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Shortening of Taro (*Colocasia esculenta*) Life Cycle by Using Plug Planting System

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Abstract: The aim of this work was to study the effect of using taro plug transplants of two different plant materials i.e., corms and cormels grown in four different substrata i.e., peat moss, field soil (clay soil), peat moss plus field soil (clay soil) 1:1 v: v and peat moss plus sand 1:1 v: v of taro on growth characters. Balady cultivar was used under greenhouse of the Experimental Farm at Kaha Vegetable Research Farm, Kaluobia Governorate, Horticulture Research Institute, Agriculture Research Center (ARC), Egypt, during 2018/2019 and 2019/2020. The experimental design was complete randomized design with three replicates. The above plug transplants were transplanted in the experimental field at three planting dates 1st May, 1st June and 1st July (after, 1.5, 2.5 and 3.5 months). The conventional corms and cormels as a control were transplanted in the experimental field on 11th and 5th March respectively in the two studied seasons at El-Kanater Horticulture Research Station (El-Kaluobia Governorate), Horticulture Research Institute, Agriculture Research Center (ARC), Egypt. The experimental design was split split design with three replicates. After transplanting, the plug transplants grew vigorously without wilting while plant in the field had weak growth. Results show clearly that peat moss substrate produced the highest number of leaves, plant height and chlorophyll content. Cut corms had the highest leaves number and chlorophyll content compared with cormels. Also planted plug transplants at 1st May (after 1.5 months) gave the highest number of corms per plant. Plants established by using rooted transplants (plug plants) after 1.5 months (1st of May) by cormels in peat moss substrate produced the highest significant total yield/plant, which increased by about 16%.

Key words: Taro · Corms · Cormels · Plug transplants · Substrate · Plant material · Transplanting date · Yield components

INTRODUCTION

Taro, (*Colocasia esculenta* L. Schott) is a major traditional vegetatively propagated crop by planting corms or cormels directly into the field [1]. It is considered one of the most important vegetables grown in Egypt due to its high nutritional and economical values. There are some factors that limit the increment of taro cultivation area such as its amount of irrigation water and long duration in land (8-9 months). In addition, in the early period of plant growth, i.e., up to 90 days from planting so, the farmer can't cultivate anther crop [2]. The growth rate is low which causes an increase in growing weeds so, it's needs a lot of labor. Water is the important factor to taro yield and drought affect plant growth where water resources are limited [3].

Generally, the advantages to growing transplants in plugs are saving growth time and labor to transplant, reduced root loss, more uniform growth, faster crop establishment and increased production [4]. Vegetable plants reduce the time needed to produce a crop, allowing them to produce a second or third crop during the growing season [5]. In this respect, He *et al.* [6], showed that the plug transplants can grow vigorously with a high survival ratio after transplanting process and thus save labor and time. Plug transplants continue growth after

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planting in the field when planted intact roots and substrate while transplants planted without roots experienced transplant shock which inhibited plant growth immediately after planting Islam *et al.* [7] and they also, found that plug transplants survival was 100% after planting in the field however 15 % of conventional cut corm died after planting. Due to the strong root system, which is not disturbed by digging up. Plug plants establish quickly after planting and renew their growth [8].

Growing media constituents include combinations of peat and other organic or inorganic materials. Commercial nurseries often mix peat with perlite or vermiculite to increase the water holding capacity of growing substrate and avoid water content volume fluctuation of solely peat substrate. Sometimes growers create self-produced mixtures using local resources such as, field or garden soil to grow vegetable transplants [9]. On the other hand, Dan Drost [10] recommended that, do not use filed soil to grow vegetable transplants. Field soil lacks good structure, may contain pests and diseases and will have weed seeds; thus, transplant growth will be poor. Peat moss is one of the most widely substrates used in the production of seedling plants due to its high physical and chemical stability. Vegetable nurseries are use soilless substrates com-posed of peat mixed with inorganic amendments such as perlite and vermiculite [11]. In this respect, Nina *et al.* [12] stated that industrial growing mixes are widely used in the vegetable seedling and transplants industry. They consist of growing media constituents and additives. Growing media constituents include combinations of peat and other organic or inorganic materials. Growing media additives include fertilizers, liming materials and biocontrol or wetting agents. Lewthwaite and Triggs [13] found that, plug transplants and rooted sprouts of sweet potato produced equivalent yields of comparable quality at commercial harvest dates. The plug transplants produced the highest marketable yield than the trimmed pulled and defoliated sprouts. Islam *et al.* [14] concluded that the plug transplants produced higher yield of storage roots than the conventional cuttings when they were planted in the field. The storage root yield of sweet potato using plug transplants was influenced by the depth of planting rather than the age of transplants in ranges yield. The plug transplants can be used as transplants for higher yield with less labor cost in the field.

Planting date is an important management practice. Mare [15] showed that delayed planting date of taro decreased cormels number per plant and fresh cormels mass. Whereas, Mare and Modi [16] reveled that delaying planting date gave significantly negative effect on starch content on taro. Late March planting was identified best to vegetative growth, marketable yield and total yield of taro. However, cormels number and weight per plant was not affected by planting dates. On the other hand, average marketable yield per plant was significantly affected by planting dates but the planting dates are similar except for mid-April [17].

Therefore, the aim of this study was to investigate the effects of plug planting system, different transplanting substrates mixture and transplanting date of taro on growth, yield and its compounds.

MATERIALS AND METHODS

Two experiments were conducted out during two successive seasons of 2018/2019and 2019/2020 to investigate the effect of using plug plants of taro for shorten its period at the field and compare it with traditional (directly cormels or corms) system on yield and its components of Balady cultivar.

This Study Was Conducted in Two Experiments

The First Experiment: This experiment was carried out at Kaha Vegetable Research Farm (El-Kaluobia Governorate), Horticulture Research Institute, Agriculture Research Center (ARC), Egypt to study the effect of using two different plant materials i.e., corm and cormels and four different substrata i.e., peat moss, clay soil, clay soil with peat moss and sand with peat moss grown under greenhouse condition on plug transplants growth characters. Peat moss was enriched with vermiculite, perlite (1:1:1 v: v: v) and pH was adjusted to (6.5) by using Calcium carbonate, as well as Ammonium nitrate, Potassium sulfate, Magnesium sulfate, Topsin fungicide and Micro elements were applied according to the recommendations. Compound fertilizer (19-19-19) was used as foliar spray during the green house (transplanting) period. Taro materials were sown on 11th and 5th March 2018 and 2019 seasons respectively, in trays (polyethylene pages) 10 cm width filled with five substrates treatments as follows:

Peat moss was enriched with vermiculite, perlite (1:1:1 v: v: v).

Field clay soil.

Field soil with peat moss (1:1 v: v).

Sand but it was recycled because it's had weak growth.
Sand with peat moss (1:1 v: v).
The experimental design was complete randomized design. After 45 days from planting 15 plants were randomly taken and the following data were recorded:
Plant height: it was measured from the ground level up to the top point.
Leaf number per plant.
Total chlorophyll content: Total chlorophyll content of five leaves was determined by using Minolta SPAD-502 Chlorophyll Meter (MINOLTA CO., LTD. Japan).

The Second Experiment: Transplants produced in the first experiment were planted in three planting dates i.e., 1st May, 3rd June and 1st July (after, 1.5, 2.5 and 3.5 months) at El-Kanater Horticulture Research Station (El-Kaluobia Governorate), Horticulture Research Institute, Agriculture Research Center (ARC), Egypt. The soil of the experimental land was clay in texture. Transplants were planted in the bottom of the ridge at the distances of 30 cm between them and 80 cm between ridges. The corm and cormels of taro were planted in the field directly at 11th and 5th March respectively (control treatment). The experimental design was split split-plot with three replications. The dates were distributed in the main plots. Meanwhile, the four mediums were distributed the sub plots and the sub sub plots were the four plant materials, with three replicates.

Data Were Recorded as Follows

Vegetative Growth: Five plants from each plot were chosen randomly from each treatment at 210 days after planting for measuring the following vegetative growth characters of taro plants expressed as plant height (cm), leaf number per plant and leaf area: it was determined by cutting out 10 leaf discs from each plant using a cork borer and then weighed. The leaf area was calculated according to following formula: fresh weight of leaves (gm.) × leaf area of disks (cm^2.) / fresh weight of disks (gm.).

Yield and its Components: Taro plants were harvested at 270 days after planting and following yield measurements were recorded:

Total Yield: At harvest stage, the mature taro corms for each experimental plot were collected and the total yield per fed. was estimated according to the following equation:

Total yield per fed. = (yield per plot x 4200) / Area of plot.
Average fresh weight, length and diameter of the main corm: It was recorded as an average of five randomly plants from each experimental plot
Number of corms/plant: It was recorded as an average of five randomly plants from each experimental plot

Chemical Composition: Samples of corms at the harvesting date were taken to determine the total carbohydrates and starch.

Total carbohydrates and starch content: were determined calorimetrically according to A.O.A.C. [18].

Statistical Analysis: All data of the experiment were subjected to proper statistical analysis of variance according to Snedecor and Cochran [19]. Duncan Multiple range test was used for comparison between means of treatments.

RESULTS AND DISCUSSION

The First Experiment

Vegetative Growth Characters

Plant Height: The effect of plant material type and different substrate mixtures on seedling growth characters was shown in Table (1). Significant differences were observed among the different substrate mixtures as regards to seedling growth characters. According to the seedling height data showed that the maximum seedling height was observed in peat moss substrate followed by clay + peat moss 1:1 v substrate during the two studied seasons. On the other hand, the lowest seedling height was obtained from clay substrate.

Concerning the effect of plant materials, the taller plant was resulted in corm which showed significant increment as compared to cormels in both seasons.

Regarding the interaction between plant materials type and different substrates, data in Table (1) reflected that the highest significant values of transplant height were obtained from plants planted with cormel in peat moss substrate followed by corms parts in the same substrate during the two growing seasons. These results are in agreement with those reported by Ayob *et al.* [11].

Leaf Number /Plant: As for leaf number per transplants, data in Table (1) indicated that there were no significant differences between different substrates and plant materials, as well as, their interaction in this character during the two studied seasons.

Table 1: Effect of plant materials and substrates as well as their interaction on plant height (cm), leaf number and total chlorophyll (Combined analysis of 2019 and 2020 seasons)

Treatments		Plant height (cm)	Leaf number/plant	Total chlorophyll (Spad)
			Effect of plant materials	
Corm		25.04 a	2.16 a	68.68 a
Cormels		24.18 b	2.05 a	55.77 b
			Effect of substrates	
Peat moss		30.53 a	2.00 a	71.97 a
Clay		21.38 d	2.08 a	53.24 d
Peat moss + clay		24.53 b	2.09 a	61.21 c
Peat moss + sand		22.11 c	2.10 a	62.47 b
			Effect of interaction	
Corm	Peat moss	28.85 b	2.20 abc	72.70 a
	Clay	24.27 d	2.10 bc	62.00 d
	Peat moss + clay	25.03 c	2.10 abc	65.77 c
	Peat moss +sand	23.75 d	2.23 a	74.05 a
Cormels	Peat moss	32.21 a	1.90 c	71.23 b
	Clay	19.00 f	2.22 abc	44.30 g
	Peat moss + clay	24.58 c	2.10 abc	56.65 e
	Peat moss + sand	21.26 e	1.95 bc	50.90 f

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 2: Effect of plant materials, substrates and planting dates on plant height (cm), leaf number and leaf area (cm^2) (Combined analysis of 2019 and 2020 seasons)

Treatments	Plant height (cm)	Leaf number	Leaf area (cm^2)
		Effect of plant materials	
Corm parts	114.00 a	4.71 a	2239.50 a
Cormels	108.31 b	4.12 b	2243.89 b
		Effect of substrates	
Peat moss	131.00 a	4.51 a	2248.10 a
Clay	101.91 c	4.43 b	2230.04 b
Peat moss + clay	109.73 b	4.40 b	2244.53 a
Peat moss + sand	101.97 c	4.31 c	2244.10 a
		Effect of planting dates	
1st May	135.77 a	4.78 a	2312.86 a
3rd June	105.47 c	4.65 b	2250.76 b
1st July	79.52 d	4.26 c	2176.46 c
Control	123.85 b	3.95 d	2226.69 d

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Total Chlorophyll: Data presented in Table (1), show the effect of different substrates and plant materials and their interaction on total chlorophyll. The results indicated that total chlorophyll was influenced by substrates. The maximum chlorophyll in transplant leaves was observed in peat moss substrates followed by sand mixed with peat moss substrates medium.

Concerning the effect of plant materials, using corm parts significantly increased total chlorophyll in transplant leaves in the both seasons.

The interaction effect between the plant material type and different substrates reflected that corm planted in peat moss or sand plus peat moss gave the highest values of chlorophyll without significant differences between them. These results are agreement with those reported by Ayob *et al.* [11]; Mohamed *et al.* [20] and Ahmed [21] whom reported that the type of substrate was strongly influence the rooting and growth. These results may be due to increase of chlorophyll of plants.

The Second Experiment

Vegetative Growth Characters: Plant height, leaf number and leaf area were influenced by both plant materials and substrates at the three planting dates as shown in (Table 2).

Effect of Plant Materials: Concerning the effect of plant materials results in Table (2), indicated that plant height, leaf number and leaf area significantly affected by the source of planting material. Corm recorded significantly

high mean of plant height and leaf number. The finding of results agree with those reported by Tsedalu *et al.* [1] who found significant difference between the type of planting material (corm and cormels). Plants grown from corm gave taller plant, higher leaf number and leaf area than plants grown from cormels.

Effect of Substrates: Substrates had significant effect on plant height, leaf number and leaf area. Data in Table (2) cleared that the maximum plant height, leaf number and leaf area of taro plant grown in field were obtained from transplants grown on peat moss substrates at the two studied seasons followed by transplants grown in mixtures content from peat moss plus clay. On the other hand, the lowest plant height and leaf number of taro plants grown in field were obtained from transplants that grown in peat moss plus clay. Similar opinions were reported by Ayob *et al*. [11] and Nina *et al*. [12], whom reported that these growing substrate contents are suitable for production of plug taro seedling because it has suitable physical and chemical properties, which led to produce better transplant quality.

Effect of Planting Dates: Regarding the effect of planting dates on vegetative growth parameters, results in Table (2) revealed that the planting on 1st May gave maximum values of vegetative growth parameters as compared with the other planting dates.

Effect of the Interaction Between Plant Materials and Substrates: Effects of the interaction between plant materials and substrates on plant height, leaf number and leaf area of taro are presented in Table (3). The interaction had positive significant effect on plant height and leaf number. Results also indicated that plants planted by cormels in peat moss medium gave the highest value of plant height and leaf number in the field whereas no significant differences in leaf area were found.

Effect of the Interaction Between Plant Materials and Planting Dates: Regarding, the interaction effect between plant materials and planting dates, planting corms in 1st may gave the highest values of plant height and leaf number values compared with other plant dates. In addition, planting coremls at 1st of May increased leaf area per plant followed by planting corms at the same date (Table 4)

Effect of Interaction Between Planting Dates and Substrates: Concerning the interaction effect between the substrates and planting dates, the results showed that the highest values of plant height and leaf number were obtained from plants planted at 1st of May in peat moss substrate. Results also indicated that plants planted at 1st of May in peat moss plus clay or sand soil gave the highest values of leaf area (Table 5).

Effect of Interaction among Planting Materials, Planting Dates and Substrates: The effect of interactions among transplanting dates, substrates and plant materials illustrated in Table (6) Results show that planting corms in peat moss substrate at 1st May significantly increased plant height compared to other tested combination treatments. While the highest leaf area per plant was obtained from planting cormels in peat moss plus sand substance at 1st May.

Yield and its Components: The parameters used for measuring total yield characters in this study are number of corm/plants, main corm fresh weight (g), main corm length and diameter and total yield (ton)/ fed.

Effect of Plant Materials: Data in Table (7) showed that plant materials (corm and cormel) had no significant effect on number of corms/plant, main corm length and diameter. Using cormels as plant material increased significantly the main corm fresh weight and corms yield compared with corms. The highest main corm length and diameter of taro were obtained by using corm part. These results may be due to the increase in vegetative growth characters (Table7). Positive yield response is the result of different individual processes, such as increased in leaf area. The obtained results are not agreeing with Tesdalu *et al.* [1] who found that corm type of planting material recorded higher values for the yield and its components. These different results may be due to the weight of planting material. While the results are in agreement with those of Lewu *et al.* [2] who reported that plants grown with large cormels showed better growth and yield than plants established with smaller cormels.

Effect of Substrates: Concerning the effect of substrates on yield and its components of taro, data in Table (7) indicated that using peat moss for transplant production increased significantly main corm fresh weight (18.47) followed by peat moss + sand (17.9) with significant difference between them, main corm length and main corm diameter of taro during and total yield (ton)/ fed. In addition, no significant difference in the number of corms per plant was found.

Table 3: Effect of interaction between plant materials and substrates on plant height (cm), leaf number and leaf area (cm^2) (Combined analysis of 2019 and 2020 seasons)

Treatments		Combined analysis of 2019 and 2020 seasons		
Plant materials	Substrates	Plant height (cm)	Leaf number	Leaf area (cm^2)
Corm parts	Peat moss	126.78 b	4.75 a	2250.52 a
	Clay	109.59 c	4.06 d	2217.09 e
	Peat moss + clay	109.50 c	4.75 a	2238.87 cd
	Peat moss + sand	110.11 c	4.10 d	2251.51 a
Cormels	Peat moss	135.22 a	4.79 a	2245.67 ab
	Clay	94.23 d	4.08 d	2242.99 bc
	Peat moss + clay	109.95 c	4.54 b	2250.19 a
	Peat moss + sand	93.82 d	4.22 c	2236.70 d

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 4: Effect of interaction between plant materials and planting dates on plant height (cm) and leaf number, leaf area (cm^2) (Combined analysis of 2019 and 2020 seasons)

Treatments		Combined analysis of 2019 and 2020 seasons		
Plant materials	Planting dates	Plant height (cm)	Leaf number	Leaf area (cm^2)
Corm	1st May	140.77 a	5.06 a	2295.30 b
	3rd June	110.02 e	4.50 d	2249.31 c
	1st July	79.27 h	4.28 d	2183.55 f
	Control 1	125.92 c	4.00 e	2229.84 d
Cormels	1st May	130.77 b	4.96 b	2330.42 a
	3rd June	100.91 f	4.34 d	2252.22 c
	1st July	79.77 g	3.63 f	2169.36 g
	Control 2	121.77 d	4.53 c	2223.54 e

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 5: Effect of interaction between planting dates and substrates on plant height (cm), leaf number and leaf area (cm^2) (Combined analysis of 2019 and 2020 seasons)

Treatments		Combined analysis of 2019 and 2020 seasons		
Planting dates	Substrates	Plant height (cm)	Leaf number	Leaf area (cm^2)
1st May	Peat moss	144.07 a	5.31 a	2317.90 b
	Clay	117.09 c	4.78 c	2255.89 c
	Peat moss + clay	134.60 b	4.32 fg	2333.01 a
	Peat moss + sand	99.57 e	4.71 cd	2344.64 a
3rd June	Peat moss	134.45 b	5.03 b	2245.05 c
	Clay	91.17 g	4.51 e	2254.68 c
	Peat moss + clay	96.50 f	4.63 d	2255.29 c
	Peat moss + sand	99.75 e	4.42 ef	2248.04 c
1st July	Peat moss	109.49 d	4.17 h	2207.88 e
	Clay	63.85 j	3.96 i	2179.71 f
	Peat moss + clay	71.73 i	3.69 j	2163.60 g
	Peat moss + sand	73.03 h	4.01 i	2154.64 g
Control 1		136.00 b	4.30 fg	2229.89 d
Control 2		135.53 b	4.28 gh	2226.21 d

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 6: Effect of interactions among planting materials, dates and substrates on plant height (cm), leaf number and leaf area (cm^2) (Combined analysis of 2019 and 2020 seasons)

Treatments			Combined analysis of 2019 and 2020 seasons		
Plant materials	Planting dates	Substrates	Plant height (cm)	Leaf number	Leaf area (cm^2)
Corm parts	1st May	Peat moss	153.00 a	5.13 b	2332.87 c
		Clay	115.03 f	4.61 efg	2254.36 f
		Peat moss + clay	134.67 c	4.63 efg	2314.76 d
		Peat moss + sand	101.00 i	5.87 a	2279.20 e
	3rd June	Peat moss	129.73 d	4.92 cd	2236.57 gh
		Clay	110.01 g	4.71 ef	2227.69 hij
		Peat moss + clay	86.00 k	5.71 a	2251.75 fg
		Peat moss + sand	114.33 f	4.52 gh	2281.22 e
	1st July	Peat moss	83.40 k	4.45 ghi	2207.96 l
		Clay	72.77 m	4.2 jkl	2151.42 m
		Peat moss + clay	76.33 l	4.2 jkl	2163.26 m
		Peat moss + sand	84.59 k	4.25 jk	2211.58 kl
Cormels	1st May	Peat moss	135.15 c	4.28 ijk	2302.92 d
		Clay	119.15 e	4.95 c	2257.42 f
		Peat moss + clay	134.67 c	4.01 lm	2351.26 b
		Peat moss + sand	98.13 j	4.76 de	2410.07 a
	3rd June	Peat moss	139.16 b	4.34 hij	2253.53 f
		Clay	72.33 m	4.32 ijk	2281.67 e
		Peat moss + clay	107.00 h	4.35 hij	2258.82 f
		Peat moss + sand	85.16 k	4.33 ijk	2214.86 jkl
	1st July	Peat moss	135.57 c	3.87 mn	2207.80 l
		Clay	54.92 p	3.17 o	2208.00 l
		Peat moss + clay	67.13 n	3.71 n	2163.94 m
		Peat moss + sand	61.47 o	3.76 n	2097.70 n
Control 1			141.00 b	4.50 fg	2224.69 hijk
Control 2			131.00 d	3.90 ml	2226.72 hijk

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 7: Effect of plant materials, substrates and planting dates on total yield/fed., number of corms/plant, main corm fresh weight (g), main corm length and diameter of taro (Combined analysis of 2019 and 2020 seasons)

Treatments	Total yield (ton/fed.)	No. of corms/plant	Main corm F.W.(g)	Main corm length (cm)	Main corm diameter (cm)
			Effect of plant materials		
Corm parts	17.500 b	4.080 a	1014.200 b	13.580 a	11.870 a
Cormels	18.026 a	4.040 a	1144.900 a	13.500 a	11.820 a
			Effect of substrates		
Peat moss	18.479 a	4.030 a	1125.20 a	13.808a	12.210 a
Clay	17.354 c	4.040 a	1070.100 c	13.270 c	11.800 b
Peat moss + clay	17.297 c	4.170 a	1097.100 b	13.557 b	11.950 b
Peat moss + sand	17.921 b	4.130 a	1026.100 d	13.528 b	11.560 c
			Effect of plant planting dates		
1st May	20.204 a	4.960 a	1352.700 a	15.080 a	12.910 a
3nd June	18.417 c	4.480 b	1166.300 b	13.940 c	11.880 c
1st July	13.635 d	2.330 c	618.600 c	10.760 d	10.320 d
Control	18.795 b	4.600 b	1180.800 b	14.390 b	12.410 b

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Effect of Planting Dates: Data in Table (7) showed that the highest number of corms, main corm fresh weight, length and diameter was achieved via transplanting taro transplant on 1st of May followed by control treatment on March. On the other side, no significant differences were detected between control and planting transplants at 1st of June in number of corms and main corm fresh weight. These results are in agreement with those Islam *et al.* [7] of the storage root yield and its components of sweet potato using plug transplants was influenced by the age of transplants in the ranges tested. The use of 11- 15day old transplants gave the highest yield. Thus, the plug transplants can be used as transplants to reduce labor cost in the field. These results might be due to the increasing vegetative growth of plug plants.

Table 8: Effect of interaction between plant materials and substrates on total yield/fed., number of corms/plant, main corm fresh weight (g), main corm length and diameter of taro (Combined analysis of 2019 and 2020 seasons)

Treatments		Combined analysis of 2019 and 2020 seasons				
Plant materials	Substrates	Total yield (ton/fed.)	No. of corms/plant	Main corm F.W.(g)	Main corm length(cm)	Main corm diameter (cm)
Corm	Peat moss	17.935 bc	3.980 b	1045.100 c	13.900 ab	12.200 a
	Clay	17.458 cd	4.030ab	1034.400 cd	13.350 cd	11.650 c
	Peat moss + clay	16.764 e	4.090 ab	1007.600 d	13.660 bc	12.090 a
	Peat moss + sand	17.842 bc	4.230 ab	969.900 e	13.420 cd	11.530 c
Cormels	Peat moss	19.022 a	4.260 a	1205.200 a	13.960 a	12.220 a
	Clay	17.250 de	4.050 ab	1105.800 b	13.190 d	11.960 ab
	Peat moss + clay	17.831 bc	4.070 ab	1186.600 a	13.210 d	11.800 bc
	Peat moss + sand	18.000 b	4.020 ab	1082.200 b	13.640 bc	11.590 c

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 9: Effect of interaction between plant materials and planting dates on total yield/fed., number of corms/plant, main corm fresh weight, main corm length and diameter of taro (Combined analysis of 2019 and 2020 seasons)

Treatments		Combined analysis of 2019 and 2020 seasons				
Planting materials	Substrates	Total yield (ton/fed.)	No. of corms/plant	Main corm F.W. (g)	Main corm length (cm)	Main corm diameter (cm)
Corm	1st May	18.792 c	5.020 a	1306.200 b	15.170 a	12.990 a
	3rd June	19.283 b	4.390 c	1159.300 d	13.880 d	12.090 c
	1st July	12.929 f	2.340 d	401.700 f	10.980 e	10.150 f
Control 1	Cormels	18.995 bc	4.570 c	1189.700 c	14.300 bc	12.240 c
	1st May	21.617 a	4.900 ab	1399.300 a	14.990 a	12.840 a
	3rd June	17.550 d	4.560 c	1173.200 cd	13.990 cd	11.670 d
	1st July	14.342 e	2.310 d	835.400 e	10.540 f	10.490 e
Control 2		18.595 c	4.630 bc	1171.800 cd	14.480 b	12.590 b

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 10: Effect of interaction between planting dates and substrates on total yield, number of corms, main corm fresh weight, length and diameter of taro (Combined analysis of 2019 and 2020 seasons)

Treatments		Combined analysis of 2019 and 2020 seasons				
Planting dates	Substrates	Total yield (ton/fed.)	No. of corms/plant	Main corm F.W. (g)	Main corm length (cm)	Main corm diameter (cm)
1st May	Peat moss	21.033 a	5.170 a	1446.600 a	15.480 a	13.039 a
	Clay	19.617 d	4.790 bc	1330.300 bc	15.200 ab	12.978 ab
	Peat moss + clay	19.650 cd	4.800 bc	1361.100 b	14.960 bc	13.061 a
	Peat moss + sand	20.517 ab	5.100 ab	1272.800 d	14.690 cd	12.561 bc
3rd June	Peat moss	20.167 bc	4.320 d	1207.100 e	14.460 cdf	12.580 bc
	Clay	17.033 f	4.530 cd	1153.300 g	13.320 g	11.450 d
	Peat moss + clay	17.550 f	4.520 cd	1292.800 cd	14.140 ef	12.190 c
	Peat moss + sand	18.917 e	4.540 cd	1011.900 h	13.810 f	11.300 d
1st July	Peat moss	13.675 g	2.300 e	739.500 i	10.380 i	10.820 e
	Clay	14.217 g	2.340 e	627.900 j	10.220 i	10.370 f
	Peat moss + clay	12.950 h	2.320 e	456.000 k	11.180 h	10.120 f
	Peat moss + sand	13.700 g	2.340 e	650.900 j	11.250 h	9.970 f
Control 1		19.040 e	4.680 c	1192.900 ef	14.430 de	12.420 c
Control 2		18.550 e	4.520 cd	1168.700 fg	14.350 de	12.410 c

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Effect of Interaction Between Plant Materials and Substrates: The interaction between plant materials and substrates had a positive significant effect on yield and its components (Table 8). Results also indicated that plants planted by cormels in peat moss substrate gave the highest values of corms characteristic per plant as well as total yield.

Effect of Interaction Between Plant Materials and Planting Dates: The effect of interaction between plant materials and planting dates on total yield/fed. and its components of taro is presented in Table (9). Data show that the highest values of number of corms, main corm fresh weight, main corm length and diameter were detected when the transplanting cormels on

Table 11: Effect of interactions among planting materials, dates and substrates on total yield / fed, number of corms/plant, main corm fresh weight, main length and diameter of taro (Combined analysis of 2019 and 2020 seasons)

Treatments			Combined 2019 and 2020 seasons				
Plant materials	Planting dates	Substrates	Total yield (ton/fed.)	No. of corms/plant	Main corm F.W.(g)	Main corm length (cm)	Main corm diameter (cm)
Corm parts	1st May	Peat moss	19.233 efg	5.350 a	1330.600 d	15.142 abcd	13.640 a
		Clay	19.133 efg	4.870 abcd	1309.300 d	15.400 ab	12.910 bcd
		Peat moss + clay	18.333 gh	5.150 abc	1343.000 cd	15.353 abc	13.280 ab
		Peat moss + sand	18.467 gh	4.710 bcde	1241.800 e	14.767 bcdef	12.130 fghi
	3rd June	Peat moss	20.500 bcd	4.350 ab	1234.000 ef	14.687 def	12.930 bcd
		Clay	18.533 gh	4.340 de	1207.800 efg	13.583 ijk	11.330 kl
		Peat moss + clay	17.033 ij	2.300 f	1173.300 g	13.783 hij	12.490 cdef
		Peat moss + sand	21.067 b	4.600 cde	1022.200 ij	13.477 jk	11.630 ijk
	1st July	Peat moss	12.817 n	2.330 f	416.600 m	11.143 lm	9.860 op
		Clay	13.367 n	2.300 f	440.000 m	10.433 no	10.270 no
		Peat moss + clay	12.500 n	2.310 c	314.800 n	10.853 mn	10.190 nop
		Peat moss + sand	13.033 n	2.310 f	435.300 m	11.467 lm	10.300 no
Cormels	1st May	Peat moss	22.833 a	4.890 abcd	1550.100 a	15.603 a	12.450 cdef
		Clay	20.100 cde	4.680 bcde	1351.400 cd	14.990 abcde	13.050 b
		Peat moss + clay	20.967 bc	5.180 ab	1391.600 bc	14.770 bcdef	12.850 bcd
		Peat moss + sand	22.567 a	4.850 abcd	1303.900 d	14.620 def	12.990 bc
	3rd June	Peat moss	19.833 def	4.280 e	1180.200 g	14.230 fgh	12.230 efgh
		Clay	15.533 k	4.720 bcde	1098.700 h	13.050 k	11.580 jk
		Peat moss + clay	18.067 hi	4.690 bcde	1412.300 b	14.503 efg	11.890 ghijk
		Peat moss + sand	16.767 j	4.540 de	1001.700 j	14.160 fghi	10.980 lm
	1st July	Peat moss	14.533 l	2.280 f	1062.300 hi	9.617 p	11.780 hijk
		Clay	15.067 kl	2.370 f	815.800 k	10.000 op	10.470 mn
		Peat moss + clay	13.400 mn	2.340 f	597.300 l	11.500 l	10.050 nop
		Peat moss + sand	14.367 lm	2.250 f	866.400 k	11.033 lmn	9.630 p
Control 1			19.190 efg	4.600 de	1199.200 efg	14.633 def	12.400 defg
Control 2			18.890 fgh	4.540 de	1186.700 fg	14.233 fgh	12.730 bcde

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

1st of May followed by planting corms plants at the same date (1st of May). Corm planted at June gave the lowest value of total yield and taro corms characters. These results might be due to the decreasing vegetative growth of taro plants.

Effect of Interaction Between Planting Dates and Substrates on Yield and its Components: The interaction between planting dates and substrates on total yield/fed., number of corms/plant, main corm fresh weight, main corm length and diameter of taro are presented in Table (10) interaction had appositive significant effect on all yield characters. Results indicated that transplants planted in peat moss and transplanted at 1st of May in the field gave the highest value of number of corms/plant, main corm fresh weight, length and diameter of taro.

Effect of Interactions among Plant Materials, Planting Dates and Substrates on Yield and its Components: Average yield and its components per plant was significantly affected by plant materials, transplant substrates and planting dates (Table 11). Maximum number of corms and main corm diameter were recorded from planting corms transplants in peat moss medium at 1st of May. On the other hand, the highest main corm fresh weight, main corm length and total yield ton/fed were recorded from planting at 1st of May by cormels in peat moss substrate. Similar finding was also reported by Susan *et al.* [22] the number of corms per plant was significantly decreased when planting date was delayed. In the same line, Dessa *et al.* [17] and Abd-Ellatif *et al.* [23] reported that early planting dates gave the highest values of weight of corm and cormels per plant under irrigation condition.

Effect of Substrates, Plant Materials, Planting Dates and Their Interactions on Starch and Total Carbohydrates Content: Regarding the starch and total carbohydrates content, data in Tables (12, 13, 14, 15 and 16) indicated that there were no significant differences between different substrates, plant materials, planting dates and their interactions on these characters during the two studied seasons.

Table 12: Effect of plant materials, substrates and planting dates on starch and total carbohydrates of taro (Combined analysis of 2019 and 2020 seasons)

Treatments	Starch %	Total carbohydrates %
	Effect of plant materials	
Corm parts	48.80 a	52.67 a
Cormels	48.91 a	51.27 b
	Effect of substrates	
Peat moss	48.35 a	52.06 a
Clay	48.90 a	51.74 a
Peat moss + clay	49.03 a	52.11 a
Peat moss + sand	49.15 a	51.95 a
	Effect of plant planting dates	
1st May	48.67 a	52.00 a
3rd June	48.19 a	53.03 a
1st July	48.93 a	51.61 a
Control 1	48. 35 a	51.63 a
Control 2	48.46 a	52.30 a

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 13: Effect of plant materials, substrates and planting dates on starch and total carbohydrates of taro (Combined analysis of 2019 and 2020 seasons)

Treatments		Combined analysis of 2019 and 2020 seasons	
Plant materials	Substrates	Starch%	Total carbohydrates%
Corm parts	Peat moss	49.08 a	52.14 a
	Clay	49.22 a	52.31 a
	Peat moss + clay	48.79 a	52.42 a
	Peat moss + sand	48.55 a	53.80 a
Cormels	Peat moss	48.73 a	51.99 a
	Clay	48.85 a	51.18 a
	Peat moss + clay	49.53 a	51.79 a
	Peat moss + sand	48.15 a	50.11 a

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 14: Effect of interaction between plant materials and planting dates on starch and total carbohydrates of taro (Combined analysis of 2019 and 2020 seasons)

Treatments		Combined analysis of 2019 and 2020 seasons	
Plant materials	Planting dates	Starch%	Total carbohydrate%
Corm parts	1st May	48.77 a	52.71 a
	3rd June	48.33 a	52.95 a
	1st July	49.23 a	52.33 a
	Control 1	48.57 a	52.45 a
Cormels	1st May	49.25 a	51.28 a
	3rd June	48.54 a	52.45 a
	1st July	48.84 a	50.06 a
	Control 2	48.69 a	52.49 a

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 15: Effect of interaction between planting date and substrates starch and total carbohydrates of taro (Combined analysis of 2019 and 2020 seasons).

Treatments		Combined analysis of 2019 and 2020 seasons	
Planting date	Substrates	Starch %	Total carbohydrates %
1st May	Peat moss	48.09 a	51.83 a
	Clay	48.54 a	52.19 a
	Peat moss + clay	48.86 a	51.38 a
	Peat moss + sand	49.21 a	52.60 a
3rd June	Peat moss	48.19 a	53.03 a
	Clay	48.93 a	51.61 a
	Peat moss + clay	49.08 a	52.71 a
	Peat moss + sand	48.83 a	53.45 a
1st July	Peat moss	48.76 a	51.33 a
	Clay	49.23 a	51.43 a
	Peat moss + clay	49.17 a	52.22 a
	Peat moss + sand	49.44 a	49.81 a
Control 1		49.35 a	52.93 a
Control 2		48.90 a	52.46 a

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

Table 16: Effect of interactions among planting materials, date and substrates on starch and carbohydrate of taro (Combined analysis of 2019 and 2020 seasons)

Treatments			Combined analysis of 2019 and 2020 seasons	
Plant materials	Planting dates	Substrates	Starch %	Total carbohydrate %
Corm parts	1st May	Peat moss	47.80 a	52.30 a
		Clay	48.93 a	52.73 a
		Peat moss + clay	49.29 a	50.95 a
		Peat moss + sand	49.07 a	54.87 a
	3rd June	Peat moss	48.33 a	51.64 a
		Clay	49.23 a	51.93 a
		Peat moss + clay	49.25 a	53.14 a
		Peat moss + sand	48.54 a	55.08 a
	1st July	Peat moss	48.33 a	52.46 a
		Clay	49.09 a	52.25 a
		Peat moss + clay	49.10 a	53.16 a
		Peat moss + sand	48.75 a	51.45 a
Cormels	1st May	Peat moss	48.39 a	51.35 a
		Clay	48.16 a	51.65 a
		Peat moss + clay	48.43 a	51.81 a
		Peat moss + sand	49.34 a	50.34 a
	3rd June	Peat moss	48.06 a	54.41 a
		Clay	48.64 a	51.29 a
		Peat moss + clay	48.90 a	52.28 a
		Peat moss + sand	49.12 a	51.82 a
	1st July	Peat moss	49.20 a	50.20 a
		Clay	49.36 a	50.61 a
		Peat moss + clay	49.23 a	51.28 a
		Peat moss + sand	50.13 a	51.16 a
Control 1			49.15 a	52.54 a
Control 2			48.79 a	51.87 a

Values having the same alphabetical letter(s) in common within each column don't significantly differ using the revised L.S.D. test at 0.05 level of probability

The results showed also that all treatments did not have any significant effect on corms starch and total carbohydrates. The obtained results are confirmed by Tattiyakul *et al.* [24].

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