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The Efficiency of Clonal Selection as A Breeding Program to Improve Chinese Garlic Cultivar (*Allium sativum* L.)

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ABSTRACT

The current study was conducted in the period from 2014/2015 – 2020/2021, by conducting six cycles of clonal selection with the aim of restoring and improving the characteristics of garlic (Chinese cultivar) grown under Egyptian conditions. These field experiments were carried out at the Experimental Station Farm (at Abies), the Faculty of Agriculture, Alex. Univ. The estimation of both the coefficient of variation and the range reflected the extent of the variation in the original population. The values of the coefficient of variation ranged from 25.00 to 44.11%. Nine clones were reached by the end of the selectorial program, which were evaluated during the seventh season along with the original population. In general, the selected clones of the Chinese garlic cultivar showed significant superiority compared to the original population for all the selected traits. Among the most prominent clones that showed superiority for the characteristics of bulb weight, cloves weight per bulb, as well as the productivity; three clones C5, C4, and C3 compared to the rest of the selected clones as well the original population. While the two clones C1 and C8 showed the highest average clove weight and the lowest cloves number per bulb compared to all the tested entries. On the contrary, the original population gave the lowest bulb weight, the lowest cloves weight per bulb, the highest orbits number per bulb, and the highest cloves number per bulb with minimum clove weight also produced the lowest total yield per feddan.

***Keywords*:** Garlic, *Allium sativum* L., Chinese cultivar, clonal selection, evaluation.

INTRODUCTION

Garlic (*Allium sativum* L.) that has a chromosome number of 2n = 2x = 16; belongs family Alliaceae; is one of the oldest horticultural crops in human history (García Lampasona *et al*. 2003) and is an important vegetable that has its origin in central Asia (Chen *et al*. 2013) where garlic grows wild. The first record of growing garlic date 4000 years ago, since then has become one of the most popular crops worldwide, both as a medicine and a vegetable. From garlic, its variety of products like garlic paste, garlic powder, garlic oil, garlic tablets, dehydrated garlic, etc. could be prepared for commercial use. Garlic bulbs can be used against diabetes, hypertension, cholesterol, cell platelet aggregation, viral, microbial, and cancer (Sandrakirana *et al*. 2020). The economic importance of the garlic crop has increased considerably in the entire world in recent years. Therefore, increasing garlic yield and improving bulb quality is an essential aim for both growers and consumers.

The cultivation of garlic in Egypt for a long time relied on the cultivation of local garlic (Egyptian cultivar), which was at the forefront for a long time. However, due to the lack of interest in the production of seeds of this cultivar and the lack of improvement for long periods; there was a significant deterioration in its productive qualities, as well as the quality of the bulb, which became small with small and thin cloves. Accordingly, many efforts were made to introduce high-yielding garlic cultivars to Egypt to overcome the problem of low yield and bulb quality. All this led to resorting to importing new cultivars, the most important of which are Chinese cultivars, which over time have become a head of Egyptian garlic in terms of export as well as at the level of local consumption.

Although garlic is asexually propagated and reproduces only by the vegetative way, shows wide morphological and agronomic variations over time in color, size of bulb, plant height, number and size of the cloves, days to harvesting, storage capacity, dormancy, and adaptation to agroclimatic situations (Mario *et al*., 2008). Similar to the deterioration of the Egyptian cultivar of garlic, which was widely grown in Egypt in the past; the same deterioration was repeated with the Chinese cultivar currently grown. Where, the emergence of clear differences in the Chinese cultivar, whether in the color and size of the bulb or cloves number per bulb and weight of the cloves.

Accordingly, the development and recommendation of high-yielding and quality cultivars are very essential to enhance the production and farmers' preference for garlic cultivation. Due to asexual propagation, the clonal selection is an important breeding method to improve garlic, and little work has been done on the improvement of different traits which are prerequisites. Therefore, this study sought in an attempt to restore and improve the head and productivity characteristics of the Chinese garlic variety, which is currently circulating in Egyptian agriculture, by conducting six cycles of vegetative progeny selection.

MATERIALS AND METHODS

The present study was carried out at the Experimental Station Farm, in Abies region, the Faculty of Agriculture, Alexandria University, Alexandria Governorate, Egypt, during the seven consecutive winter

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seasons of 2014/2015 to 2020/2022. The materials of garlic (Chinese cultivar) were collected from farmers from different parts of Egypt. Six cycles of the clonal selection program were conducted, with the aim of restoring and improving the characteristics of garlic (Chinese cultivar) grown under Egyptian conditions.

Proper cloves were planted at spacing 7 cm of both sides of ridges spaced 70 cm apart. All other agricultural practices (weeds control and irrigation, etc.), were performed when they were required and as recommended for commercial garlic production. After harvest, plants were submitted to the curing process for 30 days in a greenhouse, and afterward, bulbs were cleaned.

Statistical analysis

The mean values of each character under the study were computed and subjected to analysis of variance, following the procedures described by Al-Rawi and Khalf-Allah (1980), using Co-Stat computer software program (2004).

The following Figs 1,2, and 3 shows the steps that were followed to conduct this research to reach the desired results.

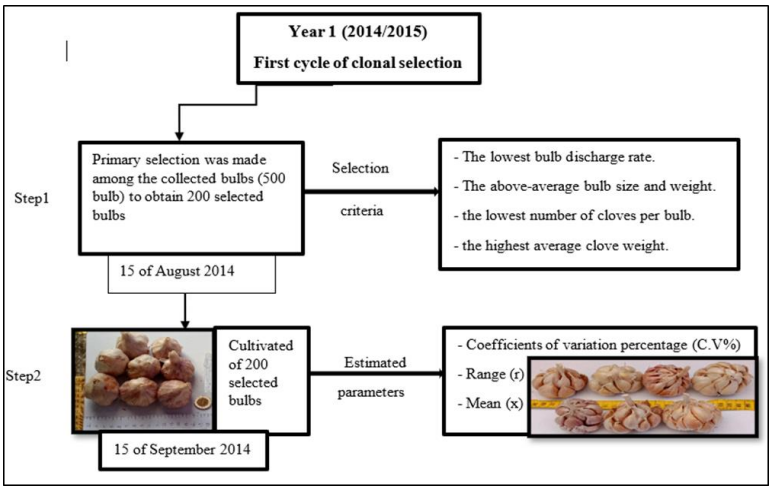

Fig. 1. The first season of the selectorial program.

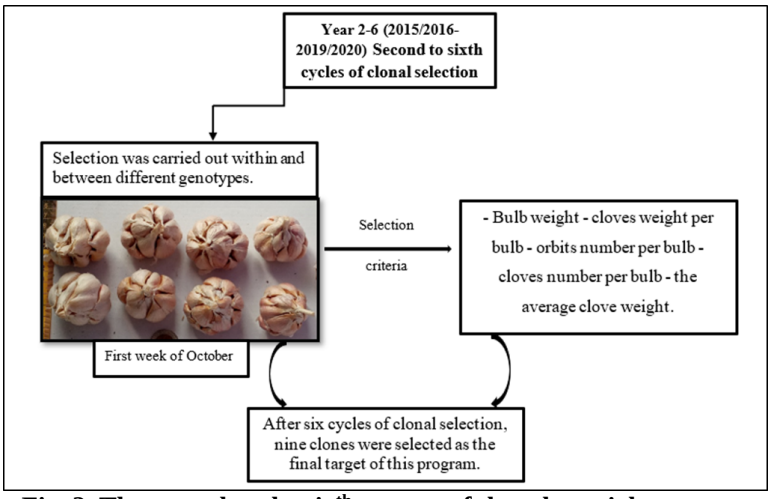

Fig. 2. The second to the sixth seasons of the selectorial program.

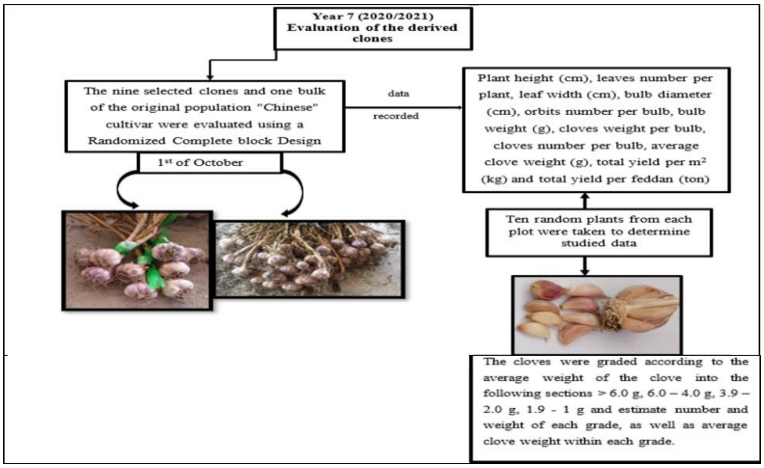

Fig. 3. The seventh season of the selectorial program.

RESULTS AND DISCUSSION

Estimates of variability parameters

Data in Table 1 and Fig. 4 shows the extent of differences within the original population (Chinese cultivar) represented in the estimation of mean, range, and coefficient of variation (C.V%) for some of the important bulb traits, namely orbits number per bulb, bulb weight (g), cloves weight per bulb (g), cloves number per bulb, average clove weight (g). By estimating the coefficient of variation, the characteristic of bulb weight reflected the highest value of the coefficient of variation (44.11%), followed by cloves weight per bulb (40.13%), then cloves number per bulb (30.00%). While the trait orbits number per bulb recorded the lowest coefficient of variation (30.00%), it preceded average clove weight (30.13%). Also, the studied traits reflected a wide range when estimating the range values as shown in Table 1. The same results were given by Saker, (1996) and Mostafa *et al*. (2020), who stated that the range of the mean values showed that the garlic Chinese genotypes reflected high degree of variation in all studied traits. Also, many investigators studied variations of bulb characteristics among garlic genotypes among them Hassan (2002), Dawood *et al*. (2011), Ankur and Tiwari (2013), Bagchi *et al*. (2020). Based on those differences that were reflected in those estimates; there will be a high probability of selecting new and distinct genotypes, whether in productivity or bulb specifications. Accordingly, it is possible to start the proposed selectorial program, which is the program for selecting clones, which is the appropriate program for vegetative crops.

Table 1. Mean (X), rang (r) and coefficient of variation (C.V%) of some bulb traits of Chinese garlic cultivar.

Traits / Parameters	Bulb weight (g)	Cloves weight per bulb (g)	Cloves No. per bulb	Average clove weight (g)	Orbits No. per bulb
Mean (X)	30.00	28.16	15.00	2.29	3.50
Rang (r)	10.56 – 70.18	6.00 – 62.00	5.00 – 38.00	1.00 – 5.45	2.00 – 4.00
Coefficient of variation (C.V.%)	44.11	40.13	30.00	29.60	25.00

Fig. 4. The degree of variation within the original population of Chinese garlic cultivar, whether in bulb color, bulb size, cloves number per bulb, average clove weight.

Evaluation of the nine selected clones after six cycles of clonal selection program

Vegetative growth characters

Data presented in Fig. 5 show clearly that there were significant differences among the selected clones as well as the original population (Chinese garlic cultivar) respecting plant height (cm), leaves number per plant, and leaf width (cm). In this concern, clone C4 was the best for plant height (75.13 cm) and leaves number per plant (10.75), followed by clone C7 for plant height (74.15 cm), and clone C9 for leaves per plant (10.61), while the clone C6 for leaf width (3.00 cm). On the other side, the Chinese garlic cultivar, original population, recorded significantly the lowest mean values for the three vegetative growth characters: 60.14 cm for plant height, 9.52 for leaves number per plant, and 2.25 cm for leaf width. These results were closer with the finding of Abouziena and El-Saeid (2013), and Anwar *et al*. (2017) when evaluated some clones of Chinese garlic.

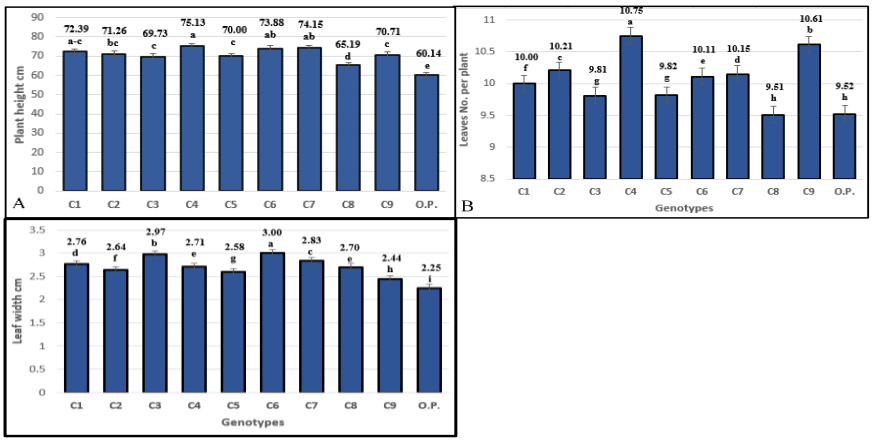

Fig. 5. Improvement of vegetative growth characters of Chinese garlic cultivar, after six cycles of clonal selection.

(A) Plant height (cm), (B) Leaves number per plant and (C) Leaf width (cm).

Error bars represent the standard deviation of the mean.

***Means in each column, followed by the same alphabetical letter(s) in common, are significantly different at 0.05.**

Yield and bulb characteristics

During this research, the garlic selection program relied on improving the bulb characteristics, which deteriorated during the recent years for the Chinese cultivar. The most important bulb traits that were selected for improvement were orbits number per bulb, bulb diameter (cm), bulb weight (g), and cloves weight per bulb (g), which is illustrated in Figs. 6 and 7. For the characteristic of orbits number per bulb; the original population recorded the highest significant mean value for this trait, while the five selected clones; C1, C5, C6, C7, and C8 reflected the lowest significant mean value for it (2.00). Where the decrease of this trait value represents the desired direction of improvement, which is reflected in the increase in the size of the clove.

As for the three traits, which are bulb diameter (cm), weight bulb, and cloves weight per bulb (g); Fig. 6 B, the selected clones did not show any significant differences between one another with respect to the trait of bulb diameter, which ranged between 7.70 to 6. 00 cm for the two clones C5 and C1, respectively. While the original population showed significant differences compared to the two selected clones C3 and C5, it also recorded the lowest mean value for the same trait (5.16 cm). The original population also recorded the lowest significant mean values for the two traits of bulb weight and cloves weight per bulb (40.18 and 35.22 g, respectively) as shown in Fig. 6C and 6D. The selected clones varied among themselves with regard to the two traits, bulb weight, and cloves weight per bulb, where clone C5 gave the highest mean values for both traits (82.53 g - 79.76 g), respectively, followed by the two clones C3 (81.22 and 79.25 g) and C4 (79.22 and 77.61 g) without any significant differences between one another. In addition, all the selected clones were significantly distinguished with respect to the mean values of these two traits compared to the original population. These results are confirmed with Dawood *et al*. (2011) and Anwar *et al*. (2017), who compared Chinese garlic cultivar with other genotypes of garlic.

As for the two characteristics, cloves number per bulb and average clove weight per bulb; it is considered one of the most important marketing characteristics that the consumer is looking for, which was one of the important features that distinguished the Chinese garlic cultivar from the Egyptian cultivar that was widespread in Egyptian agriculture. Therefore, the focus during this study was to restore those traits that had deteriorated over time through selection by reducing cloves number per bulb while increasing average clove weight per bulb. The results highlighted the extent of improvement that took place in these two traits, as shown in Fig. 8 and 9. Clone 8 reflected the highest degree of improvement compared to the different clones as well as the original population; it was followed by clone C1 with the lowest cloves number per bulb (12 and 13 cloves per bulb), which was accompanied by an increase in average clove weight per bulb, as the two clones gave the highest significant value of the average clove weight (5.52 g). On the contrary, the original population recorded the lowest significant value for the average clove weight per bulb (2.31g); while it did not differ significantly from the two clones C6 and C7 regarding cloves number per bulb. These results can be supported by Omar and Abou Hadid (1992), Saker (1996), Zepeda (1997), Zepeda *et al*. (1997).

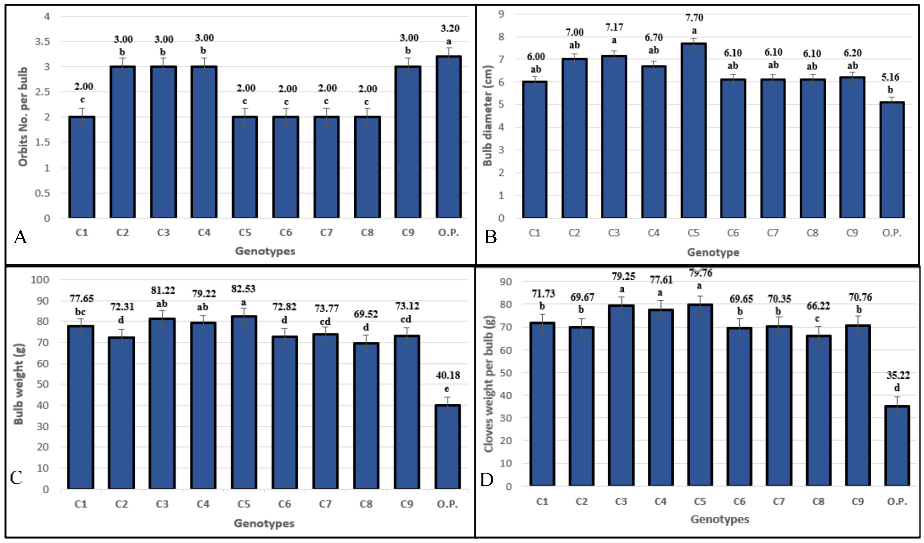

Fig. 6. Improvement of some bulb characteristics of Chinese garlic cultivar, after six cycles of clonal selection.
(A) Orbits number per plant; (B) Bulb diameter (cm); (C) Bulb weight (g) and (D) Cloves weight per bulb (g).
Error bars represent the standard deviation of the mean.
***Means in each column, followed by the same alphabetical letter(s) in common, are significantly different at 0.05.**

Fig. 7. (A) Selected clones (B) Original population (Chinese garlic cultivar).

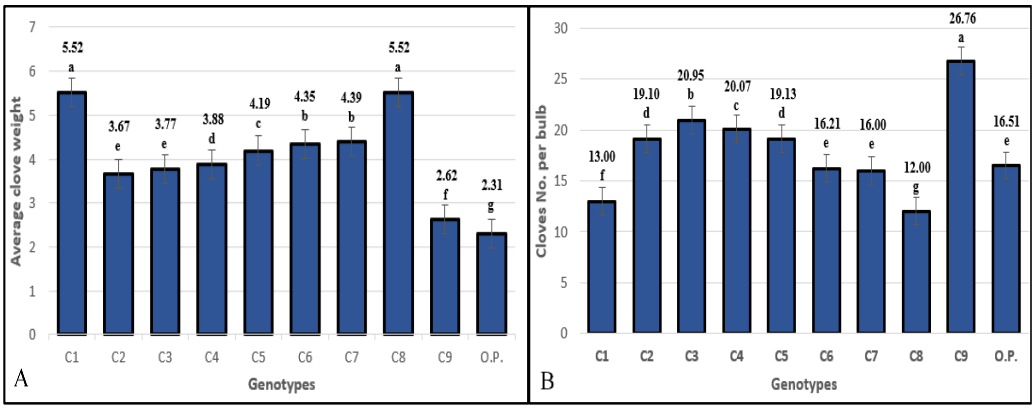

Fig. 8. Improvement of some bulb characteristics of garlic, Chinese cultivar, after six cycles of clonal selection.
(A) Average clove weight and (B) Cloves number per bulb.
Error bars represent the standard deviation of the mean.
***Means in each column, followed by the same alphabetical letter(s) in common, are significantly different at 0.05.**

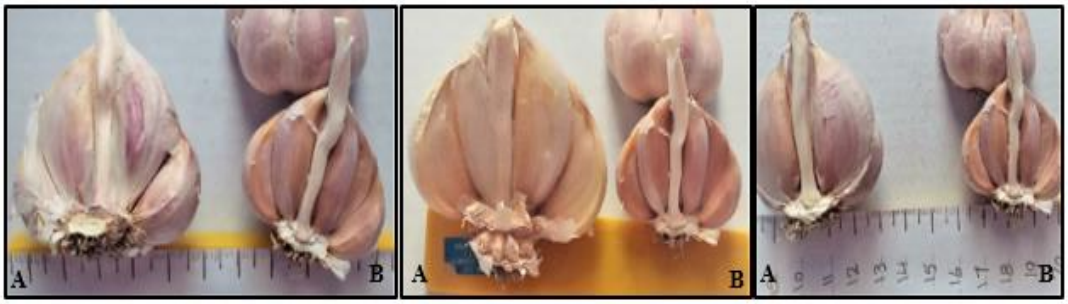

Fig. 9. Show cloves number per bulb and average clove weight.
(A) selected clones (B) original population (Chinese garlic cultivar)

The results shown in Fig. 10 and Table 2, reflect the gradation of the cloves inside the bulb according to the average clove weight into four sections: >6.0, 4.0-6.0, 3.9-2.0, and 1.9-1.0 g. Based on that grading, clone C1 recorded the largest cloves number with a weight of >6.0 g, with an average clove weight of 7.53 g (Fig. 10B). Clone C1 also contained 8.25 cloves in the case of grading 4.0-6.0 g; while it did not contain cloves less in weight than that; Meaning that the whole bulb did not contain cloves less than 4.0 g in weight. On the contrary, neither the bulbs of the original population nor clone C9 contained any cloves in the first grade (>6.0 g), and they were also significantly less in the number of cloves for the second and third gradations (4.0-6.0 and 3.9-2.0 g). While the original population contained the highest cloves number under the fourth grading (1.9-1.0 g) with an average weight of 1.48 g for the clove under that grading, as shown in Table 1 and Fig. 10. The results also showed that all selected clones except clone C9 as well as the original population did not contain any cloves under the fourth grading (1.9-1.0 g). From the above, it can be summarized that all the selected clones except for C9 had no average clove weight less than 2.0 g and that most of the cloves were located under the first and second grading (>6.0 and 4.0-6.0); whereas the original population bulbs did not contain cloves under the first gradation (> 6.0 g). While most of the bulb cloves are located under the third grade (3.9-2.0 g), with an average weight of a clove that is relatively low (2.50 g).

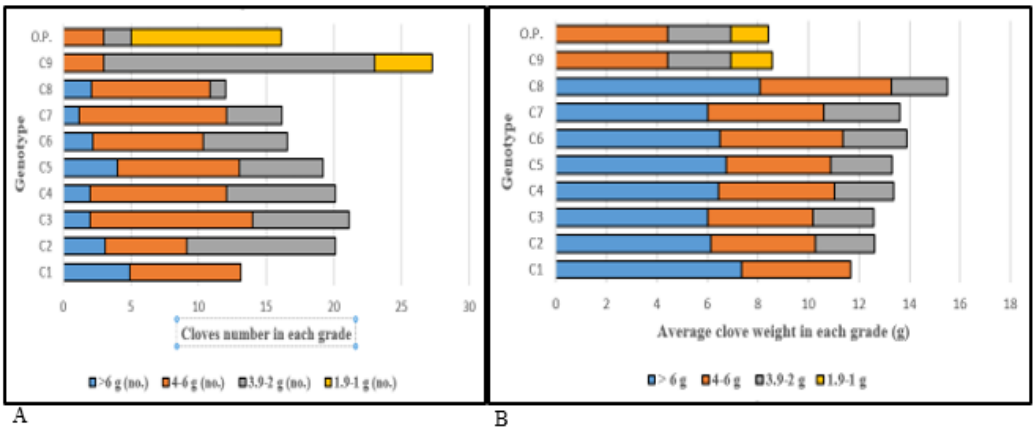

Fig. 10. Improvement of some bulb characteristics of garlic, Chinese cultivar, after six cycles of clonal selection.
(A) Cloves number in each grade (B) Average clove weight in each grade (g).

Table 2. Gradation of the cloves inside the bulb according to the average clove weight

Grades	>6.0 g		6.0-4.0g		3.9-2.0 g		1.9-1.0 g	
Genotypes	NCG	ACWG	NCG	ACWG	NCG	ACWG	NCG	ACWG
C1	4.90 a	7.35 b	8.25 bc	4.33 d	0.00 i	0.00 e	٠0.0 c	0.00 c
C2	3.10 c	6.13 c	6.00 c	4.15 e	11.00 b	2.34 bc	0.00 c	0.00 c
C3	2.00 d	6.00 c	12.00 a	4.18 e	7.13 d	2.40 bc	0.00 c	0.00 c
C4	2.00 d	6.44 c	10.08 ab	4.60 c	8.03 c	2.33 bc	0.00 c	0.00 c
C5	4.00 b	6.73 bc	9.00 a-c	4.15 e	6.22 e	2.43 bc	0.00 c	0.00 c
C6	2.21 d	6.49 c	8.14 bc	4.87 b	6.20 e	2.53 b	0.00 c	0.00 c
C7	1.15 e	6.00 c	10.92 ab	4.62 c	4.10 f	3.00 a	0.00 c	0.00 c
C8	2.06 d	8.09 a	8.80 a-c	5.20 a	1.14 h	2.20 cd	0.00 c	0.00 c
C9	0.00 f	0.00 d	3.02 d	4.43 d	20.00 a	2.50 b	4.25 b	1.65 a
O.P.	0.00 f	0.00 d	4.43 d	4.43 d	2.00 g	2.50 b	11.14 a	1.48 b

Values having the same alphabetical letter (s) within each column, don't significantly differ from one another, using Duncan's multiple range test at 0.05 level of significance. NCG: Number of cloves in grade ACWG: Average clove weight in grade

Regarding the characteristic of productivity, whether for the unit area or feddan, it was related to the characteristics of bulb weight and cloves weight per bulb. The clones C3, C4, and C5 recorded the highest bulb weight as well as the highest cloves weight per bulb, which, accordingly, reflected the highest yield of the experimental unit and the highest yield per feddan as illustrated in Fig. 11. Where the productivity of the unit area almost doubled, which was represented by the values of 19.88, 19.37, and 19.22 kg per unit area, compared to the original population (10.23 kg). Based on the previous results, whether for bulb traits or productivity traits, it can be confirmed that the six successive selection cycles of clonal selection were able to retrieve the traits of the degraded Chinese cultivar from the average clove weight per bulb, cloves number per bulb, as well as bulb weight, with improved productivity per unit area.

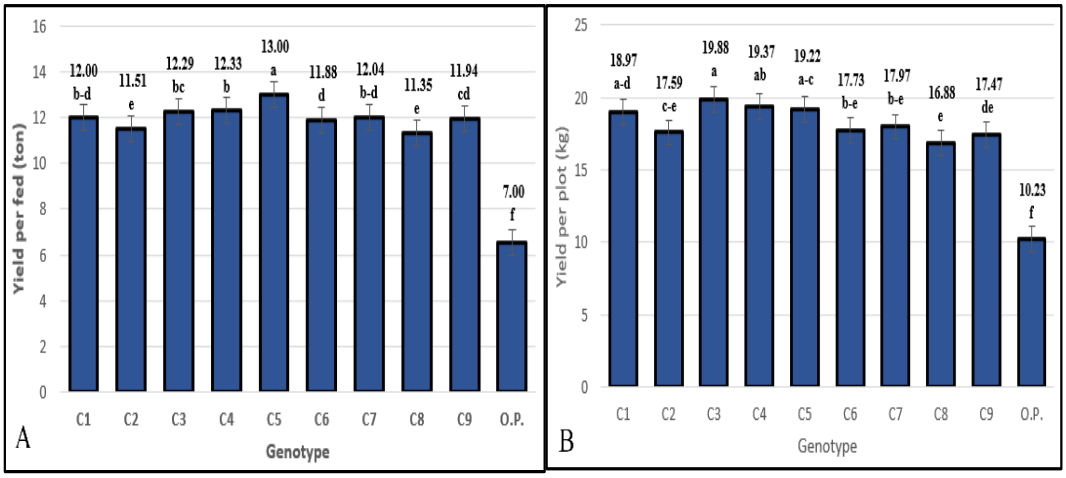

Fig. 11. Improvement yield of Chinese garlic cultivar, after six cycles of clonal selection.
(A) Total yield per feddan (B) Yield per plot.
Error bars represent the standard deviation of the mean. - Unit area = 8.40 m^2
***Means in each column, followed by the same alphabetical letter(s) in common, are significantly different at 0.05.**

CONCLUSION

Based on the previously presented results, this can be summarized in the fact that the application of clonal selection program for six cycles improvement of the characteristics of the Chinese garlic cultivar by reaching nine distinct clones for all the traits under study, whether characteristics of vegetative growth or bulb characteristics as well as productivity. Accordingly, it can be recommended to evaluate these promising new clones in more than one season, as well as many governorates where garlic cultivation is good, to recommend the best ones.

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كفاءة انتخاب السلالة الخضرية كبرنامج تربية لتحسين صنف الثوم الصيني

عصام سعيد عبد القادر حلمى و انتصار ابراهيم مسعود راغب

قسم الخضر، كلية الزراعة، الاسكندرية

أجريت الدراسة الحالية خلال سبعة مواسم متتالية فى الفترة من ٢٠١٤ - ٢٠٢٠ عن طريق إجراء برنامج انتخابى، ست دورات من انتخاب السلالة الخضرية، بهدف استعادة وتحسين خصائص الثوم (الصنف الصيني) المزروع في ظل الظروف المصرية. أجريت هذه التجارب بمزرعة المحطة التجريبية (أبيس) بكلية الزراعة جامعة بالإسكندرية. وقد عكس تقدير كلا من معامل الاختلاف والمدى درجة التباين في العشيرة الأصليه ، خاصة بالنسبة لسمات الرأس المدروسة ، وهي وزن الرأس ، ووزن الفصوص للرأس ، وعدد المدارات للرأس، وعدد الفصوص للرأس ، متوسط وزن الفص. حيث تراوحت قيمة معامل الاختلاف الذي تم تقديره للصفات السابقة بين ٢٥,٠٠ – ٤٤,١١٪ بعد ست دورات من الانتخاب. تم الوصول لتسعة سلالات خضرية بنهاية البرنامج الانتخابى، والتى تم تقييمها خلال الموسم السابع الى جانب العشيرة الاصلية. أظهرت نتائج التقييم بشكل عام أن جميع السلالات المنتخبة من الصنف الصينى قد عكست تفوقًا واضحًا وكبيرًا مقارنة بالعشيرة الأصلية لجميع الصفات المدروسة ، سواء كانت نموًا خضريًا أو خصائص الرأس أو إنتاجية. من بين أبرز السلالات التي أظهرت تفوقًا لخصائص وزن الرأس ، وزن الفصوص للراس ، وكذلك الإنتاجية ، السلالات المنتخبة C5، C4، C3 مقارنة بباقي السلالات، بالإضافة إلى العشيرة الاصلية. بينما أظهر السلالاتان C1 و C8 أعلى متوسط وزن للفص وأقل عدد من الفصوص لكل رأس مقارنة بجميع التراكيب المختبرة. على العكس من ذلك ، فإن الصنف الصيني ، أي العشيرة الاصلية ، سجلت أقل وزن للبصلة ، وأقل وزن فصوص للرأس ، وأعلى عدد من المدارات لكل رأس ، وأكبر عدد من الفصوص للرأس مع أقل وزن للفص ، كما أنتج أقل محصول للفدان.