Plant Production (Group Lotus)

Biological measures for the improvement and sustainability of tropical soils

Dr. Atef-Moawad Moawad

Institute for Crop and Animal Production in the Tropics
University of Göttingen
Göttingen, Germany

Abstract

The improvement of the food situation in the tropics will depend on reliable production methods adapted to the various conditions of these regions. Besides appropriate technologies for crop management practices, the conservation of soil-biological resources deserve special attention aiming at sustainable soil productivity. The present review emphasizes the importance of the use of the biological properties of the plants such as symbioses and semi-symbioses which substantially improve the exploitation of the macro-nutrients phosphorus and nitrogen in soil for plant nutrition. Thus, enabling a more economic utilization of expensive phosphorus and nitrogen fertilizers specially under the precarious soil conditions in the tropics. The author demonstrates the key role of biological measures under various stress conditions in relation to research activities of the „Institute for Crop and Animal Production in the Tropics" in Goettingen, and further research needs, with primary emphasis on two distinct tropical environments: the humid and arid/semiarid tropics.

Background

- Growing malnutrition, i.e., both inadequate and unbalanced nourishment, is the most pressing problem facing the majority of tropical and subtropical countries
- The demand for food is rising all the time as a result of the ever-increasing rate of population growth.
- Estimates by the FAO indicate that in order to maintain even the present level of supply, which everybody knows is insufficient, food production in the tropics will have to increase by at least 60 % in the next 20 years.
- Yet in many areas of the tropics, there are limits on how far this need to intensify agricultural production can be satisfied.
- Because of the growing populations and the resulting shortage of land, many small subsistence farmers can no longer follow the traditional practice of interposing fallow periods of adequate length (6-10 years) in tropical agriculture, such periods play an important role in restoring the humus content and promoting an accumulation of essential plant nutrients.
- The result is a decrease in the natural fertility of the soil, leading to degradation phenomena which are already apparent in agricultural soils in many regions, e.g. the salinity problem in irrigated regions, the acidification of heavy fertilized soils in West Africa, and the accumulation of detrimental residuals of pesticides all over the tropical world.

- In the short run, yields can be boosted through the use of fertilizers, but most small farmers lack the capital required for this approach.
- Because of the unfavourable soil properties, the mineral fertilizers are not well utilized, which means that the desired long-term increase in yield can only be achieved through the continuous application of fertilizer. This is particularly true for those tropical soils which tend to be subject to leaching of the nutrients and phosphate fixation.

Because of these constraints, the farmers are faced with the urgent task of securing their yields by using available local resources; furthermore, the most appropriate strategies to improve and sustain the fertility of the soils, while at the same time ensuring increased production.

Possible solutions which up to now have not been sufficiently researched is the role of biological measures. Particularly the use of useful micro-organisms and organic matter. Although, most of the biological measures have deep roots into ancient centuries, however, their potential is decreasing in the last decades due to intensive fertilization for maximizing the yields.

During the last few years , several research works world-wide have indicated the important role played by soil biology in sustaining the fertility of tropical and subtropical soils. Recently, a large and growing number of international scientists are actively searching for the combination of factors which can be used to describe the soil fertility or soil quality. Soil biology is a cornerstone in developing these indices and yet the understanding of underground biological system is in the early stages of maturity as a scientific discipline.

The biological system present in the soil ranges from the minute to the large mammals, e.g., gophers and moles. One can easily see the effect of large burrowers left by some of the mammals. The effects of the microscopic organisms like bacteria and fungi are less dramatic but they are the key to improving the soil fertility.

The role and potential of useful micro-organisms for plant nutrition in tropical and subtropical soils

The humid- and sub-humid tropics are characterized by climatic factors (near constancy of temperature and humidity) which are responsible for high plant biomass productivity throughout the year. The semiarid and arid tropics are the dry areas of meagre and undependable rainfall, in which the average precipitation often is lower than the potential evapotranspiration. In the semiarid zone the amounts of rain, are, more or less, sufficient for certain types of crops, requesting special management techniques. In arid zones, arable crop production is not possible without irrigation. With the explosive increase in world population, there is increasing pressure on dry lands which constitute fully one-third of land area of the globe.
The arid parts of a great number of countries are now usually vast empty areas. A large proportion is desert, and its contribution to food production is minimal. On the other hand, where water is available (oases) small areas produce a large variety of crops with excellent yields -an indication of the potential of these regions. A limiting factor of irrigated soils in arid areas is salinity which can drastically reduce productivity.

In general, most soils of the tropics and subtropics lacking in significant available nutrients, and phosphorus and nitrogen are considered to be the most deficient plant nutrients. Micro-organisms, the unseen citizens of the soil, control soil productivity by recycling the carbon, nitrogen and other mineral containing compounds in plant and animal residues to form once again available for use by plants. The soil microbiological community also regulates the production and destruction of environmental pollutants and biologically toxic elements and compounds.
In this context some research activities of our institute will be presented to demonstrate the key role of the useful soil micro-organisms in improving the phosphorus and nitrogen supply to plants in tropical and subtropical soils, such as the (vesicular-) arbuscular mycorrhizal fungi ((V)AMF), the phosphate-solubilizing bacteria, the nitrogen-fixing symbiotic, associative and free-living bacteria, and the Azolla/Anabaena-symbiosis in flooded rice.

Main fields of research on the use of biological measures at the „Institute for Crop and Animal Production in the Tropics“, Goettingen, Germany

A- Phosphorus nutrition of plants

I- (Vesicular-) arbuscular mycorrhiza, (V)AM
Mycorrhiza is the symbiosis between soil fungi and most higher plants. The (vesicular) arbuscular mycorrhizal fungi ((V)AMF) are obligate symbionts and cannot be propagated in axenic pure culture. The growth-promoting effect of the (V)AM is based primarily on the improved uptake of nutrients, especially of phosphorus by mycorrhizal roots, particularly on poor, marginal and P-fixing soils, which frequently occur in the tropics and subtropics.

A huge number of experiments was carried out under simulated (in the greenhouse) and natural growth conditions of the tropics and subtropics

Eco-physiological studies:
- Great number of species and strains (isolates) of (V)AMF,
- Plant species (approximately 40 tropical and subtropical plant species) and host specificity
- Soil type (acid to alkaline, soil-pH),
- Fertilization with phosphates of different solubility (soluble and hardly soluble phosphates, e.g. rock phosphates),
- Soil temperature,
- Soil water-regime,
- Soil organic matter,
- Soil salinity,
- Soil content of Al and the heavy metals Fe, Mn, Zn, Cu, Pb and Cd, and
- Atmospheric factors: light intensity (= insolation) and day-length (photoperiodism), were investigated.

Mechanisms of P uptake by mycorrhizal plants:
Investigations on „How does the (V)AM improve the P supply to plants?“, the role of organic and chelating acids and phosphatases, and the role and quantification of the external mycelium.

Taxonomy:
Isolation, propagation and identification of wide spectrum of species and strains of (V)AM fungi; our institute disposes the greatest collection of these fungi in Europe.

Practical application:
Production of inocula and their application techniques. The utilization of (V)AM in monocultures and mixed cropping systems of crops of different families (*Gramineae*, *Leguminosae*, *Solanaceae*, *Compositae* ....).

Genetic transfer of mycorrhizal efficiency:
The possibility of transferring the property „efficiency of mycorrhiza to improve plant growth by improving P uptake of mycorrhizal roots" by cross-breeding between plant varieties of different mycorrhizal efficiencies, and the breeding of nutrient efficient varieties (mainly of wheat and sorghum), to increase the production potential of these plants particularly on poor, marginal and P-fixing soils (calcareous and acid soils of the tropics).

Contribution of (V)AM to growth of micro-propagated crops:
Over the past two decades the use of *in vitro* micro-propagation as a technique for the multiplication of several plants has increased rapidly. The main problem of the *in vitro* micro-propagation is the weaning stage for plantlets after the tissue culture. In this stage plants are subjected to severe environmental stress due to poor root, shoot and cuticular formation. This results in an extended weaning stage which is often accompanied by high losses in plantlets and large quantities of chemical inputs in form of fertilizers and pesticides. Several measures such as humidity tents, anti-transpirants, additional light and CO_2 enrichment have all been employed to increase survival rates but with only limited success.
Over the last few years it has been demonstrated that with (V)AM as a biological measure can result in growth enhancement of a wide range of micro-propagated plants especially of those difficult-to-root spices. Under natural conditions, plants are normally colonized with (V)AMF and thus are mycorrhizal. In the *in vitro* micro-propagation, (V)AMF, as with all other micro-organisms, are removed. Furthermore, substrates used in the post *vitro* stages of the micro-propagation technique are normally treated in order to remove potential pathogens which at the same time removes the beneficial (V)AMF. The micro-propagated plantlets will not have the benefits of the symbiosis and only by re-introduction of the (V)AMF will the benefits be acquired.
The savings of energy and chemical inputs due to significantly shorter production cycles and the increases in survival and uniformity of produced plants as a result of inoculation are a major incentive to introduce (V)AM in such techniques, as investigations of our institute have demonstrated with oil palm. Taking these benefits of mycorrhiza into consideration it is likely that in the future inoculation with (V)AMF, will be an integral biological measure of most micro-propagation systems, but a carefully selected and produced (V)AMF inoculum based on relevant research is urgent needed.

II- Phosphate-solubilizing bacteria:
The utilization of *Bacillus megaterium* var. *phosphaticum*, *Pseudomonas fluorescens*, *Pseudomonas putida*, *Pseudomonas stukerii*, and *Citrobacter freundii* alone and combined, or in combination with (V)AMF, was investigated.

B- Nitrogen nutrition of plants

The utilization of the „Biological Nitrogen Fixation, BNF“, by *Rhizobium* and *Bradyrhizobium* bacteria with legumes, and associative and free-living bacteria (*Azospirillium*, *Azotobacter*, *Beijerinkia* and *Derxia)* with gramineous crops (cereals and millets), was tested.

<u>I- Interactions between N_2-fixing bacteria, (V)AM mycorrhizal fungi, and phosphate-solubilizing bacteria</u>

The growth and the P and N uptake of several tropical plant species could be improved by the inoculation with various combinations of these effective (useful) microorganisms (EM).

<u>II- Azolla/Anabaena-Symbiosis in flooded rice</u>

Generally, the most effective source of fixed N_2 is the *Azolla-Anabaena* complex. Known additional benefits derived from *Azolla* intercropping are weed control, water saving and temperature regulation. These benefits were recognized centuries ago by Chinese and Vietnamese farmers.

Integrated soil fertility management is essential if soil productivity is to be improved or sustained. With security in rice production assured through intensification, many scientists, policy makers and farmers are rethinking the long term approach to food security, leading to crop diversification and integrated soil fertility management practices.

The problem is how to integrate the traditional practices of the utilization of *Azolla* fern in wetland rice with modern technologies such as fertilizer use, without loosing the benefits of the BNF by this symbiosis.

Information from literature indicates that the Azolla-rice systems are capable of increasing by an average of 20%. An additional 20% can be gained by combining *Azolla* (5-6t/ha) with an application of 30 kg/ha of mineral N. The results of our greenhouse experiments showed that *Azolla* is capable of greatly reducing the losses of ammonia through volatilization, which often may reach 30-40% of the applied N (mostly in form of urea), largely by preventing the increase in pH which observed in the absence of *Azolla* as a result of algal activity. This benefit far outweighed any possible competition for the applied N and may be as important as the contribution of N to the soil/plant system from *Azolla* through its symbiosis with *Anabaena*.

Conclusions and outlook

It is increasingly evident that declining soil fertility is the most widespread and dominant limitation on yields and sustainability of cropping systems. Technologies that can be used to sustain soil fertility are still relatively scarce, especially for smallholders. If researchers and farmers do not make a more vigorous attempts to address the extensive decline in soil fertility, the productivity of the farming systems will fail to increase. The following propositions of main criteria should be considered:

- Some general features of the above mentioned biological measures are known, but their role in sustaining soil productivity under stress growth conditions such as those in humid or dry regions has not been studied effectively,
- It is very important to develop improved techniques for propagation of the obligate symbiotic (V)AM fungi and inoculation with introduced highly efficient fungal spieces and/or strains, and guide-lines for predicting cost effectiveness of inoculation with single or mixed fungi,

- Many kinds of interactions are still unknown in the rhizo-/mycorrhizosphere for different ecosystems. Mycorrhizal fungi are but a part of the microbiological community in the soil and must be considered in this context. Thus, adapted cultivation systems and crop rotations have to be developed concerning legumes, cereals and other non-legumes in sole and mixed cropping,
- For minimizing the inputs in form of chemical fertilization and pest control, maximizing the benefits of inoculations with (V)AM fungi alone or in combinations with other useful soil micro-organisms such as N_2-fixing bacteria and/or phosphate-solubilizing bacteria (bio-fertilizers) is urgent needed,
- Close co-ordinations between soil biologists/microbiologists, plant breeders, agronomists, soil reclamation specialists, producers and consumers of inocula and extension service stations is of great importance for making full use of the biological measures in practice,
- Biological fertility and sustainability depend by far on soil organic matter which is often used as index of soil fertility; adapted crop rotation help in addition of organic matter in the soil,
- As mentioned above, most of the biological measures have deep roots into ancient centuries, mainly the use of different kinds of organic matter as store and/or resource of most biological components; nowadays the benefits of these measures must be precised and their utilization should be adapted to the biotic and abiotic stress conditions of the tropics and subtropics.

„ Building on the past for a better future“

The Institute for „Crop and Animal production in the tropics“, in Goettingen, is engaged in several projects for improving the productivity of the poor marginal soils frequently found in the humid and semiarid/arid tropics, by using these biological measures as „bio-fertilizer“ and/or a tool of sustainable agricultural systems.

Yield of cotton in relation to plant density

Abdel-Aziz Galal Abdel-Hafez

Tanta University
33516 Kafr El-Sheikh, Egypt

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 × 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 × 25 cm × 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.