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Effect of Planting Date and Intra-row Spacing on Growth, Yield and Quality of Taro

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Abstract: Field experiments were conducted at the experimental farm of the Horticultural Research Station of Barrage, Qalyubia Governorate during 2007/2008 and 2008/2009 seasons to evaluate the influence of planting date (mid-November, mid-December, mid-January and mid-February) and intra-row spacing (20, 30, 40 and 50 cm) on growth, yield and quality of taro (*Colocasia esculenta* cv. Balady), with a particular attempt to establish an early planting system under Egyptian conditions. Planting date x intra-row spacing interaction had a significant effect on vegetative growth parameters and total yield/feddan. Early planting dates with closer distances between plants gave the highest values for these characters. This study demonstrated that planting date and intra-row spacing affect growth and yield of taro. Early plantings in mid-November or mid-December along with close spacing of 20 cm can be recommended for obtaining early and high production of taro under Qalyubia conditions.

Key words: Taro, *Colocasia esculenta*, Planting date, Plant spacing, yield.

INTRODUCTION

Taro [*Colocasia esculenta* (L.) Schott] is a monocotyledonous plant belonging to the Araceae family and is cultivated for its edible corms used as the staple food for people of most tropical and subtropical areas of the world [1]. The cultivated cultivars of taro may be distinguished into two main groups; the "eddoes" and the "dasheen" types. The eddoes types have side cormels that may be 5 – 20 in number and become as big as the mother corm. The cormels are usually absent in the dasheen types and it is the mother corm which is the main storage organ [2].

Taro is considered one of the most important vegetables grown in Egypt due to its high nutritional and economical values. It occupies a considerable acreage especially in Monufia, Qalyubia, Sharkia and Assuit Governorates. The corm and cormel which are the major economic parts have a nutritional value comparable to potato [3]. In addition, it is characterized by its high resistance to diseases and pests, high adaptation to moist and drought environments, tolerance to frost hazards, tolerance to post harvest pest damage, storage for longer period of time without damage [4] and high demand in local markets. However, there is very limited local research on taro compared with potato.

In the last few years, climate change becomes one of the most important problems that have several impacts over natural and human systems. The agriculture sector is highly vulnerable to the ongoing climate change impacts. These climate changes have made some farmers move forward the planting date of some vegetable crops like taro. In some regions of Sharkia and Qalyubia, some farmers cultivate taro in November or in December and others still cultivate this crop in early spring. In this respect, Miyasaka *et al.* [5] found that potential yields of taro (based on fresh weight of healthy corms) were not significantly affected by planting date. This result was not consistent with the hypothesis that spring and summer plantings would have greater yields and an earlier time to maturity because of greater average temperatures and total solar radiation during the period of rapid root and shoot development compared with those of fall and winter plantings.

The effect of spacing between plants on taro yield had not been thoroughly investigated previously under Egyptian environmental conditions. The spacing varies from 20-50 x 80-120 cm varying among farmers. Also, in the other countries the spacing varies among locations and farmers from 30 x 30 [6] to 40 x 40 cm [7] to 30-50 x 100-120 cm [8]. Many investigators reported that plant density strongly affected vegetative growth of taro [9], and yield [4,9,10,11,12,13].

The objective of this study was to evaluate the influence of planting date and intra-row spacing on growth, yield and quality of taro, with a particular attempt to establish an early planting system under Egyptian conditions.

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MATERIALS AND METHODS

Experimental site and cultivar: Two field experiments were carried out during 2007/2008 and 2008/2009 seasons at the Experimental Farm of the Horticultural Research Station of Barrage, Qalyubia Governorate, Egypt. Table 1 shows monthly maximum and minimum air temperatures, relative humidity, and mean solar radiation during the experimental period at the test site.

According to soil analysis results, soil texture of the experimental site was a sandy loam. The taro cultivar used for this study was local (Balady), the most common cultivar cultivated in Egypt.

Experimental design: The experiments were conducted to study the effects of planting date and intra-row spacing on growth, yield and quality of taro, with a particular attempt to establish an early planting system.

In both seasons, the taro cultivar "Balady" was cultivated at four dates and in each date at four intra-row spacings. The experiments were arranged in a split-plot design with four replications. Main plots were planting dates including mid-November, mid-December, mid January and mid-February and subplots were intra-row spacings of 20, 30, 40 and 50 cm. These spacings equal 6.25, 4.17, 3.13 and 2.5 plants/m^2, respectively. Each main plot was 6 m wide and 22 m long, and each subplot was composed of five rows with row spacing of 80 cm and row length of 5 m.

Cormels with the same weights of bout 100 g were used as planting materials. Cultivation and all cultural practices (irrigation, fertilization, weeding, and pest control), according to the recommendations of the Egyptian Ministry of Agriculture, were kept normal and uniform for all the treatments.

Data recorded: A random sample of five plants from the three inner rows of each experimental plot were taken during harvest (270 days after each planting date) and the vegetative growth data were recorded. Plant height (cm) was measured from the ground level to the top point of plant. Also, the standing leaves on each individual plant were counted, and average leaf area (cm^2) was estimated.

All corms from the three centre rows of each experimental plot were removed. Corms were cleaned from the residual of soil and the data for yield and its components i.e corm weight/ plant (kg), cormel weight/ plant (g), yield/plant (kg). Yield/ feddan (ton) was calculated. Corm diameter and corm length were measured and corm diameter: corm length was calculated.

Corm samples were dried to constant weight at 70 ºC for dry matter determination. Carbohydrates content of corms was determined according to A.O.A.C. [14].

Data analysis: All data were subjected to an analysis of variance with SAS statistical package [15]. Means of main effects were separated using Duncan's multiple range test [16]. Means of interactions were separated using least significance difference (LSD). All statistical determinations were made at P = 0.05.

RESULTS AND DISCUSSION

Vegetative growth characters: Data presented in Table 2 show the influence of planting date, intra-row spacing and their interactions on plant height, average number of leaves/plant and leaf area. As for the planting date, data showed that these characters were significantly increased with early planting date in mid-November during both seasons.

As for the plant spacing, the vegetative growth parameters were increased as spacing between plants decreased. Narrow spacings of 20 and 30 cm gave the highest values of vegetative growth parameters while the wider spacings gave the lowest ones.

Concerning the interaction effect between planting date and plant spacing, early planting date, mid-November, along with narrow spacings, 20 and 30 cm, gave the highest significant values of vegetative growth characters. On the other hand, late planting dates with wider spacings gave the lowest values.

The shading resulted from dense plantings and reducing values of solar radiation in early plantings might contribute much to the increasing in the vegetative growth parameters.

Yield and yield components: Data presented in Table 3 show the effect of planting date, intra-row spacing and their interactions on corm weight/plant, cormel weight/plant, average yield/plant and total yield/feddan.

As for the effect of planting date, data showed that early planting dates in mid-November and in mid-December significantly gave the highest values of weight of corms and weight of cormels per plant, plant yield and total yield/feddan in both growing seasons. Total yield/feddan increased from 12.98 to 19.74 ton (in the first season) and from 11.79 to 21.11 ton (in the second season) changing the planting date from mid-February to mid-December. The increases of total yield/feddan by planting in mid-December were 51.99 and 45.75% over the planting in mid-February in the two growing seasons. However, there was no significant differences in total yield/feddan between the planting dates of mid-December and mid-November.

As for the plant spacing, increasing the spacing between plants from 20 cm to 50 cm significantly increased the weight of corms and cormels per plant and plant yield in both seasons. On the contrary, the narrow plant spacing of 20 cm produced the greatest

Table 1: Monthly maximum and minimum air temperatures, relative humidity, and Average sunlight hours/day during the experimental period at the test site.

Month	Average maximum temperature (ºC)	Average minimum temperature (ºC)	Relative humidity (%)	Average sunlight hours/day
November	26	14	42	8.3
December	21	10	46	6.4
January	19	9	43	6.9
February	21	9	39	8.3
March	24	12	33	8.7
April	28	14	28	9.7
May	32	18	25	10.5
June	35	20	27	11.9
July	35	22	31	11.7
August	35	22	35	11.3
September	33	20	37	10.4
October	30	18	36	9.4

Source: Central Laboratory for Agricultural Climate.

Table 2: Effect of planting date, intra-row spacing and their interactions on vegetative growth of taro during 2007/2008 and 2008/2009 seasons.

Treatments	Plant height (cm)		Number of leaves/plant		Leaf area (cm^2)	
Planting date Spacings	1st season	2nd season	1st season	2nd season	1st season	2nd season
Mid-November	195.3A[a]	162.3A	4.81A	4.79A	1352.9A	1310.8A
Mid-December	193.2A	163.3A	4.49A	4.07B	1231.2AB	1117.9B
Mid-January	175.5B	157.1A	4.54A	3.78BC	1214.3B	1112.3B
Mid-February	144.8C	135.9B	3.62B	3.44C	1254.0B	1254.7AB
20 cm	184.8a	164.2a	4.36a	4.15a	1360.2ab	1256.4ab
30 cm	183.1a	157.9ab	4.53a	4.21a	1422.70a	1367.2a
40 cm	173.7b	154.3b	4.32a	4.03ab	1290.8b	1182.5b
50 cm	167.2c	142.1c	4.26a	3.69b	1082.0c	989.7c
Planting date X Spacings						
Mid-November						
20 cm	206.0	176.7	5.07	5.25	1629.5	1529.0
30 cm	201.7	166.7	4.63	5.12	1463.9	1616.5
40 cm	191.7	157.3	4.40	4.17	1203.7	1101.0
50 cm	181.7	148.3	5.13	4.63	1114.4	996.8
Mid-December						
20 cm	199.7	175.0	4.30	3.93	1555.2	1446.5
30 cm	202.3	163.3	4.97	4.50	1292.6	1141.7
40 cm	186.3	161.7	4.30	4.50	1041.9	934.2
50 cm	184.3	153.3	4.40	3.33	1035.0	949.3
Mid-January						
20 cm	181.0	161.7	4.37	3.97	890.8	785.2
30 cm	178.0	156.7	4.77	3.50	1449.5	1322.8
40 cm	175.0	155.0	4.73	4.17	1499.9	1399.5
50 cm	168.0	155.0	4.30	3.50	1017.0	941.6
Mid-February						
20 cm	152.3	143.3	3.70	3.43	1365.2	1264.7
30 cm	150.3	145.0	3.73	3.73	1484.8	1387.8
40 cm	141.7	143.3	3.83	3.30	1417.7	1295.2
50 cm	134.7	111.7	3.20	3.30	1161.7	1071.1
L.S.D $_{0.05}$[b]	9.26	14.28	0.93	0.69	245.4	278.3

[a] Means into every group within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan s multiple range test.

[b]L.S.D applies to comparison of interactions between planting date and intra-row spacing.

Table 3: Effect of planting date, intra-row spacing and their interaction on yield components of taro during 2007/2008 and 2008/2009 seasons.

Treatments	Corm weight/ plant (kg)		Cormel weight /plant (g)		Yield/plant (kg)		Yield/feddan (ton)	
Planting date Spacings	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Mid-November	1.23A[a]	1.27A	0.062A	0.064A	1.295A	1.334A	19.49A	19.97A
Mid-December	1.24A	1.31A	0.062A	0.066A	1.302A	1.376A	19.74A	21.11A
Mid-January	1.07B	1.10B	0.053B	0.055B	1.120B	1.155B	16.38B	16.91B
Mid-February	0.81C	0.76C	0.041C	0.038C	0.853C	0.796C	12.98C	11.79C

Table 3: Continue

20 cm	0.80c	0.82d	0.040c	0.041d	0.839c	0.856d	20.96a	21.41a
30 cm	1.01b	1.02c	0.050b	0.051c	1.055b	1.067c	17.60b	17.81b
40 cm	1.24a	1.21b	0.062a	0.061b	1.297a	1.268b	16.24b	15.88c
50 cm	1.31a	1.40a	0.066a	0.070a	1.379a	1.469a	13.79c	14.69c
Planting date X Spacings								
Mid-November								
20 cm	0.939	0.965	0.047	0.048	0.986	1.014	24.64	25.34
30 cm	1.143	1.107	0.057	0.055	1.200	1.162	20.02	19.39
40 cm	1.278	1.342	0.064	0.068	1.342	1.410	16.80	17.66
50 cm	1.573	1.667	0.079	0.083	1.652	1.750	16.52	17.50
Mid-December								
20 cm	0.944	1.008	0.047	0.050	0.991	1.058	24.78	26.46
30 cm	1.175	1.367	0.059	0.069	1.234	1.436	20.58	23.96
40 cm	1.427	1.491	0.071	0.076	1.498	1.567	18.76	19.62
50 cm	1.413	1.373	0.071	0.069	1.484	1.442	14.84	14.42
Mid-January								
20 cm	0.683	0.735	0.034	0.037	0.717	0.772	17.92	19.29
30 cm	0.959	0.928	0.048	0.046	1.007	0.974	16.80	16.25
40 cm	1.225	1.262	0.061	0.063	1.286	1.325	16.10	16.59
50 cm	1.400	1.476	0.070	0.074	1.470	1.550	14.70	15.50
Mid-February								
20 cm	0.629	0.554	0.031	0.028	0.661	0.581	16.52	14.53
30 cm	0.743	0.663	0.037	0.033	0.781	0.697	13.02	11.62
40 cm	1.012	0.735	0.051	0.037	1.062	0.772	13.30	9.66
50 cm	0.867	1.080	0.043	0.054	0.910	1.134	9.10	11.34
L.S.D $_{0.05}$ [b]	0.180	0.206	0.009	0.010	0.189	0.216	2.85	3.09

[a] Means into every group within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan s multiple range test.

[b]L.S.D applies to comparison of interactions between planting date and intra-row spacing.

yield/feddan in both seasons. These results indicated that higher plant density due to narrow spacing compensate for the reductions in plant yield. Total yield/feddan increased from 13.79 to 20.96 ton (in the first season) and from 14.69 to 21.41 ton (in the second season) as plant spacing decreased from 50 to 20 cm. The increases of total yield/feddan by using spacing of 20 cm were 51.99 and 45.75% over the spacing of 50 cm in the two growing seasons.

The interactions between planting date and plant spacing indicated that early planting dates, mid-November, mid-December and mid-January, along with the wider spacings of 40 or 50 cm gave the highest weight of corms and cormels per plant and plant yield in both seasons. On the contrary, the early planting dates, mid-November and mid-December, with the narrow plant spacing of 20 cm significantly produced the greatest yield/feddan in both seasons.

Fig. 1 clearly showed that under the plant spacing of 20, 30 and 40 cm, mid-December gave the highest total yield/feddan followed by mid-November, mid January and mid-February that gave the lowest total yield/feddan in both seasons. Under the plant spacing of 50 cm, mid-November gave the highest total yield/feddan followed by mid-January, mid-December and mid-February that gave the lowest total yield/feddan in both seasons.

Under the same planting date, total yield/feddan increased as the plant spacing decreased from 50 cm to 20 cm in both seasons (Fig. 2).

Physical shape of corm: Data presented in Table 4 show the effect of planting date, intra-row spacing and their interactions on corm diameter, corm length and ratio between these parameters. In both seasons, mid-December significantly gave the highest values of corm diameter, corm length and corm diameter: corm length ratio. However, corm length was not significantly affected by the three planting dates, mid-November, mid-December and mid-January.

Concerning the intra-row spacing, data showed that corm diameter and corm diameter: corm length ratio were not significantly affected by plant spacing. However, the intra-row spacing had a marked effect on the corm length since the 40 cm spacing significantly gave the highest corm length in both seasons.

The data of planting date x spacing indicated that planting in mid-December with 30 or 40 cm spacing produced the highest corm diameter. As for corm length, mid-November and mid-December with 40 cm spacing produced the highest length of corm, while mid-December gave the significant values of ratio under different plant spacings.

Corm content of dry matter and total carbohydrates: Data presented in Table 5 show the effect of planting date, intra-row spacing and their interactions on corm content of dry matter and total carbohydrates. In both growing seasons, dry matter of taro corm was neither significantly affected by planting date, nor by intra-row spacing. Also, no significant planting date x plant spacing interaction was observed for corm content of dry matter in both seasons. Corm content of total carbohydrates showed a similar trend.

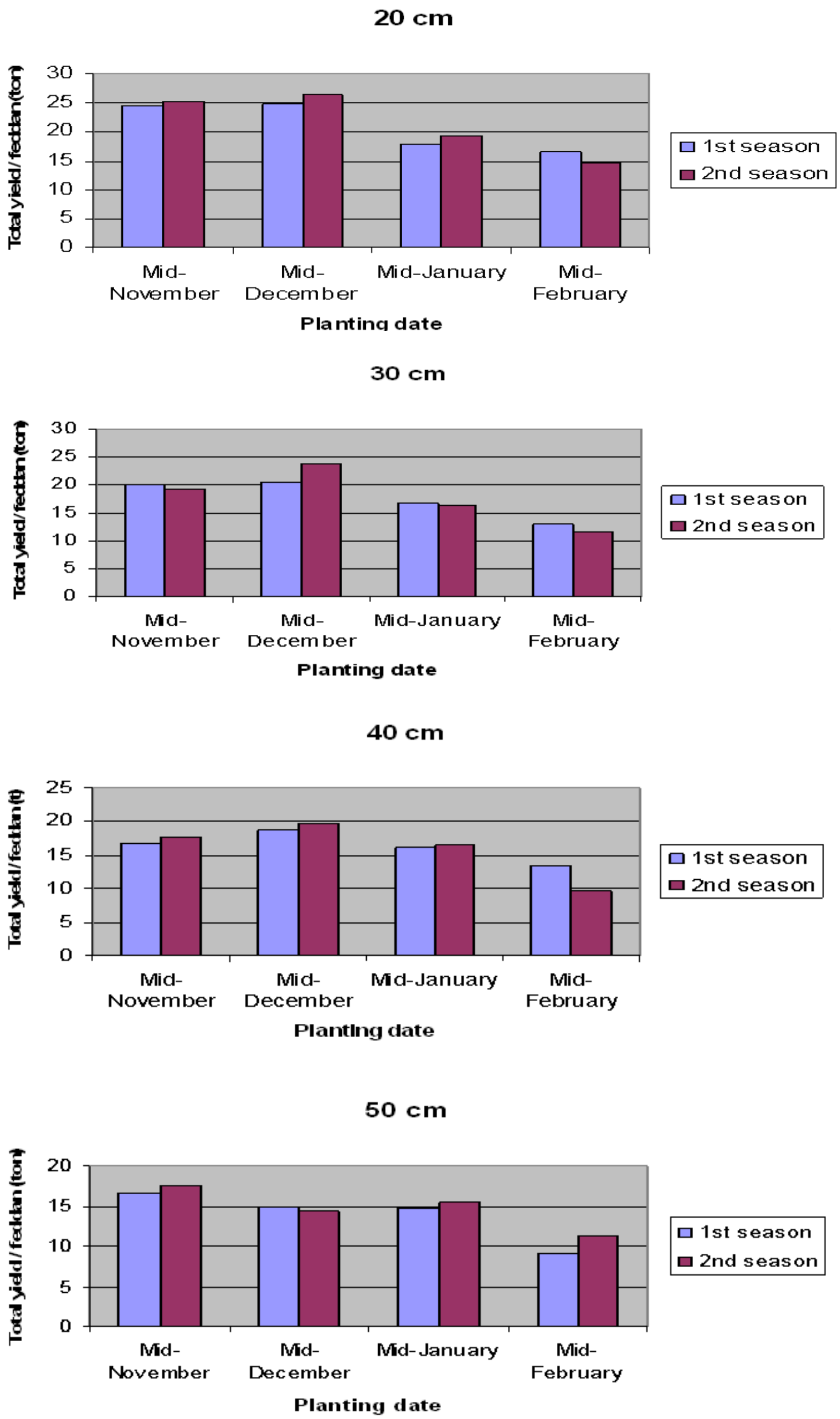

Fig. 1: Total yield of taro / feddan of different planting dates under the same plant spacing.

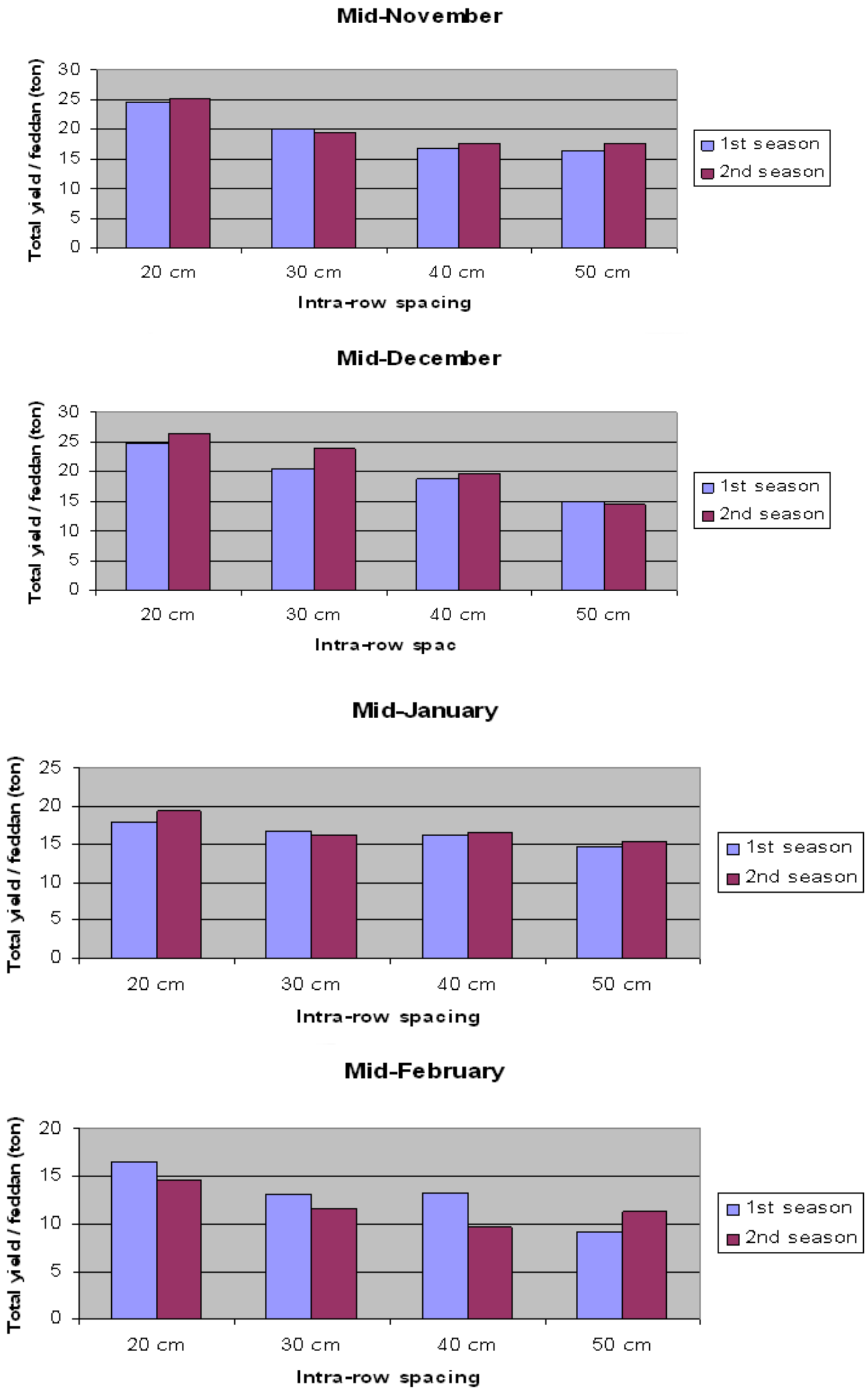

Fig. 2: Total yield of taro / feddan of different plant spacings under the same planting date.

Table 4: Effect of planting date, intra-row spacing and their interaction on taro corm shape during 2007/2008 and 2008/2009 seasons.

Treatments		Corm diameter (cm)		Corm length (cm)		Corm diameter:corm length ratio	
Planting date	Spacings	1st season	2nd season	1st season	2nd season	1st season	2nd season
Mid-November		10.09B[a]	9.82B	16.83A	16.65A	0.60B	0.59B
Mid-December		11.17A	11.61A	16.88A	16.70A	0.66A	0.69A
Mid-January		9.45BC	9.59B	16.82A	16.64A	0.56BC	0.58B
Mid-February		8.85C	8.89B	16.63B	16.46B	0.53C	0.54B
	20 cm	9.20b	9.41a	15.33d	15.15d	0.60a	0.62a
	30 cm	10.13a	10.33a	17.06c	16.88c	0.59a	0.61a
	40 cm	10.26a	10.32a	17.48a	17.31a	0.59a	0.60a
	50 cm	9.97a	9.85a	17.28b	17.11b	0.58a	0.58a
Planting date X Spacings							
Mid-November							
	20 cm	8.90	9.27	15.33	15.16	0.58	0.61
	30 cm	10.17	10.00	17.13	16.96	0.59	0.59
	40 cm	10.40	9.77	17.50	17.32	0.59	0.56
	50 cm	10.90	10.23	17.33	17.16	0.63	0.60
Mid-December							
	20 cm	9.87	10.20	15.33	15.16	0.64	0.67
	30 cm	11.60	12.53	17.07	16.89	0.68	0.74
	40 cm	12.10	12.93	17.73	17.56	0.68	0.74
	50 cm	11.10	10.78	17.37	17.19	0.64	0.63
Mid-January							
	20 cm	9.45	9.68	15.43	15.26	0.61	0.63
	30 cm	10.03	9.90	17.13	16.96	0.59	0.58
	40 cm	9.17	9.47	17.47	17.29	0.52	0.55
	50 cm	9.13	9.33	17.23	17.06	0.53	0.55
Mid-February							
	20 cm	8.57	8.50	15.20	15.03	0.56	0.57
	30 cm	8.73	8.87	16.90	16.72	0.52	0.53
	40 cm	9.37	9.13	17.23	17.06	0.54	0.54
	50 cm	8.73	9.07	17.20	17.03	0.51	0.53
$L.S.D_{0.05}$[b]		1.34	1.88	0.25	0.25	0.08	0.11

[a] Means into every group within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan s multiple range test.

Table 5: Effect of planting date, intra-row spacing and their interaction on dry matter and total carbohydrates (g/100g) of taro on a fresh weight basis during 2007/2008 and 2008/2009 seasons.

Treatments		Dry matter (g/100g)		Total carbohydrates (g/100g)	
Planting date	Spacings	1st season	2nd season	1st season	2nd season
Mid-November		38.8A[a]	40.00A	30.8A	30.8A
Mid-December		46.7A	37.8A	31.6A	30.9A
Mid-January		41.9A	39.4A	31.0A	29.8A
Mid-February		43.1A	42.5A	31.7A	30.3A
	20 cm	39.3a	38.5a	31.3a	30.5a
	30 cm	45.4a	42.3a	31.4a	30.8a
	40 cm	42.2a	38.6a	31.0a	30.0a
	50 cm	43.6a	40.2a	31.4a	30.5a
Planting date X Spacings					
Mid-November					
	20 cm	36.1	43.4	30.6	31.4
	30 cm	45.1	45.2	31.0	31.1
	40 cm	36.9	36.5	30.3	29.4
	50 cm	37.1	34.9	31.4	31.3
Mid-December					
	20 cm	39.8	36.6	31.5	30.9
	30 cm	53.3	35.6	31.8	31.5
	40 cm	45.1	38.3	31.4	30.4
	50 cm	48.8	40.8	31.8	30.7
Mid-January					
	20 cm	38.3	37.2	31.7	30.7
	30 cm	42.1	46.6	30.7	29.9
	40 cm	41.0	39.8	30.8	29.9
	50 cm	46.2	33.8	30.8	28.8

Table 5: Continue

Mid-February					
	20 cm	42.8	36.9	31.6	28.9
	30 cm	41.1	41.9	32.3	30.7
	40 cm	46.0	40.0	31.3	30.3
	50 cm	42.5	51.1	31.6	31.3
	L.S.D $_{0.05}$ [b]	ns	ns	ns	ns

[a] Means into every group within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan s multiple range test.

Discussion: In Egypt, taro is usually planted in early spring, in mid-February or in mid-March, with the spacing varying from 20-50 x 80-120 cm, and harvested at the end of November or at the end of December (9-month season). However, in some regions of Sharkia and Qalyubia, some farmers cultivate taro in November or in December and others still cultivate this crop in early spring. Those farmers make us thinking to determine the effect of these early planting dates with the usual date, under different plant spacing, on the growth, yield and quality of taro.

Reynolds [17] concluded that there were five growth stages of taro: (i) a period of establishment with root formation and leaf production during the first month, (ii) a period of rapid root and shoot development with initiation of corm development during one to four months, (iii) a climax of root and shoot growth with a rapid increase in corm formation during four to six months, (iv) a senescence period of decreasing root and shoot growth with continued increase in corm size during 6 to 9 months, and (v) a period of decreasing corm weight perhaps due to rot and of initiation of further vegetative growth with increased root and shoot growth during 8 to 10 months. Although, Sivan [18] reduced the number of growth phases by combining the third and fourth phases and eliminating the fifth phase.

Our results indicated that the vegetative growth parameters were improved with planting in early planting dates with the narrow spacings. The shading resulted from dense plantings and reducing values of solar radiation in early plantings might result in low evapotranspiration and thus the plant growth was increased. Also, the dense plantings in early planting dates might make the air temperature optimum for taro growth. These findings are in agreement with the results obtained with Singh *et al.* [19] who found that growth in tuber crops is reduced by stresses of low water, low N, and low or high temperatures. Water stress develops when evapotranspiration exceeds the uptake of available water in the soil. Nitrogen stress occurs when potential N uptake exceeds that available in the soil. Available N is modified by fertilizer and crop residue application, leaching, denitrification, NH3 volatilization, immobilization to organic matter, and mineralization from organic matter. Temperature stress develops when air temperature is above or below the optimum of 28°C.

Concerning the taro yield, early planting in mid-November and in mid- December gave the highest yield without significant differences. These early planting dates made the period characterized by a climax of root and shoot growth with a rapid increase in corm formation [17] falling from mid-March to mid-June when the average temperature in Egypt varied from 24 to 35 ºC (Table 1) that is a suitable temperature for this period of taro growth according to Follett [8] who found that the best growth of taro occurs at 25-35°C. These results were not consistent with the hypothesis that spring plantings would have greater yields and an earlier time to maturity because of greater average temperatures and total solar radiation during the period of rapid root and shoot development compared with those of fall and winter plantings. The same hypothesis was obtained by Miyasaka *et al.* [5] who found that potential yields of taro (based on fresh weight of healthy corms) were not significantly affected by planting date and found that the yield of the spring and summer plantings did not significantly differed than that of fall and winter plantings. In addition, our findings are confirmed with those obtained by Almeida *et al.* [20] who found that in Brazil, early May planting (mid autumn) of taro gave the highest yield and August planting (mid winter) gave the poorest yield.

Also, our results indicated that increasing the spacing between plants from 20 cm to 50 cm significantly increased the plant yield. This result is in agreement with Mannan [21], Siddique and Rabbani [22]. Higher plant density due to narrow spacing compensate for the reductions in plant yield. These results are supported by those of Gobeze *et al.* [4], Tumuhimbise *et al.* [9], El-Habbasha *et al.* [10], Liou [11], Scheffer *et al.* [13], Mahmoud [23], Behairy [24], Bhuyan *et al.* [25], and Pardales *et al.* [26] who found that closely spaced plant gave the highest yield of taro.

Conclusion: This study demonstrated that planting date and intra-row spacing affect growth and yield of taro. Early plantings in mid-November or mid-December along with close spacing of 20 cm can be recommended for obtaining early and high production of taro under Qalyubia conditions.

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