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SUPERIORITY OF NEW HYBRIDS DEVELOPED BY SINGLE PLANT SELECTION IN CUCUMBER ADVANCED POPULATIONS

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ABSTRACT

Breeding for yield traits in cucumber genotypes were investigated at the Experimental Farm of Dura International for Agricultural Development company in Beni-Sweif governorate, Egypt during the successive seasons from 2019 to 2023. In this program, cucumber inbreds were developed using single plant selection method. Selected inbreds were crossed and the resulting hybrids were evaluated with three widely growing hybrids (Bahi, Sakr, and Zein). Analysis of variance revealed highly significant differences among the tested genotypes for early, late, and total fruit yield. Among the crosses P13xP25, P20xP27, P27xP26, P28xP13 and P18xP21 exhibited the highest superiority effect for the yield characteristics over the best three commercially checks. Therefore, this breeding program led to selections of good cucumber inbreds which can be grown to produce early, late and total high yield of cucumber under the Middle Egypt growing conditions and similar locations. Moreover, much money which is always spent in importing seeds of foreign cucumber hybrids can be saved.

Keywords: Breeding; Cucumber; Selection; New Hybrids; Hybrid Vigor, Superiority.

INTRODUCTION

Cucumber (*Cucumis spp*.L.) is very famous in Egypt and is an economically important vegetable crop worldwide that is used for salads, pickles, and fresh consumption. Cucumber belongs to Cucurbitaceae family with chromosome number of 2n= 14 and is being monoecious, cross pollinated crop with numerous seeds per fruit and practically no inbreeding depression, offers an excellent opportunity for exploitation of heterosis. Now, it is extensively

cultivated in diverse agroclimatic conditions ranging from tropical to subtropical regions of the world. India being the primary centre of origin has accumulated a wide range of variability which can be exploited for crop improvement (Rakhi and Rajamony, 2005; Sebastian et al; 2010, Weng, 2019; Che and Zhang, 2019). They are rich in dietary fibres; different vitamins such as vitamins B, C, and K; antioxidants; and minerals, e.g., potassium and magnesium (Shan et al., 2020). al., 2010; Yang et al., 2012; Che and Zhang, 2019;). Thousands of years ago, various varieties were adapted to the Egyptian environmental conditions.

Based on the suitable climate and soil conditions as well as skilled farmers Egypt has a favorable location which is an important point of exchange and trade vegetables with the world (Gadelhak et al., 1989; Shardul Agrawala et al., 2004). Most of cucumber seeds are imported by international companies with high selling pricec. On the meantime, stability and the yield quantity and quality of the imported cultivars are fluctuating. Indeed, markets need to have local cultivars that are improved to replace totally or partially these imported cultivars. At least the new cultivars should have the yield potentiality of the imported ones. However, beside its yield and quality superiority, they must be adapted to the prevailing natural and environmental conditions.

Superiority of the F_1 resulting from cross of genetically dissimilar parents over either of the parents was reported in cucurbits (Hays et al., 1961). The heterosis phenomenon can play a vital role in increasing the yield quality of cucumber (Simi et al., 2018). The extent of heterosis over commercial hybrids in specific region is a target for commercial exploitation of hybrid vigor in cucumber for commercial purpose (Singh et al., 2015). Appreciable heterosis was detected over better parent for cucumber yield by (Pandey et al., 2005; Airina 2013, Jat et al., 2016, and Jat et al., 2017). However, little heterosis for yield and yield components in cucumber were reported by Cremar and Wehner (1991). Also, in picking cucumber, Abd Rabou and El-Magawry (2020) found negative high-parent heterosis values for number of fruits per plant and total yield traits. The objective of this study is to develop and evaluate acceptable and high productive F_1 cucumber hybrids to meet the demand of the local Egyptian markets and reduce the cost of importing cucumber hybrids and cultivars.

MATERIALS AND METHODS

More than 64 cucumber new hybrids were produced by hand crossing method and tested in the first out of three successive seasons. The parents of these hybrids were developed from selfing and selection within 5 commercial hybrids as well as one open pollinated Turkish population as shown in table 1 and figure 1

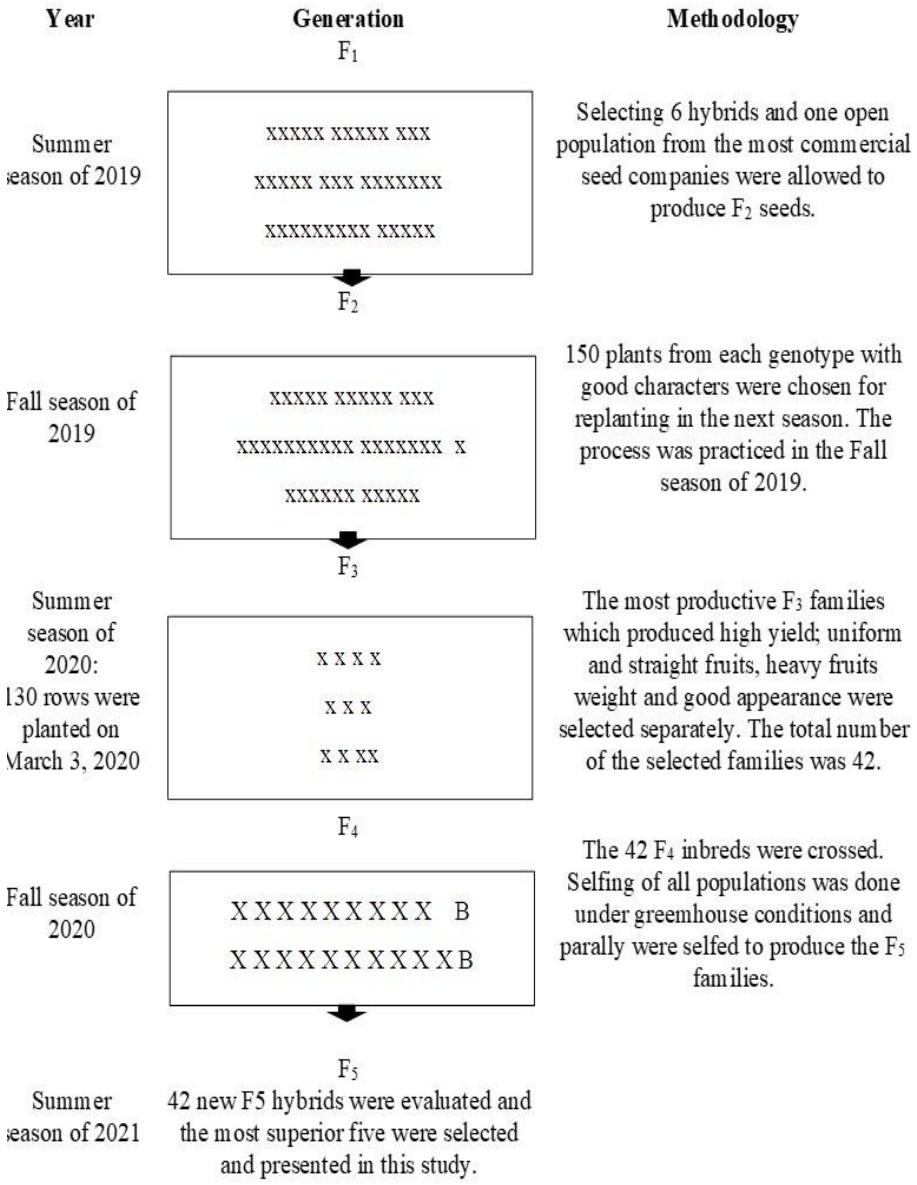

Figure 1. Outline of cucumber breeding program at Sids Horticultural Research Station, Bani Sweif, Egypt

Table 1: Fruit color, fruit length and fruit diameter of the commercial hybrids and one open Turkish population:

Genotype	Fruit color	Fruit length, cm	Fruit diameter, cm
Bahi	Green	16.5	3.2
Ghazeer	Green	17.0	3.3
Madina	Light green	15.0	3.3
Turkish population	Dark green	16.5	3.2
200 3 F_1	Green	16.0	3.4
Karm	Green	15.5	3.3
HV cc - 026	Green	15.0	3.3

These genotypes were successively selfed up to fourty generation. The F_2 population of each genotype consists of 150 plants and 64 single plants out of the total 900 plants selected visually. Also, the evaluation criteria and monitoring methods are based on flower type, fruit length, fruit diameter, fruit shape and general plant growth i.e. plant length, vigor, and number of primary branches as well as number of fruits per plant. An outline of the breeding scheme used in this study for each population is showing in figure 2.

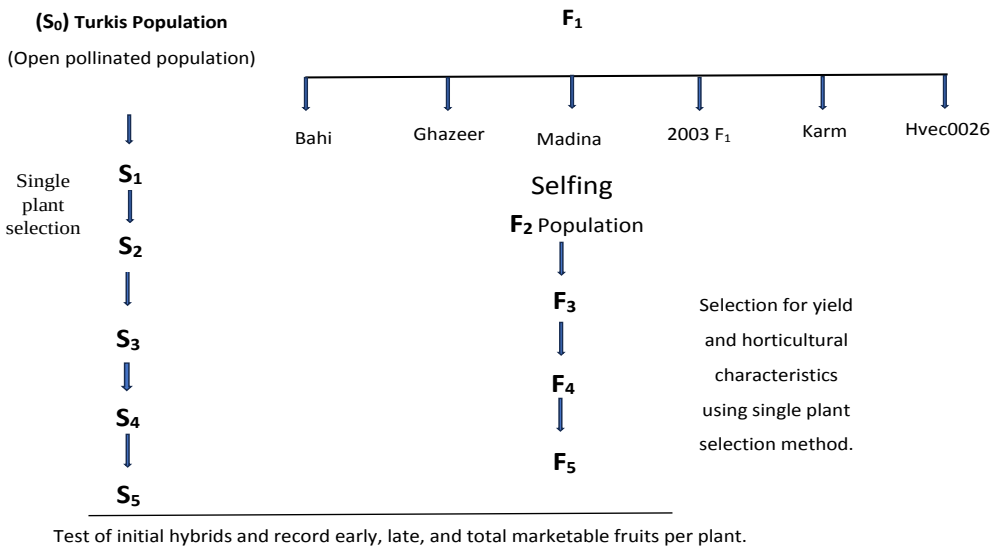

Fig 2. Developing inbreds and hybrids in cucumber.

In the summer season of 2019: original 150 seeds from each hybrid and/or open pollinated genotype, were growing in observational plots at the Experimental Farm, Dura seed Company. After selfing, the first cycle of selection was done in the F_2 population.

In the fall season of 2019: 64 selected families of F_3 population on the basis of their general performance as mentioned above were growing at the aforementioned farm. The selfing and second cycle of selection methods were done in the F_4 population.

In the summer season of 2020: 14 selected F_5 inbreds were selected and crossed to produce 64 hybrids. The seeds of these hybrids and three commercial hybrids (Bahi, Sakr and zein) were planted in two replications.

In the Fall season of 2020: By comparing and evaluating the fruited yield characteristic of the hybrid combination, 14 promising hybrids have been selected which were suitable for the market requirements Also, the selfing process are continuing on the used parents.

In summer season of 2021 and from the results of the previous experiments, 5 acceptable hybrids were selected, and their fruit and yield characteristics will be presented here.

Location: The experiments were conducted at the research station of Dura Seed Company, which is located at Sids village, Beni Sweif governorate, Egypt. The program started in 2017. Selfing and selecting are applied in each season to get new pure inbreeds for selection for some or all the major desired characteristics.

The new hybrids as well as three commercial hybrids were tested in Complete Block Design with two replications in the summer season of 2021 and retested in the fall season of 2023.

Transplanting was done in the 16, March of 2021 and 22 August 2023, in rows 120 cm wide and 3 m long. Transplants within each row were spaced at 30 cm. All cultural practices concerning cucumber production under loamy soil condition were applied according to the recommendation of the Egyptian ministry of agriculture and land reclamation.

Statistical analysis:

Variations among different genotypes were estimated according to Gomez and Gomez (1984). Phenotypic and genotypic coefficients and heritability in broad semes phenotypic and genotypic variances were estimated based on Singh and Choudary, (1979) using the following formula:

Genotypic variance ($\sigma^2 g$) = (Genotype mean square – Error mean square) / r

$\sigma^2 e$ = mean square of the error

r = replication

Phenotypic variance (σ^2 ph) = $\sigma^2 g + \sigma^2 e$

Phenotypic coefficient of variation (PCV %) = (σ^2 ph / X) x 100

Genotypic coefficient of variation (GCV %) = (σ^2 gh / X) x 100

Where: X = Grand mean of all genotypes.

Broad semes heritability (H_{bs}) = (Genotypic variance / Phenotypic variance) X 100

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among the tested hybrids for all traits table 1. The results on variability parameters, including range, mean, variance, coefficient of variation (CV) phenotypic variation coefficients (PCV %), coefficient of genotypic variation (GCV%) and heritability in broad sense were shown in table 2.

Fruit weight

A wide range was observed for fruit weight (82.45 g to 171.85 g) and its mean value was 105.26 g. however, the fruit weight in the three checks was 121.11 and 127.14 for Bahi, g and 154.67 and 91.35 g for Saker and 96.55 and 87.56 g for Zein in the summer and fall seasons, respectively. Fruit weight is a major yield contributing trait. Thus, total yield is highly dependent on number of fruits and fruit weight per plant. Highly significant variances were detected for this trait. Also, it has 37.86% and 37.84% for phenotypic and genotypic coefficients of variation, respectively. These results indicate that this character is influenced by environmental factors. However, (PCV % and GCC %) are classified into four different groups; more than 30% were categorized as high 11-30% were moderate, values below 10% were in a low category as reported by (Burton and De Vane, 1953)

Table 2. Mean, range, variance, coefficient of phenotypic variation, coefficient of genotypic variation and heritability in broad sense for early, late, total yield, number of fruits/ plant and fruit weight.

Trait	Mean	Range	variance	PCV%	GCV%	H^2%
Early yield, kg	0.34	0.0-1.66	0.205**	88.60	82.56	86.83**
Late yield, kg	0.91	0.0-188	0.398**	51.00	48.57	90.70**
Total yield, kg	2.19	1.0-4.52	0.925**	32.17	31.16	93.84**
No of Fruits	20.13	13.00-36.98	65.29**	28.84	28.74	99.27**
Fruit weight, gr	105.26	64.51-395.44	1894.20**	37.56	37.84	99.86**

** Highly significant at 0.01 level of probability (MSTAT-C)
Values with the same letter(s) in each column are not statistically different (MSTAT-C)

Number of fruit / plants

The range of number of fruits per plant was 13.00 to.36.98 fruit in the tested population and the three commercial hybrids with average 20.13 fruit per plant. Remarkable phenotypic variation was observed for this trait. The coefficient of phenotypic and genotypic variations for number of fruits per plant was 28.84 and 28.74%, respectively. These moderate values indicate that this trait is influenced moderately by environmental factors.

Early yield

The maximum range of the early yield trait was reached to 0.66 kg in Saker hybrid, while there were few hybrids that did not yield a fruits in the first two harvests. The means of this trait

were 0.42 kg in the summer and 0.26 kg per plant in the fall. The variation of this trait showed a high statistical significance, and this was clearly manifested in the high values of the coefficient of environmental and genetic variation (table 3).

The heritability value in a broad sense recorded a high value (86.83%) indicating the control of additive genetic factors in the inheritance of the trait and the production of hybrid cultivars is a successful breeding way to improve the early yield in the tested population.

Late yield

The marketing of vegetables is witnessing sharp fluctuations in prices, and the consumer always prefers fresh vegetables, and therefore, the presence and cultivations of early and late cucumber cultivars in favor of cucumber growers. In general, this study is the first to address the yield of late harvest according to the available previous studies.

The obtained results showed that late yield trait ranged from zero to 2.07 kg. As some genotypes were unable to continue growing and give late fruits. These hybrids may be suitable for mechanical cultivation and harvesting at once. The grand mean of this trait was 1.217 kg which showed highly significant differences among the tested hybrids, which means the possibility of selecting the best for this trait. The highest value was giving by the new hybrid P13 X P25.

The results also showed that the coefficient of phenotypic variation is high, and its value was 51%, and the coefficient of genetic defiance did not differ much from it, and its value was 48.57%. the heritability in broad sense of the late yield character amounted 90.7% which means that genetic factors predominate in the phenotypic expression of this trait.

Total yield

Yield is determined by numerous genetic and environmental factors, making it a primary focus for every plant breeder. Therefore, continuous improvement is essential to enhance the quality and ensure the sustainability of breeding programs for various crops. A new cultivar cannot replace an established one unless it matches or exceeds its yield, along with clear marketing or productivity advantages.

The minimum weight per plant for this trait as shown in table 2 is one kilogram, and the maximum is 4.42 kg. Statistically, there is a high variability, and the overall average yield was 3.23 and 1.15 kg. in summer and fall plantings, respectively. The phenotypic variation coefficient was 32.17%, while the genetic coefficient of variation was 31.16%.

Broad sense heritability magnitude gives impression on relative effects of environmental and genetic factors on the expression of the trait. Fruit yield exhibited high broad sense heritability (93.94%). Such result implies that this trait is controlled by additive gene effects and selection may be effective. High heritability for fruit yield in cucumber was reported by Saikia et al. (1995), Kumar et al. (2013) and Yadaw et al. (2021).

Table 3 : Superiority of the new hybrids over Bahi Hybrid in the summer season of 2021

Genotype		Average Early yield, kg	Average Late yield, kg	Average Total yield, kg	Superiority % over Bahi		
	Bahi	**0.54 D**	**1.21 D**	**3.34 A**	**Early Yield**	**Late Yield**	**Total Yield**
1	P13 x P25	1.19 C	1.88 A	4.42 A	120.37**	55.37 **	32.33**
2	P20 x P27	1.08 C	0.90 E	2.95 C	100.00**	-25.62**	-11.68*
3	P27 x P26	1.11 C	1.37 C	2.93 C	105.56**	13.11*	-12.28*
4	P28 x P13	1.35 B	1.58 B	3.06 AB	150.00**	30.58**	-8.38*
5	P18 X P21	1.83 A	1.94 A	2.26 D	238.89**	60.33**	-32.33**

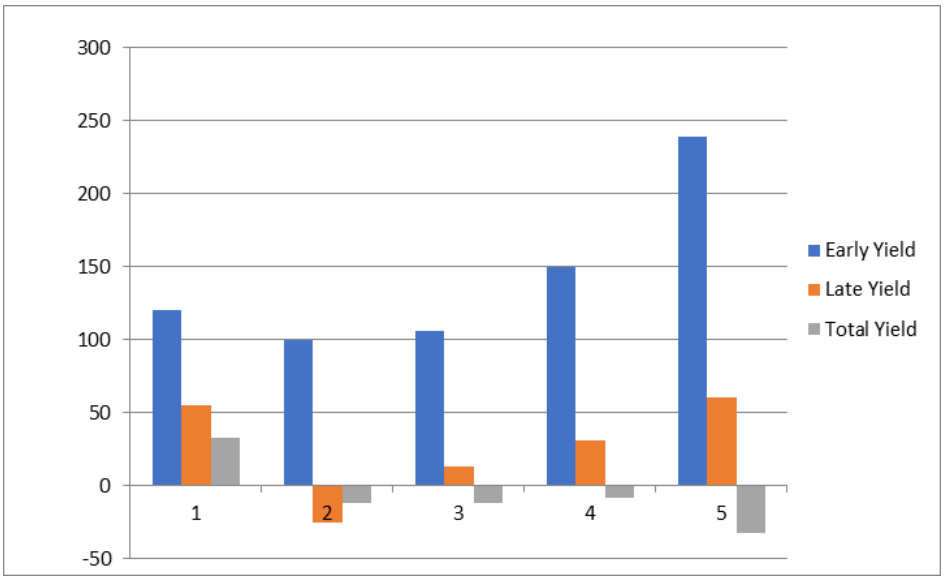

Figure 3: Superiority of the new hybrids over Bahi hybrid

Superiority %

Results on fruit yield per plant for the most acceptable hybrids are shown in table 3 and figure 5. The five hybrids namely P_{13} x P_{25}, P_{20} x P_{27}, P_{27} x P_{26}, P_{28} x P_{13} and P_{18} x P_{21} were selected and tested in 2021 and 2023. These five hybrids were exhibited superiority or inferiority results in early and late and total yield characteristics in both seasons. Three checks were tested namely: Bahi, Sakr and Zein.

The average early yield in hybrid P_{18} x P_{21} was higher than in Bahi hybrid which is known among cucumber farmers as the earliest hybrid cultivar. That means that the Egyptian farmer can grow the new hybrid cultivars. Also, the yield of late cucumber fruits was higher (1.84 kg/plant) in the hybrid P_{18} x P_{21} while it was lower in the commercial Zein hybrid. These results are in the interest of cucumber growers in Egypt who are looking for the cultivar that achieves the highest profits and the lowest cost. The total fruit yield ranged from 2.26 to 4.42 kg/plant in the summer season and from 0.85 to 1.65 kg/plant in the fall season. There were two new hybrids surpassed the total yield of the commercial hybrids in the summer and fall seasons.

If we look at the superiority or inferiority percentage of the new cucumber hybrids that have been produced and tested in this study, we find that their superiority over Bahi hybrid ranged from 100.00% to 238.89% for the early fruit yield trait and from -25.62% to 60.33% for the late fruit yield. But for the total yield trait for the five new hybrids compared to Bahi hybrid the results ranged from -32.33% to 32.37% in the summer.

Table 4: Superiority of the new hybrids over Sakr Hybrid in the summer season of 2021

	Genotype	**Average Early yield, kg**	**Average Late yield, kg**	**Average Total yield, kg**	**Superiority % over Sakr**		
	Sakr	**0.66 D**	**1.45 B**	**2.99 C**	**Early Yield**	**Late Yield**	**Total Yield**
1	P13 x P25	1.19 C	1.88 A	4.42 A	22.26*	29.66**	47.83**
2	P20 x P27	1.08 C	0.90 E	2.95 C	11.08*	-37.93**	-1.34 ^{ns}
3	P27 x P26	1.11 C	1.37 C	2.93 C	14.77*	-5.52^{ns}	-2.01^{ns}
4	P28 x P13	1.35 B	1.58 B	3.06 AB	39.23**	8.97*	2.34^{ns}
5	P18 X P21	1.83 A	1.94 A	2.26 D	88.40**	33.79**	-24.41*

Values with the same letter (s) in each column are not statistically different (MSTAT-C)

Table 5: Superiority of the new hybrids over Zein Hybrids in the summer season of 2021

Genotype		Average Early yield, kg	Average Late yield, kg	Average Total yield, kg	Superiority % over Zein		
Zein		0.51 D	1.24 D	2.80 C	Early Yield	Late Yield	Total Yield
1	P13 x P25	1.19 C	1.88 A	4.42 A	133.33**	51.16**	57.86**
2	P20 x P27	1.08 C	0.90 E	2.95 C	111.76**	-27.42**	5.36 ns
3	P27 x P26	1.11 C	1.37 C	2.93 C	117.64**	10.48*	4.64 ns
4	P28 x P13	1.35 B	1.58 B	3.06 AB	164.71**	27.42**	9.29*
5	P18 X P21	1.83 A	1.94 A	2.26 D	258.82**	56.45**	-19.29**

Values with the same letter (s) in each column are not statistically different (MSTAT-C)

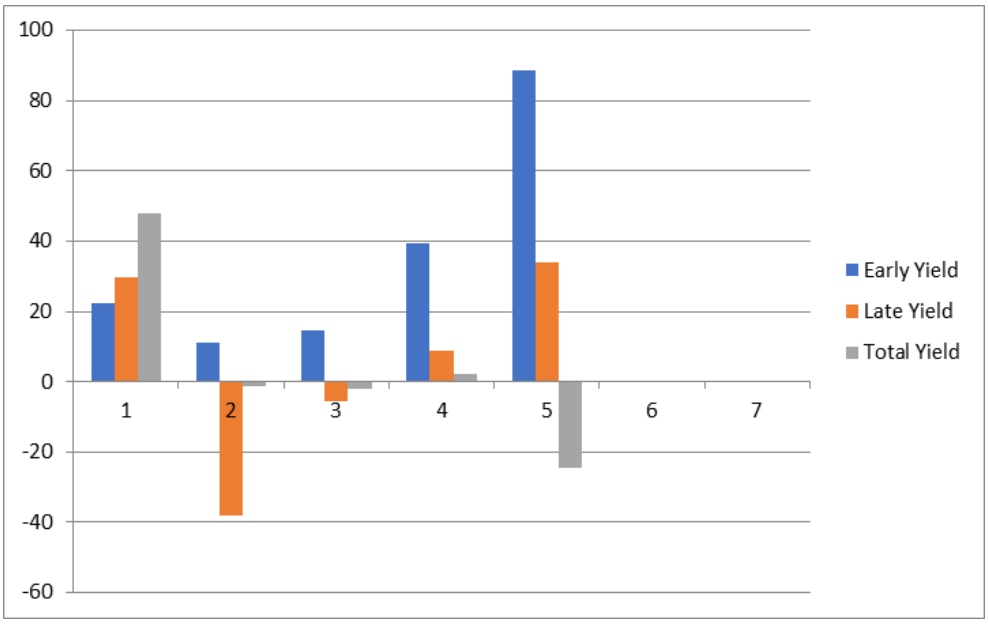

Figure 4: Superiority of the new hybrids over zein hybrid

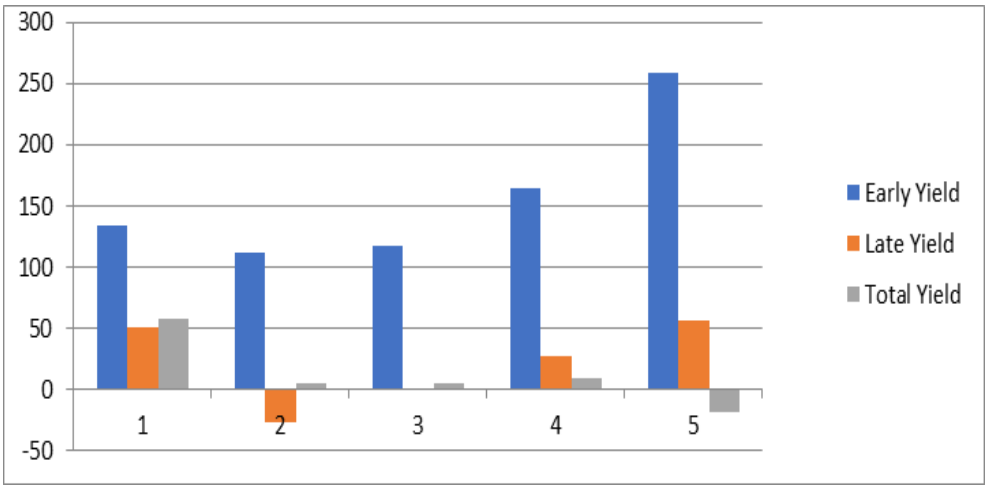

Figure 5: Superiority of the new hybrids over Zien hybrid

In the fall season, the hybrid P13 X P25 gave similar average as Bahi but exceeded Sakr and Zein. On the other hand, early yield of Sakr insignificantly differed from the new hybrids P20 XP27, P28 X P13 and P18 X P21. All tested new hybrids produced earlier fruits than Zein. The comparison among the new hybrids for late fruit yield in fall season revealed that P13 X P25 gave the highest value followed by P28 X P13. Both surpassed Sakr and Zein. Insignificant differences were found between P28 X P13 and Bahi hybrids in fall season only (table 5) and figure 6. To shed light on the superiority or inferiority of the new hybrids over Sakr hybrid, we find that the early yield in the new hybrids is higher than the Sakr cultivar in the summer season by a range of 11.08% to 88.40%. In contrast, it was from -27.59% to 1.34% in the fall season. The results also showed that cultivar Sakr had significantly the earliest yield than in four out of the five new hybrids in the fall season (Table 3). Regarding late yield of Sakr, it was moderate in both seasons and the new hybrids P_{13} X P_{25} and P_{18} X P_{21}, P_{28} X P_{13} in the summer and P13 X P25, P20 X P27 and P28 X P13 in the fall seasons gave higher values. Their superiority percentages ranged from 8.97 to 33.79% in the summer and from 6.67% to 73.33% in fall season.

The superiority of the new hybrids over the commercial hybrid Sakr ranged from -20.36% to 57.86%. These results indicate the right choice of parents and the effectiveness of selection for the new cucumber inbreeds is the backbone of the breeding program (table 5).

The commercial hybrid Zein gave the less weight of the fruits in the early harvest. At the same time, there was a significant increase in the early yield trait of the tested new hybrids in comparison with Zein yield. The superiority of the new hybrids in early fruit trait ranged from 111.76% to 258.82% compared to the commercial

hybrid Zein in the summer season. The new hybrid P_{28} x P_{21} which resulting from crossing two released inbred lines by successive self-pollination, and careful selection in this study, gave the highest percentage (258.82%) in the summer season compared to Zein hybrid. The superiority estimated values of the new hybrids in the fall season ranged from 10.53% to 68.42% over Zein hybrid (table 6).

The superiority of the late yield in the studied new developed hybrids ranged from -27.42% to 56.45% in the summer season and from -15.79% to 105.26% in the fall season.

Significant superiorities of the new genotype P_{13} X P_{25} and P_{28} X P_{13} for the early, late and total yield/plant characters were detected. The previous research had conflicting results regarding the estimations of hybrid vigor in cucumber plant. Scientists suggest the presence of weak hybrid vigor (Ghaderi and lower, 1979a and 1979c and (Cramer and Wehnes 1999). On the other hand, significant positive heterosis for yield in cucumber are reported by Soliman (2015); Mohamed, 2020 in Egypt, Preethi et al, (2019) in India, Hays et al., 1961; Tasidighi and Baker, 1981 in USA, Hossain et al., (2010) and Simi et al., (2017) in Bangladesh, Nguyen et al., (2019) in Vietnam and others. The obtained results were also in line with those reported by Preethi et al (2019) regarding the existence of superiority over the commercial hybrid). Therefore, our cucumber new materials must be tested in multi-location experiments for further evaluation to confirm their potential behavior before any recommendations, since this study was carried out only at one location.

CONCLUSION

It can be said that the results obtained from this study are of particular interest to vegetable growers in Egypt, especially after conducting site experiments to confirm the behavior of these promising hybrids. Also, the study showed the success of producing early-fruiting and late-fruiting hybrids. Two out of the new four tested hybrids exceeded the checking commercial hybrids in the total yield.

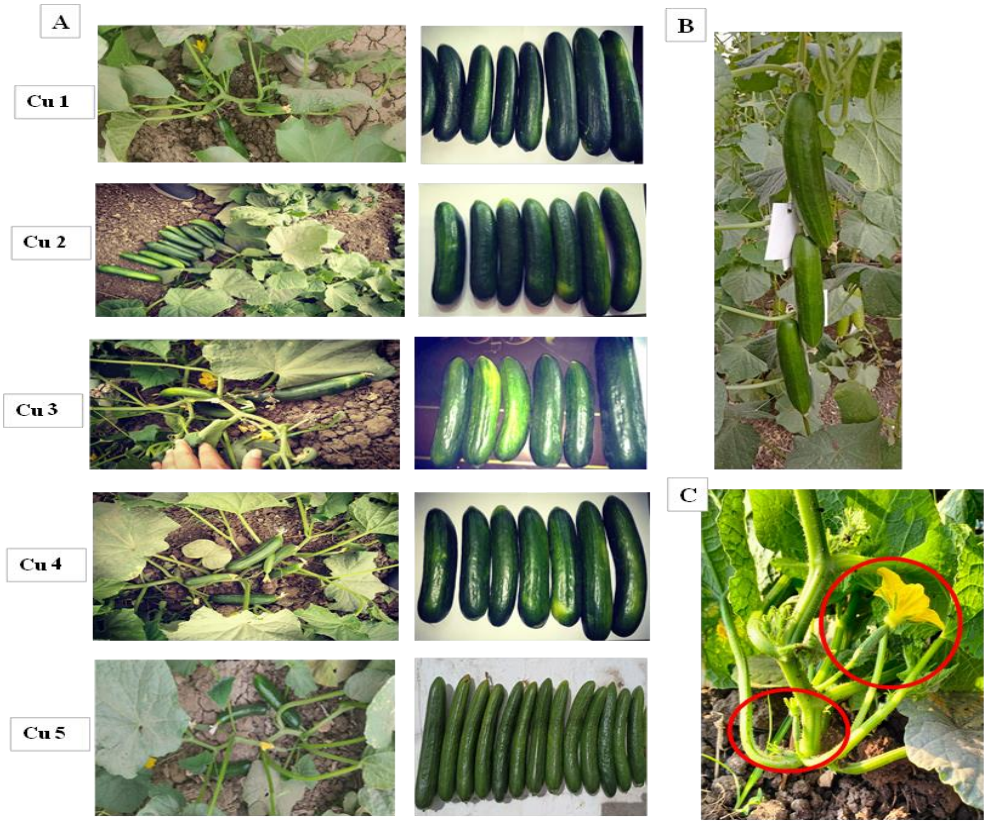

Figure 6. Photos of plants and fruits of the selected five hybrids which showed superiority in early, late, and total yield (A). Example photo of cucumber plants grown in greenhouses in winter season of the experiment (B). Example photo of cucumber plants grown in the open field in fall and summer seasons of the experiment showing the female flowers as an indication of the early fruiting of the hybrids (C).

Table 6 : Superiority of the new hybrids over Bahi Hybrid in the fall season of 2023

Genotype		Average Early yield, kg	Average Late yield, kg	Average Total yield, kg	Superiority % over Bahi		
	Bahi	**0.32 A**	**0.54 BC**	**1.25 C**	**Early Yield**	**Late Yield**	**Total Yield**
1	P13 x P25	0.32 A	0.78 A	1.65 A	0.00 ^{ns}	44.44**	32.00 **
2	P20 x P27	0.25 B	0.48 C	1.06 D	-21.88 **	-11.11**	-15.20**
3	P27 x P26	0.21 C	0.35 D	0.89 EF	-34.38**	-35.19**	-28.80**
4	P28 x P13	0.26 B	0.68 B	1.39 B	-18.75**	25.93**	11.20**
5	P18 X P21	0.27 B	0.32 DE	0.85 E	-15.63**	-40.74**	-24.00**

Values with the same letter (s) in each column are not statistically different (MSTAT-C)

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الملخص العربي:

تفوق الهجن الجديدة التي تم تطويرها عن طريق اختيار النبات الفردية في عشائر الخيار المتقدمة

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تمت دراسة تربية صفات الإنتاج في بعض الطرز الوراثية للخيار في المزرعة التجريبية لشركة دورا الدولية للتنمية الزراعية بمحافظة بني سويف بجمهورية مصر العربية خلال المواسم المتعاقبة من 2019 إلى 2023. وفي هذا البرنامج تم تطوير أصناف الخيار باستخدام طريقة الانتخاب الفردي للنبات. تم تهجين سلالات مختارة وتم تقييم الهجن الناتجة بثلاثة هجن واسعة النمو (باهي، صقر، وزين). أظهر تحليل التباين وجود فروق معنوية عالية بين التراكيب الوراثية المختبرة في محصول الثمار المبكر والمتأخر والكلي. من بين الهجن وهى P13xP25، P20xP27، P27xP26، P28xP13 وP18xP21، أظهرت أعلى تأثير تفوق لخصائص المحصول على أفضل ثلاث فحوصات تجارية. ولذلك، أدى برنامج التربية هذا إلى اختيار سلالات الخيار الجيدة التي يمكن زراعتها لإنتاج خيار مبكر ومتأخر وعالي الإنتاجية في ظل ظروف نمو مصر الوسطى والمواقع المماثلة. علاوة على ذلك، يمكن توفير الكثير من الأموال التي يتم إنفاقها دائمًا على استيراد بذور هجين الخيار الأجنبي.