Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

EVALUATION OF PHYSIOLOGICAL SEED QUALITY AND FIELD PERFORMANCE FOR DIFFERENT TYPES OF MAIZE HYBRIDS

S. A. Kakarash

College of Agricultural Engineering Science - Salahaddin University

***Correspondence to:** Sakar Asaad Kakarash, Department of Field Crop and Medicinal Plants, Agricultural Engineering Science College, Salahaddin University, Erbil, Iraq.
Email: sakar.kakarash@su.edu.krd

Article info

Received: 2024-04-21
Accepted: 2024-06-03
Published: 2024-06-30

DOI-Crossref:
10.32649/ajas.2024.148683.1228

Cite as:
Kakarash, S. A. (2024). Evaluation of physiological seed quality and field performance for different types of maize hybrids. Anbar Journal of Agricultural Sciences, 22(1): 250-264.

Abstract

Farmers use seeds with good vigor as they guarantee a higher rate of emergence compared to less robust varieties to avoid replanting and the resulting delay in maturity or lower productivity due to poor plant density, caused mainly by their genetic makeup. This study investigated seed physiological activity and field performance of maize inbred lines and their different hybrids (single, double, and three-way crosses). Significant differences were detected among genotypes for all studied traits under both laboratory and field conditions. Inbred line 5012 exhibited superior performance across multiple traits, including speed of germination (4 seeds/day), germination percentage 95%, seedling vigor 3702.0, root length 29.93 cm, and root fresh weights 3.47 g. However, inbred line kr640 surpassed in shoot fresh weight 4.296 g and shoot-dry weight 0.99 g. Backcross (5012 × 3007) 5012 demonstrated superiority in speed of germination 93.33%, seedling vigor 3464.67, and specific root length 115.58 cm/g. The study identified specific genotype combinations that exhibited high germination percentages up to 93.33% and enhanced root and shoot development. Moreover, heterosis analysis revealed both positive and negative values for various traits, highlighting the potential for trait improvement through hybridization. In the field, the backcross (5012 × 3007) 3007 exhibited the highest yield 7.93 ton/ha^{-1}, indicating its potential for commercial cultivation. Biplot provided insights into the grouping and correlation patterns among genotypes, facilitating the selection of superior parental lines for future breeding programs. This study provides valuable insights for maize breeders and researchers to optimize genotype selection and hybridization strategies for trait improvement and crop enhancement.

Keywords: Hybrids, Seedling vigor, Root/shoot ratio, Specific root length, GT biplot.

تقييم جودة البذور من الناحية الفسيولوجية والأداء الحقلي لأنواع مختلفة من هجن الذرة الصفراء

ساكار اسعد كاكةرةش

جامعة صلاح الدين – كلية علوم الهندسة الزراعية

***المراسلة الى:** ساكار اسعد كاكةرةش، قسم المحاصيل الحقلية والنباتات الطبية، كلية علوم الهندسة الزراعية، جامعة صالح الدين، اربيل، العراق.

البريد الالكتروني: sakar.kakarash@su.edu.krd

الخلاصة

يركز المزارعون على استعمال البذور ذات القوة والحيوية العالية كونها ضمان للحصول على اعلى نسبة من البزوغ الحقلي أكثر مقارنة باستعمال البذور منخفضة القوة لأن ذلك سيحول دون أعادة الزراعة وما يترتب عليها من تأخير في النضج أو انخفاض في الإنتاجية بسبب رداءة الكثافة النباتية والذي يرجع بالأساس الى التركيب الوراثي للصنف. ومن هنا، أجريت هذه الدراسة لمقارنة تراكيب وراثية مختلفة من الذرة الصفراء بالاعتماد على المؤشرات الفسيولوجية والمورفولوجية وحاصل البذور ومكوناته، تم تنفيذ التجربة بتصميم القطاعات العشوائية الكاملة (RCBD) بثلاثة مكررات خلال الموسم الزراعي الممتد من شهر ايار 2020 إلى ايلول 2021. أظهرت النتائج إلى وجود فروق معنوية بين التراكيب الوراثية لجميع الصفات المدروسة في الظروف المختبرية والحقلية. أظهرت السلالة الفردية 5012 أداءً متفوقًا عبر عدة صفات، بما في ذلك سرعة الانبات (4 بذرة/يوم)، ونسبة الانبات 95%، وقوة البادرة 3702.0، وطول الجذر 29.93 سم، والوزن الطري للجذر 3.47 جرام. كذلك، فقد تفوقت السلالة الفردية kr640 في الوزن الطري للرويشة 4.296 جرام والوزن الجاف للرويشة 0.99 جرام. أظهرت الهجين الرجعي (5012 × 3007) 5012 تفوقًا في سرعة الانبات 93.33%، وقوة البادرة 3464.67، وطول الجذر النوعي 115.58 سم/جم. حددت الدراسة تراكيب وراثية معينة تظهر نسب انبات عالية تصل إلى 93.33% وتحسينًا في تطور الجذور والأجزاء الخضرية. علاوة على ذلك، أظهر تحليل

التغاير قيمًا إيجابية وسلبية لصفات مختلفة، مما يسلط الضوء على الإمكانات لتحسين الصفات من خلال التهجين. اما النتائج الحقلية، أظهر الهجين الرجعي (5012 × 3007) 3007 أعلى حاصل 7.93 طن/هكتار، مما يشير إلى إمكانية زراعتها تجاريًا. قدمت تحليلات الرسم الثنائي حول تجميع التراكيب الوراثية وأنماط الارتباط بينها، مما يسهل اختيار السلالات الأبوية المتفوقة لبرامج التربية المستقبلية. تقدم الدراسة رؤى قيمة لمربي الذرة والباحثين لتحسين اختيار التراكيب الوراثية الجيدة واستراتيجيات التهجين لتحسين الصفات. أن التركيب الوراثي 5012 أظهرت أعلى القيم لمعظم مؤشرات البزوغ الحقلي، في حين اظهر الهجين الرجعي 3007 (3007 × 5012) والهجين الرجعي 5012 (5012×3007) أعلى القيم. هذا يؤكد الى ان التركيب الوراثي 5012 والهجين 3007 (3007 × 5012) هي المادة الوراثية الأفضل بين التراكيب الوراثية الداخلة.

كلمات مفتاحية: الهجن الذرة الصفراء، قوة البادرات، نسبة الجذر/الساق، طول الجذر النوعي، GT.

Introduction

Choosing high-quality maize hybrids is essential for increasing yield and quality in modern agriculture (18). Significant progress was made in genetic enhancement of maize between 1950 and 1990, leading to the release and commercialization of several open-pollinated varieties and tropical hybrids (11). Seed quality is a critical factor affecting the early performance and productivity of maize crops (8). It is influenced by the genetics of inbred lines, its chemical composition, and environmental conditions during seed production. The early selection of inbreds with high seed quality plays a beneficial role in improving germination and field performance (9 and 10). Seed and seedling vigor, important aspects of seed quality, significantly impact field establishment and overall crop productivity. Poor seedling establishment poses a challenge in the field, and is influenced by seed quality, climatic conditions, and field management practices (22). Seed quality encompasses various attributes that contribute to maximum germination capacity and the production of seedlings with rapid emergence and uniform growth (6). Standardized laboratory germination procedures have been criticized for their inability to accurately predict field performance, leading to suggestions for using diverse test conditions to determine the optimum for each seed lot. Vigor testing, such as growth, conductivity, cold test, accelerated aging, and brick grit tests, have been developed to predict the field emergence of seed lots (12). Vigorous seeds germinate, metabolize, and establish rapidly in the field, indicating their high seed vigor (5). To overcome the challenges in seed production of single-cross hybrids, breeding programs for tropical regions have developed double crosses, three-way crosses, backcrosses, and other methods. These approaches utilize the advantages of heterosis in commercial maize seed production, employing high-yield simple crosses as the female parent and inbred lines with good performance as the male parent and possess excellent general combinatorial ability and high pollen production. Evaluating agronomic traits is crucial in assessing hybrids for maize seed production (20). Although several studies have estimated seed yield in hybrids and their parents, continued assessment of the superiority of new hybrids across different environments and years is essential for the benefit of seed producers (1, 2, 4 and 16).

Seed vigor, assessed through germination and vigor tests, including speed of germination, seedling emergence, seedling length, and primary root protrusion, plays a vital role in evaluating seed physiological potential (13). Seed traits, including seed vigor and storage conditions, significantly influence plant growth at the beginning of the vegetation period, particularly root morphology, length, weight, and the number of root tips and root hairs.

Root morphology and physiology are affected indirectly by heterosis (8). The selection of the root system based on seedling stress tolerance has been supported by recent research. Seed and seedling traits provide valuable insights for the evaluation of seed and seedling characteristics after hybridization. (1) indicated that the superior maize F1 hybrid L1×T2 is recommended for large scale multi locational trials prior to commercial cultivation in the Kurdistan region.

Therefore, this research studied seed physiological activity for different inbred lines and their hybrids, heterosis for the different hybrids, and biplot analysis to determine the relation between the genotypes and traits.

Materials and Methods

Four inbred lines were utilized to generate various maize hybrids (single, double, and three-way crosses) during the autumn season of 2020 at the Grdarash Agronomical Research Station, College of Agricultural Engineering Sciences, Salahaddin University-Erbil. The hybridization process resulted in the production of eleven hybrids, as illustrated in Table 1.

Table 1: Sources of Inbred Lines and generated hybrids.

No.	Inbred line and Hybrid	Source
1	3007	Agri_Res_Cen. Baghdad
2	Kr640	Poland
3	5012	FAO
4	MSI4279	FAO
5	3007 × kr640	
6	(3007× kr640) 30007	
7	(3007 × kr640) Kr640	
8	5012 × 3007	
9	(5012×3007) 3007	
10	(5012×3007) 5012	
11	MSI4279 × kr640	
12	(MSI4279 × kr640) kr640	
13	(MSI4279 × kr640) MSI4279	
14	(3007 × kr640) 5012	
15	(MSI4279× kr640) × (5012×3007)	

During the 2020 autumn season, the seeds of the parents and hybrids were planted in plastic pots with a diameter of 30 cm. Five seeds of each genotype were planted in each pot. Upon seed germination, the emerged plants were thinned to three plants per pot. When the plants reached one month of age, the following seed germination parameters and seedling physiological activities were evaluated using germination and vigor tests: standard germination (%), speed germination (first count) (%), seedling length (root and shoot) (cm), seedling weight (root and shoot) (dry and wet) (g), root/shoot ratio (Root/shoot ratio = root dry weight / shoot dry weight) (23), and specific root length - SRL which was calculated using the following equation: (SRL cm g^{-1}) = root length in cm / root dry weight in g) (19).

Field Experiment: In the following autumn of 2021, a comparative experiment was conducted under field conditions to evaluate and compare maize hybrids, including single crosses, double-crosses, and three-way crosses and their parental lines. The experiment followed a complete block design (RCBD). The field trial was conducted at the Grdarash Agronomical Research Station, College of Agricultural Engineering Sciences, Salahaddin University-Erbil. The specific traits assessed included: date to silking, plant height (cm), ear height (cm), ear length (cm), number of rows per ear, 150 kernel weight (g), total yield (ton ha^{-1}). The heterosis parameter was estimated according to (18).

Heterosis = F_1- mean of parents / mean of parents × 100

The results obtained were subjected to statistical analysis using the analysis of variance (ANOVA) method. Mean comparisons were conducted using the Duncan multiple test at a significance level of 5%. The statistical analysis and mean comparisons were performed using the SAS program (17). In addition, the - XLSTAT program was used to show GT biplot analysis.

Results and Discussion

The mean values of physiological seedling traits for the 15 genotypes are shown in Table 2. Significant differences were observed among all inbred lines and hybrids for all the studied traits. The speed of germination was represented by the germination percentage at the first count (10). The inbred line 5012 demonstrated higher value for the most characters, namely speed germination seed/day, germination (%), seedling vigor, root length, root fresh and dry weight (g). while the inbred line kr640 had a higher value in the shoot fresh and dry weight (g) aspects. The hybrids had different attributes for each studied character. The backcross (5012 × 3007) 5012 surpasseds other hybrids for their speed germination seed/day, germination (%), seedling vigor, root length, shoot fresh weight (g), and specific root length cm g^{-1}. Reasons for the backcross superiority can attributed to its better performance other inbred lines, thus improving the hybrid involved. The three-way cross (5012 × 3007) 5012, backcrosses (3007 × kr640) kr640 and both inbred line 5012 and kr640, recorded the highest speed values of 93.33%, 86.67%, 73.33%, and 73.33%, respectively.

Most genotypes exhibited high germination percentages, except for the seeds resulting from the backcross and (MSI4279 × kr640) kr640 with values of 60% and 63.33%, respectively. The backcross (5012 × 3007) 5012 recorded longer root length value of 25.873 cm. This is due to the inbred line 5012 which recorded the highest value of 29.93cm for root length. In contrast, the three-way cross (3007 × kr640) 5012 and double cross (MSI4279 × kr640) × (5012 × 3007) had shorter root lengths of 12.61 and 13.11 cm, respectively. Inbred line 5012 showed high performance in most crosses, indicating its potential for increasing root length, particularly in dry land regions. Crossing between the single cross (5012 × 3007) with the inbred line obtained the tallest shoot 9.50 cm which was a significant value when compared with other genotypes. We noticed the same case with the single cross (3007 × kr640) when we crossed with inbred lines 3007 and kr640 which gave the highest shoot length values of 8.25, 8.0, and 9.21 cm respectively. Among the inbred lines, 5012 showed the highest seedling vigor value at 3702.0, while MSI4279 had a lower value of 2380.33.

The highest seedling vigor 3464.67 was for the backcross (5012 × 3007) 5012, followed by the single cross (MSI4279 × kr640) at 3149.33, whereas, the lowest value was observed in the single cross (5012 × 3007) 1408.67. Significant differences were observed in traits of the root fresh and dry weights, with the inbred line 5012 giving the highest root fresh weight 3.47 g and lowest dry weight 0.39 g which means that where an opposite correlation between fresh and dry weight. As for hybrids, the single cross (MSI4279 × kr640) and their backcross and three-way cross (3007 × kr640) 5012 had the highest root dry weight at value 0.69, 0.66, 0.71, and 0.60 g respectively. The backcross (3007 ×kr640) kr640 significantly exceeded other crosses in terms of shoot fresh and dry weight, with values of 4.296 g and 0.99 g, respectively. This reflects the superiority of the kr640 hybrid over the rest hybrids.

The backcross (MSI4279 ×kr640) kr640 significantly exceeded other hybrids in terms of root shoot ratio, with a value of 2.62, which did not differ from the three-way cross (3007 × kr640) 5012 that recorded 2.11, for specific root length the lowest SRL was demonstrated by the three-way cross (3007 × kr640) 5012 at 21.02 cm g^{-1}, followed by the backcross (MSI4279 × kr640) kr640 at 27.20 cm g^{-1} with the backcross (5012 × 3007) 5012 recording the highest value at 115.58 cm g^{-1}. (17) obtained that the hybrid seeds have higher germination rate 100%, and the seedlings were more vigorous compared to the parents.

Table 2: Means of seed physiological quality traits for each genotype.

Genotypes	Speed germination seed/day	Germination %	Root length (cm)	Shoot length (cm)	Seedling vigor	Shoot fresh weight (gm)	Root fresh weight (gm)	Shoot dry weight (gm)	Root dry weight (gm)	Root shoot ratio	Specific root length (cm gm^{-1})
3007	46.67 b-e	100.00 a	22.22 bcd	6.90 def	2911.67 abc	3.21 a-e	1.94 bcd	0.83 abc	0.35 bc	0.93 cde	75.36 a-f
Kr640	73.33 abc	100.00 a	18.45 def	6.60 ef	2505.33 c-f	3.90 abc	1.63 cd	0.92 ab	0.24 bc	0.26 e	83.85 abc
5012	73.33 abc	100.00 a	29.93 a	7.09 c-f	3702.00 a	3.88 abc	3.47 a	0.88 ab	0.39 b	0.45 e	76.73 a-f
MSI4279	60.00 a-d	100.00 a	14.74 fg	9.06 ab	2380.33 c-f	3.36 a-e	1.49 d	0.66 a-e	0.28 bc	0.71 de	100.07 ab
3007 × kr640	23.33 de	76.67 bcd	15.68 efg	8.25 a-e	1835.27 efg	3.95 ab	2.02 bcd	0.87 ab	0.28 bc	0.33 e	59.18 b-g
(3007× kr640) 3007	23.33 de	60.00 d	15.25 efg	8.00 a-e	1408.67 g	3.13 b-e	2.19 bcd	0.73 a-d	0.23 bc	0.34 e	67.91 a-g
(3007 × kr640) Kr640	86.67 ab	100.00 a	18.83 c-f	9.21 ab	2804.00 bcd	4.29 a	2.51 bc	0.99 a	0.30 bc	0.30 e	65.73 a-g
5012 × 3007	16.67 de	63.33 cd	14.11 fg	6.16 f	1283.60 g	2.57 de	2.33 bcd	0.72 a-d	0.17 c	0.25 e	82.71 a-d
(5012×3007) 3007	53.33 a-e	83.33 abc	23.33 bc	9.50 a	2785.50 bcd	3.56 a-d	2.75 ab	0.45 cde	0.30 bc	0.69 de	77.66 a-e
(5012×3007) 5012	93.33 a	100.00 a	25.87 ab	8.77 abc	3464.67 ab	4.30 a	2.36 bcd	0.58 b-e	0.24 bc	0.43 e	115.58 a
MSI4279 × kr640	60.00 a-d	100.00 a	22.83 bcd	8.66 a-d	3149.33 abc	2.95 b-e	2.55 bc	0.42 de	0.69 a	1.66 a-d	33.00 d-g
(MSI4279 × kr640) kr640	26.67 de	100.00 a	17.33 efg	8.10 a-e	2543.33 c-f	2.94 b-e	2.34 bcd	0.34 de	0.66 a	2.62 a	27.20 g
(MSI4279 × kr640) MSI4279	36.67 cde	100.00 a	19.83 cde	6.58 ef	2640.67 cde	2.81 cde	2.50 bc	0.37 de	0.71 a	1.98 abc	27.92 fg
(3007 × kr640) 5012	56.67 a-d	100.00 a	12.61 g	7.82 a-f	2042.67 d-g	2.44 de	2.07 bcd	0.30 e	0.60 a	2.11 ab	21.02 g
(MSI4279× kr640) × (5012×3007)	10.00 e	86.67 ab	13.11 g	7.49 b-f	1774.07 fg	2.40 e	1.48 d	0.33 de	0.32 bc	1.00 b-e	41.53 c-g

The agronomical character of inbred lines and hybrids are summarized in Table 3, which show highly significant differences among the studied traits. For the inbred lines, kr640 showed the highest plant and ear heights of 165.8 and 91.07 cm respectively, and a higher number of row/ear 18.40 While 5012 recorded 14.67 cm for ear length and gave the highest yield 5.24 t. ha^{-1}. For the hybrids, the backcross (MSI4279 × Kr640) MSI 4279 requireds more days for silking (54.67 days) compared to other hybrids, while three way cross (3007 × Kr640) 5012 and double cross (MSI4279 × Kr640) (5012×3007) both required 44.33 days. The single cross (5012 ×3007) and (5012 × 3007) 3007 three-way cross had higher plant heights at 187.9 and 185.55 cm, respectively, and the backcross (5012 ×3007) 3007 had 103.4 cm for ear height. The three-way cross (3007 × Kr 640) 5012 recorded 37.71 g for 150 kernel weight and single cross (MSI4279 × Kr640) gave 51.04 g. The highest yield/ha^{-1} was found in the backcross (5012 × 3007) 3007 at 7.93 ton.h^{-1}. This demonstrates that the inbred lines 3007 and 5012 can increase yields for most hybrids.

Table 3: Means of some growth and yield component traits for each genotype.

Genotypes	Silking period (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	No_ of rows/ear	150 kernel weight	Yield t ha^{-1}
3007	53.33 a	160.73 d	81.07 bcd	13.07 f	13.47 ef	39.07 bc	3.40 bc
Kr 640	48.33 dc	165.80 bcd	91.07 abc	14.07 def	18.40 ab	40.89 abc	4.89 bc
5012	49.00 bcd	164.00 d	81.77 bcd	14.67 d-f	17.67 ab	36.93 bc	5.24 abc
MSI 4279	53.57 ab	151.37 d	65.87d e	12.99 f	13.00 ef	45.38 abc	2.53 c
(3007 × Kr 640)	47.00 ed	179.67 abc	100.20 ab	16.23 a-e	16.10 bcd	44.86 abc	5.95 ab
(3007 × Kr 640) 3007	51.00 abc	171.80 abc	91.00 abc	15.20 b-f	16.13 bcd	47.57 ab	4.45 bc
(3007 × Kr 640) Kr 640	51.67 abc	150.90 d	54.37 e	13.60 ef	13.20 ef	47.06 abc	2.61 c
(5012 × 3007)	48.00 dc	187.90 a	93.03 abc	16.43 a-e	15.33 cde	43.97 abc	5.73 ab
(5012 × 3007) 3007	48.67 dc	185.50 ab	103.40 a	16.27 a-e	19.17 a	39.99 bc	7.93 a
(5012 × 3007) 5012	53.00 ab	163.23 d	81.00 bcd	14.17 d-f	14.93 cde	45.23 abc	3.87 bc
(MSI 4279 × Kr 640)	49.50 bcd	180.23 abc	88.93 abc	17.10 abc	16.83 bc	51.04 a	4.91 bc
(MSI 4279 × Kr 640) Kr 640	53.00 ab	161.43 d	78.20 cd	15.73 b-f	13.87 def	50.78 a	4.94 bc
(MSI 4279 × Kr 640) MSI 4279	54.67 a	146.97 d	62.93 de	18.10 ab	12.53 f	46.35 abc	4.63 bc
(3007 × Kr 640) 5012	44.33 e	176.15 abc	75.62 cd	18.33 a	13.11 ef	37.71 bc	4.35 bc
(MSI 4279 × Kr 640)(5012×3007)	44.33 e	171.30 abc	76.00 cd	16.67 a-d	12.93 ef	44.00 abc	4.03 bc

Heterosis values for all crosses are presented in Table 4 where negative and positive values were recorded for all studied traits. The highest heterosis for speed germination (germination % at first count) was found in the single cross (MSI4279 × Kr640) (271.46) followed by back cross (3007 × Kr640) 3007 (99.97) and TC (3007 × Kr640) 5012 (80.12). Negative heterosis was shown by the backcross (MSI4279 × Kr640) Kr640 (-72.96) followed by the backcross (5012 × 3007) 5012 (-60.00). These cross combination with negative heterosis decrease in trait values to the lower parent.

For germination traits, the backcross (MSI4279 × Kr640) Kr640 and (5012 × 3007) 3007 had the lowest values of heterosis at -0.36 and -0.23, respectively. The higher heterosis was recorded for backcross (3007 × kr640) 5012 (48.45) followed by backcross (3007 × kr640) Kr640 (42.23) for seedling vigour. The negative heterosis indicated a decrease in seedling vigour. The backcross (MSI4279 × Kr640) kr640 had a higher negative value of heterosis (-53.79) followed backcross (5012 × 3007)5012 (-32.46).

Positive heterosis was recorded for shoot length of the single cross (MSI4279 × Kr640) (30.99) followed by three way cross (3007 × Kr640)5012 (19.18). These hybrids can be used in the selection program to increase shoot length. conversely, the backcross (MST 4279 × Kr640) Kr640 and the backcross (3007 × Kr 640) Kr640 recorded highly negative heterosis (-12.91, -17.29) indicating that these hybrids may decrease these trait values in the next generation.

High positive heterosis was found in most crosses, except for four hybrids that exhibited negative heterosis for root length (Table 4). The three-way cross (3007 × Kr640) 5012 showed the highest positive heterosis value 48.58, followed by the backcross (MSI4279 × Kr640) MSI4279 (46.10) and the backcross (3007 × Kr640) Kr640 (42.36). The backcross (MSI4279 × Kr640) Kr640 displayed the highest negative heterosis value for root length (-27.00).

Table 4: Heterosis values for seedling physiological quality traits for all genotypes.

Genotypes	Speed germination (first count)	Germination %	Seedling vigour	Shoot length (cm)	Root length (cm)	Shoot fresh weight (gm)	Root fresh weight (gm)	Shoot dry weight (gm)	Root dry weight (gm)	Root shoot ratio	Specific root length (cm gm^{-1})
(3007 × Kr640)	47.36	0	19.48	-6.02	19.47	11.84	-20.24	134.60	-48.46	-59.70	173.43
(3007 × Kr640) 3007	99.97	0	-6.71	-17.29	-6.68	120.11	-23.65	56.30	-53.35	-84.96	63.51
(3007 × Kr640) Kr640	75.97	0	42.23	5.20	42.36	82.64	56.20	45.75	-25.98	-68.84	48.56
(5012 × 3007)	43.98	0	-1.45	13.81	-1.53	25.20	-32.60	113.33	-11.41	-70.12	75.90
(5012 × 3007) 3007	-46.15	-0.23	-25.11	-4.89	-2.23	25.53	5.59	74.00	-48.07	-80.76	29.90
(5012 × 3007) 5012	-60.00	-0.4	-32.64	-6.26	11.55	8.07	23.17	52.08	-67.35	-85.59	296.85
(MSI4279 × Kr640)	271.46	0.07	21.16	30.99	14.34	64.80	26.13	181.71	-42.52	-79.65	89.26
(MSI4279 × Kr640) Kr640	-72.96	-0.36	-53.79	-21.91	-27.00	-28.12	-6.98	16.41	-74.95	-82.23	197.03
(MSI4279 × Kr640) MSI4279	10.33	-0.16	32.43	13.67	46.10	6.58	37.34	-15.53	3.06	5.70	44.80
(3007 × Kr640) 5012	80.62	0	48.45	19.18	48.58	10.01	18	2.85	-40.57	-17.95	139.84
(MSI4279 × Kr640)× (5012×3007)	-18.17	0	35.79	-5.16	36.01	-22.89	27.81	-24.05	141.25	229.36	-60.19

The heterosis of some agronomical characters and yield components of hybrids is showen in Table 5. The negative heterosis for silking period means early hybrids which need less days to silking. The three way cross (3007 × Kr640) 5012 was the earlier hybrid (-8.8), while positive heterosis was found in the backcross (5012 × 3007) 5012 at 8.71. the backcross (5012 × 3007) 3007 exceeded other hybrids for plant and ear heights, number of row/ear and grain yield. Further, the double cross (MSI4279 × Kr640) × (5012 × 3007) hybrid gave a negative heterosis for six out of seven studied characters. The negative and positive heterosis show the high combination among the inbred line, which provided the opportunity to make the selection for different characters, high yield, early or late hybrids according the combining ability of some inbred lines.

Table 5: values of heterosis for yield and components.

Genotypes	Silking period (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Number of row/ear	150 kernel weight	Yield $t.ha^{-1}$
(3007 × Kr640)	7.66	11.65	12.13	19.69	1.06	6.30	17.39
(3007 × Kr640) 3007	1.49	3.33	2.50	3.82	9.15	16.65	7.50
(3007 × Kr640) Kr640	8.07	-6.27	-42.03	-10.17	-23.47	12.90	-46.40
(5012 × 3007)	-6.79	3.41	14.27	18.54	-1.47	15.73	32.63
(5012 × 3007) 3007	-5.41	17.80	18.79	10.31	33.19	-3.66	73.90
(5012 × 3007) 5012	8.71	-0.65	-7.31	-8.88	-9.46	11.81	-29.56
(MSI4279 × Kr640)	-2.75	4.52	13.34	26.47	7.19	18.33	32.07
(MSI4279 × Kr640) Kr640	8.38	-13.78	-13.10	0.96	-21.29	10.48	2.04
(MSI4279 × Kr640) MSI4279	5.82	-9.62	-18.68	20.34	-15.96	-3.87	24.79
(3007 × Kr640) 5012	-8.80	4.69	-15.15	18.71	-22.33	-5.06	-14.03
(MSI4279 × Kr640) × (5012×3007)	-9.74	-1.66	18.77	-0.53	-19.58	-7.36	-24.10

Biplot analysis used to compare the inbred lines based on multiple traits to classify inbred lines that are good in positive aspects. The relative performance of each inbred line and hybrids were compared simply by the length of their projections on the vector of a specific variable. The inbred lines and their hybrids were classified into four different groups based on seed and seedling physiological activity. Inbred lines and hybrids in Group 1 (TZS, FZO, BC2, and BC4) were found to have speed germination, SG- germination (%), seedling vigor, shoot length, root length, shoot fresh weight, and root fresh weight. Inbred lines and hybrids in Group 2 were found to have root/shoot and root dry-weight. Inbred lines and hybrids in Group 3 did not share any of the measurements. Inbred lines and hybrids in Group 4 revealed high shoot dry weight and specific root length. In the biplot, the approximate correlation coefficient is the cosine of the angle between any two or more trait vectors. Acute angles of less than 90° indicate a positive correlation, obtuse angles exceeding 90° indicate a negative correlation, and right angles, which are equal to 90° indicate no correlation. The trait might not be correlated with other traits if the vector is small (14). This demonstrates that the inbred lines and hybrids belong to different heterotic groups. It is suggested that the inbred lines selected from these different heterotic groups be utilized as parents in crosses for producing new corn hybrid varieties having good or bad traits.

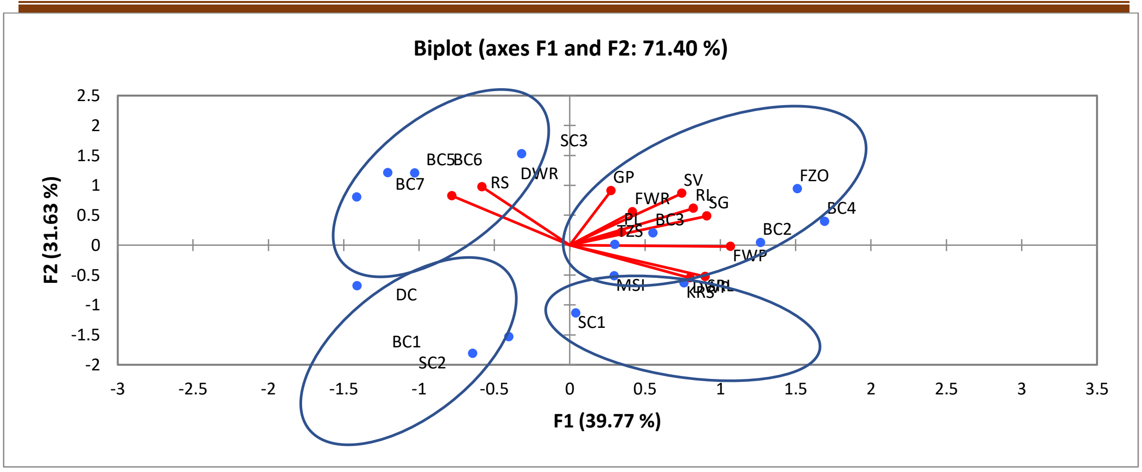

Figure 1: Principal component analysis (PCA)-biplot of 15 maize inbred lines and their hybridizations based on the variance in 11 seed and seedling morpho-physiological traits Bar plots (B) with variations above represent the contribution of each PC to the total variation.

Figure 1 Principal component analysis (PCA)-biplot of 15 maize inbred lines and their hybridizations based on the variance in 11 seed and seedling morpho-physiological traits Bar plots (B) with variations above represent the contribution of each PC to the total variation. Red dashed lines (C, D) in the bar plots denote reference lines, and the variable bars above the reference lines are considered most important in contributing to the PC1 and PC2. Speed germination, SG- % germination, GP- seedling vigor, SV- shoot length, PL- root length, RL- shoot fresh weight, FWP- root fresh weight, FWR- shoot dry weight, DWP- root dry weight, DWR- root/shoot, RS- SRL, SRL. 3007, TZS: Kr640, KRS- 5012, FZO- MSI4279, MSI- 3007 × kr640, SC1- (3007× kr640) 30007, BC1- (3007 × kr640) Kr640, BC2- 5012 × 3007, SC2- (5012×3007) 3007, BC3- (5012×3007) 5012, BC4- MSI4279 × kr640, SC3- (MSI4279 × kr640) kr640, BC5- (MSI4279 × kr640) MSI4279, BC6- (3007 × kr640) 5012, BC7- (MSI4279× kr640) × (5012×3007), DC.

Principal component analysis (PCA) was performed on a dataset consisting of 4 maize inbred lines and 11 different hybridizations to determine any potential correlations existing between the measured characteristics in this study (Figure 2). PC1 and PC2 were projected based on the first two principal components obtained from the correlations between traits and inbred lines and their hybrids. As the first two PCs accounted for the highest proportion of variance (65.55%), the PCA-biplot was produced with PC1 (49.27%) and PC2 (16.28%). The results of the biplot show all characteristics except El (ear length) clustered in the leftmost region and rightmost part of the biplot. All the inbred lines and their hybrids except FZO, DC, and BC7 gathered into two groups in the rightmost area (under normal conditions). Similar results were shown by (14 and 15) The singular value decomposition biplot analysis confirmed the findings by grouping the inbred lines into five main categories based on their agronomic traits.

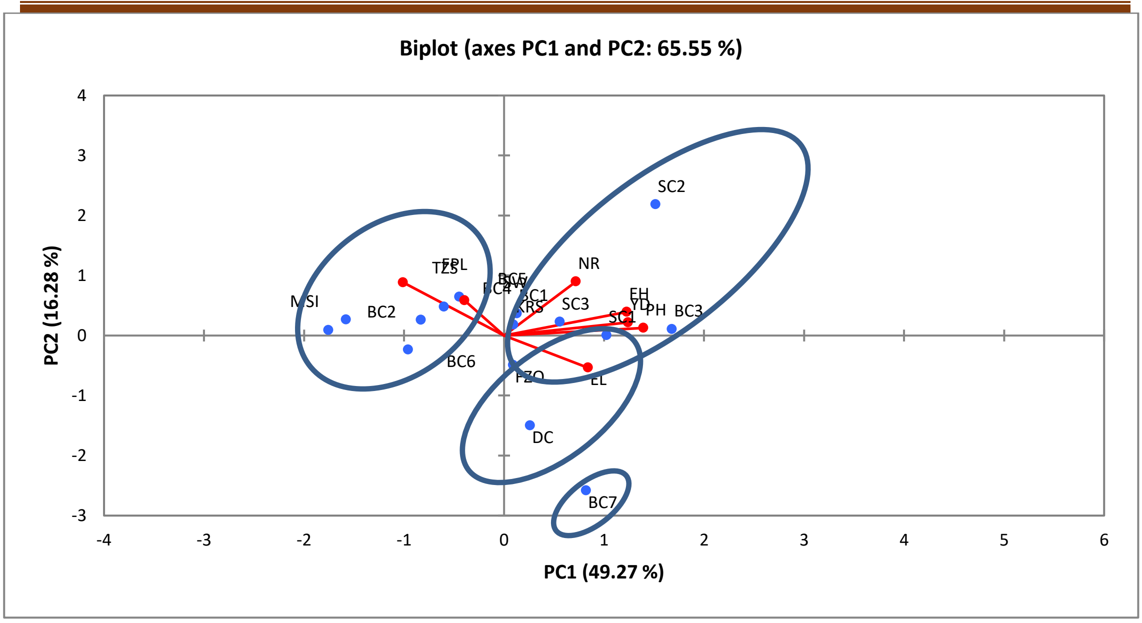

Figure 2: principal component analysis (PCA)-biplot of 15 maize inbred lines and their hybridizations based on the variance in 7 field morpho-physiological traits.

Figure 2 principal component analysis (PCA)-biplot of 15 maize inbred lines and their hybridizations based on the variance in 7 field morpho-physiological traits. (B) Bar plots with% variation above represent the contribution of each PC to the total variation. (C, D) Red dashed lines in the bar plots denote reference lines. The variable bars above the reference lines are considered most important in contributing to the PC1 and PC2. flowering plant length (day), FPL- plant height(cm), PH- ear height (cm), EH- ear length (cm), EL- number row, NR- 150 weight (g), SW- Yield(t.ha^{-1}) ,YD. 3007,TZS- Kr640,KRS: 5012,FZO: MSI4279,MSI- 3007 × kr640, SC1- (3007× kr640) 30007, BC1- (3007 × kr640) Kr640, BC2- 5012 × 3007,SC2- (5012×3007) 3007, BC3- (5012×3007) 5012, BC4- MSI4279 × kr640, SC3- (MSI4279 × kr640) kr640, BC5- (MSI4279 × kr640) MSI4279, BC6- (3007 × kr640) 5012, BC7- (MSI4279× kr640) × (5012×3007) DC.

Conclusions

Significant variations were seen in seed physiological activities and field performance for 15 genotypes. Inbred line 5012 was selected as a genotype for enhancing seedling vigor and root development, while kr640 exhibited good shoot characteristics. Among the hybrids produced, backcross (5012 × 3007) 5012 demonstrated robust performance in multiple traits, underscoring the importance of parental selection in hybrid breeding. Heterosis analysis revealed both positive and negative values among the hybrids, indicating the potential for trait improvement through hybridization. In the field, specific hybrids, such as backcross (5012 × 3007) 3007, exhibited high yield potential, providing valuable insights for commercial cultivation. Biplot analysis were represented by four different groups among genotypes and traits for both lab and field experiments. The result indicate the superiority of parental lines for future breeding efforts aimed at developing high-yielding and resilient maize varieties. Overall, the study provides valuable insights for maize breeders and researchers to optimize genotype selection and hybridization strategies for trait improvement and crop enhancement.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Author S. A. Kakarash; methodology, writing—original draft preparation, writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted in accordance with the protocol authorized by the College of Agricultural Engineering Science, Head of the Field Crops and Medicinal Plants Dept., Scientific Committee, Kurdistan region, Iraq.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

The authors are thankful for the help of the Field Manager, College Dean, and the Head of the Field Crops and Medicinal Plants Dept. College of Agriculture, University of Salahaddin, Iraq.

Disclaimer/Journal's Note:

The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of AJAS and/or the editor(s). AJAS and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

References

1. Abdulazeez, S. D., Kakarash, S. A., and Ismael, N. B. (2021). Estimation of heterosis and combining ability for yield, yield component using line× tester methods in maize (Zea Mays L.). In IOP Conference Series: Earth and Environmental Science, 761(1): 012083. DOI: 10.1088/1755-1315/761/1/012083.
2. Al-jughaify, A. S. F., & Sh. J. Alobaidy, B. (2023). Effect Of Osmo-Hardening Seed On K And Na Concentration And Some Growth Properties Of Wheat Under Salt Stress. Anbar Journal Of Agricultural Sciences, 21(1), 32-43. doi: 10.32649/ajas.2023.179713.
3. Alvarenga, R. O., Marcos-Filho, J., and Timóteo, T. S. (2013). Assessment of the physiological potential of super sweet corn seeds. Journal of Seed Science, 35: 340-346.

4. Andrés-Meza, P., Sierra-Macías, M., Palafox-Caballero, A., Rodríguez-Montalvo, F. A., and Espinosa-Calderón, A. (2013). Líneas de maíz convertidas al carácter de alta calidad de proteína. Universidad y ciencia, 29(3): 317-323.
5. Association of Official Seed Analysts. (1983). Seed vigor testing handbook: Contribution No. 32 to the Handbook on Seed Testing. Association of Official Seed Analysts.
6. Black, M., and Bewley, J. D. (Eds.). (2000). Seed technology and its biological basis. Crc Press.
7. Davidson, R. L. (1969). Effect of root/leaf temperature differentials on root/shoot ratios in some pasture grasses and clover. Annals of Botany, 33(3): 561-569. https://doi.org/10.1093/oxfordjournals.aob.a084308.
8. Elias, S. G. (2018). The importance of using high quality seeds in agriculture systems. Agricultural Research and Technology: Open Access Journal, 15(4): 1-2. https://doi.org/10.19080/ARTOAJ.2018.14.555961.
9. Elsahookie, M. M., and Cheyed, S. H. (2011). Predicting percent of plants in the field giving cultivar mean grain yield and up (+ Ẍ) by vigorous seedlings emerged from sand (SE/96h). Iraqi Journal of Agricultural Sciences, 42(5): 19-26.
10. Goggi, A. S., Pollak, L., Golden, J., Goggi, A. S., DeVries, M., McAndrews, G., and Montgomery, K. (2007). Impact of early seed quality selection on maize inbreds and hybrids. Maydica, 52: 223-233.
11. International Seed Testing Association, ISTA. (1987). Handbook of Vigor Test Methods. 2nd ed., International Seed Testing Association, Zurich, Switzerland.
12. International Seed Testing Association. (1999). Handbook of Vigour Test Methods 3rd edition International Seed Testing Association Zurich Switzerland Supplement to Seed Sci. and Technol. Technol. V. 27.
13. Marcos Filho, J. (2015). Seed vigor testing: an overview of the past, present and future perspective. Scientia agricola, 72: 363-374. http://dx.doi.org/10.1590/0103-9016-2015-0007.
14. Mustafa, B. S., Ismael, N. B., Mustafa, N. R., Kakarash, S. A., and Abdulazeez, S. D. (2024). Chlorophyll content and leaf area correlated with corn (Zea mays) yield components in F1 hybrids. The Indian Journal of Agricultural Sciences, 94(4): 352-357. https://doi.org/10.56093/ijas.v94i4.140666.
15. Mustafa, N. R. (2020). Diversity, performance and selection of tropical sweet corn inbred lines, and their combining abilities in hybrid combinations (Doctoral dissertation, School of Graduate Studies, Universiti Putra Malaysia).
16. Nelson, P. T., Krakowsky, M. D., Coles, N. D., Holland, J. B., Bubeck, D. M., Smith, J. S. C., and Goodman, M. M. (2016). Genetic characterization of the North Carolina State University maize lines. Crop Science, 56(1): 259-275. https://doi.org/10.2135/cropsci2015.09.0532.
17. Omar, S., Tarnawa, Á., Kende, Z., Ghani, R. A., Kassai, M. K., and Jolánkai, M. (2022). Germination characteristics of different maize inbred hybrids and their parental lines. Cereal Research Communications, 50(4): 1229-1236. https://doi.org/10.1007/s42976-022-00250-9.

18. Sadalla, H. A., Guznay, J. B., Kakarash, S. A., Galalay, A. M., and Haji, O. G. (2016). Succession of maize with some winter crops 2–effects on maize and winter crop characters. The Iraqi Journal of Agricultural Sciences, 47(2): 667-671. https://doi.org/10.36103/ijas.v47i2.613.
19. SAS Institute. (2002). SAS/SAT. Version 9.00. Cary, NC.: SAS.
20. Sesay, S., Ojo, D. K., Ariyo, O. J., Meseka, S. K., Fayeun, L. S., Omikunle, A. O., and Oyetunde, A. O. (2017). Correlation and path coefficient analysis of top-cross and three-way cross hybrid maize populations. African Journal of Agricultural Research, 12(10): 780-789. DOI: 10.5897/AJAR2016.11997.
21. Yan, W. (2001). GGEbiplot—A Windows application for graphical analysis of multienvironment trial data and other types of two-way data. Agronomy journal, 93(5): 1111-1118. https://doi.org/10.2134/agronj2001.9351111x.
22. Zhu, S. Y., Hong, D. L., Yao, J., Zhang, X. L., and Luo, T. K. (2010). Improving germination, seedling establishment and biochemical characters of aged hybrid rice seed by priming with KNO3+ PVA. African Journal of Agricultural Research, 5(1): 78-83. DOI: 10.5897/AJAR09.389.
23. Zobel, R. W., and Wright, S. F. (2005). Roots and soil management: interactions between roots and the soil (Vol. 48). American Society of Agronomy. DOI:10.2134/agronmonogr48.