3% increase in dry mass of plants could be ascribed to stem diameter increase. The number of leaves was positively but not significantly ($p > 0.05$) correlated to dry mass ($r = 0.748$; $n = 24$; $R^2 = 56.0\%$) and indicated that 56% increase in dry mass could be associated with increased number of leaves. It was concluded that sowing okra early (as in early September) delayed seedling emergence, occasioned by lower soil temperatures. Small-scale okra farmers should grow okra when in temperatures are warmer, as in October or November. Further research is suggested.

Key words: *Abelmoschus esculentu* · Okra · Seed emergence · Seed physiology · Seedling vigor

INTRODUCTION

Okra or edible hibiscus [*Abelmoschus esculentus* (L.) Moench.] is a member of the Malvaceae (or Mallow) family. Many other species of hibiscus are used as foods in various parts of the world. In this genus belong many species of ornamental flowering hibiscus, several of which are natives of the United States [1]. Okra is a warm-season; the minimum soil temperature for okra seed germination is about 15°C, but the optimum germination temperature is 35°C. At soil temperatures of about 15°C, germination takes 27 days, whereas at about 24°C, germination may take only 13 days and in ideal conditions perhaps a week. Lamenting on the need for a warm environment in order to grow okra in Alabama State (U.S.A), [2] suggested the need for heat mats (electric "heating pads" for use under seedling trays).

The optimum temperatures for growth and production of high quality pods range between 24 and 30°C [3]. According to Tailour and Harman [3], germination of okra seeds can be accelerated by soaking the seeds in water for several hours prior to planting. This tends to soften the seed coat and make emergence of young seedlings easier. Some gardeners have reported success in speeding okra germination by freezing (0-5°C) the seeds thoroughly prior to planting. The frozen seeds are taken directly out of the freezer and submerged in lukewarm water. This could break the seed coat and accelerate germination

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According to Kemble [4], the hard seed coat of okra interferes with water up-take and is a major physiological constraint to uniform stand establishment and performance. Researchers have had limited success in improving germination performance of okra seeds.

Seed vigor is the property of the seed that determines the potential of rapid growth and uniform emergence. Seed vigor is a concept that embraces the idea that speed of germination, emergence and establishment are important for early growth, competition against weeds and tolerance to herbicides. In the absence of conducive conditions, the properties of the seed would take over the growth of the plant. The role of seeds is to produce plants in the field[1]. The factors that may induce seed vigor may include the accumulation of nutrients. Other factors include dry seeds and seed dormancy also plays a role. The change in morphological and physiological development that alters the potential performance of the plant is called physiological maturity [1]. Crop yield could be influenced by seed vigor through both indirect and direct effects. The direct effect could be that the crop is genetically incapable to perform well. The indirect effects include climatic conditions and soil acidity. High germination percentage and rapid field emergence are essential features of seed vigor [4].

Delayed and erratic seedling emergence is a serious problem for okra farmers in Swaziland. This problem creates other challenges relating to fertilizer utilization, post-emergence weed control and uniform harvesting. In Swaziland, farmers are faced with poor seedling germination and vigor, as they engage themselves in okra production. Okra seedling emergence and vigor varies a lot in different planting times, as most farmers start producing crops in the months of September to December. Hence there is a great need to investigate how planting time could influence seedling emergence and vigor. The objective of the investigation was to assess the effects of time of planting on the emergence and vigor of okra seedlings in Swaziland.

MATERIALS AND METHODS

Site of Experiment: The field experiment was conducted at Malkerns Research Station, Malkerns, which is in the Middleveld agro-ecological zone of Swaziland and geographical at 26.34°S, 31.10°E; it is 750 m above sea level. The average rainfall ranges between 800 mm and mean annual temperature of 18°C[5].

Experimental Design and Treatments: The experiment was conducted during the 2009/10 growing season, from in September-November 2010. The experimental design was a randomized complete block design of eight treatments, each replicated three times. The treatments were: T_1, seeds planted in week 3 of September 2010; T_2, seeds planted in week 4 of September 2010; T_3, seeds planted in week 1 of October 2010; T_4, seeds planted in week 2 of October 2010; T_5, seeds planted in week 3 of October 2010; T_6, seeds planted in week 4 of October 2010; T_7, seeds planted in week 1 of November 2010; and T_8, Seeds planted in week 2 of November 2010.

Black plastic bags with a capacity for 15 kg of soil were used in this experiment. Inside each plastic bag were sown 10 okra seeds. To protect seedlings against fungal attacks, all seeds were dusted with a fungicide, Dithane M-45, before planting. After emergence, seven seedlings were uprooted in each bag, leaving the three most vigorous seedlings to grow. Data were collected from these three seeds per plot.

Data Collection: Data were collected on the number of emerged seedlings; stem diameter per plant; number of leaves per plant; length of petioles per plant, plant height, dry mass of plants and soil temperature. Emergence count was done at the same time each day, between 1400 and 1600 hours, from three days after planting (DAP). Stem diameter was measured taken using a vernier caliper at 5 cm above the soil level. Number of leaves per plant was recorded once every week, starting from five days after emergence, DAE; length of petioles per plant was taken using a ruler, from the first four leaves per plant. Plant height was measured with a ruler every two days, starting from two DAE). Mass of plants per treatment was measured at the end of the experiment. Harvested plants were oven-dried in a hot-air oven regulated at 100°C for 48 hours[6]. Soil temperature was recorded once a week at 5-cm and 10-cm depths on bright days without rain. Soil temperature was recorded using the Fisher brand bimetal, dial thermometers with a gauge diameter of 4.5 cm, a stem length of 20.3 cm and an accuracy of plus/minus 1.0% of dial range at any point on the dial [7]. Three readings were made at each depth per pot; a 30-second interval was allowed to elapse before readings were taken in order to allow the thermometers to stabilize. Soil temperatures were taken on bright, sunny days without any rain.

Data Analysis: Data were analyzed using MSTAT-C statistical package, version 1.3 [8]; mean separation was done by using the least significant difference test [9].

RESULTS

Number of Emerged Seedlings: Table 1 shows there were significant ($p < 0.05$) differences in the number of seedlings that emerged after planting. Seeds planted in the third week of Setember took significntly longer to emerge, compared with seeds sown later in the season. Seedling emergence was positively and significantly correlated to dry mass of plants ($r = 0.728$). The coefficient of determination ($R^2 = 0.53$), implied that 53% increase in dry mass could be ascribed to seedling emergence. Seedling emergence was negatively correlated to plant height ($r = - 0.035$; $n = 24$).

Stem Diameter: Table 2 indicates that stem diameter increased as the cropping season progressed. The significant ($p < 0.01$) differences showed that seedling growing from seeds sown in the third week of October typically had the largest stem diameters.

Stem diameter was positively and significantly ($p < 0.05$) correlated to seedling emergence ($r = 0.516$; $n = 24$); the R^2 (0.27; $n = 24$) implied 26.6% increase stem diameter was associated with increasing seedling emergence. Stem diameter was positively but not insignificantly ($p > 0.05$) correlated to plant dry mass ($r = 0.181$). The coefficient of determination ($R^2 = 0.033$), showed that 3.3% increase in dry mass of plants could be associated with stem diameter. Similarly, R^2 indicated stem diameter was positively correlated with the number of leaves per plant ($r = 0.590$; $n = 24$; $R^2 = 34.8\%$) and with plant height ($r = 0.649$; $n = 24$; $R^2 = 42.1\%$).

Number of Leaves per Plant: As shown in Table 3, there was a general increase in the number of leaves per plant with time. The mean number of leaves per plant ranged from a low of 3.07 when seeds were sown in week 3 of September, to a high of 4.10 when seeds were sown in week 2 of November. There was a decrease in the number of leaves per plant in the fifth week. The number of leaves per plant was positively and significantly ($p < 0.05$) correlated to the number of seedlings emerged ($r = 0.840$; $n = 24$); the R^2 (70.6%) implied that 70.6% increase in the number of leaves per plant could be ascribed to the number of seedlings that emerged after planting.

Number of leaves per plant was also positively correlated to dry mass ($r = 0.748$; $n = 24$; $R^2 = 0.748$, showing that 56% increase in dry mass could be ascribed to increased number of leaves per plant. The number of leaves per plant was negatively correlated to petiole length ($r = - 0.277$; $n = 24$; $R^2 = 7.7\%$) and plant height ($r = - 0.079$; $n = 24$; $R^2 = 0.6\%$).

Length of Petioles: As shown in Table 4, there were significant ($p < 0.05$) differences in petiole length among the seedlings planted on different dates. Mean petiole length was 1.08 cm for seedling from 3 week October planting, to 1.76 cm (from week 1 October planting.

Table 1: Emergence count of okra seedlings at 1-14 days after planting in Swaziland

	Days after planting										
Planting date	5	6	7	8	9	10	11	12	13	14	Means
Week 3 September	0.00a	0.00a	0.97a	3.43a	5.77a	6.47a	7.33a	8.13a	8.60a	8.73b	4.94
Week 4 September	0.00a	0.33a	2.80b	6.00b	6.97ab	7.23ab	7.87a	7.97a	7.97a	8.20a	5.53
Week 1 October	3.57b	6.10b	7.57c	7.97b	8.00b	8.10b	8.37b	8.57a	9.00ab	9.13b	7.64
Week 2 October	1.23c	6.27b	6.87c	7.33b	7.77b	7.60b	8.77b	8.90ab	9.17b	9.33b	7.24
Week 3 October	2.50d	4.60b	7.43c	7.93b	8.43b	8.57b	8.83b	9.00b	9.10b	9.17b	7.56
Week 4 October	2.87d	3.97b	6.30c	7.60b	7.77b	7.77b	7.83ab	7.83abc	8.07a	8.20a	6.82
Week 1 November	1.60e	1.77c	4.43d	5.63bc	7.17cb	8.10b	8.43a	8.53b	8.90ab	9.43b	6.37
Week 2 November	3.17bf	3.43d	5.37d	5.90bc	6.50c	7.10ac	8.03b	8.80b	8.87ab	9.60b	6.68

Numbers followed by the same letters in the same column are not significantly ($p > 0.05$) different according to the least significant difference test.

Table 2: Stem diameter (mm) at 1- 5 weeks after planting okra in Swaziland

	Weeks and stem diameter (mm)					
Planting date	1	2	3	4	5	Means
Week 3 September	2.10a	2.40a	2.87a	3.00a	3.23a	2.92
Week 4 September	2.50b	2.67ab	3.00b	3.16a	3.37a	3.34
Week 1 October	2.47b	2.73b	2.93a	3.30ba	3.47a	3.50
Week 2 October	2.53b	2.87b	3.27b	3.50b	3.57b	3.94
Week 3 October	2.50b	3.00b	3.27b	3.43b	3.53b	4.15
Week 4 October	2.60b	2.90b	3.10b	3.33b	3.36b	4.25
Week 1 November	2.50b	2.87b	3.17b	3.30b	3.37b	4.44
Week 2 November	2.40b	2.90b	3.30b	3.47b	3.50b	4.71

Numbers followed by the same letters in the same column are not significantly ($p > 0.05$) different according to the least significant difference test.

Table 3: Number of leaves per plant in potted okra plants at weeks 1-5 in Swaziland

Planting date	Week 1	Week 2	Week 3	Week 4	Week 5	Means
Week 3 September	2.00a	3.33a	3.67a	4.33a	2.00a	3.07
Week 4 September	2.33a	3.33a	4.00a	4.67a	3.00a	3.47
Week 1 October	2.52a	3.45a	4.55a	5.00a	3.07a	3.72
Week 2 October	2.17a	4.00a	3.83a	5.00a	5.50b	4.10
Week 3 October	2.67a	3.33a	4.00a	5.16a	4.00ab	3.83
Week 4 October	2.67a	3.67a	4.00a	5.00a	4.33b	3.93
Week 1 November	2.00a	3.67a	4.33a	5.00a	3.00a	3.60
Week 2 November	2.33a	3.33a	4.00a	5.00a	3.66a	3.66

Numbers followed by the same letters in the same column are not significantly ($p > 0.05$) different according to the least significant difference test.

Table 4: Length (cm) of petioles per plant in potted okra plants at 2-14 weeks after planting

	Days after emergence and weeks after planting							
Planting date	2	4	6	8	10	12	14	Means
Week 3 September	0.50b	0.77b	1.23a	1.63b	1.87a	2.27b	2.03a	1.47
Week 4 September	0.26a	0.75ab	1.51a	1.82b	2.01a	2.26b	2.30a	1.56
Week 1 October	0.40a	1.40b	1.62b	1.87b	2.18a	2.48b	2.35a	1.76
Week 2 October	0.43a	0.60a	0.90ab	1.30ab	1.27a	1.77a	2.23a	1.21
Week 3 October	0.41a	0.69a	0.88a	1.14b	1.27a	1.46a	1.70a	1.08
Week 4 October	0.40a	1.02a	1.47a	1.81b	2.05a	2.35b	2.19a	1.61
Week 1 November	0.43a	1.26b	1.60a	1.76b	1.99a	2.39ab	2.36a	1.68
Week 2 November	0.51b	0.57ab	0.90ab	1.17b	1.22b	1.82ab	2.21a	1.20

Numbers followed by the same letters in the same column are not significantly ($p > 0.05$) different according to the least significant difference test.

Table 5: Plant height (cm) of okra at 2-20 days after emergence

	Days after emergence and height (cm) per plant									
Planting date	2	4	6	8	10	12	14	16	18	20	Means
Week 3 September	1.10a	1.67a	2.03a	2.77a	3.27b	3.80a	4.17a	4.87a	5.17a	5.73a	3.46
Week 4 September	1.30a	1.90a	2.07a	2.47a	2.53b	2.80b	3.40b	4.43a	5.23bc	5.56a	3.17
Week 1 October	1.57a	1.93a	2.03a	2.60a	2.50b	2.67ab	2.97b	4.60a	5.77b	5.80a	3.24
Week 2 October	1.63ab	1.90a	2.03a	2.37a	2.67a	2.77b	3.20b	4.13a	5.90b	6.20a	3.28
Week 3 October	1.73b	2.07a	2.00a	2.30b	2.43a	2.60b	3.60b	4.37a	6.50c	7.03b	3.46
Week 4 October	1.77b	2.33ab	2.40a	2.53b	2.63a	2.77ab	3.10c	4.47a	6.16c	6.83b	3.50
Week 1 November	1.60b	2.10a	2.40a	2.53b	2.80a	2.97ab	3.37c	4.60a	6.36c	7.00b	3.57
Week 2 November	1.73b	2.17a	2.47a	2.70b	2.93a	3.23ab	3.47c	4.60a	6.23bc	6.70b	3.62

Numbers followed by the same letters in the same column are not significantly ($p > 0.05$) different according to the least significant difference test.

Length of petioles was negatively and not significantly ($p > 0.05$) correlated to plant height ($r = -0.232$; $n = 24$; $R^2 = 0.05$), implying that 5.4% decreases in length of petioles could be attributed to plant height increases.

Plant Height: Mean plant height ranged from 3.62 cm to 3.17 cm (Table 5). There was a significant difference ($p < 0.01$) in 2, 12, 14, 18 and 20 days after emergence. There were significant differences among treatments, except at 6 and 16 days after emergence. Plant height was positively and significantly ($p < 0.05$) correlated to stem diameter ($r = 0.649$); the coefficient of determination ($R^2 = 0.42$), implied that 42.1% increase in stem diameter could be associated with increase in plant height.

Plant height was negatively and not significantly ($p > 0.05$) correlated with plant dry mass of plants ($r = -0.215$), the coefficient of determination ($R^2 = 0.046$) implying that a 4.6% decrease in dry mass of plants could be associated with increased plant height.

Table 6: Dry mass (g) of okra plants at 20 weeks after emergence

Planting date	Dry mass (g) of okra plants
Week 3 September	0.815b
Week 4 September	0.877b
Week 1 October	0.660b
Week 2 October	0.687b
Week 3 October	0.440a
Week 4 October	0.317a
Week 1 November	0.288a
Week 2 November	0.359a

Numbers followed by the same letters in the same column are not significantly ($p > 0.05$) different according to the least significant difference test.

Dry Mass of Plants: Table 6 showed that seedlings originating from seeds sown in week 4 of September had significantly ($p < 0.05$) higher dry mass than seedlings from week 3 of October to week 2 of November. Seedling dry mass was positively correlated ($r = 0.728$; $n = 24$) to the number of emerged seedlings. The R^2 indicated that 53.0% increase in seedling dry mass could be attributed to increased number of seedlings that emerged after sowing.

Table 7: Soil temperature (°C) at 4-24 days after planting okra

		Days after planting and soil temperature (°C)						
Planting date	Soil depth (cm)	4	8	12	16	20	24	Means
Week 3 September	5	23.37a	32.33a	31.63a	34.73a	30.80b	35.77a	31.44
	10	20.43a	32.37a	33.53a	32.07a	37.93b	30.77a	31.18
Week 4 September	5	27.27a	30.33a	33.80a	32.57a	31.77b	33.60a	31.56
	10	31.23b	31.50a	34.50a	30.70a	37.20b	31.80a	32.82
Week 1 October	5	31.37ab	33.13a	33.07a	33.33a	31.97b	33.53a	32.73
	10	31.90b	31.97a	34.00a	32.90a	36.37b	29.93a	32.85
Week 2 October	5	36.70b	32.70a	32.03a	33.27a	31.00b	33.47a	33.20
	10	32.40b	31.20a	34.37a	32.30a	36.23b	31.23a	32.96
Week 3 October	5	28.83a	30.00a	35.53a	33.00a	24.67a	25.00b	29.51
	10	26.33a	25.90b	28.33a	28.27a	22.80a	28.03a	26.61
Week 4 October	5	27.33a	30.57a	33.53a	27.20b	31.97b	26.03b	29.44
	10	25.37a	30.17a	31.00a	27.80a	29.47bc	30.83a	29.11
Week 1November	5	34.73b	29.83a	30.13a	27.03b	32.63b	35.13a	31.58
	10	30.77b	25.10b	24.07b	27.07a	30.00b	28.97a	27.67
Week 2 November	5	27.33a	31.93a	32.83a	33.54a	31.51b	34.30a	31.91
	10	27.85b	31.94a	34.01a	31.89b	37.16b	32.87a	32.62

Numbers followed by the same letters in the same column of the same soil depth are not significantly different ($p > 0.05$), according to the least significant difference test.

Soil Temperature: Generally, soil temperature (Table 7) at 5-cm depth was higher (mean, 29.44-33.20°C) than temperature (26.61-32.96°C) at 10-cm depth. Significant differences ($p < 0.01$) were observed among treatments. Soil temperature at 5-cm depth was positively and significantly ($p < 0.01$) correlated to several parameters: soil temperature at 10-cm depth ($r = 0.691$; $n = 24$); number of leaves per plant ($r = 0.811$; $n = 24$); stem diameter ($r = 0.536$; $n = 24$); seedling emergence ($r = 0.867$; $n = 24$). The coefficients of determination, R^2, were 0.477; 0.658; 0.287; and 0.752, respectively. This implied that 47.7% increase 10-cm depth temperature, 65.8% increase in the number of leaves, 28.7% increase in stem diameter and 75.2% increase in seedling emergence were all associated with an increase in soil temperature at 5-cm depth.

Soil temperature at 10-cm depth temperature was positively and significantly ($p < 0.05$) correlated to the number of leaves per plant ($r = 0.497$; $n = 24$) and seedling emergence ($r = 0.473$). The coefficients of determination ($R^2 = 0.2470$ and 0.2237, respectively) implied that 24.7% and 22.4% increase in the number of leaves and number of emerged seedlings, respectively, were associated with increase in soil temperature at 10-cm depth.

DISCUSSION

The slowness of seedling emergence in the first and second plantings (planted in the 3rd and 4th week of September, respectively) was probably associated with lower temperatures, since it was the beginning of the spring. In the first week of October onwards, temperatures were high. Khattak and Pearson[10] reported that delayed germination and delayed seedling emergence in okra could result from less than optimum soil temperature.

Stem diameter is important for plant support. Stem diameter is determined by lignin and water content within the stem. Akanda *et al.* [11] reported okra stem diameter to increase when different soil amendments were applied to the soil. The trend of increasing stem diameter observed in this investigation was consistent with normal plant stem growth and development. [12] reported that upright okra plants could grow 1-2 m or more in height, with a base stem of 10 cm in diameter.

The decrease in the number leaves per plant in the 5th week was associated with the incidence of a disease called leaf-curl [13]. This group of researchers found leaf-curl incidence varied from 68.5% to 72.5% among accessions of the local okra cultivar, whereas commercial cultivars were much less infected (8.7-16.2%).

The loss of leaves adversely affected the number and length of petioles per plant that could be recorded. The falling off of leaves might have been due to virus-like diseases occurring above-ground in okra. Ndunguru and Rajabu [14] observed that okra plants infected by virus diseases showed a 32% reduction in the length of petioles. Otherwise, loss of leaves in mature plants is usually associated with leaf aging (senescence). The most widely used biomarker for senescent and aging cells is senescence-associated beta-galactosidase (SA-beta-gal), which is defined as beta-galactosidase activity detectable at pH 6.0 in senescent cells, but the origin of SA-beta-gal and its cellular roles in senescence are not known [15].

Ames and Johnson [16] reported that the growth of an annual plant is related to time, resulting in an S-shaped curve. Low soil temperatures experienced in the week (3rd week of September) after planting might have adversely affected plants, not allowing them to grow as vigorously as expected. One technique of improving plant height is to prime seeds; Guan *et al.* [17] reported that seed priming improved plant height much more than plant stand in sweet corn. Hegazi and Hamideldin [18] concluded that pre-sowing treatments either by soaking okra seeds in water (hydropriming) or irradiated them by doses (300, 400, 500 Gy) of gamma rays were effective in improving plant growth, seed yield and seed quality.

Seedlings arising from seeds grown from the second week of October had lower dry mass compared to earlier-grown seedling. This could be because seedlings from the later-planted seeds did not have the same amount of growing time to accumulate biomass like the treatments that have been growing from September. Also, the younger seedlings might have contained a lot of water in their tissues. Varela[16] reported that since plants have a high composition of water and the amount of water would depend on the amount of water in the environment (which is very difficult to control), using dry mass as a measure of plant growth tends to be more reliable.

Winter in Swaziland, when lower air and soil temperatures are experienced, is from May to August. Soil temperatures in both 5-cm and 10-cm depths was low for the optimum growth of okra seeds. Seed germination in the 3rd and 4th week of September was low probably because the environment was recovering from winter. Khattak and Pearson[10] reported that the optimum soil temperature for okra seed germination is 30°C; lower soil temperatures might delay germination. Soil temperature data (Table 7) were consistent with these observations: mean temperature in week 3 in October was 29.51°C at 5-cm depth and in week 4 of October, mean soil temperature at 5-cm depth was 29.44°C. Prasad *et al.* [20], investigating soil temperatures and seed germination in peanut (*Arachis hypogaea* L.) observed that all cultivars exhibited low germination at low soil temperatures.

Conclusion and Recommendation: This investigation showed that sowing okra early in the planting season (as in early September) delayed seedling emergence, probably because of prevailing low soil temperatures at that time of the year. It is recommended that small-scale okra farmers should grow okra when temperatures are warmer, as in week 3 of October. It would be useful to conduct further research on okra seedling emergence and vigor.

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