Yield of cotton in relation to plant density

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Introduction

Acid-delinted cottonseed is the highest improved seed quality approaches introduced in Egypt. In 1998, an experiment was carried out on the cultivar Giza 87 to investigate the effect of acid-delinted seed on the plant population and their influence on the productivity of cotton at Sakha, Kafr El-Sheikh, Egypt. The results discovered the plant population could be reduced to 30-40 thousand plants per fed. Without negative effects on yield from unit area in comparison to the traditional growing pattern, that recommend 60-70 $\times$ 10^3 plants per fed. Also, the yield of the first harvest was improved.

Such results are not strange, thus the breeding processes and improvement of the modern cultivars with different branching patterns and earliness. In other words the present varieties are different in one or another way from the old ones and reed more suitable culture practices, e.g. in terms of planting patterns.

Moreover, the use of high quality acid-delinted cotton seed allows control of pacing facilitates the use of planters or even seed dull for narrow spacing, dressing seed with pesticides and fertilizers and ensure agricultural value of seed. It allows the reduction of the required seed amounts and a lot of funds expended for seed multiplication, contracts, isolation requirements, and processing as well as conditioning. Further more quantities of seed can be saved, as edible oil seed in the country where self produced edible oil is very limited.

Therefore, the present investigation was planed to study the effect of different plant population densities and or planting pattern on cotton yield of the Giza 89 cultivar, under the use of acid-delinted cottonseed. Of the Giza 89 cultivar. This cultivar is spread over two governorates, i.e El-Monofia and El-Behira.

The obtained information shall provide the basis for further recommendations to improve the quality of cottonseed production under field conditions and to provide information about cotton plant spacing which yield best.

Material and methods

An experiment was carried out in 1999 season at El-Magd village, Rahmania, El-Behira Governorate. The soil structure is mostly silt and the soil is highly fertile. The preceding crop was Berseem (two cuts) as early winter crop. The soil was operated and P_2O_5 fertilizer in form of monosuperphosphate 15.5% at the rate of 60 kg P_2O_5 feddan corporated in the soil before ridging and dividing. Also 50 kg Kalium sulfate (24 units and 18 units sulfur) was added.

Three different ridge widths was used, 65 cm, 75 cm and 90 cm widths. Cotton was planted on one ridge-side in hills 20, 75 and 90 cm apart.

Planting date: April 1999:

Planting was done with special instruments prepared for this experiment that allows only unique depth of 3 cm for the seeds.

The seeding rate:
3 different seed-numbers per hill were put. First, the control (Zero) plots on ridges 65 cm wide had to ensure presence of 64×10^3 plants per fed and therefore, four seeds were put per hill and the seedlings were thinned to leave two plants per each hill. Second, the hills spaced 25 cm on the 75cm wide ridges and spaced 30 cm on the 90 cm wide ridges contained only 3 seeds. So, the number of seeds in each hill in the last two planting patterns; 75×25 cm and 90×30 cm; differed, from the control (65×20 cm). Herein, only three seeds were planted in each hill and not more than two plants were left per hill after emergence. Theoretically, the number of plants per feddan within the three planting patterns was 65×10^5 (60×20 cm $\times$ 2 plants), 33.600×10^3 (75×25 cm $\times$ 1-2 plants) and 23.333×10^3 (90×3 cm $\times$ 1-2 plants).
The plants received the same normal growing culture practices.

Experimental design

The treatments were arranged in a randomized complete block design (RCBD) with four replication. The plot size was $7 \times 9m^2$ area in which the plot included the following number of ridges:
14 ridges for the planting pattern (65×20 cm).
12 ridges for the planting pattern (75×25 cm). and
10 ridges for the planting pattern (90×30 cm).
The two outer rows were left as guard rows and:
12 central ridges were used for evaluation of the (65×20 cm) pattern,
10 central ridges, were used for evaluation of the (75×25 cm) pattern.
8 central ridges were used for evaluation of the (90×30 cm) pattern.

The following data were recorded for the field experiment:

1- No. germinated hills for ridge seven day after planting counted as an average of all the central ridges.
2- No. of germinated hills ridge 11 days after planting counted as an average of all the central ridges.
3- No. of plants in each replicate (plot) at harvest and No. of plants per ridge, No. of plants/m^2, and number of plants/fed. were calculated.
4- No. of fruiting branches (sympdia) per plant in each replication on June 18 (73 days from planting) assessed in 5 guarded hills in each replication.
5- No. of fruiting branches (sympdia) per plant on July 30 (115 day from planting) assessed in 5 guarded hills in each replication.
6- No. of bolls per hill at harvest counted on 5 guarded hills in each replication.
7- Boll weight of first yield, recorded for 10 random open bolls within each replicate in grams.
8- Boll weight of second yield, recorded for 10 random open bolls within each replicate in grams.
9- Seed cotton yield at first harvest/plot in kg in the guarded ridges of the plot.
10- Seed cotton yield at second harvest/plot in kg in the guarded ridges of the plot.
11- The total seed cotton yield and yields per m^2, per fed. were calculated in ton and in Kenntar (each Kenntar = 157.5 kg)

12- Lint percentage first harvest: The percentage of lint produced from a certain weight of seed cotton.
13- Lint percentage for second harvest.
14- Seed index first harvest: Weight of 100 seeds in first harvest.
15- Seed index second harvest: Weight of 100 seeds in second harvest.

Results and discussion

1- the emergence of the seedlings was not possible after four days from planting under field conditions due to cool temperature during the night. However emergence of most hills was first possible after giving a second irrigation to help the seedling to come out through the soil. The mean number of emerged hills/ridge after 7 days compared to that emerged at 11 days from planting are presented in Tables 1 and 2. The results show the significant higher germinated hills within control (65/20 cm pattern) than that germinated within the 75/25 cm pattern and highly significantly higher than that within the 90 /30 cm pattern. This is naturally a result of experimental scheme.

2- Mean number of plants per plot:
Mean number of plants per plot in Table 3, mean number of plants per ridge (7 m long) in Table 4 and mean number of plants per m^2 in Table 5 show the highly significantly higher number of plants in the control compared to the other two plant population densities, having less population.

Table (1): Means number of germinated hills/ridge *seven* days after sowing of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	28.808	-
75/25	1-2	23.083	-5.725*
90/30	1-2	17.713	-11.095**
Mean		23.201	

** = Significant at 1% level.
* = Significant at 5% level.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	1.818	4.448	6.73

Table (2): Means number of germinated hills/ridge *eleven* days after sowing of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	31.065	-
75/25	1-2	23.685	-7.380**
90/30	1-2	18.743	-12.323**
Mean		24.498	

** = Significant at 1% level.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	1.823	4.461	6.758

Table (3): Means number of plants/plot of Giza 89 cotton *at harvest* planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	721.875	-
75/25	1-2	343.313	-378.563**
90/30	1-2	279.688	-442.188**
Mean		4.292	

** = Significant at 1% level.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	19.804	48.458	73.416

Table (4): Mean number of plants/ridge of Giza 89 cotton *at harvest* planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	49.753	-
75/25	1-2	29.910	-19.843**
90/30	1-2	27.970	-21.783**
Mean		35.878	

** = Significant at 1% level.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	2.095	5.127	7.767

Table (5): Mean number of plants/m^2 of Giza 89 cotton *at harvest* planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	10.933	-
75/25	1-2	5.695	-5.238**
90/30	1-2	4.445	-6.488**
Mean		7.024	

** = Significant at 1% level.

3- Number of fruiting branches (sympdia):

The fruiting sympdia carry the squares, flowers and bolls of cotton plant as the generative organs of the plant. In the study, this character was assessed and recorded at begin of the flowering season and at the end of the productive flowering season on guarded random plants. This parameter is of most importance because it is related to the capacity of the plant to develop the best yield of cotton, thus the flowers produced during this period give bolls that can develop-grow and mature to opening during the most suitable growing season. The later produced flowers (after July) produce bolls that are mostly smaller in size and do open producing immature fibers as well as immature seeds and a lot of mites and mostly infested with boll- worms.

The results shown in Table 11 and 13 disclosed that the cotton plants produced more sympdia under spacing in terms of wider ridges and, wider spacing among hills compared to the control. Also, the number of sympdia increased in a linear way as the plant population was decreased. So, cotton plant is a plant that can do nice compensation in its productivity. Such results are very clear to observe 73 days and 115 day from planting. Tables 6 and 7 show that the number of sympdia was increased linearly by reducing the plant population and the linearity become more obvious on July 30

where the relative increase in mean number of fruiting symposia was strongly increased as the spacing was widen from 65 × 20 cm, 75 × 25 cm to 90 × 30 cm with highly significant differences according to the DMRT as well as LSD comparisons.

Table(6): Mean number of fruiting branches/plant on *June 18 (73 days from planting)* of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	9.215	-
75/25	1-2	11.690	2.475*
90/30	1-2	13.280	4.065**
Mean		11.395	

** = Significant at 1% level.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	0.771	1.886	2.857

Table (7): Mean number of fruiting branches/plant on *July 30 (115 days from planting)* of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	15.418	-
75/25	1-2	21.083	5.665**
90/30	1-2	25.723	10.305**
Mean		20.741	

** = Significant at 1% level.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	1.257	3 .075	4.659

4- Number of bolls per hill :

At harvest, when the total number of bolls per hill was counted on 20 guarded hills; 5 plants from each replication. This was done at harvest to avoid the effect of shedding of young bolls during development. The mean number of bolls/hill at harvest is presented in Table 8. It indicates that the number of bolls was highly significantly increased under less plant population, compared to the control treatment (the old recommended plant spacing). However, both suggested 75 × 25 cm and 90 × 30 cm plant spacing patterns produced highest bolls number and did not differ from each other, even they had only one plant in more than 50% of its hills. This result indicates again that one can produce enough cotton bolls per plant by wise and rational less plant population.

Table (8): Mean number of bolls/hill at harvest of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	56.250	-
75/25	1-2	75.500	19.250**
90/30	1-2	74.250	18.000**
Mean		68.667	

** = Significant at 1% level.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	2.424	5.931	8.985

5- Boll weight of first harvested yield (g):

The plant growth in the experimental location reached nice growth and under such high fertile soil condition (beside the Nile coast), the boll weight of the cultivar Giza 89 reached wonderful weight for Egyptian cotton (*Gossypium barbadense* L.). However, the differences in mean boll weight were not statistically significant (See Tables 9 and 10). This character, boll weight of the first yield was negatively influenced by the vigorous growth of the plants, where shading and the high humid microclimate among the plant bases, caused *Fusarium* infection and shedding (drop) of young bolls. Such early lower plant part fruits had to add more yield and bigger first harvest bolls of high yield and high lint as well as seed quality. Such conditions were partially controlled through the reduction of the nitrogen fertilizer level and increase of the phosphorous fertilizer.

Table (9): Mean boll weight g at first harvest of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	3.605	-
75/25	1-2	3.271	-0.334 ns
90/30	1-2	3.443	-0.162 ns
Mean		3.439	

** = Significant at 1% level.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	0.161	0.394	0.597

6- Boll weight of the second harvested yield (g):

This character was similar in response to that of the first harvest yield. However, the size of bolls was some what smaller and therefore, lighter in weight compared to that of the first harvested yield (see Tables 11 and 12).

Table (10): Mean boll weight g at second harvest of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	2.908	-
75/25	1-2	2.678	-0.229 ns
90/30	1-2	2.924	0.016 ns
Mean		2.837	

ns = not significant.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	0.105	0.258	0.391

The analysis of variance showed highly significant treatment, significant harvest time mean squares, significant population mean squares and highly significant harvest $\times$ population interaction mean squares.

Within all the patterns the first harvest had highly significant increase in boll weight than the second harvest. The pattern 75 $\times$ 25 cm $\times$ 1-2 plants produced, smaller boll weight compared to the other two patterns. However, this result is mainly due to the differences in the first harvest. But, the general mean of boll weight in the first harvest was highly significantly higher than that of the second harvest.

Table (11): Mean boll weight (g) in 1st harvest compared to 2nd harvest of Giza 89 cotton planted by acid-delinted seed in 1999.

Planting pattern cm	Plants/hill	Harvest (H)		Means (p)	Difference
		1st	2nd		
65/20 (control)	2	3.605 a	2.908 a	3.256 a	0.697 **
75/25	1-2	3.300 b	2.678 a	2.989 b	0.622 **
90/30	1-2	3.368 ab	2.924 a	3.146 ab	0.443 **
Mean		3.424	2.837	3.130	0.587 **

** = significant at 1% level.
In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-H*P means	0.122	0.259	0.358
2-p means	0.086	0.183	0.253
2-H means	0.070	0.150	0.207

6- Cotton Yield:

Seed cotton and lint yields are the end products of the plant as raw yield. All the research work can develop the plant characteristics as desired in quality but the yield per unit of land and unit of water should not be reduced. Also, the cultural packages for cotton production can require high investment of land, seed, plant protection, labor, irrigation… etc., but the yield must be enough to cover the costs and satisfy the cotton gr, even, if the selling price is world over controlled.

The reduction of plant population permits the use of minimized seed rate. This can save a lot o,as high quality acid-delinted seed is not expensive and the farmer should pay all its real costs.

In the present study, two plant populations were suggested in comparison to the normal population. The data in table 13 show that the seed cotton yield/plot was not reduced by use of lower plant populations, but it was somewhat higher than that of the recommended control. However, the differences were not enough high to reach the significance level..

In our study, yield was harvested twice. Data in Table 12 show also, that the first yield of the plant densities 75/25 cm and 90/30 cm were not significantly different from that of the traditional control, however they exhibit, a trend to produce higher yields.

Table (12): Mean total seed cotton yield/plot kg of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	15.340	-
75/25	1-2	16.783	1.443 ns
90/30	1-2	15.990	0.650 ns
Mean		16.038	

ns = not significant.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	0.650	1.591	2.411

Table (13): Mean seed cotton yield/plot kg at first harvest of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	9.883	-
75/25	1-2	10.610	0.727 ns
90/30	1-2	10.288	0.405 ns
Mean		10.260	

ns = not significant.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	1.037	2.537	3.843

Similar results were also obtained for the second harvest. However, the yield of the first harvest was almost two times that of the second harvest. (Tables 13 and 14).

Table (14): Mean seed cotton yield/plot kg at second harvest of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	5.688	-
75/25	1-2	6.198	0.510 ns
90/30	1-2	5.703	0.015 ns
Mean		5.863	

ns = not significant.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	0.573	1.402	2.124

When the total seed cotton yield was adjusted to international area units, the yield comparisons per square meter are presented in Table 15 and that per hectare are presented in Tables 1. Thus, the reasonable and rational low plant population around 30 thousand plants per fed. can produce the same or better yield than the higher populations.

Table (15): Mean total seed cotton yield/m^2 g of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	0.291	-
75/25	1-2	0.318	0.028 ns
90/30	1-2	0.317	0.026 ns
Mean		0.309	

ns = not significant.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	0.013	0.032	0.049

Table (16): Mean total seed cotton yield/fed. *ton* of Giza 89 cotton planted by acid-delinted seed.

Planting pattern cm	Plants/hill	Means	Difference
65/20 (control)	2	1.247	-
75/25	1-2	1.347	0.100 ns
90/30	1-2	1.332	0.085 ns
Mean		1.309	

ns = not significant.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-P means	0.053	0.130	0.190

8- Seed Index :

The seed index data (Table 17) showed that the plant populations used herein did not effect the seed index strongly. But, this trait was strongly affected by the harvest time. The seeds produced from the first harvest were higher in weight than that of the second harvest. This means, that second harvest produce low quality seeds, that are not suitable for cultivation.

The differences in seed index between the two harvests were highly significant.

Table (17): Mean seed index (g) of Giza 89 cotton planted with acid-delinted seed in 1999.

Planting pattern cm	Plants/hill	Harvest (H)		Means (p)	Difference
		1st	2nd		
65/20 (control)	2	9.058 a	11.265 a	10.162 a	-2.208**
75/25	1-2	8.912 a	11.308 a	10.110 a	-2.396**
90/30	1-2	9.187 a	11.261 a	10.224 a	-2.074**
Mean		9.052	11.278	10.165	-2.226**

** = Significant at 1% level.
ns = not significant.
In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-H*P means	0.258	0.550	0.761
2-p means	0.149	0.318	0.439

9- Lint percentage:

The lint percentage of the first harvest was highly significantly lower than that of the second harvest (Table 18). This is mainly caused due to the high seed index in the first harvest compared to that of the second one. However, these differences were only significant in both 65/20 cm (the control treatment) and 75/25 cm plant population patterns. But, the difference was highly significant in the 90/30 cm plant population pattern that produced high seed index besides its higher yields than the control in the first harvest.

Table (18): Mean lint percentage of Giza 89 cotton planted by acid-delinted seed in 1999.

Planting pattern cm	Plants/hill	Harvest (H)		Means (p)	Difference
		1st	2nd		
65/20 (control)	2	0.362 a	0.396 a	0.379 a	-0.034 *
75/25	1-2	0.370 a	0.404 a	0.387 a	-0.034 *
90/30	1-2	0.358 a	0.399 a	0.378 a	-0.041 **
Mean		0.363	0.400	0.381	-0.036 **

** = Significant at 1% level.
ns = not significant.
In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Comparison	S.E.D.	LSD (5%)	LSD (1%)
2-H*P means	0.013	0.029	0.039
2-H means	0.008	0.016	0.023

Conclusions

It can be concluded from the above results that:
It is possible to reduce the amount of needed seed to plant the unit area *fed.* With *less than twenty kg* of the acid-delinted cottonseed. However, it needs intensive extension and close activity with the farmers.
The results are very promising to reduce the plant population and get good yield and quality.
Our experience this year showed that special care should be given to the first irrigation. Thus, the heavy irrigation is not required, but wide ridges in case of low plant population water should go through the ridge mass to help enough germination.
The results should be ascertained by another experiment.
The back history of the soil fertility or/and soil analysis to have idea about the soil fertility, structure, drainage and requirements of fertilizers are important behind the preceding crop.
The farmers around our experiment and not only in adjacent fields were highly satisfied by our experiment and many of them like to go with lower plant populations and follow our practices.