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Effect of sowing time and spacing on growth parameters and yield of winter squash (*Cucurbita maxima* D.) cv. Arka Suryamukhi under south Gujarat condition

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Abstract
An experiment, "Effect of sowing time and spacing on growth, yield and quality of winter squash (*Cucurbita maxima* D.) cv. Arka Suryamukhi under South Gujarat condition" was conducted during winter 2020-2021 and 2021- 2022 at Vegetable Research Farm, RHRS, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India. The experiment comprised of four sowing time *viz.*, P1: 1st fortnight of December, P2: 2nd fortnight of December, P3: 1st fortnight of January and P4: 2nd fortnight of January and three spacings *viz*., S1: 2.0 m x 0.5 m, S2: 2.0 m x 0.75 m and S3: 2.0 m x 1.0 m and laid out in Split Plot Design with four replications. Impact of sowing time and spacing was studied on growth and yield parameters and recorded that sowing at first fortnight of December produced significantly higher number of primary branches vine^{-1}, vine length, number of nodes on main vine, minimum internodal length, early number of nodes on first male flower appearance, early number of nodes on first female flower appearance, days required for first male flower appearance and days required for first female flower appearance. In case of spacing, significantly higher number of primary branches vine^{-1}, vine length, minimum days required for first male flower appearance, days required for first female flower appearance. Whereas, shorter internodal, early appearance of node number on first male flower, early appearance of node number on first female flower and higher number of nodes on main vine noticed in spacing 2.0 m x 0.5 m. In case of yield the results showed that, higher fruit yield (20.88, 21.91 and 21.39 t ha^{-1}) was recorded sowing at 1st fortnight of December. Whereas, spacing 2.0 m x 0.5 m (S1) observed higher fruit yield (17.28, 18.61 and 17.95 t ha^{-1}). Whereas, the interaction effect of sowing at 1st fortnight of December with spacing 2.0 m x 0.5 m recorded the significantly highest fruit yield (24.41 t/ha).

Keywords: Winter squash, sowing time, spacing, yield

Introduction
Vegetables are important constituents of nutritional and livelihood security due to their short duration, high yield, nutritional value, economic viability and ability to generate on- farm and off-farm employment. India contributes 13.90% of world's vegetable production with an area of 9.4 million hectares and the average productivity of 17.4 t ha^{-1}. Productivity of vegetables in India is seen to be lower than China (23.4 t ha^{-1}) and world average 19.6 t ha^{-1} (Anon., 2019) [4]. To cater the future vegetable needs in India, the present production of 156.33 million tonnes is to be raised to 350 million tonnes by 2030 (Anon., 2011) [3].

Squash is one of the most versatile and delicious vegetables grown throughout the globe and it also packs good vitamins and an excellent health benefit. Squash is herbaceous annual viny, creeping and trailing plant and produces vegetable that is large and variable in shape, size, colour and markings with a peduncle that is corky on the surface. It belongs to the family "*Cucurbitaceae*' and genus "*Cucurbita*". Winter squash is a taxonomically diverse group of vegetables in the Cucurbita genus. Cultivars may belong to one of several species: *Cucurbita pepo* (acorn and spaghetti squashes), *C. maxima* (Hubbard, buttercup and Kabocha), *C. moschata* (butternut), and *C. mixta* (cushaw). The chromosome number is 2n=40. Squashes are mostly monoecious; because these squashes are harvested when mature and rinds have hardened, most types can be stored for use during the winter. Winter squash that matures during cooler weather has a higher sugar content and stores better. Honey bees are necessary for pollination and are essential for obtaining high yields of good quality fruit.

Squash is a rich source of vitamin A, phosphorus and calcium. Generally, the young and tender shoots are used in culinary purpose.

Time of planting is one of the important factors as optimum date of planting brings about proper growth and development of plants resulting in maximum yield of the crop and economic use of land (Islam *et al*., 2010) [7].

The use of spacing in crop production is very important because it reduces competition for sunlight, water and fertilizers between weeds and plants. Therefore, plant population can affect the yield directly or indirectly. Increased plant population resulted in a significantly linear decrease in average fruit size (Reiners and Riggs, 1997) [12]. Hence, present study was an attempt (1) to study the effect of sowing time on growth and yield of winter squash (2) to study the effect of spacing on growth and yield of winter squash (3) to assess the interaction effect of sowing time and spacing on growth and yield of winter squash.

Materials and Methods

Experimental site: The experiment was conducted at Vegetable Research Farm, Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, India. The farm is situated at 20° 37' N latitude and 72° 54' E longitude at an altitude of 11.98 meter above the mean sea level. It is about 12 km away from the great historical place "*The Dandi*" on the Arabian Sea coast, where the Father of Nation "Mahatma Gandhi" launched a salt satyagrah, '*Dandi March*' in the year of 1930.

Experimental details: The experiment was laid out in Split plot design each treatment being replicated four times with four sowing time and three spacings of winter squash cv. Arka Suryamukhi. There were 48 plots (Gross size: 8.0 m x 6.0 m, net size S1: 4.0 m x 5.0 m, S2: 4.0 m x 4.5 m, S3: 4.0 m x 4.0 m). The experiment consisted of twelve treatment combinations comprising of four sowing time *viz*., P1: 1st fortnight of December, P2: 2nd fortnight of December, P3: 1st fortnight of January and P4: 2nd fortnight of January and three spacings of winter squash *viz*., S1: 2.0 m x 0.5 m, S2: 2.0 m x 0.75 m and S3: 2.0 m x 1.0 m. The experimental site was prepared mechanically and the soil was made to a fine tilth after removing the weeds and stubbles. Three seeds were sown per hole at a spacing of S1: 2.0 m x 0.5 m, S2: 2.0 m x 0.75 m and S3: 2.0 m x 1.0 m which were later thinned down to one plant per stand 3 weeks after sowing. Five plants from the net plot were tagged from which the growth and yield parameters were recorded. After land preparation spot application of 20 tons of organic manures (FYM**)** were applied at the time of sowing. Whereas, recommended chemical fertilizers dose of 100:80:60 kg NPK ha^{-1} (Urea, SSP and MOP) used as a source of NPK. The full dose of phosphorus and potassium with half dose of nitrogen applied at the time of sowing and remaining half dose of nitrogen was applied as top dressing at 30 DAS. Cultural practices including irrigation were carried out following the standard commercial procedures.

Spraying for pests and diseases were applied whenever it appeared necessary throughout the growing season. Harvesting of the winter squash fruits was done by hand picking as and when matured. The parameters recorded were number of primary branches per vine, vine length, number of nodes on main vine, leaf area, internodal length, number of nodes on first male flower appearance, number of nodes on first female flower appearance, days required for first male flower appearance, days required for first female flower appearance and total fruit yield per hectare was the accumulated records of fruits over the entire harvesting periods.

Statistical interpretation: The experimental layout was set to be Split Plot design with four replications. The analysis of variance (ANOVA) was performed to find out the significance of variation among the treatments while the statistical significance of various effects was tested at 5% probability level.

Results and discussion

Growth Parameters: Effect of sowing time and spacing on growth parameters and yield of winter squash (*Cucurbita maxima* D.) cv. Arka Suryamukhi under South Gujarat conditions was found to produce significant effect at 5% level of probability. It was observed that in table 1 & 2. At harvesting time, maximum number of primary branches $vine^{-1}$ (5.35, 5.28 and 5.32, respectively), vine length (2.60, 2.63 and 2.61 m, respectively), number of nodes on main vine (26.10, 26.68 and 26.39, respectively), early first male flower node (9.55, 9.58 and 9.57, respectively), early first female flower node (13.20, 13.27 and 13.23, respectively), minimum days to first male flower (41.00, 42.53 and 41.76 DAS, respectively), days to first female flower (45.52, 47.44 and 46.48 DAS, respectively) and shortest internodal length (12.01,11.93 and 11.97cm, respectively) recorded when sowing at first fortnight of December (P1). Whereas, minimum number of primary branches $vine^{-1}$ (4.73, 4.65 and 4.69, respectively), vine length (2.32, 2.37 and 2.34 m, respectively), numbers of nodes on main vine (21.85, 22.30 and 22.08, respectively), late first male flower node (10.63, 10.66 and 10.65, respectively), late first female flower node (14.72, 14.75 and 14.74, respectively), maximum days to first male flower (47.24, 48.52 and 47.88 DAS, respectively), days to first female flower (52.37, 53.84 and 53.10 DAS, respectively) and longest internodal length (13.39, 13.39 and 13.39 cm, respectively) were recorded sowing at second fortnight of January (P4). Variations in the growth of cucurbits due to planting dates noted by Sant *et al.* (1994) [13] in pumpkin and Mulkey and Talbut (1989) [10] in *Cucurbita pepo*, which may be ascribed to the fact that plant growth occurred in suitable temperature range which might have attributed to the enhanced plant metabolic activities like photosynthesis due to favorable weather conditions. Hao *et al.* (2010) [6] have also suggested that optimum temperature range for cucumber is between 25-30oC as the temperature range is lower growth is more than the flower development. The production of male flowers per plant was mainly due to the production of some hormones and also there might be an endogenous synthesis of Indole Acetic Acid (IAA) like substances. These results were in line with the findings of Anjanappa *et al.* (2012) [2] in cucumber. The favorable microclimate prevailing might have enhanced the better uptake of nutrients, which results in faster plant growth and increases the more production of female flowers. These results were in agreement with Anjanappa *et al.* (2012) [2] in cucumber.

The spacing 2.0 m x 1.0 m observed maximum number of primary branches $vine^{-1}$ (5.35, 5.34 and 5.35, respectively), vine length (2.79, 2.82 and 2.80 m, respectively), early first

male flower (41.87, 43.69 and 42.78 DAS, respectively), early first female flower (47.61, 48.23 and 47.92 DAS, respectively), maximum internodal length (13.02, 12.99 and 13.01 cm, respectively) and late first male flower node (10.53, 10.57 and 10.55, respectively).Whereas, least internodal length (12.11, 12.03 and 12.07 cm, respectively), maximum number of nodes on main vine (27.40, 28.13 and 27.76, respectively), early first male flower node (9.80, 9.84 and 9.82, respectively), early first female flower node (13.43, 13.33 and 13.38, respectively), minimum vine length (2.12, 2.17 and 2.15 m, respectively), number of primary branches vine- 1 (4.59, 4.54 and 4.56, respectively) and late first female flower node (14.58, 14.58 and 14.58, respectively) was noted in spacing S1. Number of primary branches vine^{-1} more due to wider plant spacing produced significantly higher primary branches than closer plant spacing. Under wider spacing, there might be sufficient availability of nutrients, moisture, space and better interception of sunlight within the plant canopy than closer spacing. These results are in line with the findings of Ban *et al.* (2006) in watermelon and Adeyeye *et al.* (2017) [1] in sweet melon. Days required for production of male flowers may be due to higher capacity of plants to make available assimilates to the apex during the complex phase before initiation this could be accredited to the vigorous growth of plants due to prevailing microclimate condition. These results are in line with the observation as recorded by Arshad *et al.* (2014) [5] in cucumber, Ravikant (1998) [11] in summer squash and Kapuriya *et al.* (2017) [8] in cucumber. There is no any significant difference of interaction between sowing time and spacing on growth parameters and it was found non-significant.

Yield: Higher fruit yield ha^{-1} (20.88, 21.91 and 21.39 t ha^{-1}, respectively) was observed sowing at first fortnight of December (P1). Whereas, lowest fruit yield per hectare (9.42, 9.69 and 9.55 t ha^{-1}, respectively) recorded sowing at second fortnight of January (P4). Spacing 2.0 m x 0.5 m (S1) recorded higher fruit yield ha^{-1} (17.28, 18.61 and 17.95 t ha^{-1}, respectively). However, lowest fruit yield ha^{-1} (13.54, 13.76 and 13.65 t, respectively) noticed in 2.0 m x 1.0 m (S3). In case of interaction, higher fruit yield ha^{-1} (24.41 t) was recorded sowing at first fortnight of December with spacing 2.0 m x 0.5 m (P1S1)) was found at par with sowing at second fortnight of December in pooled analysis (Table-3). While, minimum fruit yield ha^{-1} (11.95 t) was recorded in pooled analysis P4S1. Plants at higher densities produced maximum fruit yield compare to wider spacing. This was possibly due to increase in plant number per unit area, which might contribute to the production of more yield per unit area and leading to higher yield. Similarly, Kavut *et al.* (2014) [9] in fodder watermelon, Sullivan (1980) [14] in pickling cucumber also reported higher yield per unit area under closer spacing.

Table 1: Effect of sowing time and spacing on growth parameters of winter squash cv. Arka Suryamukhi

Treatments	NPBV^{-1}			VL (m)			IL (cm)			NNMV		
Sowing time	**Y1**	**Y2**	**Pooled**	**Y1**	**Y2**	**Pooled**	**Y1**	**Y2**	**Pooled**	**Y1**	**Y2**	**Pooled**
P1	5.35	5.28	5.32	2.60	2.63	2.61	12.01	11.93	11.97	26.10	26.68	26.39
P2	5.10	5.05	5.08	2.50	2.53	2.52	12.27	12.23	12.25	24.77	25.50	25.13
P3	4.93	4.88	4.91	2.39	2.42	2.40	12.76	12.74	12.75	23.13	23.92	23.53
P4	4.73	4.65	4.69	2.32	2.37	2.34	13.39	13.39	13.39	21.85	22.30	22.08
S.Em±	0.13	0.12	0.09	0.06	0.06	0.04	0.30	0.32	0.22	0.67	0.60	0.45
CD at 5%	0.41	0.39	0.27	0.18	0.19	0.12	0.96	1.04	0.66	2.16	1.92	1.34
CV (%)	8.94	8.66	8.80	8.15	8.43	8.30	8.26	8.94	8.61	9.75	8.43	9.10
Spacing												
S1	4.59	4.54	4.56	2.12	2.17	2.15	12.11	12.03	12.07	27.40	28.13	27.76
S2	5.14	5.03	5.08	2.44	2.47	2.46	12.70	12.70	12.70	23.68	24.26	23.97
S3	5.35	5.34	5.35	2.79	2.82	2.80	13.02	12.99	13.01	20.81	21.41	21.11
S.Em±	0.11	0.10	0.07	0.05	0.05	0.03	0.24	0.27	0.18	0.54	0.48	0.36
CD at 5%	0.31	0.28	0.21	0.14	0.14	0.10	0.69	0.78	0.51	1.58	1.41	1.03
CV (%)	8.58	7.77	8.19	8.02	7.89	7.96	7.47	8.45	7.97	9.01	7.85	8.43
Interaction (P x S)												
S.Em±	0.22	0.19	0.14	0.10	0.10	0.07	0.47	0.53	0.35	1.08	0.97	0.72
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.58	7.69	8.16	8.02	7.89	7.96	7.47	8.45	7.97	9.01	7.85	8.43

Note: NPBV^{-1}-Number of primary branches vine^{-1}, VL- Vine length (m), IL- Internodal length (cm), NNMV- Number of nodes on main vine

Table 2: Effect of sowing time and spacing on growth parameters and yield of winter squash cv. Arka Suryamukhi

Treatments	NNFMFA			NNFFFA			DRFMF			DRFFF			Yield (t/ha)		
Sowing time	**Y1**	**Y2**	**Pooled**	**Y1**	**Y2**	**Pooled**	**Y1**	**Y2**	**Pooled**	**Y1**	**Y2**	**Pooled**	**Y1**	**Y2**	**Pooled**
P1	9.55	9.58	9.57	13.20	13.27	13.23	41.00	42.53	41.76	45.52	47.44	46.48	20.88	21.91	21.39
P2	9.85	9.86	9.85	13.32	13.25	13.28	43.53	43.51	43.52	49.46	48.29	48.88	19.23	20.01	19.62
P3	10.39	10.42	10.41	14.68	14.60	14.64	44.44	46.56	45.50	50.68	51.51	51.10	12.03	12.36	12.19
P4	10.63	10.66	10.65	14.72	14.75	14.74	47.24	48.52	47.88	52.37	53.84	53.10	9.42	9.69	9.55
S.Em±	0.25	0.25	0.18	0.42	0.42	0.30	1.30	1.35	0.94	1.48	1.42	1.02	0.49	0.51	0.35
CD at 5%	0.80	0.80	0.53	1.34	1.33	0.88	4.16	4.32	2.79	4.74	4.53	3.05	1.56	1.62	1.05
CV (%)	8.54	8.59	8.57	10.37	10.34	10.35	10.24	10.34	10.29	10.37	9.75	10.06	10.99	11.00	11.00
Spacing															
S1	9.80	9.84	9.82	13.43	13.33	13.38	45.62	47.19	46.40	51.92	52.41	52.16	17.28	18.61	17.95
S2	9.99	9.99	9.99	13.94	14.00	13.97	44.67	44.97	44.82	49.00	50.16	49.58	15.35	15.60	15.47
S3	10.53	10.57	10.55	14.58	14.58	14.58	41.87	43.69	42.78	47.61	48.23	47.92	13.54	13.76	13.65

S.Em±	0.20	0.21	0.15	0.25	0.31	0.20	1.03	0.93	0.69	1.14	1.12	0.80	0.32	0.27	0.21
CD at 5%	0.60	0.61	0.42	0.73	0.91	0.57	3.02	2.71	1.98	3.32	3.26	2.27	0.93	0.79	0.60
CV (%)	8.11	8.26	8.19	7.17	8.91	8.09	9.39	8.20	8.80	9.18	8.88	9.03	8.26	6.80	7.54
Interaction (P x S)															
S.Em±	0.41	0.42	0.29	0.50	0.62	0.40	2.07	1.86	1.39	2.27	2.23	1.59	0.64	0.54	0.42
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.86	1.59	1.19
CV (%)	8.11	8.26	8.19	7.17	8.91	8.09	9.39	8.20	8.80	9.18	8.88	9.03	8.26	6.80	7.54

Note: NNFMFA-Node number on which first male flower appears, NNFFFA-Node number on which first female flower appears, DRFMF-Days required for first male flower, DRFFF-Days required for first female flower

Table 3: Interaction effect of sowing time (P) and spacing (S) on yield of winter squash cv. Arka Suryamukhi

Treatments	Yield (t/ha)		
Interaction PXS	**Y1**	**Y2**	**Pooled**
P1S1	23.13	25.69	24.41
P1S2	21.09	21.20	21.15
P1S3	18.42	18.83	18.63
P2S1	20.57	22.67	21.62
P2S2	20.46	20.07	20.26
P2S3	16.68	17.30	16.99
P3S1	13.43	14.20	13.81
P3S2	11.42	11.73	11.58
P3S3	11.24	11.15	11.20
P4S1	12.00	11.90	11.95
P4S2	8.42	9.40	8.91
P4S3	7.83	7.77	7.80
S.Em±	0.64	0.54	0.42
CD at 5%	1.86	1.59	1.19
CV (%)	8.26	6.80	7.54

Conclusion

From the results of two-year experiment, it is concluded that environmental factors are mainly influencing the crop to boost the crop growth and yield. Winter squash cv. Arka Suryamukhi sown at 1st fortnight of December with spacing 2.0 m x 0.5 m resulted in better growth and higher fruit yield (24.41 t ha^{-1}) under South Gujarat Condition.

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