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Effect of planting distance on growth and tuber yield of greater yam (*Dioscorea alata* L.) Under different growing conditions

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Abstract
An experiment was carried out, with a view to study the Response of Greater Yam (*Dioscorea alata* L.) to different growing conditions at Vegetable Research Scheme, Regional Horticultural Research Station of the Navsari Agricultural University, Navsari, Gujarat, India during 2015-2016 and 2016-2017. The experiment was conducted in Large Plot; analysis as CRD with factorial concept (FCRD) with three repetitions which included three growing conditions (G_1 :Naturally Ventilated Poly house, G_2 : Net house and G_3 :Open field),three planting distance (D_1: 60 cm x 60 cm, D_2 : 60 cm x 45 cm and D_3: 90 cm x 90 cm) and two varieties (V_1 : Round type and V_2 : Long type). The results indicated that **s**ignificantly higher amount of growth attributes were recorded with D_2 : 60 cm x 45 cm *viz.*, total number of tillers (7.32), vine length (8.04 m) and fresh weight of tuber (1493.54 g) which was followed by D_3 : 90 cm x 90 cm. Yield characters *viz*. tuber girth (27.94 cm) was significantly higher with D_3 : 90 cm x 90 cm followed by D_1 : 60 cm x 60 cm. Tuber length (cm) was non-significant during 2015-16, 2016-17 but in pooled analysis it was found significant (19.65 cm) with D_3 : 90 cm x 90 cm. Tuber yield 1000 m^2 (2810.79 kg) were significantly higher with D_2 : 60 cm x 45 cm followed by D_1 : 60 cm x 45 cm during pooled analysis while it was significantly lower with D_3 : 90 cm x 90.

Keywords: Greater yam, planting distance, naturally ventilated poly house

Introduction
Greater yam is primarily used for human consumption in the tropical and sub tropical regions. The yam tubers are rich source of carbohydrates, protein and amino acid. Normally tubers are consumed as boiled, baked or fried vegetables. It is also useful for making chips, flakes and flour. Greater yam is basically a dioceious twining herbaceous vine. Stems are 10 m or more in length and freely branching above. It possesses four wings on the thick stem, which twines to the right. The petiole has also wings. Leaves are ovate, cordate, bigger and opposite in phylotaxy. Tubers are variable in shape but mostly cylindrical. The skin of the tuber is black and brown, whereas flesh is white, yellowish, or purplish. Each plant may produce 1 to 3 tubers. Its cultivars rarely flower. Flowers are small, occasional, male and female arising from leaf axils on separate plants (*i.e.* dioecious species), male flowers having panicle which is 30 cm long, female flowers having smaller spikes. Fruit is botanically a 3 parted capsule and seeds are winged (Chadha, 2002) [3].

Plant population is defined as the total number of plants present at unit area of land, while plant spacing is the arrangement of plants on an area. The yield of crop is directly influenced by population of plant. It is always good to follow the recommended crop spacing guidelines. Overcrowding of crops may reduce yields and it may also lower quality of the yield produced because of competition for light and soil nutrients.

As far as concern to protected cultivation plant spacing is one of the key factor for achieving the good crop yield. Plant spacing greatly affected leaf area and canopy photosynthesis because vertically grown crops requires good plant architecture for good canopy development which is the key for better utilization of photosynthetic photon flux density.Recently many progressive farmers of Gujarat have started the cultivation of greater yam under protected conditions like (Poly house, Net house etc. but it was observed (on the basis of survey) that they were in need of some recognize technical information regarding planting density (spacing) for achieving higher marketable tuber yield from unit area.

Keeping in view of farmers survey, this research was set up to find out better growing condition for greater yam growth and yield.

Materials and Methods

The experiment was undertaken at the Vegetable Research Scheme, Regional Horticultural Research Station of the Navsari Agricultural University, Navsari, Gujarat, India during 2015 -16 and 2016-17. The experiment was conducted in Large Plot; analysis as CRD with factorial concept (FCRD) with three repetition which included three growing conditions (G_1 : Naturally Ventillated Poly house, G_2 : Net house and G_3 : Open field), three planting distance (D_1: 60 cm x 60 cm, D_2 : 60 cm x 45 cm and D_3: 90 cm x 90 cm) and two varities (V_1: Round type and V_2 : Long type).The experiment was included 18 combinations namely, $G_1D_1V_1$; $G_1D_1V_2$; $G_1D_2V_1$; $G_1D_2V_2$; $G_1D_3V_1$; $G_1D_3V_2$; $G_2D_1V_1$; $G_2D_1V_2$; $G_2D_2V_1$; $G_2D_2V_2$; $G_2D_3V_1$; $G_2D_3V_2$; $G_3D_1V_1$; $G_3D_1V_2$; $G_3D_2V_1$; $G_3D_2V_2$; $G_3D_3V_1$ and $G_3D_3V_2$..The experiment was conducted on same location without changing the randomization for the succesive year to access treatment effects.Tuber pieces of 200 g were used for planting material for both variety. The experimental growing conditions for all three locations were thoroughly prepared as our treatment includes different spacing treatments. The beds inside the poly house and net house were made symmetrical and levelling was done with the help of wooden plank. Cultural practices for three growing conditions (Naturally Ventilated Poly house, Net house and Open field) were maintain same for two seasons.

For recording different field observations, five plants of greater yam from each net plot area were selected randomly in the beginning and tagged with the labels. Total number of tillers was recorded by counting the total number of tillers at harvest.Vine length was measured from base of the plant to tip of the main shoot with the help of meter tape at final harvest and fresh weight of tuber recorded immediately after harvest. Tuber girth and length were measured with measuring tape. The collected data were subjected to statistical analysis as per Panse and Sukhatme (1967) [8].

Results and Discussion

Total number of tillers at harvest differed significantly due to different planting distance applied to greater yam during both the years of experimentation and pooled analysis. Significantly maximum total number of tillers at harvest was recorded with D_2 (60 cm x 45 cm) during 2015-16 (7.96), 2016-17 (6.68) and in pooled (7.32). While, significantly lower total number of tillers at harvest was recorded with D_1 (60 cm x 60 cm) during 2015-16 (6.37), 2016-17 (5.07) and in pooled analysis (5.72).

D_2 (60 cm x 45 cm) produced significantly higher vine length in 2015 -16 (8.44 m), 2016-17 (7.64 m) and in pooled analysis (8.04 m). Significantly lower greater yam's vine length was noted with D_1 (60 cm x 60 cm) during individual years of experimentation as well as in pooled analysis (6.50 m, 5.65 m and 6.08 m; respectively).

From different planting distances, significantly higher total number of tillers at harvest and vine length were recorded with closer spacing 60 cm x 45 cm (D_2) as compared to wider spacing 60 cm x 60 cm (D_1) and 90 cm x 90 cm (D_3). This might be due to the great competition for space and light thereby forcing the plants to grow taller. The short and stout plants were produced at wider spacing because of availability of more growth space where in plants were able to exploit more nutrients from the soil and light sources. Similar increase in growth rate at closer spacing were noticed and reported by Rajewar *et al.* (1981) [11]in tomato, Papadopoulos and Ormrod (1991) [9] in tomato, Narayan *et al.* (2017) [6] in cherry tomato and Stoffella and Bryan (1988) [16] in capsicum.

Fresh weight of tuber (g) differed significantly due to different planting distance during individual years of experimentation and pooled analysis.Significantly higher fresh weight of tuber at harvest was recorded with D_2 (60 cm x 45 cm) during 2015-16 (1530.65 g), 2016-17(1456.43 g) and in pooled analysis (1493.54 g). Significantly lower fresh weight of tuber at harvest was recorded with D_1 (60 cm x 60 cm) during 2015 – 16, 2016 – 17 and in pooled analysis (1157.10 g, 1114.40 g and 1135.75 g; respectively).

Significantly higher fresh weight of tuber were observed with closer spacing 60 cm x 45 cm (D_2) as compared to wider spacing 60 cm x 60 cm (D_1) and 90 cm x 90 cm (D_3). This could be due to increased uptake of more nutrients and build up of sufficient photosynthesis enabling the increase in size of tubers (length and width), ultimately resulted in the higher tuber weight. The results are in conformity with the findings of Sulikeri *et al.* (1973) [18] and Randhawa *et al.* (1975) [12] in tomato, Singh and Naik (1990) [15] in capsicum.

As concern to different yield attributes, different planting distances significantly affected tuber girth (cm). D_3 (90 cm x 90 cm) produced significantly higher tuber girth during 2015 – 16, 2016 – 17 and in pooled analysis (27.20 cm, 28.67 cm and 27.94 cm; respectively). While, significantly lower tuber girth was noted with D_2 (60 cm x 45 cm) during individual years of experimentation as well as in pooled analysis (21.38 cm, 21.57 cm and 21.47 cm ; respectively). Different planting distances did not show any significant effect on tuber length (cm) during 2015 – 16 and 2016 – 17. In pooled analysis, D_3 (90 cm x 90 cm) was recorded significantly higher tuber length (19.65 cm) whereas; D_2 (60 cm x 45 cm) recorded significantly lower tuber length (18.11 cm). Significantly higher yield 1000 m^{-2} was recorded in D_2 (60 cm x 45 cm) during consecutive years of experimentation and in pooled analysis. (2966.51 kg, 2655.07 kg and 2810.79 kg; respectively). While, significantly lower yield 1000 m^{-2} was recorded with D_3 (90 cm x 90 cm) during 2015 – 16, 2016 – 17 and in pooled analysis (1599.83 kg, 1383.16 kg and 1491.50 kg; respectively).

Significantly higher tuber girth was observed with wider spacing D_3 (90 cm x 90 cm) while lowest tuber girth was observed with closer spacing D_2 (60 cm x 45 cm) during individual years of experiment and in pooled analysis. But significantly higher tuber yield m^{-2} was registered with the spacing of D_2 (60 cm x 45) cm then of wider spacing of D_3 (90 cm x 90 cm) and D_1 (60 cm x 60 cm); which might be due to higher plant population per unit area, greater crop biomass and increased availability of total assimilates for distribution to tuber which intern helps to increase harvest index. Similar results were obtained by Sulikeri *et al.* (1973) [18], Randhawa *et al.* (1975) [12], Streck *et al.* (1996) [17], Papadopoulos and Pararajasingham (1997) [10], Sandri *et al.* (2002) [13], Ogbomo and Egharevba (2009) [7], Agarwal and Zakwan (2011) [1] in tomato, Ahmed (1984) [2], Granges and Leger (1989) [5], Singh and Naik (1990) [15], Savic *et al.*(1992) [14] as well as Choudhary and Singh (2006) [4] in capsicum.

Tuber length did not affect significantly due to different planting distances during individual years of experimentation. Similar finding was also reported by Narayan *et al.* (2017) [6] in cherry tomato.

Table 1: Response of different treatments on total number of tillers at harvest

Treatments	Total number of tillers at harvest		
	2015-16	2016-17	Pooled
Growing conditions (G)			
G_1 (Poly house)	8.77	7.51	8.14
G_2 (Net house)	7.34	6.06	6.70
G_3 (Open field)	5.29	3.98	4.63
S.Em. ± (G)	0.20	0.15	0.12
C.D.at 5 % (G)	0.57	0.42	0.34
Planting distance (D)			
D_1 (60 cm x 60 cm)	6.37	5.07	5.72
D_2 (60 cm x 45 cm)	7.96	6.68	7.32
D_3 (90 cm x 90 cm)	7.08	5.80	6.44
S.Em. ± (D)	0.20	0.15	0.12
C.D. at 5 % (D)	0.57	0.42	0.34
Variety (V)			
V_1 (Round type)	6.95	5.66	6.30
V_2 (Long type)	7.32	6.04	6.68
S.Em. ± (V)	0.16	0.12	0.10
C.D. at 5 % (V)	NS	0.34	0.28
C.D. at 5 % (GD)	NS	NS	NS
C.D.at 5 % (GV)	NS	NS	NS
C.D.at 5 % (DV)	NS	NS	NS
C.D. at 5 % (GDV)	NS	NS	NS
S.Em. ± (YG)			0.17
C.D. at 5 %			NS
S.Em. ± (YD)			0.17
C.D. at 5 %			NS
S.Em. ± (YGD)			0.30
C.D. at 5 %			NS
S.Em. ± (YV)			0.14
C.D. at 5 %			NS
S.Em. ± (YGV)			0.25
C.D. at 5 %			NS
S.Em. ± (YDV)			0.25
C.D. at 5 %			NS
S.Em. ± (YGDV)			0.43
C.D. at 5 %			NS
C.V. %	11.76	10.63	11.38

Table 2: Response of different treatments on vine length (m) at harvest

Treatments	Vine length (m) at harvest		
	2015-16	2016-17	Pooled
Growing conditions (G)			
G_1 (Poly house)	9.44	8.66	9.05
G_2 (Net house)	7.69	6.87	7.28
G_3 (Open field)	5.20	4.30	4.75
S.Em. ± (G)	0.18	0.15	0.12
C.D.at 5 % (G)	0.52	0.42	0.33
Planting distance (D)			
D_1 (60 cm x 60 cm)	6.50	5.65	6.08
D_2 (60 cm x 45 cm)	8.44	7.64	8.04
D_3 (90 cm x 90 cm)	7.38	6.55	6.96
S.Em. ± (D)	0.18	0.15	0.12
C.D. at 5 % (D)	0.52	0.42	0.33
Variety (V)			
V_1 (Round type)	7.21	6.37	6.79
V_2 (Long type)	7.67	6.85	7.26
S.Em. ± (V)	0.15	0.12	0.13
C.D. at 5 % (V)	0.43	0.34	0.39
C.D. at 5 % (GD)	NS	NS	0.56
C.D.at 5 % (GV)	NS	NS	NS
C.D.at 5 % (DV)	NS	NS	NS
C.D. at 5 % (GDV)	NS	NS	NS
S.Em. ± (YG)			0.17
C.D. at 5 %			NS
S.Em. ± (YD)			0.17

C.D. at 5 %			NS
S.Em. ± (YGD)			0.28
C.D. at 5 %			NS
S.Em. ± (YV)			0.14
C.D. at 5 %			NS
S.Em. ± (YGV)			0.23
C.D. at 5 %			NS
S.Em. ± (YDV)			0.23
C.D. at 5 %			NS
S.Em. ± (YGDV)			0.41
C.D. at 5 %			NS
C.V. %	10.40	9.44	10.01

Table 3: Response of different treatments on average fresh weight of tuber (g)

Treatments	**Fresh weight of tuber (g)**		
	2015-16	**2016-17**	**Pooled**
Growing conditions (G)			
G_1 (Poly house)	1723.45	1632.97	1678.21
G_2 (Net house)	1386.05	1324.03	1355.04
G_3 (Open field)	904.05	882.70	893.37
S.Em. ± (G)	32.37	30.57	22.14
C.D.at 5 % (G)	92.90	87.74	62.49
Planting distance (D)			
D_1 (60 cm x 60 cm)	1157.10	1114.40	1135.75
D_2 (60 cm x 45 cm)	1530.65	1456.43	1493.54
D_3 (90 cm x 90 cm)	1325.80	1268.87	1297.33
S.Em. ±(D)	32.37	30.57	22.00
C.D. at 5 % (D)	92.90	87.74	62.08
Variety (V)			
V_1 (Round type)	1293.67	1239.44	1266.56
V_2 (Long type)	1382.03	1320.35	1351.19
S.Em. ± (V)	26.43	24.96	18.05
C.D. at 5 % (V)	75.85	71.64	50.96
C.D. at 5 % (GD)	NS	NS	105.89
C.D.at 5 % (GV)	NS	NS	NS
C.D.at 5 % (DV)	NS	NS	NS
C.D. at 5 % (GDV)	NS	NS	NS
S.Em. ± (YG)			31.48
C.D. at 5 %			NS
S.Em. ± (YD)			31.48
C.D. at 5 %			NS
S.Em. ± (YGD)			54.53
C.D. at 5 %			NS
S.Em. ± (YV)			25.71
C.D. at 5 %			NS
S.Em. ± (YGV)			44.52
C.D. at 5 %			NS
S.Em. ± (YDV)			44.52
C.D. at 5 %			NS
S.Em. ± (YGDV)			77.11
C.D. at 5 %			NS
C.V. %	10.27	10.13	10.21

Table 4: Response of different treatments on tuber girth (cm)

Treatments	**Tuber girth (cm)**		
	2015-16	**2016-17**	**Pooled**
Growing conditions (G)			
G_1 (Poly house)	27.63	28.93	28.28
G_2 (Net house)	23.98	24.99	24.49
G_3 (Open field)	20.32	20.80	20.56
S.Em. ± (G)	0.34	0.50	0.30
C.D.at 5 % (G)	0.99	1.43	0.85
Planting distance (D)			
D_1 (60 cm x 60 cm)	23.36	24.48	23.92
D_2 (60 cm x 45 cm)	21.38	21.57	21.47
D_3 (90 cm x 90 cm)	27.20	28.67	27.94
S.Em. ± (D)	0.34	0.50	0.30

C.D. at 5 % (D)	0.99	1.43	0.86
Variety (V)			
V_1 (Round type)	26.70	27.77	27.23
V_2 (Long type)	21.25	22.05	21.65
S.Em. ± (V)	0.28	0.41	0.25
C.D. at 5 % (V)	0.81	1.17	0.69
C.D. at 5 % (GD)	NS	NS	1.46
C.D.at 5 % (GV)	NS	NS	NS
C.D.at 5 % (DV)	1.40	2.03	1.20
C.D. at 5 % (GDV)	NS	NS	2.11
S.Em. ± (YG)			0.43
C.D. at 5 %			NS
S.Em. ± (YD)			0.74
C.D. at 5 %			NS
S.Em. ± (YGD)			0.74
C.D. at 5 %			NS
S.Em. ± (YV)			0.35
C.D. at 5 %			NS
S.Em. ± (YGV)			0.61
C.D. at 5 %			NS
S.Em. ± (YDV)			0.61
C.D. at 5 %			NS
S.Em. ± (YGDV)			1.05
C.D. at 5 %			NS
C.V. %	6.09	8.51	7.45

Table 5: Response different treatments on tuber length (cm)

Treatments	**Tuber length (cm)**		
Growing conditions (G)	**2015-16**	**2016-17**	**Pooled**
G_1 (Poly house)	21.98	22.06	22.02
G_2 (Net house)	17.24	17.00	17.12
G_3 (Open field)	16.89	16.85	16.87
S.Em. ± (G)	0.54	0.69	0.43
C.D.at 5 % (G)	1.55	1.98	1.22
Planting distance (D)			
D_1 (60 cm x 60 cm)	18.22	18.29	18.26
D_2 (60 cm x 45 cm)	18.42	17.81	18.11
D_3 (90 cm x 90 cm)	19.48	19.82	19.65
S.Em. ± (D)	0.54	0.69	0.43
C.D. at 5 % (D)	NS	NS	1.22
Variety (V)			
V_1 (Round type)	11.84	11.88	11.86
V_2 (Long type)	25.57	25.39	25.48
S.Em. ± (V)	0.44	0.56	0.36
C.D. at 5 % (V)	1.26	1.62	1.00
C.D. at 5 % (GD)	NS	NS	NS
C.D.at 5 % (GV)	2.19	2.80	1.73
C.D.at 5 % (DV)	NS	NS	1.74
C.D. at 5 % (GDV)	NS	NS	2.97
S.Em. ± (YG)			0.62
C.D. at 5 %			NS
S.Em. ± (YD)			0.62
C.D. at 5 %			NS
S.Em. ± (YGD)			1.07
C.D. at 5 %			NS
S.Em. ± (YV)			0.50
C.D. at 5 %			NS
S.Em. ± (YGV)			0.88
C.D. at 5 %			NS
S.Em. ± (YDV)			0.88
C.D. at 5 %			NS
S.Em. ± (YGDV)			1.52
C.D. at 5 %			NS
C.V. %	12.24	15.72	14.08

Table 6: Response of different treatments on tuber yield 1000 m^{-2} (kg)

Treatments	Tuber yield 1000 m^{-2} (kg)		
	2015-16	2016-17	Pooled
Growing conditions (G)			
G_1 (Poly house)	2699.42	2408.34	2553.88
G_2 (Net house)	2351.89	2075.65	2213.77
G_3 (Open field)	1769.06	1541.53	1655.29
S.Em. ± (G)	45.63	38.92	29.71
C.D.at 5 % (G)	130.97	111.71	83.83
Planting distance (D)			
D_1 (60 cm x 60 cm)	2254.02	1987.29	2120.66
D_2 (60 cm x 45 cm)	2966.51	2655.07	2810.79
D_3 (90 cm x 90 cm)	1599.83	1383.16	1491.50
S.Em. ± (D)	45.63	38.92	29.84
C.D. at 5 % (D)	130.97	111.71	84.20
Variety (V)			
V_1 (Round type)	1753.64	1587.74	1670.69
V_2 (Long type)	2793.27	2429.27	2611.27
S.Em. ± (V)	37.26	31.78	70.03
C.D. at 5 % (V)	106.93	91.21	NS
C.D. at 5 % (GD)	226.84	193.49	142.77
C.D.at 5 % (GV)	185.21	157.99	118.54
C.D.at 5 % (DV)	185.21	157.99	119.26
C.D. at 5 % (GDV)	320.80	273.64	201.84
S.Em. ± (YG)			42.41
C.D. at 5 %			NS
S.Em. ± (YD)			42.41
C.D. at 5 %			NS
S.Em. ± (YGD)			73.46
C.D. at 5 %			NS
S.Em. ± (YV)			34.63
C.D. at 5 %			97.75
S.Em. ± (YGV)			59.98
C.D. at 5 %			NS
S.Em. ± (YDV)			59.98
C.D. at 5 %			NS
S.Em. ± (YGDV)			103.89
C.D. at 5 %			NS
C.V. %	8.52	8.22	8.40

Conclusion

Apart from the research results of two years of experiment, it was concluded that higher growth and yield attributes of greater yam was recorded with planting distance 60 cm x 60 cm.

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