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IMPACT OF PLANT SPACING ON THE GROWTH AND FRUIT YIELD OF WATERMELON VARIETIES IN SOUTH-WEST NIGERIA

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Abstract

Growth and yield of watermelon are significantly influenced by spacing and variety. To quantify these effects, field experiments were conducted from August to November 2016 in Ogbomoso and Sepeteri, Oyo State, Nigeria. The treatments consisted of four watermelon cultivars (Sugar baby, Kaolack, Grey belle and Collos F1) and five spacings (1.0 × 0.5 m, 1.0 × 0.75 m, 1.0 × 1.0 m, 1.0 × 1.5 m and 1.0 × 2.0 m). Data collection on reproductive and fruit yield attributes. Results showed that the growth parameters of the crop grown at Sepeteri were significantly better while those grown at Ogbomoso had higher fruit yield/yield parameters. In both locations, spacing significantly ($p \leq 0.05$) influenced the fruit yield parameters for all the varieties. In Collos F1, vine line, number of secondary vines, leaves, flowers and rotten fruits were the highest while the number of fruits/plot and fruit yield (t/ha) were significantly higher in Kaolack cultivar. Spacing however had no significant influence on growth parameters but significantly affected number of fruits/plot and fruit yield/ha. In Ogbomoso, Kaolack sown at 1.0 x 0.75 m had highest fruit yield (41.7 t/ha) while the least (9.3 t/ha) was obtained from Sugar baby sown at 1.0 x 0.5m. Similarly, in Sepeteri, Kaolack sown at 1.0 x 0.75 m produced the highest fruit yield (19.4 t/ha) while the least (5.0 t/ha) was obtained from Collos F1 at 1.0 x 1.5 m. Planting Kaolack at spacing 1.0 x 0.75 m in both Ogbomoso and Sepeteri was the best agronomic practices for achieving the best fruit yield.

Key words: *Citrullus lanatus, cultivar, fruit yield, location, plant spacing*

INTRODUCTION

Watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai] is native to drier areas of south central Africa [19]. Environment is the aggregate of all external conditions that influences growth and development of plant. Crops are not profitable unless they are adapted to the region in which they are produced. Among environmental factors such as temperature, light intensity, relative humidity and rainfall pattern have effect on crop growth and development. Temperature as the major regulator of development process. Higher temperature has more adverse effect on net photosynthesis than lower temperature leading to decreased production of photosythates above a certain temperature.

Plant spacing is an important factor affecting watermelon production [24]. Suitable plant spacing can lead to optimum fruit yield while too few or too many plants can result in waste of growth factors and poor yield per unit area of land.

Plant spacing determines level of competition among crops. Vine length, diameter, number of leaves and branches linearly increase with increase in spacing of watermelon [1]; [25]. One of the most important factors in vegetable production is correct spacing because it allows plants to develop to their full potential. Adequate space ensures less competition for sunlight, water, and fertilizers [7]; [26]; [31]. Adequate intra-row plant spacing enhanced total yield of watermelons while total yield and fruit number decreased with increased intra-row plant spacing and the fruit mass increased at wider plant spacing [7]. There is no consensus about the optimum spacing for watermelon.

The objective was to determine the best spacing for growth and fruit yield of watermelon.

MATERIALS AND METHODS

Experimental site

Field experiments was conducted at two locations from August to November in 2016 at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Nigeria and Ogun – Osun River Basin Project Site at Sepeteri, Oyo State, Nigeria. Ogbomoso lies at latitude 8°10'N, longitude 4°16' E, in the Guinea savanna zone of Southwest Nigeria. Temperature of the area ranges from 23 to 25°C with relative humidity of about 75% all year except in January. Rainfall distribution is bimodal and extends to 8 to 9 months of the year. On average, total annual rainfall is about 1,131.4 mm while Sepeteri lies between latitude 8°30' and longitude 3°37', in the humid tropical region within the Guinea Savanna Zone of Nigeria. Temperature ranges from 28 to 30°C with humidity of about 82%. The area had a bimodal rainfall pattern and on average, total annual rainfall is about 1,500.4 mm.

Soil Sampling and analysis: Before the experiments were set up, ploughing was done twice and soil samples analyses was done for physical and chemical properties in both locations. Soil samples were collected at the depth of 0 – 15 cm. The sample was air-dried, crushed and sieved for the determination of pH, organic carbon, organic matter, total nitrogen, available phosphorus (P); Exchangeable K, Ca, Mg and Na.

Experimental design and treatments

In both locations, treatments consisted of factorial combination of the four watermelon cultivars: Sugar baby, Kaolack, Grey belle and Collos F1 and plant spacings of 1.0 × 0.5 m, 1.0 × 0.5 m, 1.0 × 1.0 m, 1.0 × 1.5 m and 1.0 × 2.0 m. The treatments were arranged in a randomized complete block design (RCBD) and replicated thrice. The gross experimental area was 1,027 m^2 (13 × 79 m) divided into 3 replicates each measuring 3 × 79 m (237 m^2). Each replicate was subdivided into 20 plots making a total of 60 plots. Plot size was 3 × 3 m (9 m^2) and contained 8, 12, 16, 24 or 28 plants according to the spacing. Other cultural practices were adequately performed as required, Data collection began 2 weeks after sowing (WAS) and continued fortnightly for a period of 8 weeks. Four plants per plot were tagged for growth, reproductive and fruit yield attributes. Growth parameters measured were: number of leaves, primary vine length, and number of branches, leaf area and number of flowers/plant. Leaf area was estimated using the linear model method of [32]. Mature fruit were picked at 10 WAS. Fruits were counted and weighed to determine number and yield per plot and these were extrapolated ha^{-1}. Six fruits per plot were randomly selected to assess mean fruit length and diameter. Thereafter, selected fruit were split open and seeds and pulp extracted separately. Numbers and weight of seed per fruit, pulp and rind weights were determined. Data were subjected to analysis of variance according to Statistical Analysis System (SAS Institute, 2009) and treatment means were compared using least significant difference at 5% probability.

RESULTS AND DISCUSSIONS

Weather data

Data on the temperature and rainfall of the two locations were presented on Table 1.

Table 1. Temperature (°C) and rainfall (mm) data of experimental sites

	Ogbomoso		**Sepeteri**	
	Temperature (°C)	Rain fall (mm)	Temperature (°C)	Rain fall (mm)
August	23.29	134.8	28.38	362.4
September	23.42	180.2	29.33	231.7
October	24.20	158.6	29.94	0
November	24.73	0	30.43	5.70
Total	23.91	473.6	29.52	599.8

Source: Nigeria Airport Meteorological Station, Ilorin and Ogun-Osun River basin, Abeokuta [22].

Sepeteri had the higher temperature and rainfall during the growing season than Ogbomoso.

Pre-cropping soil properties

The physico-chemical properties of the soils used for the experiments was presented in Table 2. The soil particle size of both locations showed that the soil was sandy-loam in texture. The organic carbon (2.19 and 2.14 %), organic matter (3.79 and 3.70 %), total N (0.68 and 0.52 gkg^{-1}) of Ogbomoso and Sepeteri, respectively, showed low soil fertility. The soil pH of Ogbomoso (6.48) and Sepeteri (6.58) was slightly acid. At Ogbomoso and Sepeteri, the available phosphorus (7.62 and 5.58 cmol kg^{-1}) was low while exchangeable K (078 and 0.75 cmol kg^{-1}), Na (0.18 and 0.22 cmol kg^{-1}), Ca (1.92 and 2.15 cmol kg^{-1}) and Mg (0.49 and 0.84 cmol kg^{-1}) respective, was medium based on the rating of [32] [12] [16].

Table 2. Pre-cropping chemical and physical characteristics of soil used for the study at Ogbomoso and Sepeteri

Location		
Property	Ogbomoso	Sepeteri
pH (H_2O)	6.48	6.58
Organic carbon (%)	2.19	2.14
Organic Matter (%)	3.79	3.70
Total N (gkg^{-1})	0.68	0.52
Available P (mg kg^{-1})	7.62	5.58
Exchangeable K (cmol kg^{-1})	0.78	0.75
Exchangeable Na (cmol kg^{-1})	0.18	0.22
Exchangeable Ca (cmol kg^{-1})	1.92	2.15
Exchangeable Mg (cmol kg^{-1})	0.49	0.84
Acidity (cmol kg^{-1})	0.1	0.1
Sand (%)	85.46	86.46
Silt (%)	8.00	7.00
Clay (%)	6.54	6.54

Source: Own primary data.

Length of primary vines/plant at various time of sowing

Effects of varieties, plant spacing and their interaction on length of primary of watermelon in Ogbomoso and Sepeteri were presented on Table 3. Variety significantly influenced the length of primary vine at all growth stages in both locations. In Ogbomoso, at 2 WAS, Kaolack variety had the longest (4.90 cm) primary vine while Sugar baby had the shortest (3.79 cm). At 4 WAS, Grey belle had the longest (66.53 cm) but statistically not different from Kaolack (65.19 cm) and Collos F1 (65.91 cm) while the shortest (47.58 cm) was recorded with Sugar baby variety. At 6 and 8 WAS, Collos F1 had the longest (108.75 and 219.54 cm) primary vine while Sugar baby had the shortest (87.69 and 166.14 cm), respectively. At Sepeteri 2, 4 and 8 WAS Collos F1 consistently had the longest (4.27, 42.31, 345 cm) primary vine while Sugar baby had the shortest (2.65, 20.02 and 204.99 cm) primary vine. At 6 WAS, there was no significant effects on length of primary vine among all the varieties.

In Ogbomoso, Spacing had no significant had no significant at 2 and 6 WAS but significant at 4 and 8 WAS on length of primary vine. At 4 and 8 WAS, 1.0 m × 2.0 m had the longest (68.58 and 217.71 cm) while 1.0 m × 1.0 m had shortest (54.36 cm) primary vine at 4 WAS and 1.0 m × 1.5 m had the shortest (171.79 cm) primary vine at 8 WAS. At Sepeteri, spacing was only
significant at 8 WAS. At 8 WAS, 1.0 m × 2.0 had the longest (331.71 cm) primary vine while 1.0 m × 1.0 m had the shortest primary vine. The interaction effects of variety and spacing was not significant at all growth stages in the two locations (Table 3).

Number of leaves/ plant at various time of sowing

The main effects of variety, spacing and their interaction effects on number of leaves/plant at all growth stages in Ogbomoso and Sepeteri were presented in (Table 4). Varietal effects were significant ($p \leq 0.05$) at 2 and 8 WAS in Ogbomoso. At 2 WAS, Kaolack had the highest (3.74 leaves /plant) foliage production while Grey belle had the least (3.35 leaves /plant). At 8 WAS, the highest (85.22 leaves/plant) foliage production was recorded with Collos F1.

At Sepeteri, significant effects occurred at 8 WAS. The highest number of leaves (86.00 leaves/plant) was recorded with Collos F1while Sugar baby had the least (72.50 leaves/plant) number of leaves.

Table 3. Effect of spacing on length of primary vine of watermelon varieties plants in Ogbomoso and Sepeteri

	Ogbomoso				**Sepeteri**			
Treatments	Weeks after sowing							
	2	4	6	8	2	4	6	8
Variety(V)								
Sugar baby	3.79b	47.58b	87.69b	166.14b	2.65c	20.02b	152.47a	204.99c
Kaolack	4.90a	65.19a	96.73ab	185.93b	3.09b	28.02b	155.25a	311.47ab
Grey belle	4.67ab	66.53a	106.69a	195.77ab	3.25b	29.13b	144.87a	262.50bc
Collos F1	4.61ab	65.91a	108.75a	219.54a	4.27a	42.31a	152.45a	345.73a
Spacing(S)								
1 m x 0.5 m	5.02a	64.04ab	99.78a	189.42ab	3.05a	28.63a	150.26a	285.75ab
1 m x 0.75 m	4.40a	61.03ab	107.42a	198.01ab	3.04a	27.83a	151.63a	278.04ab
1 m x 1.0 m	4.37a	54.36b	100.59a	182.30ab	3.46a	32.78a	155.68a	240.03ab
1 m x 1.5 m	4.63a	58.50ab	93.38a	171.79b	3.16a	34.78a	155.38a	270.04ab
1 m x 2.0 m	4.05a	68.58a	98.66a	217.71a	3.41a	25.35a	143.35a	331.71a
Interaction								
V x S	Ns	ns	Ns	Ns	ns	ns	ns	ns

Note: Means along the column with the same letter are not significant at $p \leq 0.05$, ns = not significant.
Source: Own primary data.

Effects of different spacing on number of leaves in Ogbomoso was significant at 6 and 8 WAS. 1.0 m × 0.75 had the highest number of leaves (34.81 and 73.33 leaves/ plant) at 6 and 8 WAS while 1.0 m × 1.5 had the least (26.29 leaves /plant) at 6 WAS and 1.0 m × 1.30 m (32.27 leaves /plant) at 8 WAS, respectively. In Sepeteri, significant effects occurred at 2 WAS. At 2 WAS, 1.0 m × 0.75 had the highest (3.73 leaves /plant) while 1.0 m × 2.0 had the least (3.47 leaves /plant) number of leaves. The interaction effects of variety and spacing on number of leaves in both locations were not significant at all growth stages (Table 4).

Table 4. Effect of spacing on number of leaves of watermelon varieties plants in Ogbomoso and Sepeteri

	Ogbomoso				**Sepeteri**			
Treatments	Weeks after sowing							
	2	4	6	8	2	4	6	8
Variety(V)								
Sugar baby	3.74a	18.69a	30.42a	60.55b	3.37b	6.45b	47.97a	72.50b
Kaolack	3.58ab	19.71a	32.70a	72.07b	3.67a	7.59ab	49.26a	78.50ab
Grey belle	3.35b	19.01a	28.69a	70.27b	3.67a	7.66a	43.98a	75.20b
Collos F1	3.72ab	19.73a	33.14a	85.22a	3.83a	8.48a	48.40a	86.00a
Spacing(S)								
1 m x 0.5 m	3.59a	21.22a	30.24ab	66.79b	3.67ab	7.39a	44.67a	83.21a
1 m x 0.75 m	3.36a	19.11a	34.81a	73.33a	3.73a	7.36a	43.63a	78.63a
1 m x 1.0 m	3.53a	21.30a	32.27ab	32.27ab	3.62ab	7.77a	51.99a	76.95a
1 m x 1.5 m	3.75a	16.57a	26.29b	67.88ab	3.70ab	7.99a	48.97a	77.00a
1 m x 2.0 m	3.76a	18.23a	33.08ab	33.08ab	3.47ab	7.22a	47.74a	74.46a
Interaction								
V x S	ns	ns	ns	ns	ns	ns	ns	ns

Note: Means along the column with the same letter are not significant at $p \leq 0.05$, ns = not significant.
Source: Own primary data.

Leaf area/plant at different stages

Leaf area was significantly ($p \leq 0.05$) influenced by varietal differences in both locations at all growth stages (Table 5). Variability in leaf production in watermelon variety was influenced at 2 and 8 WAS in Ogbomoso and 2 WAS in Sepeteri. At 2 WAS in Ogbomoso Kaolack had the highest leaf area /plant (10.21 cm^2/plant) which is statistically not different from Sugar baby (9.71 cm^2/plant) while Grey belle and Collos F1 jointly had the least (7.83 cm^2/plant). In Sepeteri plants, leaf area was significantly influenced by variety only at 2 WAS. At this stage, Sugar baby had the widest leaf (8.27 cm^2/plant) while the narrowest leaf (4.18 cm^2/plant) was observed with Collos F1.

In Ogbomoso, spacing was only significant ($p \leq 0.05$) at 8WAS on leaf area/plant (Table 5). At 8 WAS, it was observed that Kaolack variety had the widest leaf (95.83 cm^2/plant) while 1.0 m × 1.0 m had the narrowest (86.28 cm^2/plant) leaf area. In Sepeteri, spacing had no significant effects of leaf area development. The interaction effects of variety and spacing are not significant on leaf area development in both locations (Table 5).

Table 5. Effect of spacing on leaf area (cm^2) of watermelon varieties plants in Ogbomoso and Sepeteri

	Ogbomoso				**Sepeteri**			
Treatments	Weeks after sowing							
	2	4	6	8	2	4	6	8
Variety(V)								
Sugar baby	9.71a	58.07a	66.00a	83.04c	8.27a	29.43b	75.76a	99.15a
Kaolack	10.21a	52.18a	75.97a	91.148ab	6.03ab	42.29a	79.14a	111.80a
Grey belle	7.83b	56.17a	69.00a	88.06bc	6.01ab	46.19a	77.83a	108.35a
Collos F1	7.83b	55.96a	71.09a	96.64a	4.18b	49.73a	76.32a	111.66a
Spacing(S)								
1 m x 0.5 m	8.72a	58.65a	73.77a	95.83a	6.40a	39.94a	74.80a	112.18a
1 m x 0.75 m	9.63a	57.34a	70.59a	86.31b	5.28a	40.25a	75.45a	103.58a
1 m x 1.0 m	9.59a	55.40a	63.52a	86.28b	6.61a	44.25a	78.78a	107.61a
1 m x 1.5 m	7.98a	54.62a	116.29a	88.10ab	5.34a	45.25a	82.04a	107.61a
1 m x 2.0 m	8.54a	52.00a	70.92a	92.11ab	6.98a	39.86a	75.24a	109.85a
Interaction								
V x S	Ns	ns	Ns	Ns	ns	ns	ns	ns

Note: Means along the column with the same letter are not significant at $p \leq 0.05$, ns = not significant.
Source: Own primary data.

Reproductive and fruit parameters of watermelon varieties as influenced by spacing in Ogbomoso and Sepeteri: Effects of variety, spacing and their interaction on number of flower/plant, number of fruit /plant and fruit yield in Ogbomoso and Sepeteri are presented in Table 6.

In Ogbomoso, varietal differenced significantly ($p \leq 0.05$) influenced the reproductive and fruit yield parameters. The highest number of flowers (7.34 flowers /plant) in Ogbomoso was observed with Collos F1 while the least (5.01 flowers /plant) was recorded with Sugar baby.

Grey belle had the highest number of rotten fruit (3.60 /plot) while the least was taken from Sugar baby (2.47/plot).

The highest fruit yield (29.89 t/ha) was recorded with Kaolack while the least (14.78 t/ha) was recorded with Sugar baby.

In Sepeteri, there was no significant effects of varieties on number of flowers /plant and fruit yield t/ha.

In Ogbomoso, watermelon plants spaced at 1.0 m × 2.0 m had significant highest number of flowers (6.84 flowers /plant) while 1.0 m × 1.0 m had the least number of flowers (5.10 flowers /plant).

The highest fruit yield (28.35 t/ha) was recorded with 1.0 m × 0.75 m while 1.0 m × 1.5 m had the least fruit yield (17.69 t/ha). Spacing had no significant effects on number of rotten fruits.

In Sepeteri, the highest fruit yield (14.27 t/ha) was recorded with 1.0 m × 0.75 m while the least (8.54 t/ha) was recorded with 1.0 m × 1.5 m which was not significantly different from 1.0 m × 1.0 m and 1.0 m × 2.0 m.

The interaction effects of variety and spacing was not significant on reproductive and fruit yield parameters in the two locations (Table 6).

Effect of locations

The significant differences among the two location on with respect to growth and fruit yield indicated that different environmental have great impact on the growth and yield outcome of watermelon. This differences in yield could be associated to differences in amount of rainfall and temperature as this result is in line with [11]; [23].

Table 6. Effect of plant spacing on reproductive and fruit yield parameters watermelon varieties planted in Ogbomoso and Sepeteri

	Ogbomoso			Sepeteri		
Treatment	No. of flower /plant	No. of rotten fruit/ plot	Fruit yield (t/ha)	No. of flower /plant	No. of rotten fruit/ plot	Fruit yield (t/ha)
Variety(V)						
Sugar baby	5.01b	2.47b	14.78b	13.92a	4.07ab	8.70a
Kaolack	5.19b	2.87ab	29.89a	15.31a	3.00b	10.69a
Grey belle	6.29ab	3.60a	20.75ab	14.57a	3.47ab	9.27a
Collos F1	7.34a	3.33ab	21.38ab	16.35a	3.60a	12.04a
Spacing(S)						
1 m x 0.5m	6.00ab	3.50a	19.00ab	14.56a	3.92a	10.57ab
1m x 0.75m	6.05ab	3.08a	28.35a	15.75a	3.92a	14.27a
1 m x 1.0m	5.10b	2.92a	24.40ab	14.55a	3.42a	8.68b
1 m x 1.5m	5.79ab	3.33a	17.69b	14.12a	3.75a	8.54b
1 m x 2.0m	6.84a	2.50a	19.07ab	16.20a	3.67a	8.81b
Interaction						
VxS	Ns	ns	ns	ns	ns	ns

Note: Means along the column with the same letter are not significant at $p \leq 0.05$; ns = Not significant
Source: Own primary data

In addition, watermelon expresses their genetic attributes differently with different ecological zone.

Effects of varieties on vegetative growth

Varietal differences were obtained with respect to vegetative development in the four varieties of watermelon used in this study. In most cases, Collos F1 variety had the highest values over other watermelon varieties tested except number of secondary vines which could be attributed to differences in its genetic constitution with the respect to its hybrid and higher growth rate of the vine, and to suitability of its agro-ecological conditions. This result is similar to the findings of [15] who reported that genetic constitution of crop varieties influences the growth characters. It is also in harmony with the findings of [18] who attributed the growth and yield differences among crop varieties to right choice of suitable agro-ecological zone. Similar observation was recorded by [2]; [29]; [3] on maize and okra. They reported variability in plant genetic potential which leads to differences in the observed performance.

Higher number of secondary branches/plant was recorded in Kaolack variety possibly because kaolack variety combined its good genetic make-up to exploit the agro-ecological conditions of the study area for rapid growth and branching. This report is similar to the findings of [9]; [10]; [4] who attributed the growth characters of crop species not only to genetic constitution of the crop but also to the suitability of agro-ecological zone where they can express their full genetic resources for growth and yield enhancement.

Effects of varieties on fruit yield

The highest fruit yield was observed in Kaolack variety. This yield could be attributed to its highest stomatal conductance, better partitioning of photosynthetic materials towards economic yield, better genetic structure and highest potential transport photosynthetic material within plants. This result is in line with the findings of [20]; [34] who attributed the yield difference in crop cultivars to stomatal conductance value and to difference in partitioning of photosynthetic materials towards economic yield. It is also in conformity with the findings of [15]; [21] attributed the difference in yield and its components between crop genotypes to variations in genetic structure, mineral concentration and potentials to transport photosynthetic materials within plants.

Effects of plant spacing on vegetative growth

Higher vegetative growth in plant with less population density is as a result of less competition for water, nutrient and light. The result showed that as spacing increases, watermelon vegetative growth also increases [30]. These results are in agreement with the findings of [14] who reported that the spacing has positive effect on growth parameters.

These results also in support with [7] who reported that spacing had significant effect on the growth and yield of watermelon. These results are also supported by [26] who reported an increase in watermelon vegetative growth with an increase in spacing. Inappropriate plant density has accounted for poor yields of watermelon among most small scale watermelon farmers. If plants are widely spaced, not all land area is covered by leaves and much light available for photosynthesis is wasted, also water and mineral resources in the soil [13].

Effects of plant spacings on fruit yield: Plant density is another factor that affects watermelon production. Suitable plant spacing ensures optimum fruit yield while too high or too low plant spacing could result to relatively low yield and quality. Spacing did not significantly influence the vegetative parameter. Adequate plant spacing strategies and nutrient management has been reported to have a positive impact on watermelon yield [7]; [5]; [17]; [8]. The highest vegetative growth was observed as plant spacing increases, but contrary to yield and yield parameters. This result is similar to the findings of [33] on maize and yield component. Ban [8] also reported increase in yield of watermelon fruit weight slightly increased with plant spacing up to 1.2m. The result also showed that vegetative growth and yield parameters are under the influence of plant spacing and varieties. Also in the study of [7] reported the significant increase in yield with decreased plant spacing on watermelon. In melon, yield generally increases with decrease spacing [27]; [28]. Awere and Onyeacholem [6] also reported the increased in vegetative growth as plant spacing increases but highest yield was noticed as plant spacing decreases on watermelon.

CONCLUSIONS

The experiment was carried out to study the effect of plant spacing on growth and fruit yield of watermelon varieties in southwest, Nigeria. Plant spacing significantly enhanced the growth, yield and yield attributes of the watermelon varieties. Based on the findings, it could be concluded that agro-ecological condition plays a vital role on the growth and yield likewise the variety as well as spacing. In both locations is it revealed that Kaolack variety and 1.0 m x 0.75 m are suitable for achieving higher economical yield of watermelon fruit.

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