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RELEASING OF SIX NEW COMMERCIAL MAIZE HYBRIDS FOR ENHANCING YIELD PRODUCIBILITY IN EGYPT

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ABSTRACT

Increasing maize production in Egypt is one of the most important goals of the breeding program of the Maize Research Department. Registration and releasing of superior new hybrids for grain yield is one of the most important factors to achieve this goal. This study included four promising white maize single crosses; SC-Sk138, SC-Sk148, SC-Sk153 and SC-Sk154, one promising yellow single cross SC-Sk150 and one promising red single cross SC-Sk1. These six new hybrids were evaluated in several stages according to the Egyptian hybrid registration program which includes two tests; value for cultivation and use (VCU) and distinction, uniformity and stability (DUS). Six new hybrids were succeeded from all the Egyptian hybrid registration rules during the period from 2019 to 2024 summer season. So, these hybrids were registered as new commercial hybrids. The white hybrid SC-Sk138 was commercially named SC133, the yellow hybrid SC-Sk150 was commercially named SC187 and the red hybrid SC-Sk1 was commercially named SC190. These three hybrids had high performance and broad adaptability for grain yield. Therefore, this study recommended to planting them in various regions in Egypt. Meanwhile the white hybrids SC-Sk148, SC-Sk153 and SC-Sk154 were commercially named SC134, SC135 and SC136, respectively; these three hybrids had high performance and were well adapted to specific environments for grain yield. Therefore, this study recommends planting them in Middle and Upper Egypt.

Key words: ***Hybrids, Adaptability, VCU, DUS, G×E interaction, Parametric, Non-parametric, Stability.***

INTRODUTION

Globally maize is the highest productive crop followed by wheat and rice (FAO 2022). Also, maize is a significant global food crop playing a vital role in the international agricultural system. It is primarily used for animal feed, human consumption and various food products (Erenstein *et al* 2022). In Egypt, the production of maize is sufficient for nearly 50% from consumption, hence the total cultivated area and grain yield/unit area should be increased (Mosa *et al* 2022). Maize is influenced by various factors, including environmental conditions, growing seasons, climatic elements and agronomic management, all of which impact maize growth and yield (Azrai *et al* 2023, Petrovic *et al* 2023 and Zendrato *et al* 2024). Sustainably increasing maize productivity requires a deep understanding of the factors that affect grain yield (Rusinamhodzi *et al* 2020 and Kipkulei *et al* 2024).

Also to increase maize productivity through; genetic approaches, agronomic practices, land management strategies and other technologies (Albahri *et al* 2023). Evaluation of genotypes in multi-environments can help to identify well adapted and stable genotypes before commercial release (Abakemal *et al* 2016 and Rezende *et al* 2020). Also, multi-environment trials are being used by breeders to identify superior genotypes which are broadly adapted or those which are adapted to a specific environment (Musundire *et al* 2021 and Yan 2001). As a result from multi-environment trials, measuring genotype × environment (G×E) interaction is important in optimizing breeding strategies for selecting genotypes that are well adapted to specific environments (Abakemal *et al* 2016 and Matongera *et al* 2023). Awareness of G×E interaction provides valuable insights for selection of maize hybrids that consistently deliver high yield across diverse conditions, helping mitigate grain yield variability a significant challenge for farmers and breeder (Konate *et al* 2023 and Singamsetti *et al* 2023). Strong G×E interaction in agronomic traits like yield can complicate analysis and limit the indent location of superior genotypes, reducing the number of genotypes commended for diverse environment and encouraging environments specific selection (Van Eeuwijk *et al* 2016 and Ligarreto-Moreno and Pimentel-Ladino 2022). So, the task of identifying and breeding genotypes that exhibit exceptional performance and stability across multiple environment conditions is challenging. The genotypes are considered stable if their variations among environments are small. Stable genotype does not change or at least change the performance, regardless of changes in the environment conditions (Becker and Lean 1988). An analysis of yield stability can be used to identify genotypes that maintain consistent performance across various environments (Begna 2019 and Adjebeng-Danquah *et al* 2017). Hence, the objectives of the present study were to estimate the productivity of six promising maize hybrids under different environments to be released as new commercial hybrids and to identify superior hybrids which are broadly adapted or those which are adapted to a specific environment.

MATERIALS AND METHODS

In Egypt, the passing tests; value for cultivation and use (VCU) and distinction, uniformity and stability (DUS) are two conditions to approve and register new hybrid to release as a new commercial hybrid.

VCU test

The new hybrid submitted for registration as a commercial hybrid must pass three trials, the first trial (B) to estimate grain yield across five Research Stations, *i.e*. Sakha, Gemmeiza, Sids, Mallawi and Nubaria, the second trial (C) for resistance to late wilt disease under artificial infestation at four Research Stations, *i.e*. Sakha, Gemmeiza, Sids and Mallawi and the third trial (D) for estimating grain yield in farmer fields across eleven locations, *i.e*. Behera, Kafr El-Sheikh, Dakahlia, Gharbia, Menufiya, Sharkia, Giza, Beni-Suef, Minia, Assiut, and Sohag. Genetic materials used in this study were four promising white maize single crosses, *i.e*. SC-Sk138, SC-Sk148, SC-Sk153 and SC-Sk154, one promising yellow single cross (SC-SK150) and one promising red single cross (SC-Sk1). The hybrid SC-Sk138 was evaluated in 2019 season in B-trial, meanwhile the hybrid SC-Sk148 was evaluated in 2020 season in B-trial, while the hybrids SC-Sk153, SC-Sk154, SC-Sk150 and SC-Sk1were evaluated in B trial in 2021 seasons. The above six hybrids were evaluated in C-trial and D-trial in 2022 and 2023 summer seasons, respectively. Generally, all new hybrids in (B) or (D) trials were compared with one commercial check (white SC128, yellow SC168 and red SC-Yaqoot). The randomized complete block design was used for all above trials with four replications in B-trial and six replications in (C) and (D) trials. Plot consisted of four rows, 6m in length with spacing of 0.8 m in (B) and (C) trials and with spacing of 0.70 m in (D) trial, and 0.25 m between hills in all trials. The fertilizer was applied at planting using 30 kg of P_2O_5 and 24 Kg of K_2O per feddan (fed), meanwhile the nitrogen fertilization was120 kg of N/fed splitted into two equal doses and added before the first and second irrigation in urea form (46%). The internal two rows of each plot were harvested and grain yield in ardab per feddan (ard/fed) adjusted at 15.5% grain moisture content was measured for (B) and (D) trials while resistance% for late wilt disease was estimated in (C) trial. The combined analysis across locations was done according to Snedecor and Cochran (1989) after performing the homogeneity test by Bartlett (1937) using computer application of Statistical Analysis System (SAS-institute 2008) in all trials. Stability parameters were performed in (D) trial using three parametric stability approaches; the variance of genotypes across environments (S^2) proposed by Roemer (1917), determination coefficient (R^2) proposed by Pinthus (1973) and regression coefficient (b_i) proposed by Eberhart and Russell (1966) and two non-parametric stability approaches; genotype absolute rank difference mean as tested across environments ($S_i^{(1)}$) and the variance between the ranks across environments ($S_i^{(2)}$) according to Huehn (1990). The stability analysis was done using GEA-R software Version 4.1 (Pacheco *et al* 2015).

DUS test

The morphological traits were performed by Central Administration of Seed Certification (CASC) in two seasons according to the International Union for the Protection of New Varieties of Plants (UPOV). The DUS-test was carried out during two years; in 2020 and 2023 summer seasons for the new hybrid SC-Sk138, also in 2023 and 2024 summer seasons for the new hybrids, SC-Sk148, SC-Sk153, SC-Sk154, SC-Sk150 and SC-Sk1.

RESULTS AND DISCUSSION

Value for cultivation and use (VCU) test

1. B-trial

Mean performance of six promising crosses for days to 50% silking, plant height and grain yield and their superiority relative to a commercial hybrid are presented in Table 1. For days to 50% silking, the hybrids ranged from 59 days for SC-Sk1 to 64 days for SC-Sk154, meaning that these hybrids ranged from early to medium for time of silking emergence. The earliest hybrid was the red hybrid SC-Sk1 followed by the white hybrids SC-Sk138 and SC-Sk153. For plant height the tallest hybrid was the white hybrid SC-Sk154 followed SC-Sk148, while the shortest hybrid was the white hybrid SC-Sk138. For grain yield, according to the Egyptian hybrid new registration protocol, the hybrid is selected to move up to the second stage of the evaluation (C-trial) when it is not differed significantly (±) or when it shows a significant increase in grain yield compared to the check hybrid. Two white promising hybrids (SC-Sk138 and SC-Sk154) were significantly out-yielded the check hybrid SC128 as well as the promising yellow hybrid SC-Sk150 which was superior to the yellow check SC168. Mean while the two white promising hybrids SC-Sk148 and SC-Sk153 did not significantly out-yield the check SC128. The red promising hybrid SC-Sk1 was selected without comparison because there was no registration of red hybrids in Egypt during this period. Hence, all above six promising hybrids were advanced to the second stage of evaluation (C-trial).

Table 1. Mean performance of six promising crosses for days to 50% silking, plant height and grain yield and their superiority (%) to the check hybrid across five locations.

Hybrid	Days to 50% silking	Plant height (cm)	Grain yield	
			Mean (ard/fed)	Superiority to the check (%)
SC-Sk138 (white)	**60**	**236**	**33.34**	**6.24***
SC-Sk148 (white)	**62**	**263**	**33.06**	**4.75**
SC-Sk153 (white)	**61**	**240**	**33.25**	**5.35**
SC-Sk154 (white)	**64**	**266**	**35.02**	**10.96***
SC-Sk150 (yellow)	**63**	**247**	**29.66**	**8.12***
SC-Sk1 (red)	**59**	**251**	**27.40**	**-**

*** Indicate significant at 0.05 level of probability.**

2. C-trial

The percentage of resistance to late wilt disease under artificial infection by late wilt disease at the four Agricultural Research Stations, Sakha, Gemmaiza, Sids and Mallawi (Table 2), ranged from 95% to 100% for SC-Sk138, from 99% to 100% for SC-Sk148, 100% under all locations for SC-Sk153 and SC-Sk154, from 98% to 100% for SC-Sk150 and from 97% to 98% For SC-Sk1. According to Egyptian rules for hybrid registration, the hybrid is rejected if its resistance percentage is less than 90% at any location; hence, all the six promising hybrids were advanced to the third stage of evaluation (D-trial).

Table 2. Resistance (%) of six hybrids under artificial infection by late wilt disease at four locations.

Hybrid	Location			
	Sakha	Gemmeiza	Sids	Mallawi
SC-Sk138 (white)	100	95	100	100
SC-Sk148 (white)	100	100	99	100
SC-Sk153 (white)	100	100	100	100
SC-Sk154 (white)	100	100	100	100
SC-Sk150 (yellow)	100	100	98	100
SC-Sk1 (red)	97	98	97	98

3. D-trial

Mean performance of six promising hybrids and their superiority relative to the check for grain yield across eleven locations is presented in Table 3. The results showed that hybrids, ranged from 29.52 ard/fed for SC-Sk1 to 31.66 ard/fed for SC-Sk138, white hybrid SC-Sk138 and yellow hybrid SC-Sk150 were significantly superior to the white check SC128 and yellow check SC168, respectively. Meanwhile, the white hybrids SC-Sk148, SC-Sk153 and SC-Sk154 did not differ significantly for grain yield from the check SC128, also hybrid SC-Sk1 did not differ significantly for grain yield from the check SC-Yaqoot. According to the Egyptian registration protocol these hybrids were successful in D-trial. Hence these six promising hybrids were characterized by high yield, resistance to diseases and insects; thus, they passed from VCU-test.

Table 3. Mean performance of six promising hybrids and their superiority (%) to the check for grain yield across eleven locations.

Hybrid	Mean (ard/fed)	Superiority to the check (%)
SC-Sk138 (white)	**31.66**	**7.22***
SC-Sk148 (white)	**30.08**	**1.87**
SC-Sk153 (white)	**30.03**	**1.71**
SC-Sk154 (white)	**28.84**	**-2.32**
Check SC128 (white)	**29.53**	**-**
SC-Sk150 (yellow)	**31.40**	**5.92***
Check SC168 (yellow)	**29.65**	**-**
SC-Sk1 (red)	**29.52**	**-2.49**
Check SC-Yaqoot (red)	**30.28**	**-**

*** Indicate significant at 0.05 level of probability.**

To identify superior hybrids which have consistent performance across various environments or which are adapted to specific environments, this study used some parametric and non-parametric stability measures to estimate the yield stability for these promising hybrids.

Estimates of parametric and non-parametric stability measures for grain yield of nine hybrids are presented in Table 4. According to (S^2), ($Si^{(1)}$) and ($Si^{(2)}$) measures, the stable hybrid is one that has lower value than the average value, while the reverse is true for, (R^2) measure, where a stable hybrid should have higher value than the average value. Meanwhile according to (b_i) measure, the stable hybrid is not significantly different from 1. Hence the promising hybrid SC-Sk138 was stable based on all stability measures (S^2, b_i, R^2, $Si^{(1)}$ and $Si^{(2)}$). While, the two hybrids SC-Sk150 (S^2, b_i, $Si^{(1)}$ and $Si^{(2)}$) and SC-Sk1 (R^2, $Si^{(1)}$ and $Si^{(2)}$) were stable according to most stability parameters in this study. So, above promising hybrids, SC-Sk138, SC-Sk150 and SC-Sk1 were stable with high performance for grain yield. Therefore, this study recommended to planting these hybrids in various regions in Egypt. Meanwhile, the promising hybrids SC-Sk148, SC-Sk153 and SC-Sk154 were of high performance but not stable for most stability measures. Therefore, it can be recommended to be planted in specific areas.

Table 4. Estimates of parametric and non-parametric stability measures of nine hybrids for grain yield.

Hybrid	S^2	b_i	R^2	$S_i^{(1)}$	$S_i^{(2)}$
SC-Sk138 (white)	**13.07**	**0.81**	**0.77**	**0.42**	**6.00**
SC-Sk148 (white)	**26.02**	**1.14**	**0.77**	**0.64**	**8.00**
SC-Sk153 (white)	**25.32**	**1.12**	**0.77**	**0.65**	**9.50**
SC-Sk154 (white)	**28.12**	**1.20***	**0.79**	**0.53**	**7.80**
Check SC128 (white)	**18.95**	**1.01**	**0.84**	**0.35**	**3.80**
SC-Sk150 (yellow)	**17.29**	**0.86**	**0.67**	**0.47**	**6.40**
Check SC168 (yellow)	**14.49**	**0.85**	**0.78**	**0.38**	**4.90**
SC-Sk1 (red)	**27.57**	**1.24***	**0.87**	**0.47**	**6.50**
Check SC-Yaqoot (red)	**14.14**	**0.79***	**0.69**	**0.53**	**6.20**
Mean	**20.55**	**1.00**	**0.76**	**0.49**	**6.57**

*** Indicate significant at 0.05 level of probability.**

The results in Table 5, showed that promising hybrids SC-Sk148, SC-Sk153 and SC-Sk154 gave higher grain yield at Middle and Upper Egypt (across five locations) than in North Egypt (across six location). Therefore, this study recommends planting them in Middle and Upper

Egypt. Elto and Hallauer (1980) stated that the selection of hybrids for mean yield across environments should be emphasized first and then the relative stability of elite hybrids across environments should be determined. Gauch (2013) stated that overarching goal of any breeding program is to breed elite genotypes in relation to a particular environment, but the genotype × environment interaction makes selection more complicated. Begna (2019) stated that plant breeders aim to develop cultivars adaptable to diverse conditions.

Table 5. Mean performance of the three promising hybrids SC-Sk148, SC-Sk153 and SC-Sk154 for grain yield at North Egypt and middle and Upper Egypt.

Hybrid	North Egypt	Middle and Upper Egypt
SC-Sk148 (white)	29.47	30.81
SC-Sk153 (white)	28.18	32.26
SC-Sk154 (white)	27.58	30.35

Distinction, uniformity and stability (DUS) test

The morphological characteristics of the six promising hybrids based on the International Union for the Protection of new varieties of plants (UPOV) are presented in Table 6. Central Administration Seed Certification (CASC) evaluated six promising hybrids in two seasons for the distinction, uniformity and stability (DUS) test. The six new hybrids succeeded in this test, where thirty-five characteristics were measured for each promising hybrid. The most important characteristics for SC-Sk138, anthocyanin coloration of sheath of the first leaf was medium, leaf angle between blade and stem was small, time of anthesis on tassel was early, while time of silking emergence was medium, length of main axis above both lowest side branch and upper side branch of tassel was long, ear length was very long, ear diameter was large, color of tip of grain was white and anthocyanin coloration of glumes of cob was absent. For SC-Sk148, anthocyanin coloration of sheath of the first leaf was strong, leaf angle between blade and stem was small, time of anthesis was medium while time of silking emergence was medium to late, anthocyanin coloration at base of glume was strong, length of main axis above both lowest side branch and upper side branch of tassel was long, plant height was long, ear length was long, ear diameter was large, color of tip of grain was white and anthocyanin coloration of glumes of cob was absent. For SC-Sk153, anthocyanin coloration of sheath of first leaf was strong, leaf angle between blade and stem was small, time of anthesis was early to medium, time of silk emergence was medium, plant height was very tall, ear length was long, ear diameter was large, color of tip of grain was white, and anthocyanin coloration of glumes of cob was absent. For SC-Sk154, anthocyanin coloration of sheath was strong, leaf angle between blade and stem was small, time of anthesis was early to medium, while time to silk emergence was medium, anthocyanin coloration of silks was absent, plant height was very tall, ear length was long, ear diameter was large, number of rows of grain was medium, color of tip of grain was white, anthocyanin coloration of glumes of cob was absent. For SC-Sk150, the angle between blade and stem was small, time of anthesis was early to medium, time of silk emergence was medium, length of main axis above the lowest side branch was very long, plant height was long, ratio height of insertion of ear to plant height was large, ear length was tall, ear diameter was medium, color of tip of grain was orange and anthocyanin of coloration of glumes of cob was present and weak. For SC-SK1, anthocyanin coloration of sheath of first leaf was absent or very weak, leaf angle between blade and stem was small, time of anthesis was early to medium, time of silk emergence was medium, plant height was tall, ear length was medium, ear diameter was small, color of tip of grain was dark red and anthocyanin of coloration of glumes of cob was present and weak.

From above results the six promising hybrids were succeeded for all the Egyptian hybrid registration rules. So, the promising hybrid SC-Sk138 registration was approved by Ministerial Resolution No120 of 2024 and named SC133. Meanwhile, the promising hybrids SC-Sk148, SC-Sk153, SC-Sk154, SC-Sk150 and SC-Sk1 registration was approved in accordance with the Ministerial Resolution No. 128 of 2025 and named SC134, SC135, 5C136, SC187 and SC190, respectively. These hybrids will produce certified seed for farmers.

Table 6. Morphological characteristics of six promising hybrids based on the International Union for the Protection of New Varieties of Plant (UPOV).

Trait	Description					
	SC-Sk138	SC-Sk148	SC-Sk153	SC-Sk154	SC-Sk150	SC-Sk1
First leaf: anthocyanin coloration of sheath	5	7	7	5	1	1
First leaf: shape of apex	3	1	3	1	3	3
Foliage: intensity of green color	2	2	2	2	3	2
Leaf: undulation of margin of blade	2	3	2	2	2	2
Leaf: angle between blade and stem	3	3	3	3	3	3
Leaf: curvature of blade	3	5	3	3	3	3
Stem: degree of zig-zag	2	2	2	2	2	2
Tassel: time of anthesis	3	5	4	4	4	4
Tassel: anthocyanin coloration at base of glume	1	7	1	1	1	1
Tassel: anthocyanin coloration of glumes excluding base	3	3	3	3	3	3
Tassel: anthocyanin coloration of anthers	3	3	3	1	3	3
Tassel: angle between main axis and lateral branches	5	3	3	3	5	5
Tassel: curvature of lateral branches	5	3	3	5	3	5
Tassel: number of primary lateral branches	3	3	3	3	3	5
Ear: time of silk emergence	5	6	5	5	5	5
Ear: anthocyanin coloration of silks	3	3	3	1	3	3
Stem: anthocyanin coloration of brace roots	5	3	5	5	5	3
Tassel: density of spikelet's	3	3	3	5	5	5
Leaf: anthocyanin coloration of sheath	1	3	1	1	1	1
Stem: anthocyanin coloration of internodes	3	3	5	3	1	1
Tassel: length of main axis above lowest lateral branch	7	7	7	7	9	5
Tassel: length of main axis above highest lateral branch	7	7	5	7	5	5
Tassel: length of lateral branch	5	5	5	5	5	5
Plant: hybrids length	7	7	9	9	7	7
Plant: ratio height of insertion of peduncle of upper ear to plant length	5	5	3	5	7	5
Leaf: width of blade	5	5	5	3	3	3
Peduncle: length	5	1	3	3	3	3
Ear: length	9	7	7	7	7	5
Ear: diameter	7	7	7	7	5	3
Ear: shape	2	3	2	2	2	3
Ear: number of rows of grain	3	5	5	5	5	5
Ear: type of grain	3	3	3	3	3	2
Ear: color of top of grain	1	1	1	1	5	8
Ear: color of dorsal side of grain	1	1	1	1	5	8
Ear: anthocyanin coloration of glumes of cob	1	1	1	1	3	3

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إطلاق ست هجن تجارية جديدة من الذرة الشامية لزيادة إنتاجية المحصول فى مصر

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قسم بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية

زيادة إنتاجية الذرة الشامية فى مصر أحد أهم أهداف برنامج التربية لقسم بحوث الذرة الشامية. تسجيل وإطلاق الهجن الجديدة المتفوقة فى المحصول من أهم العوامل لتحقيق هذا الهدف. إشتملت هذه الدراسة على أربع هجن فردية بيضاء مبشرة هى:- (SC-Sk138) و (SC-Sk148) و (SC-Sk153) و (SC-Sk154) ، وهجين فردى أصفر مبشر (SC-Sk150) ، وهجين فردى أحمر مبشر (SC-Sk1). تم تقييم هذه الهجن فى مراحل متعددة طبقاً لقواعد تسجيل الهجن المصرية والتى تشتمل على إختبارات (VCU) للتقييم الإقتصادى ، وكذلك إختبارات (DUS) للتمايز والتجانس والثبات. إجتازت هذه الهجن الستة جميع الإختبارات الخاصة ببروتوكول تسجيل الهجن المصرية خلال المدة من (2019) حتى (2024) ، وتم تسجيلها كهجن تجارية جديدة حيث تم تسجيل الهجين الفردى الأبيض (SC-Sk138) تحت إسم تجارى هجين فردى (SC133) ، وتسجيل الهجين الفردى الأصفر (SC-Sk150) تحت إسم تجارى هجين فردى (SC187) ، وتسجيل الهجين الفردى الأحمر (SC-Sk1) تحت إسم تجارى هجين فردى (SC190) ، وتمتاز هذه الهجن الثلاثة بالمحصول العالى والثبات تحت مختلف البيئات ، وتوصى الدراسة بزراعتها بمختلف الأماكن فى مصر. بينما تم تسجيل الهجن الفردية البيضاء التالية (SC-Sk148) و (SC-Sk153) و (SC-Sk154) تحت الأسماء التجارية (SC134) و (SC135) و (SC136) على التوالى ، وتمتاز هذه الهجن الثلاثة بالمحصول العالى خاصة فى بعض المناطق ، وتوصى الدراسة بزراعتها فى مناطق وسط وجنوب مصر.

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