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Sayed Gebril
Saddam O. Ahmed Al-Amir
Hazem A. Obiadalla-Ali
Horticulture Department
Faculty of Agriculture
Sohag University
Sohag
Egypt

Abdelnasser G. Mohamed
Onion Research
Field Crops Research Institute
Agricultural Research Center (ARC)
Giza
Egypt

Corresponding author:
Sayed Gebril
sgebril@agr.sohag.edu.eg

Mass Selection and Npk Management Reduce Bolting and Bulb Doubling In Giza 6 Mohassan Onions (*Allium Cepa L*)

Sayed Gebril, Saddam Omran Ahmed Al-Amir, Abdelnasser Gamal Mohamed and Hazem Abd El-Rahman Obiadalla-Ali

Abstract

Egypt is key producer and exporter of dry onion globally. One of the best performing varieties in Upper Egypt that is very desirable for exportation is Giza 6 Mohassan. However, local farmers producing the seeds of this variety often do not follow proper seed production practices, leading to increased bolting (premature flowering) and bulb doubling over time. This investigation examines the efficacy of mass selection practiced by farmers against bolting and bulb doubling in improving onion bulb quality of Giza 6 Mohassan and also, to test the effect of NPK level on the newly selected genotypes. Two cycles of mass selection as practiced by farmers were applied to locally produced Giza 6 Mohassan (base population) collected from farmers' fields. Our results showed that mass selection decreased inside doubling by 4.45% and 7.9% in the first and second cycles, respectively, and overall, by 12% over two cycles. Outside doubling was reduced by 12.1% in first cycle and by 34% in the second cycle, with an overall decrease of 34.41% over two cycles. Bolting was reduced by 44.1% and 15% in the first and second cycle, respectively, with a total reduction of 53.94% over two cycles. High levels of NPK reduced bolting but increased bulb doubling, while also increasing yield and marketable yield. These findings indicate that mass selection significantly improves onion bulb quality and reduces bolting and doubling rates. High NPK enhances yield, but it needs to be managed accurately to avoid increasing bulb doubling.

Keywords: Plant breeding, Egyptian onion variety, fertilization, premature flowering, bulb quality and yield

INTRODUCTION

Onion is an important vegetable and an indispensable culinary commodity in Egypt and all over the world. It is consumed fresh, cooked, pickled, green and mature. Egypt is a key producer and exporter of both green and dry onion in the world. Sohag governorate is major region in dry onion production in Egypt. It has the advantage of producing early onion and supply the market with onion in February and March and sometimes in late January. Giza 6 Mohassan is an Egyptian onion variety produced by the agricultural research center ARC in Giza. The variety is one of the best-performing varieties in Egypt, particularly in Sohag and all Upper Egypt. Giza 6 Mohassan has high quality traits such as roundness, average size, bronze color as well as large number of scales and high storability that make the variety very desirable for exportation. However, the extensive use of the variety and the production of seed by local farmers without adhering to the proper seed production practices such following the isolation distances or avoiding the physical mix with other varieties and genotypes led to deterioration of the of bulb quality. Therefore, the inside and outside doubling increased, the bolting (premature flowering) increased as well as the overall quality of the bulb decreased. Mass selection, a traditional plant breeding method first practiced by farmers long time ago, has significantly contributed to the improvement of crop varieties over centuries. This technique involves selecting and propagating plants with desirable traits from a larger population, ensuring that these favorable characteristics are passed on to the next generation. Studies have shown that mass selection has led to enhanced yield, disease resistance, and adaptability to local conditions. For instance, farmers in Ethiopia have successfully used mass selection to develop barley varieties that are more resistant to drought and pests (Teshome et al., 2001). Similarly, in India, mass selection has been instrumental in improving the genetic diversity and resilience of rice crops (Rana et al., 2007). Riviere et al (2015) investigated the efficacy of mass selection practiced by French farmers on improving wheat genotypes. They found that mass selection improved some traits such thousand kernel weight and grain weight per spike. This method is valuable tool in crop improvement, enabling farmers to maintain and enhance the genetic resources of their crops (Ceccarelli, 1994). Mass selection can significantly decrease the incidence of bolting, which negatively impacts bulb formation (Brewster, 2008). Additionally, studies have shown that mass selection helps in reducing bulb doubling (Currah and Proctor, 1990). For instance, a long-term study conducted in Spain demonstrated that through rigorous mass selection, the frequency of bolting in onion crops was reduced by over 40% and bulb doubling by 30% (Villanueva and Esteban, 2011). Gamie, (2000) found that the bulb doubling decreased after on cycle of mass selection. The application of NPK fertilizers significantly influences the vegetative growth of onions, impacting attributes such as plant height, leaf number, and overall biomass. Nitrogen is particularly crucial as it promotes leaf growth and enhances photosynthetic activity, leading to increased vegetative vigor (Brewster, 2008). Phosphorus is essential for root development and energy transfer within the plant, while potassium improves overall plant health and resistance to diseases (Bachmann & Earles, 2000). Studies have demonstrated that balanced NPK fertilization leads to optimal growth conditions for onions. For instance, research conducted by Shukla and Maurya (2008) found that onions treated with a balanced NPK fertilization exhibited significantly higher plant height and leaf number compared to those receiving suboptimal or imbalanced fertilization. It an established fact that the excessive supplies of NPK especially nitrogen promotes bulb doubling incidence. On the other hand, an inadequate supply of NPK promotes bolting. Hassan (1983); Abdissa et al. (2011); Al-Fraihat and Ahmed (2009) found that NPK high level increases bulb doubling. Abdissa et al. (2011) stated that high NPK level decreased bolting %. Al-Fraihat and Ahmed (2009) on the other hand found that high level of NPK increases bolting %. It is a well-known fact that high level of fertilizers and nitrogen especially promotes growth and the incidence of onion doubling, while low level of nitrogen promotes plant bolting. A balanced NPK fertilization has been shown to minimize the occurrence of bolting and bulb doubling. For example, a study by Rizk and Shaheen (2013) demonstrated that optimal levels of NPK significantly reduced bolting rates in onions, suggesting that a balanced nutrient supply can help manage this issue. Similarly, a study by El-Bassiony et al. (2010) indicated that appropriate NPK fertilization reduced the frequency of bulb doubling, leading to a higher percentage of single bulbs. These findings indicate the importance of balanced NPK fertilization in decreasing bolting and bulb doubling, thus improving the overall quality and yield of onion crops. NPK significantly affects the yield and its components in onions, such as bulb size, weight, and overall productivity. Studies have shown that balanced NPK fertilization leads to substantial improvements in onion yield. For example, Singh et al. (2010) reported that optimal NPK levels significantly increased the number and weight of marketable bulbs, highlighting the importance of these nutrients in maximizing yield. Similarly, research by Ayub et al. (2010) demonstrated that onions fertilized with appropriate NPK ratios exhibited improved bulb size and total yield compared to those an inadequate or excessive nutrient supply. The objectives of this study are two folds. The first one is to test the efficacy of mass selection as practiced by farmers in improving the bolting and doubling in onion. The second one is to test the effect of NPK level on the performance and quality of the selected genotypes.

MATERIALS AND METHODS

1. Experimental design and plant material

This experiment was conducted in the Experimental Farm of the Faculty of Agriculture, Sohag University, Elkawthar suburban, Sohag, Egypt in the seasons of 2017-2023. The soil of the experiment was reclaimed sandy where the soil was amended by addition of clay residue more than twenty years ago. Giza 6 Mohassan bulbs collected from Sohag governorate. Bulbs free of inside and outside doubling and bolting were selected to from the base population and produce the base population seeds, S0. Three genotypes S0, S1 and S2 represent three populations resulted from mass selection program for the improvement of Giza 6 Mohassan variety. S0 represent the initial (base) population, S1 represent the population resulted from the first cycle of mass selection and S2 represent the population resulted from the second cycle of mass selection. Two cycles of mass selection were carried out to improve variety Giza 6 Mohassan from bulb doubling and bolting which accumulated over years. The two mass selection cycles were carried out against the inside doubling, outside doubling and bolting simultaneously. The selection process (breeding program) started in 2017 by collecting bulbs of Giza 6 Mohassan from local farmers in Sohag governorate to form the base bulb population (B1). This primary/base bulb population (B1) was planted in November 2017 to produce the base population seed (S0) in April 2018. Seeds of S0 population were planted in August and transplanted in October 2018. At the end of growing season in April 2019, bulbs free of inside and outside doubling and bolting were selected and planted in November 2019 to get the seeds of S1 population in April 2020. In August 2020 the seeds of S1 were planted in the nursery and transplanted in October 2020. At the end of the growing season in April 2021, bulbs free of inside doubling, outside doubling and bolting were selected and kept until November. In November 2021 selected bulbs were planted to produce S2 seeds in April 2022. Seeds of S0, S1 and S3 were kept in the fridge at 5 ^{o}C to be cultivated simultaneously in 2022-2023 season. The performance of the three populations S0, S1 and S2 resulted from Giza 6 Mohassan mass selection against inside doubling; outside doubling and bolting were tested under three levels of NPK. The fertilization quantities applied were: Nitrogen (90, 120 and 150 kg) in form of ammonium nitrate 33.5 % (268, 385 and 447 kg) form ABU-QIR FERTILIZES AND CHEMICAL INDUSTRIES CO. S.A.E., P_2O_5 (30, 45 and 60 kg) in form of modified mono phosphate 12.5 % (240, 360 and 480 kg) from Abu Zaabal Fertilizers & Chemical co. (A. Z. F. C.) and K_2O (25, 50 and 75 kg) in form of potassium sulfate (50, 100 and 150 kg). The first fertilization rate (T1) included 90 kg N, 30 kg

P_2O_5 and 25 kg K_2O, the second fertilization rate (T2) included 120 kg N, 45 kg P_2O_5 and 50 kg K_2O and the third fertilization rate (T3) included 447 kg N, 480 kg P_2O_5 and 150 kg K_2O. super phosphate was added once during soil preparation. Nitrogen was added three times in equal dosages; 21, 51 and 81 days after transplanting. Potassium was added once: 80 days after transplanting. The seeds of onion were planted in the nursery in September and transplanted in the permanent field in 21 November 2021. Unhealthy, dwarfed and yellow transplants were removed. Only transplant 12-15 cm height, healthy and free of diseases were used. The plots area was 10.5 m^2 including 5 rows. Each raw was 3 m length and 0.6 m width. The transplants were planted on both sides of the row at 10 cm between plants. Each plot contained about 300 plants ~ 30/m^2. All agricultural practices were followed as recommended.

2. Measurements

The following measurements were taken as follows:

The measurement was recorded on 5 -10 plants from each replicate (plot). The time of the measurements taken is indicated too. Measurements from 1-7 were taken at the end of growing season and immediately after the canopy fall over. Measurement from 10- 13were taking bulb pullout and curing after the canopy dried out.

1. Plant height (cm) measured from the base of swelling sheath to the top of the longest tubular blades.2. Number of leaves/plant.

3. Plant weight (gm): calculated as an average weight of plants after root removal.

4. Bulb weight (gm): calculated by subtraction of foliage fresh weight from plant fresh weight.

5. Neck diameter (cm)

6. Bulb diameter (cm): measured from the widest point of the bulb

7. Bulbing ratio: measured as follows:

$$Bulbing\ ratio = \frac{neck\ diameter\ (cm)}{bulb\ diameter\ (cm)}$$

8. Yield per feddan (tonnes): determined by weighing the harvested bulbs from each experimental plot and multiplied by 400.

9. Marketable yield %: Bulbs free from bolters, inside doubling, outside doubling and of diameter more than 4 cm is considered marketable and was measured as follows:

$$Marketable\ yield\ \% = \frac{weight\ of\ marketable\ bulbs}{weight\ of\ total\ bulbs} X100$$

10. Cull Bulbs %: bulbs with bolters, inside doubling, outside doubling and of diameter less than 4 cm is considered cull (unmarketable) and measured as follows:

$$Cull\ bulbs\ \% = \frac{weight\ of\ cull\ bulbs}{weight\ of\ total\ bulbs} X100$$

11. Inside doubling %: calculated as follows:

$$Inside\ doubling\ \% = \frac{number\ of\ bulbs\ with\ inside\ doubling}{number\ of\ total\ bulbs} X100$$

12. Outside doubling %: calculated as follows:

$$Outside\ doubling\ \% = \frac{number\ of\ bulbs\ with\ outside\ doubling}{number\ of\ total\ bulbs} X100$$

13. Bolting %: calculated as follows:

$$Bolting\ \% = \frac{number\ of\ bulbs\ with\ bolters}{number\ of\ total\ bulbs} X100$$

3. Statistical analysis:

The collected data on various parameters were statically analyzed using SAS package program. The experimental layout of the selection experiment was RCBD, and the experimental layout of the fertilization experiment was split plot. The mean for all the treatments was calculated and analyses of variances of all the characters were performed by F-variance test. Data obtained during the study were statistically analyzed and treatment means were compared using the Duncan’s multiple range tests (Gomez and Gomez, 1984)

RESULTS

Two cycles of mass selection were applied on variety Giza 6 Mohassan to reduce the bulb doubling and bolting which accumulated over years and to test the efficacy of mass selection practiced by farmers in improving onion genotypes. The selection process started with collecting of bulbs of Giza Mohassan from Sohag governorate to form the base population S0. Two cycled of mass section were carried out and resulted in S1the first selected population and S2 the second selected population. The three genotypes were tested under three levels of NPK fertilizers.

1. The efficacy of two mass selection cycles against bulb doubling and bolting on onion plant and bulb quality in Giza 6 Mohassan variety.

1.1. The impact of two mass selection cycles against bulb inside doubling, outside doubling and bolting (premature flowering) on traits of bulb inside doubling %, outside doubling %, bolting %, marketable yield % and cull yield %.

Data in figure 1 show that the two cycles of mass selection improved the undesirable traits of inside doubling, outside doubling and bolting, yet in varying degrees. The marketable yield % and cull bulbs %, also, indirectly improved. Figure 1(A) illustrates the data for inside doubling % as influenced by two cycles of mass selection. Surprisingly, the inside doubling % in the base genotype S0 was initially very high (24.89 %). The two cycles of mass selection slightly but not significantly improved the inside doubling in S1 and S2. The first and second cycles of mass selection decreased the inside doubling by 4.45 % and 7.9 % in S1 and S2 respectively. However, the overall inside doubling % decreased only by 3 % over two cycles of mass selection from 24.89 % to 21.89 % which means it decreased 12%. On the contrary of the inside doubling %, the outside doubling % was initially low (2.15%) in the base population S0. Two cycles of mass selection significantly improved the outside doubling % in S2 comparing to base genotype S0. The first cycle of mass selection decreased the outside doubling % in S1 by 12.1% and the second cycle of mass selection decreased the outside doubling % in S2 by 34%. The overall decrease in outside doubling was 0.74% over the two cycles of mass selection from 2.15 % to 1.41% which means it decreased by 34.41%. Data presented in figure 1 (B). The initial bolting % (early flowering) was low (1.52%), also, in the population base S0. Two cycles of mass selection highly but not significantly improved the bolting % in S1 and S2 as shown in figure 1(c). The first and second cycles of mass selection decreased the bolting % in onion plants by 44.1% and 15% in S1and S2 respectively. The two cycles of mass selection caused 0.82 % overall decrease in the bolting % which decreased from 1.52 % to 0.7 % which means it decreased by 53.94 %. Figure 1(D) and (E) show the marketable yield % and cull bulbs % improvement as affected by the indirect mass selection. Two cycles of mass selection of bulb doubling and bolting slightly but not significantly improved the marketable yield % indirectly. The first and second cycles of selection improved the marketable yield % by 3 % and 1.3 % in S1 and S2 respectively. The overall marketable yield increased by 4.3 % from 67.7 % to 72 %. The cull bulbs % decreased by 22% in the first cycle of selection and 0 % in the second cycle of selection. The overall reduction in cull bulb % was 0.97 % from 4.41 % to 3.44 %.

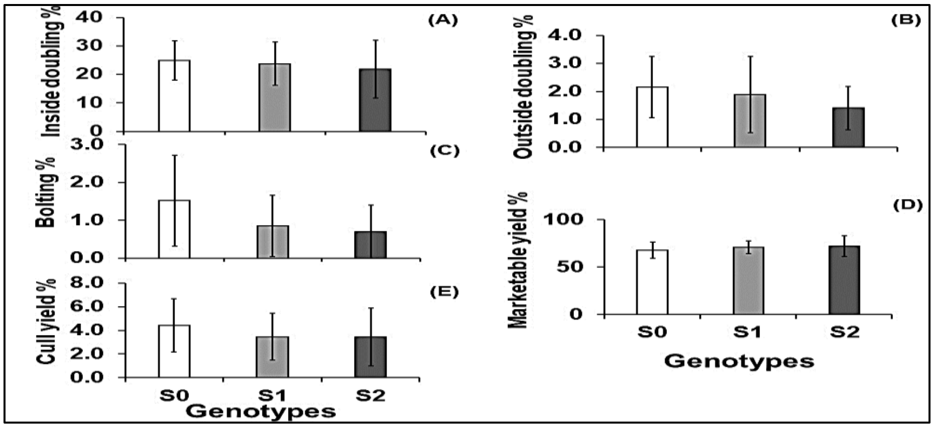

Figure 1. The impact of two cycles of mass selection against bulb doubling and bolting on inside doubling % (A), outside doubling % (B), bolting % (C), marketable yield % (D) and cull % (E). S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for (A) = 6.16, (B) = 0.864, (C) = 1.45, (D) = 7.34 and (E) = 2.32. Values are the mean of 9 replicates ± the standard deviation.

1.2. The impact of two mass selection cycles against bulb inside doubling, outside doubling and bolting (premature flowering) on traits of plant height, number of leaves, plant fresh weight and yield/fed.

Data for plant height, number of leaves per plant, plant fresh weight and yield per feddan are presented in figure 2 (A), (B), (C) and (D). In general, all these traits slightly but not significantly improved as affected by two cycles of mass selection for bulb doubling and bolting. The plant height increased by 3.3 % in S2 plants over two cycles of mass selection. The overall increase in plant height was 2.07 % which increased from 62.46 cm to 64.53 cm. Number of leaves increased by 3.57 % in the second cycle of selection in S2 plants and the overall increase in plant leaves was 0.31 %. Which increased from 8.69 to 8.99. Plant fresh weight, also increased in S1 and S2 by 2.7 % and 4.8 % in the first and second cycles respectively. The final increase in the plant fresh weight was 7.71% which equals approximately 13 grams. The yield per feddan increased by 5.4 %. over two cycles of mass selection.

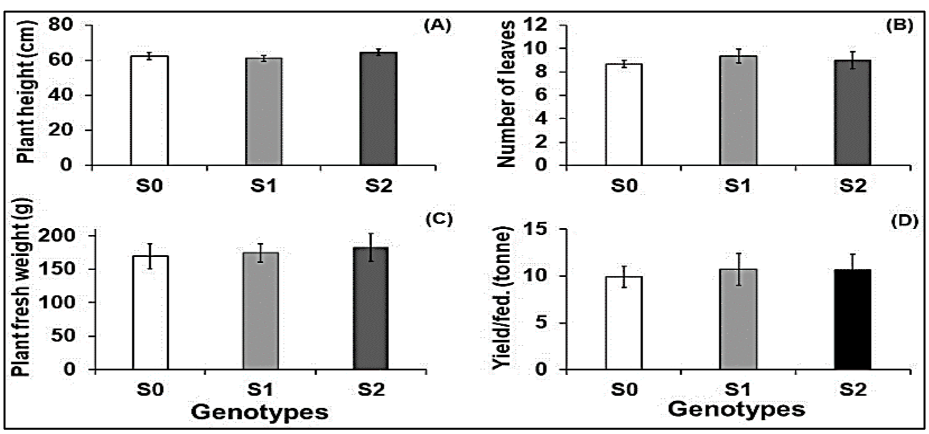

Figure 2. The impact of two cycles of mass selection against bulb doubling and bolting on the plant height (A), number of leaves (B), plant fresh weight (C) and yield/feddan (D). S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for (A) = 2.18, (B) = 0.621, (C) = 14.05 and (D) = 1.49. Values are the mean of 9 replicates ± the standard deviation.

1.3. The impact of two mass selection cycles against bulb inside doubling, outside doubling and bolting (premature flowering) on traits of bulb weight, neck diameter, bulb diameter and bulbing ratio. Figure 3 illustrate the effect of two mass selection against bulb doubling and bolting on traits of bulb weight, neck diameter, bulb diameter and bulbing ratio. In general, there are no significant differences among the three genotypes which represent three generations of mass cycle regarding these traits. Bulb weight slightly but not significantly increased in S1 and S2 compared to S0. Surprisingly Bulb weight for S2 was less than S1. Neck diameter, Also, increased slightly but in not significantly in S1 and S2. Bulb diameter increased in the first cycle of mass selection but, surprisingly, decreased in the second one. Bulbing ratio increased in the first and second cycle of mass selection but there is no difference between S1 and S2.

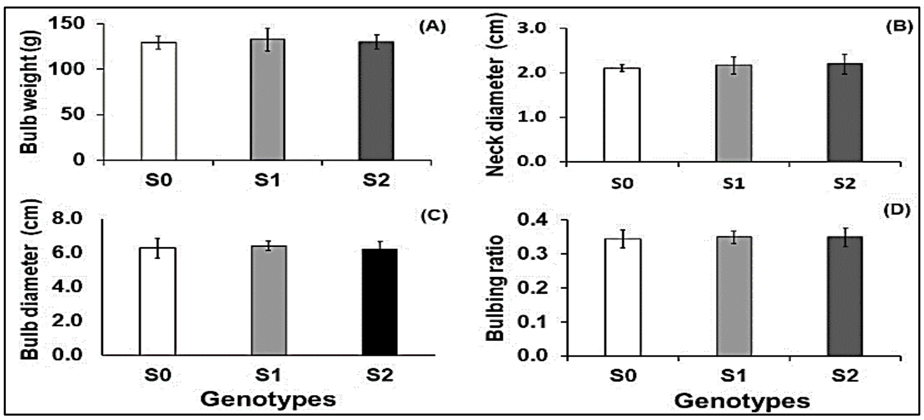

Figure 3. The impact of two cycles of mass selection against bulb doubling and bolting on bulb weight (A), neck diameter (B), bulb diameter (C) and bulbing ratio (D). S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for (A) = 10.20, (B) = 0.201, (C) = 0.287 and (D) = 0.023. Values are the mean of 9 replicates ± the standard deviation.

1.4. The impact of two mass selection cycles against bulb inside doubling, outside doubling and bolting (premature flowering) on the correlation among the traits.

The correlations among the measured traits as affected by the selection against bulb doubling and bolting are exhibited in table 1. The highest significant positive correlation (0.828) was noticed between bulb weight (BW) and the yield per feddan (YF), followed by the correlation (0.743) between neck diameter (ND) and plant fresh weight (PFW). Moderate correlations were noticed among the traits. Moderate correlations were noticed between plant height PH and plant fresh weight PFW, neck diameter ND, bulb diameter BD, plant fresh weight PFW and bulb weight which ranged from 0.520 to 0.66. The number of leaves also showed moderate significant positive correlation with three traits; plant fresh weight, neck diameter and bulb weight which ranged from 0.549 to 0.639. Moderate significant positive correlation was found between plant fresh weight and bulb diameter and bulb weight which ranged from 0.604 to 0.606 and between neck diameter and bulb diameter, yield per feddan and bulb weight which ranged from 0.517 and 0.640, and between yield per feddan and marketable yield % (0.648). A high significant negative correlation (-0.789) was notice between marketable yield % and inside doubling %.

Table 1. the correlation among the measured traits as affected by two cycles of mass selection against bulb doubling and bolting. PH = plant height, NL = number of leaves, PFW = plant fresh weight, ND = neck diameter, BD = bulb diameter, BR = bulbing ratio, YF = yield per feddan, BW = bulb weight, ID % = inside doubling %, OD % = outside doubling, B % = bolting %, MY % = marketable yield %, CY % = cull yield %.

Trait	NL	PFW	ND	BD	BR	YF	BW	ID %	OD %	B %	MY%	CY%
PH	0.45**	0.64**	0.66**	0.52**	0.04	0.53**	0.62**	0.18	-0.07	-0.31**	0.10	-0.38**
NL	-	0.55**	0.64**	0.50**	-0.20*	0.47**	0.55**	0.18	0.10	-0.02	0.12	-0.52**
PFW	-	-	0.74**	0.61**	-0.01	0.48**	0.60**	0.12	0.12	-0.09	0.07	-0.27*
ND	-	-	-	0.62**	-0.01	0.52**	0.64**	0.13	0.07	-0.05	0.07	-0.31**
BD	-	-	-	-	0.15	0.47**	0.47**	0.03	-0.00	-0.00	0.17	-0.27*
BR	-	-	-	-	-	-0.10	-0.10	0.02	0.11	0.01	-0.04	0.01
YF	-	-	-	-	-	-	0.83**	-0.35**	-0.18	-0.14	0.65	-0.44**
BW	-	-	-	-	-	-	-	0.14	-0.02	-0.12	0.12	-0.40**
ID %	-	-	-	-	-	-	-	-	0.10	-0.16	-0.79**	-0.28*
OD %	-	-	-	-	-	-	-	-	-	0.19	-0.27*	-0.00
B %	-	-	-	-	-	-	-	-	-	-	-0.07	0.05
MY %	-	-	-	-	-	-	-	-	-	-	-	-0.29**

Values are the mean of 9 replicates. * Indicates significand and ** indicates highly significant.

2. **Performance of three selected genotypes S0, S1 and S2 as affected by NPK fertilization rate.**

Three populations of Giza 6 mohassan, namely S0, S1 and S2 were tested in this experiment. These populations resulted from the simple mass selection used by farmers to improve the cultivar of Giza 6 mohassan for the traits of bulb doubling and bolting which accumulated over years. S0 is the original population, S1 the population resulted from the first cycle of selection and S2 is the population resulted from the second cycle of selection. the seeds of the populations were cultivated together and received three levels of NPK fertilizers. The performance of three populations were tested in this experiment.

2.1. The impact of three NPK rates on plant height (cm) of three onion genotypes.

Data for the impact of three fertilization rates and three onion genotypes resulted from mass selection on plant height is presented in figure 4. In general, there are significant differences among fertilization rates, genotypes and their interaction. The highest plant height was obtained from the third erotization rate T3 with 4.4% increase over the control T2 and the lowest value obtained from T1 which decreased by 9.7 % less than T2. The highest plant height value was obtained from genotype S2 which increased by 4.3 % over the control S0. The lowest value was obtained from S1. In the interaction between the realization rates and the genotypes, the highest value was obtained from T3 and S1 and the lowest value was obtained from T1 and S1. The correlation between the amount of fertilizer and plant height figure 4 (B) was positive and high where the plant height increased by increasing the fertilizer rate.

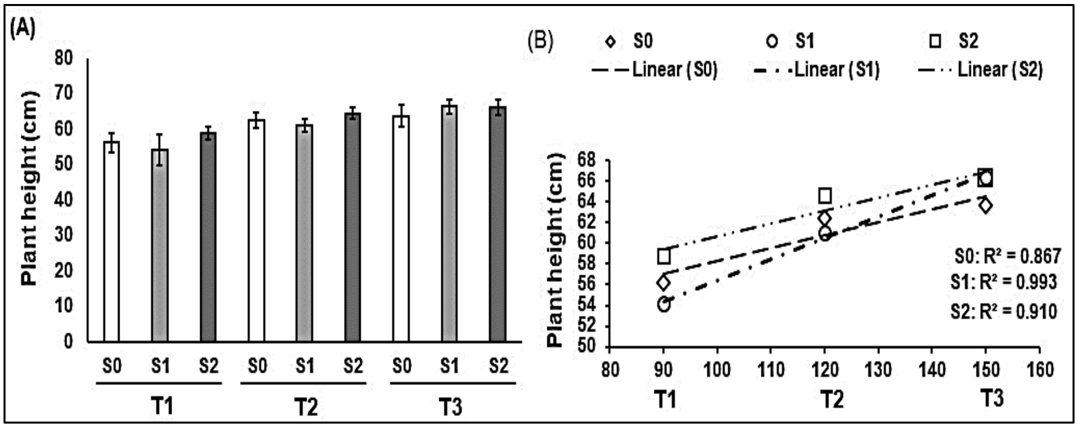

Figure 4. The impact of three rates of NPK fertilizers (T1, T2 and T3) on plant height (cm) of three onion genotypes (S0, S1 and S2). (A) represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the plant height in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 1.69, S = 0.621, and T*S = 2.35. Values are the mean of 9 replicates ± the standard deviation

2.2. The impact of three NPK rates on number of leaves of three onion genotypes.

The number of leaves for three onion genotypes as affected by NPK fertilization rate is presented in figure 5. It has been noticed that there are no significant differences among the genotypes nor among their interaction with the fertilization rate, but there are significant differences among the fertilization rates. The highest number of leaves was obtained from S1 and the lowest from S0. T3 produced the highest number of leaves and T1 produced the lowest number of leaves. Supplying S2 plants with the highest fertilization rate gave the highest number of leave, while supplying S0 with the lowest fertilization rate gave the lowest number of leaves. The number of leaves and the fertilization amount are highly positively correlated in the three genotypes with the highest value was in S0.

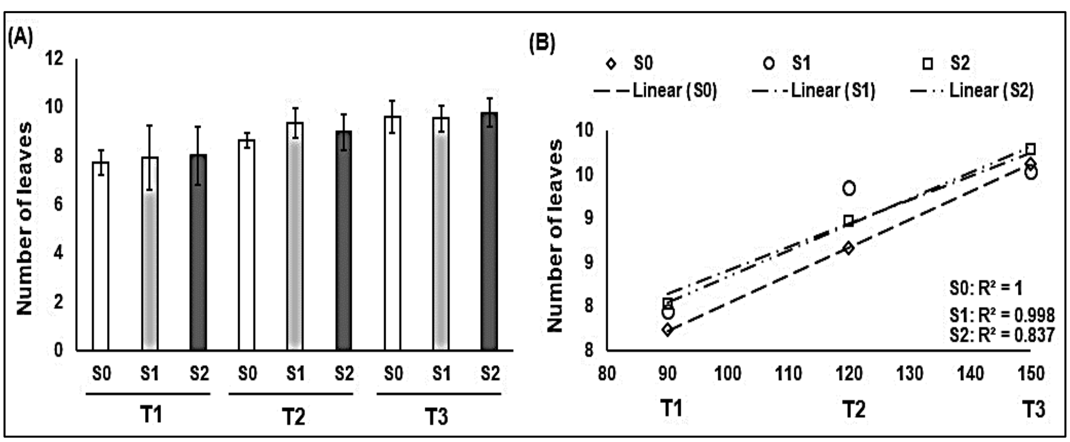

Figure 5. The impact of three rates of NPK fertilizers (T1, T2 and T3) on number of leaves of three onion genotypes (S0, S1 and S2). (A) represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilization and number of leaves in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 0.446, S = 0.489, and T*S = 0. 847.Values are the mean of 9 replicates ± the standard deviation.

2.3. The impact of three NPK rates on plant fresh weight (g) of three onion genotypes.

Fresh weight of three onion genotypes resulted of mass selection and fertilized with three NPK rates are illustrated in figure 6. There are significant differences among the genotypes, the fertilization rate and their interaction. S2 produced the highest fresh weight, meanwhile S0 produced the lowest. T3 produced the highest plant fresh weight; meanwhile T1 produced the lowest plant fresh weight. The highest plant fresh weight was produced from S2 and T3 and the lowest was produced from S0 and T1. There is high positive correlation between the plant fresh weight and the fertilization rate in the three genotypes.

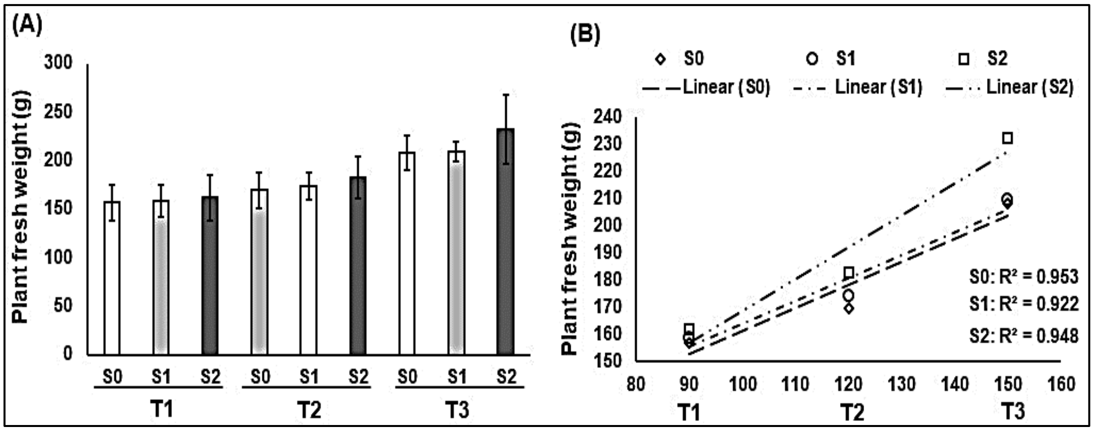

Figure 6. The impact of three rates of NPK fertilizers (T1, T2 and T3) on plant fresh weight (g) of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the plant fresh weight in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 14.34, S = 11.09, and T*S = 19.22. Values are the mean of 9 replicates ± the standard deviation

2.4. The impact of three NPK rates on neck diameter (cm) of three onion genotypes.

Figure 7 show the data of neck diameter of S0, S1 and S3 genotypes as affected by the NPK fertilization rate. There are no significant differences among the genotypes, however, there are significant differences among the fertilization rates and among their interactions with the genotypes. The highest neck diameter was obtained from S2 and the lowest was obtained from S0. Regarding the fertilization rate, the highest neck diameter was obtained from T3 and the lowest was obtained from T1. The interaction of S1 and T3 gave the widest neck diameter, meanwhile the interaction of S1 and T1 gave the narrowest neck diameter. Neck diameter is highly positively correlated with increment of fertilizers in the three genotypes with the highest correlation in S1

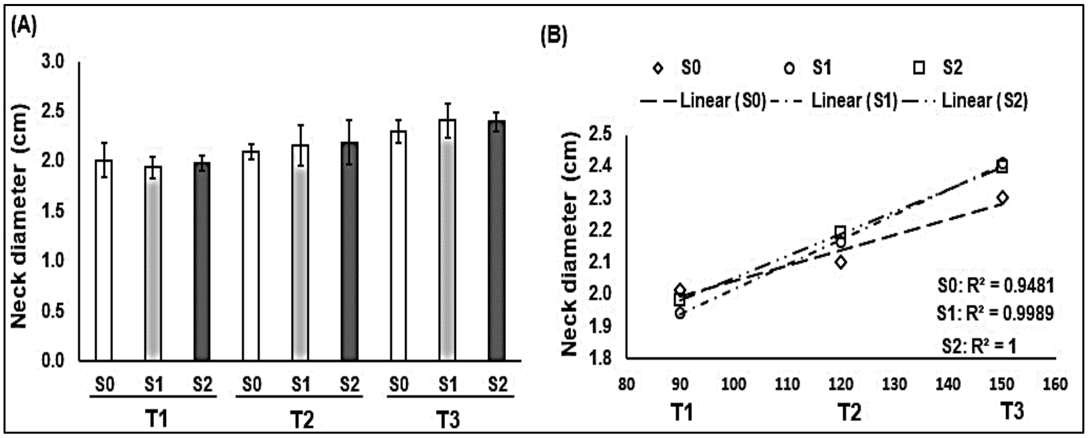

Figure 7. The impact of three rates of NPK fertilizers (T1, T2 and T3) on neck diameter (cm) of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the neck diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 0.069, S = 0.080, and T*S = 0.149. Values are the mean of 9 replicates ± the standard deviation

2.5. The impact of three NPK rates on bulb diameter (cm) of three onion genotypes.

Figure 8 illustrates the effect of the fertilization rate on the bulb diameter of three onion genotypes. It has been noticed that there are no significant differences among S0, S1 and S2, however, there are significant differences among the fertilization rates and among the interaction of the fertilization rates and the genotypes. S2 gave the largest bulb diameter and S0 gave the smallest bulb diameter. T3 gave the largest bulb diameter and T1 gave the smallest. Supplying S2 with T3 fertilization rate yielded the largest bulb diameter. On the other hand, S1 and T1 gave the smallest bulb diameter. The three genotypes exhibited high positive correlation figure 8 (b) between the bulb diameter and the fertilization rate. S1 genotype had the highest correlation.

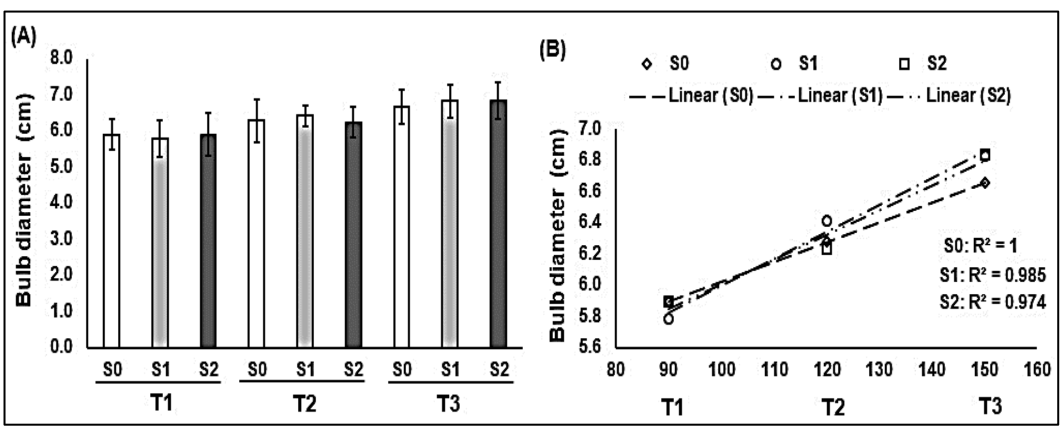

Figure 8. The impact of three rates of NPK fertilizers (T1, T2 and T3) on bulb diameter (cm) of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 0.289, S = 0.280, and T*S = 0.486. Values are the mean of 9 replicates ± the standard deviation.

2.6. The impact of three NPK rates on bulbing ratio of three onion genotypes.

The impact of three NPK fertilizers on the bulbing ratio of S0, S1 and S2 shown in Figure 9. There are significant differences among genotypes, and between the genotypes and fertilization rate interaction, but there is no significant difference among the fertilization rates. S2 gave the highest bulbing ratio and S0 gave the lowest value. T1 gave the highest bulbing ratio and T2 and T3 gave the lowest bulbing ratio. The highest bulbing ratio was obtained by using of the T 1 and S2. The correlation between the fertilization rate and the bulbing ratio in the three genotypes varied figure 9 (B). S0 showed high positive correlation and S2 showed moderate positive correlation, however, S1 showed high negative correlation.

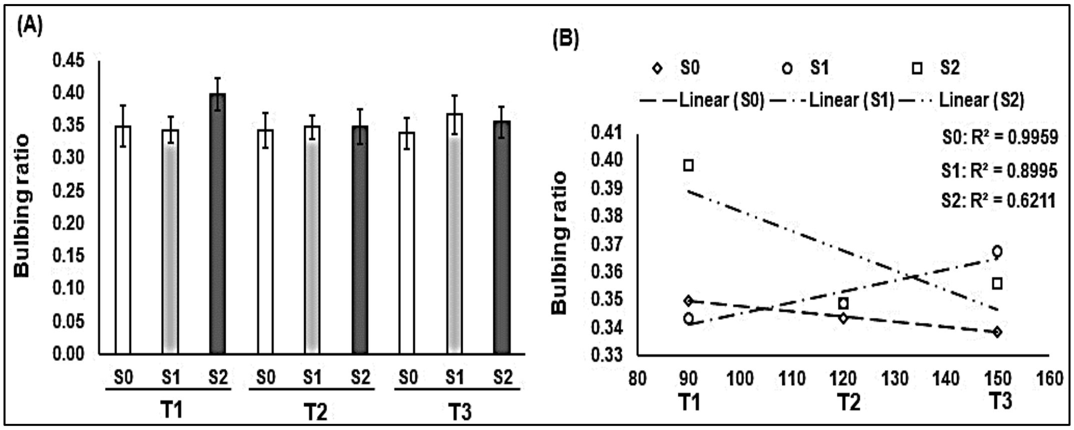

Figure 9. The impact of three rates of NPK fertilizers (T1, T2 and T3) on bulbing ratio of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 0.029, S = 0.028, and T*S = 0.055. Values are the mean of 9 replicates ± the standard deviation.

2.7. The impact of three NPK rates on bulb weight (g) of three onion genotypes.

Bulb weight of three genotypes as influenced by NPK fertilization rates presented in figure 10. In general, there is no significant difference between genotypes. However, there are significant differences among the fertilization rates and among the interactions between the genotypes and the fertilization rates. The largest onion bulb size was obtained from S0 and the smallest from S0. Similarly, the largest onion bulb size was obtained from T3 and the smallest from T1. Regarding the interaction, the largest onion bulb size was obtained when the third fertilization rate T3 was applied to the S2 genotype plants. There is a strong positive correlation between the onion weight and the fertilization rate which was very close among the three genotypes.

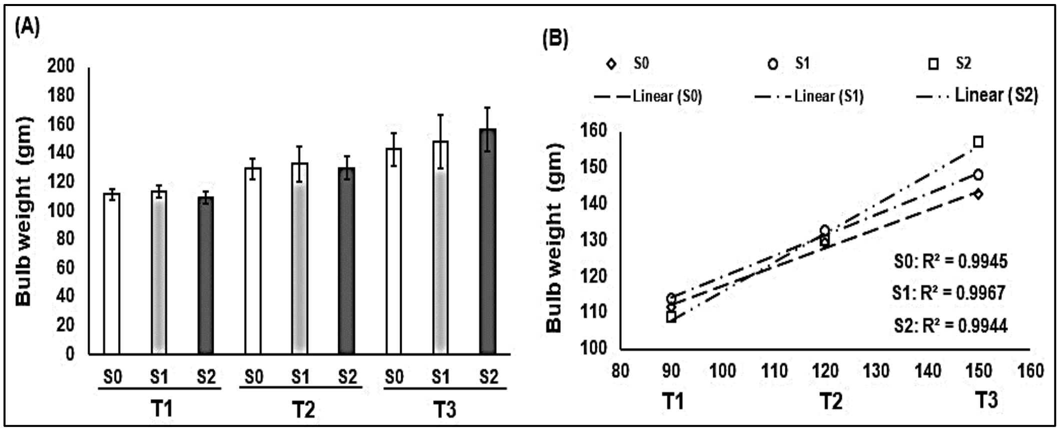

Figure 10. The impact of three rates of NPK fertilizers (T1, T2 and T3) on bulb weight (g) of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 8.98, S = 5.06, and T*S = 8.77. Values are the mean of 9 replicates ± the standard deviation.

2.8. The impact of three NPK rates on yield per feddan (tonne) of three onion genotypes.

Figure 11 illustrates the impact of three rate of NPK fertilization on the yield per feddan in three onion genotypes. The results show that there are significant differences among the genotypes, among fertilization rates and among their interactions. S2 gave the highest yield per feddan and S0, the base population gave the lowest yield per feddan. T3 gave the highest yield per feddan and T1 gave the lowest yield per feddan. In the interaction, the highest yield was obtained from application of the third rate of fertilization T3 to S2 genotype plants, meanwhile the lowest yield per feddan was obtained from application of the first rate of fertilization T1 to S0 plants. There is a high positive correlation between the yield per feddan and the amount of NPK fertilizer applied in the three genotypes.

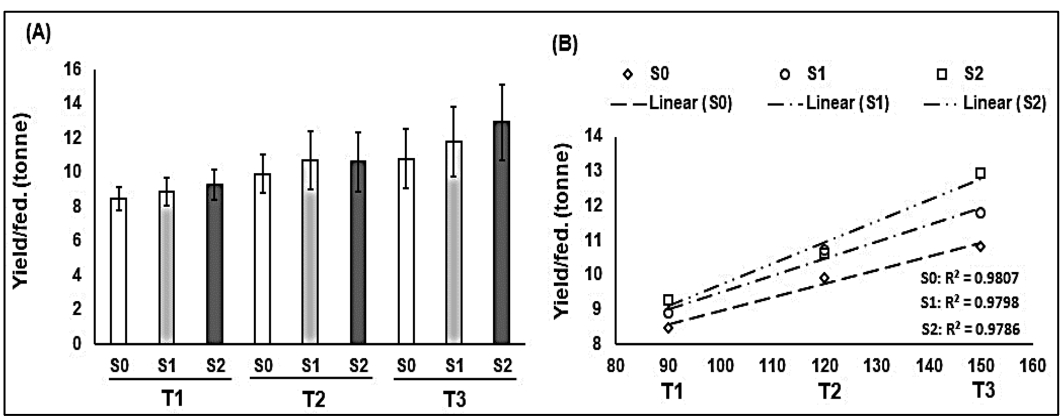

Figure 11. The impact of three rates of NPK fertilizers (T1, T2 and T3) on yield/fed. (tonne) of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 0.95, S = 0.74, and T*S = 1.28. Values are the mean of 9 replicates ± the standard deviation.

2.9. The impact of three NPK rates on inside doubling % of three onion genotypes

The inside doubling % of three onion genotypes as affected by fertilization rate is presented in figure 12. There is no significant difference among the genotypes nor among the fertilization rates. However, there is significant difference among their interaction. S2 gave the least inside doubling % and S0 gave the highest inside doubling %. The first fertilization rate T1 gave the least and the third fertilization rate gave the highest inside doubling %. The least inside doubling % was recorded for S2 plants received T1 fertilization rate. The inside doubling % is highly positively correlated with the amount of fertilization in the three genotypes.

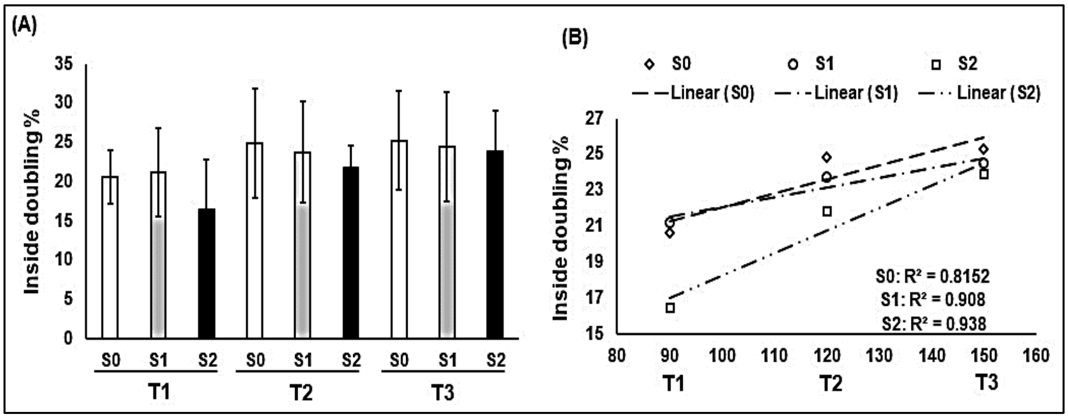

Figure 12. The impact of three rates of NPK fertilizers (T1, T2 and T3) on inside doubling % of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 5.72, S = 3.07, and T*S = 5.32. Values are the mean of 9 replicates ± the standard deviation.

2.10. The impact of three NPK rates on outside doubling % of three onion genotypes

Figure 13 show the data of outside doubling % as influenced by the fertilization rate in three genotypes of onion. Data show that there are no significant differences among the genotypes. However, there are significant differences among the fertilization rates and among the interactions of the genotypes and fertilization rates. The least outside doubling percentage was recoded for S2 genotype, meanwhile the highest was recorded for S0. The least outside doubling was recorded for T2 and the highest was recorded for T3. The lowest outside doubling % in the experiment was recorded for S2 plants received the second fertilization rate T2, meanwhile the highest was recorded for S0 plants received. The correlation between the outside doubling % and amount of fertilizers varied. S0 and S1 plants showed strong positive correlation, however, S2 plants showed weak negative correlation.

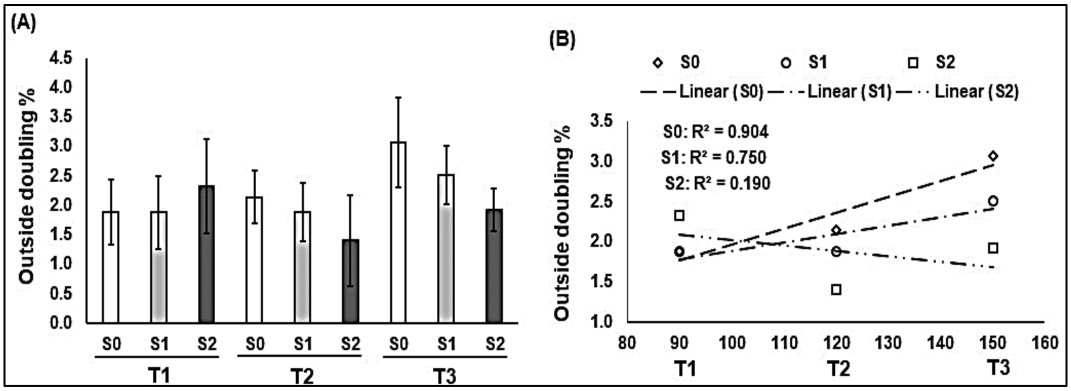

Figure 13. The impact of three rates of NPK fertilizers (T1, T2 and T3) on outside doubling % of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 0.68, S = 0.81, and T*S = 1.39. Values are the mean of 9 replicates ± the standard deviation.

2.11. The impact of three NPK rates on bolting % of three onion genotypes

The effect of NPK fertilizer rates application on the bolting % of three onion genotypes S0, S1 and S3 is presented in figure 14. There are no significant differences among the genotypes, however, there are significant differences among the fertilization rates and among the interactions of the genotypes and fertilization rates. The lowest bolting % was obtained from S2 genotypes and the highest was obtained from S0 genotypes. T3 fertilization rate produced the least bolting plants, meanwhile T1 fertilization rate produced the highest bolting plants. Application of T2 fertilization rate to S3 plants produced the least bolting %, however, S0 plants received the least fertilization rate produced the highest bolting %. There are moderate to high negative correlations between bolting % and the quantity of fertilizers applied the plant of the three genotypes. S0 plants showed high correlations, however, S2 showed moderate correlations.

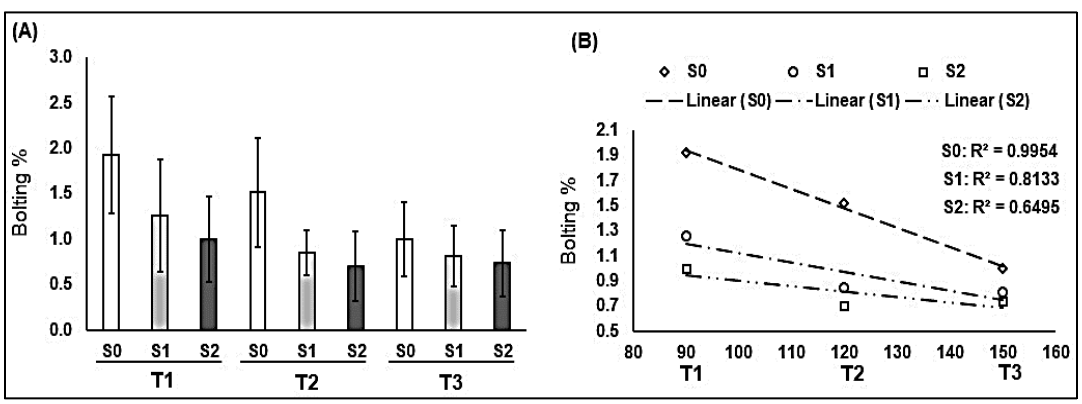

Figure 14. The impact of three rates of NPK fertilizers (T1, T2 and T3) on bolting % of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 0.66, S = 0.68, and T*S = 1.17. Values are the mean of 9 replicates ± the standard deviation.

2.12. The impact of three NPK rates on marketable yield % of three onion genotypes.

Figure 15 exhibits the effect of three levels of NPK fertilizers on the marketable yield % of three onion genotypes. There are significant differences among the genotypes and among their interaction with the fertilization rate. However, there are no significant differences among the fertilization rates. The highest marketable yield % was obtained from S2 plants and the lowest was obtained from S0 plants. T2 fertilization rate gave the highest marketable yield % and T3 gave the lowest marketable yield. S2 plants which received the lowest NPK fertilization rate gave the highest marketable yield and S0 plants which received the highest NPK fertilization rate gave the lowest marketable yield. The correlation of marketable yield and the number of fertilizers consumed varied among the genotypes in strength and direction. While S0 and S0 showed. A strong positive correlation was found in S2, but weak positive correlation was found in S0. However, moderate negative correlation was found in S1 plants.

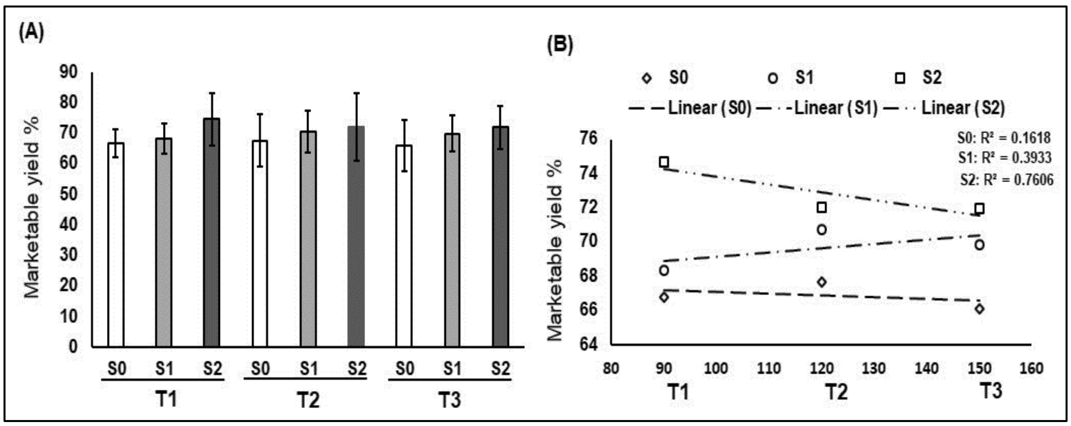

Figure 15. The impact of three rates of NPK fertilizers (T1, T2 and T3) on marketable yield % of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 5.38, S =3.48 , and T*S = 6.03 .Values are the mean of 9 replicates ± the standard deviation.

2.13. The impact of three NPK rates on cull bulbs % of three onion genotypes

Cull bulbs % as affected by the NPK fertilization rate is exhibited in figure 16. There are no significant differences among the genotypes, however, there are significant differences among the fertilization rates and among their interactions with the genotypes. The least cull bulbs % was obtained from S2 plants and the highest from S0 plants. T3 fertilization rate gave the least cull bulbs % and T1 gave the highest cull bulbs %. S2 plants which received the highest NPK rate produced the lowest cull bulbs, meanwhile S0 which received the lowest NPK rate produced the highest cull bulbs. There is high positive correlation between the NPK rate and the cull bulb % for all the three genotypes. The highest correlation was found in S2 plants.

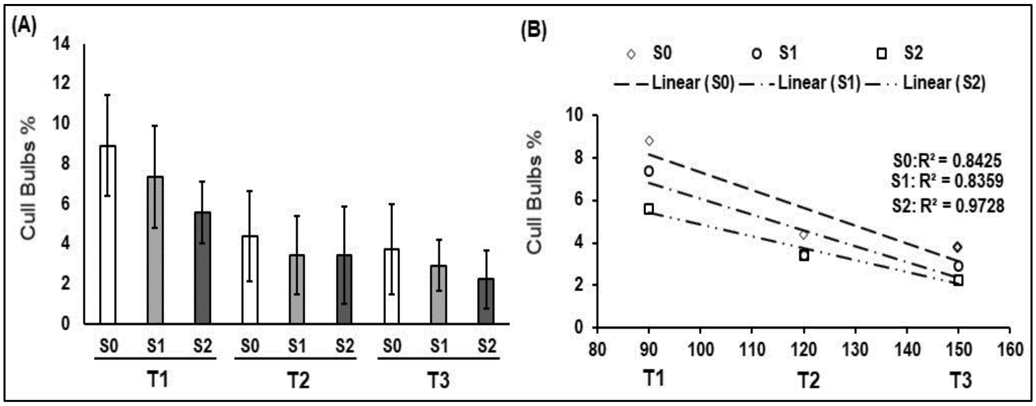

Figure 16. The impact of three rates of NPK fertilizers (T1, T2 and T3) on cull bulbs % of three onion genotypes (S0, S1 and S2). (A) the interaction represents the interaction of NPK fertilization rate and genotypes. (B) the correlation between the amount of fertilizer and the bulb diameter in the three genotypes. T1: 90 kg N, 30 kg P_2O_5 and 25 kg K_2O; T2: 120 kg N, 45 kg P_2O_5 and 50 kg K_2O; T: 150 kg N, 60 kg P_2O_5 and 75 kg K_2O. S0: the base population (control), S1: the population resulted from the first selection cycle, S2: the population resulted from the second selection cycle. $LSD_{0.05}$ for T = 2.33, S =2.20, and T*S = 3.82. Values are the mean of 9 replicates ± the standard deviation.

DISCUSSION

Onion is a very important crop for Egypt. Besides its nutritional and culinary value, it has become a very important exportation crop lately. The importing markets are seeking onion with very high quality and free from defects such diseases, bolting and doubles. Bulb doubling and bolting are undesirable traits that reduce the quality and yield of onion, and the breeder selects against them in the breeding programs. Mass selection is practiced by farmers for thousands of years to improve their seed stocks. The objective of this research is to investigate of the efficacy of mass selection practiced by farmers to improve traits doubling and bolting accumulated in Giza 6 Mohassan variety. Riviere et al (2015) investigated the efficacy of mass selection practiced by French farmers on improving wheat genotypes. They found that mass selection improved some traits such thousand kernel weight and grain weight per spike. Our results showed that two cycles of mass selection decreased the bolting %, inside doubling % and outside doubling %. S2 population which resulted from the second cycle of mass selection outperformed S0 (the base population) and S1 (the population resulted from the first mass selectin cycle in most traits. These results agree with Wall et al (1996), Gamie etal (2000), Gamie (2000) and Barakat et al (2021). Wall et al (1996) found after one cycle of selection using half-sib family method that the single growing point increased by 19 and 22% in two selected populations. Gamie et al (2000) on the other hand found after one cycle of selection using mass selection method that single growing point increased, meanwhile and internal doubling, external doubling and bolting decreased. Gamie et al (2000) found that inbreeding of Giza 20 onion resulted in increasing of onion with single growing point and bulb centers and decreasing of internal and external doubles and bolters. However, single growing point decreased in the progeny of the selected population by Barakat et al (2021) who carried out one cycle of mass selection in Giza whie onion. In selection, beside the traits which are selected for or against, the other traits are affected. In our study we found that most of the traits studied are affected with the two cycles of selection. Gamie etal (2000) found cull bulbs and bulb weight decreased by one inbreeding cycle of Giza 20 onions. Gamie (2000) found that cull bulbs % and yield decreased after one cycle of mass selection. Barakat et al (2021) found that the single selection point population had the highest total yield, marketable yield, average bulb weight. Our results showed that there are correlations of different traits. This correlation varies from weak to strong and from positive to negative. Similar results have been shown by research such Mohanty (2001); Golani et al. (2006); Lakshmi et al (2015); Deb et al. (2021). Mahanty (2001) found that bulb yield was significantly correlated phenotypically and genotypically with plant height, number of leaves per plant, diameter, and bulb weight, but not with neck thickness. Golani et al. (2006) found that the number of leaves per plant, bulb length, bulb girth, and 10-bulb weight all had significant positive phenotypic and genotypic associations with bulb yield. Lakshmi et al (2015) fount that at both the phenotypic and genotypic levels, yield was found to be positively correlated with plant height, neck thickness, weight, length, and the equatorial diameter of the bulb. Deb et al. (2021) found that at both the genotypic and phenotypic levels, the correlation coefficient between bulb yield and plot was highly significant and positive. NPK fertilizers are used in crops production extensively since the Green Revolution in mid of the twentieth century. NPK play a pivotal role in plant growth and development. The depletion of these fertilizers in the plant growing environment causes reduction in yield quantity and quality. Our results showed that onion plants responded very well to the fertilization of NPK applied. This response was reflected in the high correlation values exhibited in most of the traits in response to NPK quantities Amare (2020). These high responses imply that more quantities are needed to be supplied since that a fertilizer such nitrogen is with low efficiency and as a result, recommendations for the best N application rates must be developed locally Geisseler et al. (2022). NPK efficiency differ from plant to plant form soil to soil and onion is one of the least efficient crops in N and P fertlizers Fohse et al. (1988); Amare (2020) ; Geisseler et al. (2022). The results in this study showed that the vegetative traits such as plant height, number of leaves per plant and plant fresh and neck diameter increased by increasing the amount of NPK fertilizers applied. Fertilization onion with NPK increased plant length, number of leaves, leave length, neck diameter, leaves fresh and dry weight Syed et al. (2000); Ghoname et al. (2007); Nasreen et al. (2007); Abdissa et al. (2011); Adem et al (2014); Simon et al. (2014); Al-Fraihat (2016); Tekeste et al (2018). NPK fertilizers plays key role in increasing the plant biomass and nutrients absorption and translocation. Nitrogen for instance is the main constituent in the photosynthesis system which produce carbohydrates. It is also a main constituent in amino acids and protein chains. Phosphorus is pivotal for root growth and main constituent in ATP, ADP and many biomolecules. Potassium plays a key role in carbohydrates accumulation and translocation. Our results showed also that an increase occurred in the yield and yield components in response of NPK fertilizers applied. Bulb diameter, bulb weight and yield per feddan increased by increasing the NPK amounts. Bulbing ratio, however, decreased by increasing NPK level except for S1 genotype. The same results have been seen by many researchers such as Syed et al. (2000); Ghoname et al. (2007); Nasreen et al. (2007); Resende and Costa (2014); Simon et al. (2014); Al-Fraihat (2016); Tekeste et al (2018). It is expected that the yield and yield components will increase, since high NPK levels resulted in high biomass in form of large and tall plants with high number of leaves. Potassium in particular is very important in the stage of bulbing because it promotes the translocation of photo-assimilates to the tuberous parts such as bulbs. The inside doubling %, outside doubling % and bolting % varied in their response to NPK level. While inside doubling % and outside doubling % increased by increasing the NPK level, the bolting % decreased by increasing the NPK level. Hassan (1983); Abdissa et al. (2011); Al-Fraihat and Ahmed (2009) found that NPK high level increases doubling. Abdissa et al. (2011) stated that high NPK level decreased bolting %. Hassan (1983); Al-Fraihat and Ahmed (2009) on the other hand found that high level of NPK increases bolting %. It is a well-known fact that high level of fertilizers and nitrogen especially promotes growth and the incidence of onion doubling, while low level of nitrogen promotes plant bolting. Our results showed that marketable yield % response to NPK level varied by genotype, meanwhile the cull bulbs % decreased by increasing. Syed et al. (2000); Ghoname et al. (2007); Resende and Costa

(2014); Simon et al. (2014); Al-Fraihat and Ahmed (2009) It is expected that cull bub % decreases by increasing the NPK level because it encourages the growth and enlargement of bulbs, so bulbs with diameter less than 6 centimeters will be of low percentage. Surprisingly, however, the marketable yield % of one genotype decreased by increasing the NPK level. Many traits affect the marketable yield such as bulb size, inside doubling %, outside doubling % and bolting %. The high NPK encourages the high incidence of inside doubling %, outside doubling % which decrease the marketable yield, and it also encourages the incidence of large bulb size and low bolting % which increase the the marketable yield. So, it is normal to see fluctuations in this trait.

CONCLUSION

In conclusion, mass selection is efficient tool in improving the defects of onion plants. As we saw in or results the inside doubling, outside doubling and bolting decreased after two cycles of mass selection. Inside doubling % was high (24.89%) from the beginning in the base population. Inside doubling % decreased by only 4.45 % and 7.9 % in the first and second cycles respectively and by overall 12.05 % of the initial inside doubling % over two cycles of mass selection. Outside doubling %, however, was low from the beginning in the base population and decreased by 12.1 % and 34. % in the first and second cycles of mass selection. the overall decrease of outside doubling over two cycles of selection was 34.41%. The initial bolting % was also low. However, the mass selection highly decreased the percentage of bolting by 53.94 % over two cycles. Moreover, the mass selection enhanced most the traits studied such as the yield per feddan, bulb weight, marketable yield and other traits. We can say that mass selection practiced by farmers is a powerful and efficient tool in improving doubling and bolting and other traits of onion crop with varying degrees. Outside doubling and bolting were more responsive for improvement by mass selection than inside doubling. NPK fertilizers application improved most of the studied traits in the three genotypes except for few traits which deteriorated by increasing the NPK rate. The yield per feddan, bulb weight, bulb diameter, plant height, plant fresh weight, Marketable yield increased and highly positively correlated with the increase of NPK rate. Bolting %, bulbing ratio and Cull yield % decreased and highly negatively correlated by increasing the NPK rate. The only traits adversely affected by the increase of NPK rate are the inside and outside doubling %.

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