*J. Plantarum.,* 6(2): 67-78

ISSN PRINT 2710-4079
ISSN ONLINE 2710-4087

# COMPARATIVE ANALYSIS OF GERMINATION ATTRIBUTES TO ASSESS VARIABILITY IN MAIZE HYBRID GERMINATION POTENTIAL

**ZARGHOONA NAZ[1], SUMMERA JAHAN[1,2], AUDIL RASHID[1], FAHD RASUL[3], SOBIA SHAHZAD[4]**

1. *Department of Botany, University of Gujrat, Gujrat, Pakistan.*
2. *Institute of Botany, University of the Punjab, Lahore, Pakistan.*
3. *Department of Agronomy, University of Agriculture Faisalabad, Faisalabad, Pakistan.*
4. *Department of Botany, The Islamia University of Bahawalpur, Bahawalnagar Campus, Bahawalnagar, Pakistan.*

Corresponding Author's email: summera.botany@pu.edu.pk

Received on: 17-03-24; Reviewed on: 29-10-24; Accepted on: 07-11-2024; Published on: 10-12-2024

**Abstract**

The germination potential of different cereal crops is the key factor in determining their productivity. The purpose of this study was to identify the highest germination of seed between different hybrids of maize**.** Maize is one of the most prevalent and oldest cereal crops and is commonly used in food and fodder. Corn seed breeders provide high-quality, superior seed for the growth and cultivation of maize on a national and international scale. Screening of maize hybrids at the initial stage is a useful tool for better crop production. To evaluate the high performance of the maize hybrid screening experiment, a completely randomized design (CRD) with three replications was used, and the seed of seven maize hybrids was sown in the laboratory to access suitable hybrids for field trials. The present study revealed that the farmer showed a strong interest in accessing maize hybrids. A large number of hybrids are available on the market; that's why the selection of the right hybrid is difficult for farmers. This article explores the best hybrid seed selection for farmers to gain more yield and fodder for animals. The data was analyzed using a one-way ANOVA on Minitab 21. The present result showed that the hybrids Dk-2088, Yh-5427, and Dk-6317 gave better results as compared to other hybrids. The highest germination percentage (M=100 (%), SE=1), plant fresh weight (M=0.641(g), SE=0.008), and dry weight (M=0.175 (g), SE=0.006) were noted in Dk-6317. While the highest leaf length (M = 6.08 (cm), SE = 1.26) and seedling vigour index were found in Yh-5427 (M = 5.73(%), SE = 1.13).

**Keywords**: Maize; seed yield; seedling vigor index; maize hybrid screening

## Introduction

Maize (*Zea mays* L.) belongs to the Poaceae family, an important crop cultivated all around the globe; it is considered the third most important cereal crop after wheat and rice. It accounts for 62% of the total cereal production (Farhad *et al*., 2011). The national production of maize is increasing continuously with various uses, but mainly it is used to fulfill the demand for the animal feed industry (Zanuddin and Azrai, 2015). The national production of maize in 2018 was 30 million tonnes, and it is predicted that it will reach approximately 28 million tonnes in 2024 (FAO, 2017). In developing countries, a significant amount of maize is used in daily food. It is considered yellow gold because of its many uses, like animal feed, manufacturing food, and non-food materials. Many studies have been conducted on maize due to its large economic importance (Badu-Apraku and Fakorede, 2017).

It is mostly used in numerous types of products, such as snacks, flour, cornmeal, and breakfast cereals. Corn kernels provide oil that can be

used for domestic cooking and as food additives, including pharmaceuticals (Oladejo and Adetunji, 2012). A large number of researchers and breeders gain attention because of its genetic enhancement, which makes it suitable to grow and easy to handle for the collection of data (Chen *et al*., 2015). The edible oil prepared from maize contains a low level of saturated fatty acids in contrast to other protein sources. Maize contains a large number of vitamins, minerals, and micronutrients like antioxidants, magnesium, manganese, and copper, as well as many unsaturated fatty acids like oleic acid and linoleic acid that can be part of our daily lives and help prevent many diseases (Wang *et al.*, 2013).

To evaluate seed quality, which has a direct impact on crop output and plant establishment under varied environmental conditions, germination studies are essential. They provide information on how seeds will behave in controlled or natural environments, acting as an early indicator of seed viability (Finch-Savage and Bassel, 2016). For strong seedling establishment, which is the basis of high productivity and crop resilience, it is imperative to assess the germination potential of maize seeds (Serrano *et al*., 2020). The germination of seed is an indicator of seed viability, which describes the ability of seed to germinate in natural conditions (Baldwin *et al*., 2006). Seed germination is an important stage of the plant life cycle; this stage helps in seedling development.

Among the different stages of the plant life cycle, seed germination, seedling emergence, the establishment of radicles, and plumules are the key processes for plant survival and development. The most important criteria in plants are shoot and root length, which play an important role in plant anchorage to soil and absorption of water and minerals (Muga *et al.,* 2013). Furthermore, germination tests conducted under various environmental stressors, like salt, temperature fluctuations, and drought, offer important information about how well-suited particular maize hybrids and cultivars to harsh climates. Therefore, germination trials help farmers choose high-quality seeds that retain vigor and productivity in the face of adversity by identifying high-performing genotypes appropriate for sustainable agriculture (Miransari and Smith, 2019).

Germination trials play a crucial role in assessing seed quality, which directly influences crop yield and plant establishment in various environmental conditions. Germination trials allow researchers and growers to identify the best seed lots with high germination rates and vigor, ultimately leading to improved crop stand and performance under diverse field conditions (Steinbrecher and Leubner-Metzger, 2017). By selecting hybrids that demonstrate superior performance in germination tests, researchers can support the development of maize varieties with enhanced genetic traits and resilience. Such varieties are not only better suited for commercial cultivation but also contribute to food security and sustainable agricultural practices, addressing the increasing global demand for staple crops (Paparella *et al*., 2015).

The challenges facing current and future crop production extend beyond meeting grain demand; they also encompass the development of environmentally sustainable cereal varieties to facilitate agricultural expansion. The objective of this study was to identify and select robust-growing hybrids suitable for cultivation under natural conditions, thereby enabling farmers to access high-quality maize seeds for large-scale commercial

cultivation. Furthermore, the selection of superior varieties enhances yield production. In the contemporary agricultural landscape, farmers prioritize seed quality alongside quantity.

**Material and Methods**

The experiment was conducted at the University of Gujrat, Gujrat, on February 2, 2023, in the plant physiology laboratory. The seven maize hybrid names DK-1429, Dk-2088, YH-5427, Dk-6317, Dk-6321, Dk-7024, and Dk-8108, with three replications, were sown in the laboratory. The seeds of this hybrid were purchased from registered multinational seed companies Bayer Crop Pvt Ltd. The seeds were treated with the 200 ml of Hombre Excel Imidacloprid Tebuconazole to prevent fungal attack as recommended by Bayer Crop Sciences.

**Growing environmental condition**

The environmental conditions, including temperature, humidity, wind speed and pressure during the experiment were collected from Accu-weather and the World Weather Information site. In February 2023, Gujrat, the average daily temperature fluctuated between 9°C minimum and 28°C maximum. The climate was moderate due to moderate humidity, frequently varies between 65 and 70 percent. Wind speed during the germination experiment was around 5-10 km/ hour with infrequent reaching up to 15 km/ hour. The range of atmospheric pressure in the study site was typically persisted between 1015 to 1025 hPa with light variation due to regional weather patterns.

The ten maize seeds were sown in 13.5 cm Petri plates from each hybrid, and the plates were covered with filter paper and moistened with 5 ml of distilled water (Karrfalt, 2011). The seeds were sown at a uniform distance. The germination data were counted daily, and after fifteen days of germination, three plants were randomly selected from each Petri plate for analysis of the data. The data were collected for germination (%), root length (cm), shoot length (cm), and seedling vigour index (%).

**Germination percentage**

Germination percentages were calculated using the following formula **(**Ista, 1996).

$$\text{Germination (\%)} = \frac{\text{seed germinated}}{\text{Total seeds}} \times 100$$

**Seedling vigor Index**

The seedling vigor index can be calculated using the following formula:

$$\text{Seedling vigor index} = \text{percentage of seed germinated} \times \text{total plant length}$$

**Morphological parameters**

Root length, shoot length, and leaf length were measured using ImageJ software model (v1.51j8, USA). The fresh and dry weights of the plant were noted on the electrical wing balance. After taking a fresh weight, the sample was placed in an oven and dried for 73 hours at 60 °C, and dry weights were noted.

**Sampling Technique**

Three samples were collected from each Petri plate on random basis. There was total seven hybrid each with three replicates.

**Statistical Analysis**

The statistical design was CRD (completely randomized design), and analysis was performed by

one-way ANOVA on MINITAB 21 software to analyze the difference between maize hybrids. Microsoft Excel was used to investigate the primary data. The Tuckey LSD method at a 95% confidence interval was used to determine the significance level between treatments.

**Results**

Seeds of seven maize hybrid varieties were screened to find out their germination percentage (Fig.1 a-d). Significantly highest germination percentage was traced in hybrids Dk-6317 (M = 100 (%), SE = 1), Dk-2088 (M = 97.8(%), SE = 4.41), and Yh-5427 (M = 94.44(%), SE = 5.27), in contrast to other varieties (Fig. 1d). The lowest germination percentages were found in Dk-7024 (M = 75.5(%), SE = 7), Dk-6321 (M = 62 (%), SE = 5), and Dk-1429 (M = 45.5 ) (%), SE = 5.29).

The significantly highest plant fresh weight was noted in Dk-6317 (M = 0.641 (g), SE = 0.008), Dk-2088 (M = 0.5116 (g), SE = 0.04), and Yh-5427 (M = 0.4943 (g), SE = 0.05). The lowest plant fresh weight was observed in Dk-8108, Dk-7024, and Dk-1429 (M = 0.41 (g), SE = 0.16, M = 0.40 (g), SE = 0.14, M = 0.35 (g), SE = 0.10) (Fig. 2 a and Table 1). The significantly highest plant dry weight was noted in Dk-6317 (M = 0.177 (g), SE = 0.006), Dk-2088 (M = 0.155 (g), SE = 0.004), and Yh-5427 (M = 0.174 (g), SE = 0.02) in contrast to other varieties, while the lowest plant dry weight was found in Dk-6321 (M = 0.076 (g), SE = 0.065), and Dk-7024 (M = 0.069 (g), SE = 0.027). and Dk-8108 (M = 0.047 (g), SE = 0.01) (Fig. 2b and Table 2).

The highest increases in leaf length (Fig. 2c and Table 3) were found in Yh-5427 (M = 6.08 (cm), SE = 1.26), Dk-6317 (M = 5.14 (cm), SE = 1.67), and Dk-2088 (M = 3.81(cm), SE = 0.518) among all other hybrids. The lowest increase in leaf length was found in Dk-6321 (M = 2.50, SE = 2.38), Dk-7024 (M = 1.95 (cm), SE = 0.35), and Dk-8108 (M = 0.67 (cm), SE = 0.168). The highest increase in root length was found in Dk-6317 (M = 8.31 (cm), SE = 3.41), Yh-5427 (M = 4.80 (cm), SE = 2.1), and Dk-2088 (M = 4.55 (cm), SE = 1.20) as compared to other hybrids (Fig. 2d and Table 4). The lowest increase in root length was found in Dk-1429 (M = 3.80 (cm), SE = 1.03), Dk-6321 (M = 3.57 (cm), SE = 3.84), and Dk-7024 (M = 1.93, SE = 0.18). Compared to other hybrids, Dk-6317 (M = 5.096, SE = 0.58), Yh-5427 (M = 3.65 (cm), SE = 0.80), and Dk-2088 (M = 2.947 (cm), SE = 0.45) had the longest shoots. Dk-6321 (M = 2.46 (cm), SE = 1.73), Dk-7024 (M = 1.67 (cm), SE = 1.53), and Dk-8108 (M = 0.83 (cm), SE = 0.28), had the shortest shoots (Fig. 2e and Table 5).

The seedling vigour index showed a statistically significant difference at > 0.05. The highest seedling vigour index was found in Yh-5427 (M = 5.73 (%), SE = 1.13), Dk-6317 (5.14 (%), E = 1.67), and Dk-2088 (M = 3.68 (%), SE = 1.34), while the lowest seedling vigour index was noted in Dk-7024 (M = 1.45, SE = 0.28), and Dk-8108 (M = 0.39, = 0.07) (Fig. 2f and Table 6).

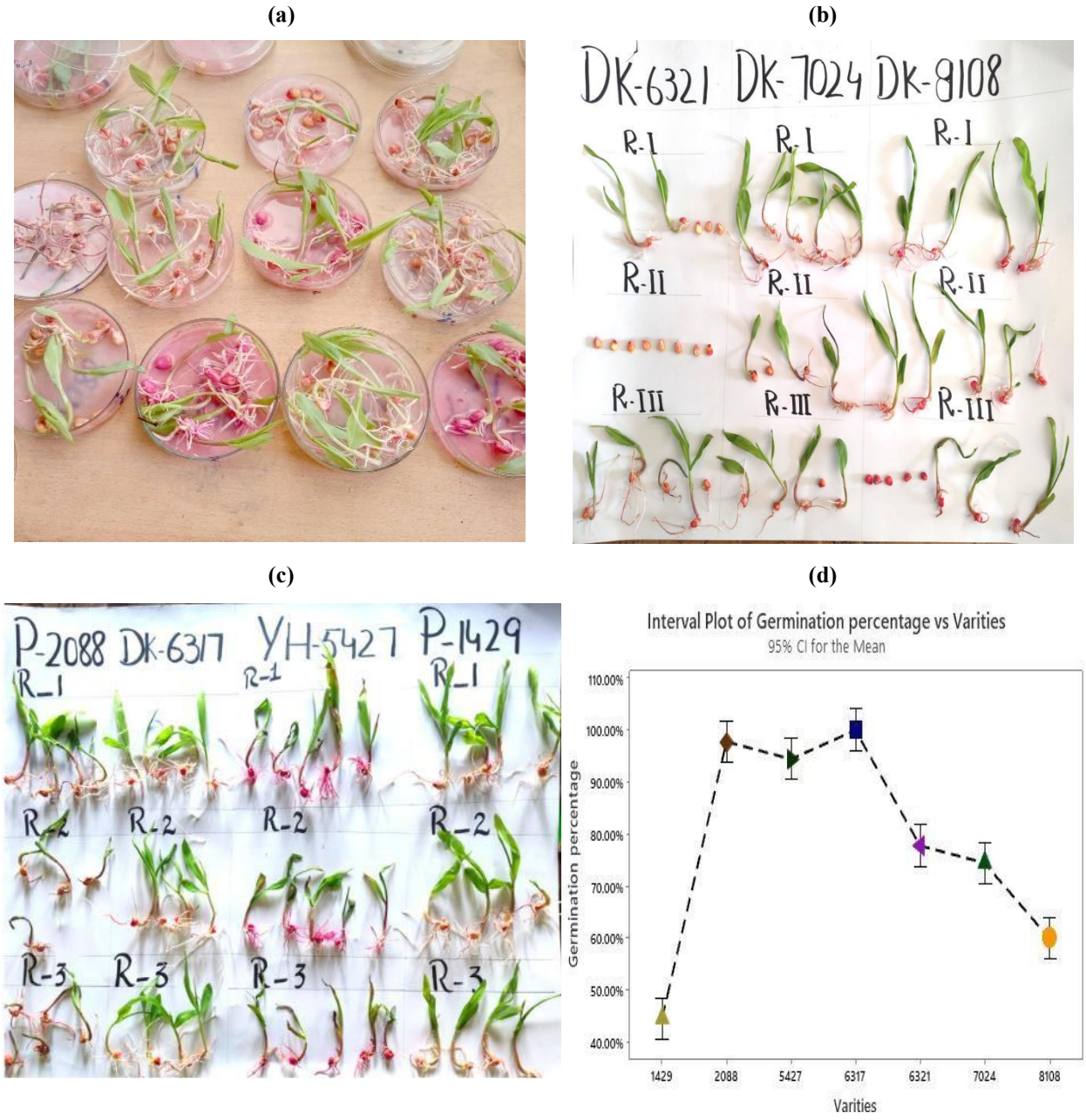


**Fig. 1.** Germination percentage of seven hybrids Dk-1429, Dk-2088, Yh-5427, Dk-6317, Dk-6321, Dk-7024 and Dk-8108 **(a)** Seed germination after fifteen days **(b)** Seedling status of DK-6321, DK-7024, and DK-8108 **(c)** Seedling status of DK-2088, DK-6317, Yh-5427 and DK-1429 **(d)** germination percentage (%)

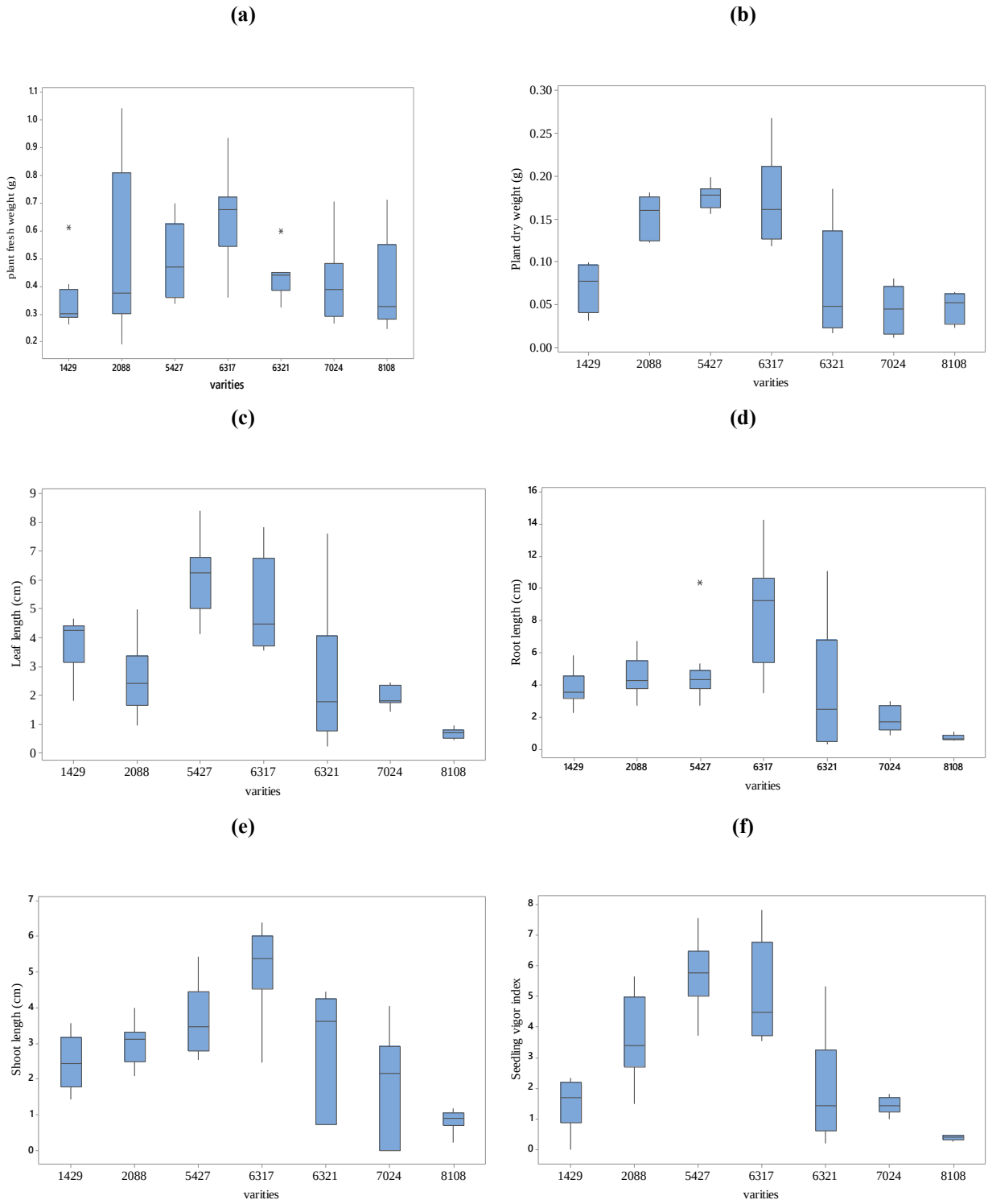


**Fig. 2.** Comparative analysis of germination attributes to assess variability in maize hybrid (Dk-1429, Dk-2088, Yh-5427, Dk-6317, Dk-6321, Dk-7024 and Dk-8108) germination potential **(a)** plant fresh weight **(b)** plant dry weight **(c)** leaf length **(d)** root length **(e)** shoot length **(f)** seedling vigor index

Principal component analysis was conducted using Minitab 21 to assess the germination potential across seven maize hybrids (Fig. 3a and 3b). The results of the analysis are depicted in a biplot loading plots of maize hybrids and germination markers. The first component (PC-1) accounted for 64.1% of the variance, while the second component (PC-2) explained 16% of the variance. Variation between the hybrids on the score plot reflects differences in germination potential. Hybrids with lower germination potential exhibited minimal distance and closely resembled each other. Characteristics that are closely aligned on the loading plot indicate a positive correlation, whereas those further apart indicate a negative correlation.

In PC-1, variables such as plant fresh weight, germination percentage, plant dry weight, root length, shoot length, leaf length, and seedling vigor index exhibited positive correlations. Dk-2088, Dk-6317, and Yh-5427 were clustered together in this region. Conversely, Dk-8108, Dk-1429, Dk-7024, and Dk-6321 were associated with PC-2, which showed a negative correlation. Overall, the results suggest that Dk-2088, Dk-6317, and Yh-5427 displayed superior germination performance under natural conditions.

(a) (b)

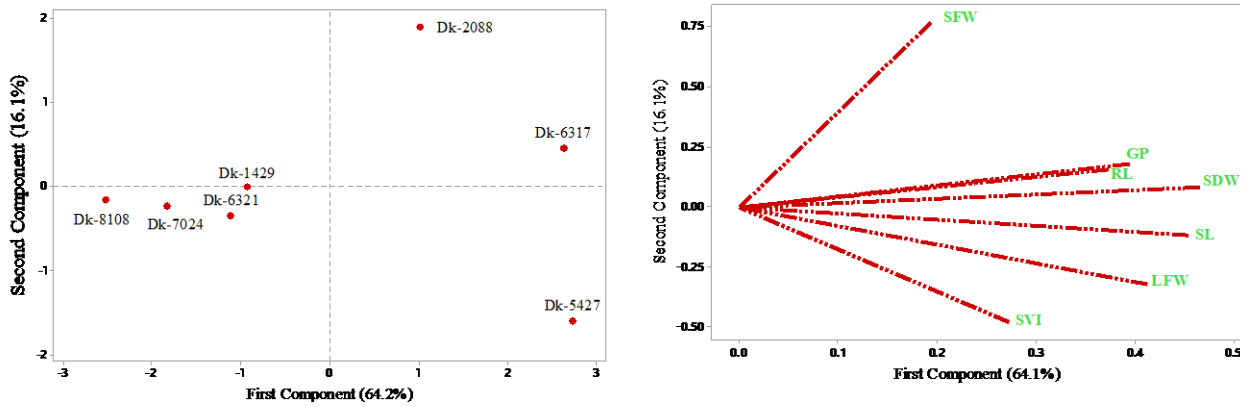


**Fig. 3** Comparative analysis of germination attributes to assess variability in maize hybrid (Dk-1429, Dk-2088, Yh-5427, Dk-6317, Dk-6321, Dk-7024 and Dk-8108) germination potential **(a)** Loading plot of seven maize hybrid Dk-1429, Dk-2088, Yh-5427, Dk-6317, Dk-6321, Dk-7024 and Dk-8108 **(b)** loading plot showing different germination markers PFW (plant fresh weight), GP (germination percentage), RL (root length), PDW (plant dry weight), SL (shoot length), LF (leaf fresh weight), SVI (seedling vigor index)

## Discussion

The enzymatic activity was enhanced in cereal crops with germination, and it has many advantages, like increasing the growth of seedlings. During the germination process, hydrolysis occurs, which provides energy to seedlings. In the early growth stages of cereal crops, the enzyme α-amylases are less active, and plants gain energy through the hydrolysis process. During the germination process in cereal crops, the β-glucanases are synthesized in seed layers like aleurone and scutellum or directly released from the endosperm. In cereal crops, the developing

seed consists of triploid endosperm, which is the major source of lipids and protein and provides food to developing embryos (Borisjuk *et al*., 2013). A comparative analysis of germination attributes is a novel approach to assess variability in germination potential among maize hybrids.

**Table.1. ANOVA (Analysis of variance) of plant fresh weight (g)**

Analysis of Variance

| Source | DF | Adj ss | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Varieties | 6 | 0.18791 | 0.031318 | 22.83 | 0.000 |
| Error | 56 | 0.07683 | 0.001372 | | |
| Total | 62 | 0.26473 | | | |

**Table.2. ANOVA (Analysis of variance) of plant dry weight (g)**

Analysis of Variance

| Source | DF | Adj ss | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Varieties | 6 | 0.09092 | 0.0151151 | 5.58 | 0.0000 |
| Error | 203 | 0.55098 | 0.002714 | | |
| Total | 209 | 0.64189 | | | |

Maize (*Zea mays* L.) is a staple crop that requires consistent germination under varied environmental conditions. The analysis involves the identification of specific germination parameters like germination rate, vigor, and response to various environmental factors. The rate at which seed germinates is sign of their vigor, fast germinating seed establish more rapidly and show better resilience in field conditions. Previous literature reported that high germination rates are often associated with early seed emergence and establishment (Ghassemi-Golezani *et al*., 2010). The analysis comprises estimating specific germination parameters

In agronomy and plant breeding certain hybrid perform optimal condition like variety of genetics, physiological, and environmental factor. Some hybrid possesses unique genetics characteristics that can enhance the ability to adapt various environmental changing like their genetic makeup help the seed disease resistance capacity, pest control, heat tolerance or drought tolerance. Some hybrid possesses unique characteristics like deeper root system to increase the water use efficiency. The potential of a plant to adapt and survive in severe situations becomes apparent by the germination of seeds under stress conditions, such as drought, salt, extreme temperatures, and nutrient limits

The germinating seed contains the endosperm, which stores protein and starch and provides food to developing seedlings (Olsen and Gounder, 2001). The current findings give information about the germination percentage and seedling vigour evaluation. The germination of seed started after the third day and was completed on the seventh day after sowing, and our results conform among the seven hybrids. The three maize hybrids,

Dk-2088, Yh-5427, and Dk-6317, gave better germination percentages and seedling vigour index. Farmers prefer maize hybrids because they exhibit higher yields as compared to non-hybrid varieties. The highest production of maize hybrids is a significant factor, which is why farmers choose hybrid seeds in large numbers, but there are certain variations among hybrids regarding germination (Duvick, 2005). It is widely observed that hybrid maize gains uniformity in terms of characteristics such as height, maturity, and cob weight (Vivek and Krivanek, 2007).

**Table 3. ANOVA (Analysis of variance) of Leaf Length(cm)**

Analysis of Variance

| Source | DF | Adj ss | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Varieties | 6 | 188 | 31.340 | 15.46 | O.000 |
| Error | 56 | 113 | 2.027 | | |
| Total | 62 | 301.6 | | | |

**Table.4. ANOVA (Analysis of Variance) Table of root length (cm) of maize hybrids**

Analysis of Variance

| Source | DF | Adj ss | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Varieties | 6 | 313.1 | 52.185 | 10.63 | 0.000 |
| Error | 56 | 274.8 | 4.908 | | |
| Total | 62 | 588 | | | |

Seedling vigour, root fresh, and dry weight are important factors in assessing the physiology and quality of seeds under natural conditions. Many studies have analyzed the link between seedling vigor and the weight of the root (Ozturk, 2020). In the current result, the highest vigour index and root length were found in Yh-5427 as compared to other hybrids. Different vigour tests for accessing the quality and physiology of seed in beans provide efficient information about the evaluation and quality of seed (Amaro *et al.*, 2015). A positive correlation was found between seedling height and fresh and dry weight in rice seed (Xu *et al*., 2005). In current findings, the highest plant fresh and dry weight was found in Dk-6317; this result matches with the Xu *et al*., (2005).

Germination testing is the main factor in determining the percentage of seeds that germinate or are alive and identifying the potential rate of seed germination. Moreover, the germination percentage is also associated with the seedling vigor, and it provides an excellent clue for field performance. The rate of seed germination varies with different seed hybrids; mostly seeds show germination within two days and develop the first radicle and plumule. At this point, the seed was considered a seedling or germinated seedling. A higher germination percentage was an important factor in determining the quality of the seed that is associated with the viability and seedling vigor index, which allow seedlings to grow in different field conditions. The vigorous emergence of seed will

ensure the good quality of seed, plant population, and yield (Shirin *et al*., 2008). In the current result, a higher seedling vigor index was found in Yh-5427.

**Table .5. ANOVA (Analysis of variance) of Shoot Length(cm)**

Analysis of Variance

| Source | DF | Adj ss | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Varieties | 7 | 199 | 41.340 | 11.46 | O.000 |
| Error | 59 | 133 | 5.027 | | |
| Total | 68 | 351.6 | | | |

**Table.6. ANOVA (Analysis of Variance) of Seedling-Vigor index (%) of maize hybrids**

Analysis of Variance

| Source | DF | Adj ss | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Varieties | 6 | 223.82 | 37.304 | 27.38 | 0.000 |
| Error | 56 | 76.30 | 1.362 | | |
| Total | 62 | 300.12 | | | |

According to Hochholdinger *et al.* (2018), the highest root, shoot, and leaf lengths in hybrids are due to their better genetic potential in maize seed hybrids. The structure of the root is important, and it contributes to gaining more grain yield improvement (Ning *et al.*, 2014). In the current result, the highest length of the root was found in Yh-5427. The information related to emergence and germination is important and directly linked with field emergence performance and seedling establishment (Abbasian *et al*. 2013). In the future, this information will ensure the promising hybrid that produces the best result after planting such hybrid in the field on the basis of seed germination and seedling vigour index. This seed screening test also provides beneficial information for different seed industries (Marcos, 2015).

**Conclusion**

Presently, farmers are showing significant interest in maize hybrid seeds due to their high yield potential and economic benefits. The selection of new hybrid provides new breeding strategies that enhance the germination attributes and also help farmers to select the best hybrid for planting and gaining more yields. These hybrids are extensively cultivated in developing nations owing to their ability to produce abundant green fodder and grain yields. Based on the findings of screening experiments evaluating the germination potential of seven maize hybrids, three specific hybrids Dk-2088, Yh-5427, and Dk-6317 are out performed as can be witnessed by highest germination percentage, and seedling vigor index. The physiological and yield responses of these hybrid can be studied under field conditions as well as under various abiotic stress conditions for final recommendation to farmers.

**Acknowledgments**

The authors would like to extend their sincere appreciation to the National Research Program

for Universities (NRPU Project No. 20-16716), Higher Education Commission (HEC) of Pakistan.

**Conflict of interests**

The authors have no relevant financial or non-financial interests to disclose.

**Funding**

National Research Program for Universities (NRPU Project No. 20-16716), Higher Education Commission (HEC) of Pakistan.

**Authors Contribution**

Zarghoona Naz; Experimentation and Methodology, Summera Jahan; Supervision and Validation, Audil Rashid; Statistical and Formal analysis, Fahd Rasul; Conceptualization and Investigation, Sobia Shahzad; Conceptualization and Investigation.

**References**

Abbasian, A., Moemeni, J., Rahmani, M., Oskoii, B., Hamidi, A. and Sedghi, M. 2013. Comparison of different hybrid maize seed size with smaller under sieve size in standard germination, cold, accelerated ageing and electrical conductivity tests. *Tech. J. Eng. Appl. Sci.*, 3: 385-393.

Amaro, H.T., David, A.M., Assis, M.O., Rodrigue, B.R.A., Cangussú, L.V. and Oliveira, M.B. 2015. Vigor tests to evaluate the physiological quality of bean seeds. *Sociedade de Ciências Agrárias de Portugal*, 383-389.

Badu-Apraku, B. and Fakorede, M.A.B. 2017. Maize in Sub-Saharan Africa: importance and production constraints. Advances in genetic enhancement of early and extra-early maize for Sub-Saharan Africa, 3-10.

Baldwin, I.T., Halitschke, R., Paschold, A., Von Dahl, C.C. and Preston, C.A. 2006. Volatile signaling in plant-plant interactions: "talking trees" in the genomics era Science, 311: 812–815.

Borisjuk, L., Neuberger, T., Schwender, J., Heinzel, N., Sunderhaus, S., Fuchs, J., Hay, J. O., Tschiersch, H., Braun, H.P., Denolf, P., Lambert, B., Jakob, P. M. and Rolletschek, H. 2013. Seed architecture shapes embryo metabolism in oilseed rape. *Plant Cell*, 25(5): 1625-1640.

Chen, D., Lan, Z., Hu, S. and Bai, Y. 2015. Effects of nitrogen enrichment on belowground communities in grassland: Relative role of soil nitrogen availability vs. soil acidification. *Soil Biol. Biochem*., 89: 99-108.

Duvick, D.N. 2005. The Contribution of breeding to yield advances in maize (*Zea mays* L.). *Adv. Agron*., 86: 83–145.

FAO. 2017. Food security statistic.

Farhad, W., Cheema, M.A., Saleem, M.F. and Saqib, M. 2011. Evaluation of drought tolerance in maize hybrids. *Int. J. Agric. Biol*., 13: 523–528.

Finch-Savage, W.E. and Bassel, G.W. 2016. Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of Experimental Botany*, 67(3): 567-591.

Ghassemi-Golezani, K., Taifeh-M.Noori, M., Oustan, S., Moghaddam, M. and Seyyed-Rahmani, S. 2010. Oil and protein accumulation in soybean grains under salinity stress. *Not Sci Biol.*, 2(2): 64-67.

Hochholdinger, F., P. Yu, C. Marcon. 2018. Genetic control of root system development in maize. *Trends Plant Sci.,* 23: 79–88.

Ista, L.K., Fan, H., Baca, O. and López, G.P. 1996. Attachment of bacteria to model solid surfaces: oligo (ethylene glycol) surfaces inhibit bacterial attachment. *FEMS Microbiol. Ecol*., 142(1): 59-63.

Karrfalt, R.P. 2011. Seed testing. *The woody plant seed manual. Agriculture Handbook*, 727: 97-115.

Marcos, F.J. 2015. Seed vigor testing: an overview of the past, present and future perspective. *Sci. Agric.,* 72: 363-374.

Miransari, M. and Smith, D.L. 2019. Sustainable agriculture and climate change: The role of seed germination and seedling growth. *Environmental and Experimental Botany,* 153:104-116.

Ning, R., Li, S., Li, X. and Li, C. 2014. New maize hybrids had larger and deeper post-silking root than old ones. *Field. Crop Res*., 166: 66-71.

Oladejo, J.A. and Adetunji, M.O. 2012. Economic analysis of maize (*Zea mays* L.) production in Oyo state of Nigeria. *Agric. Res. J.*, 2(2): 77-83.

Olsen, J.K. and Gounder, R.K. 2001. Alternatives to polyethylene mulch film—a field assessment of transported materials in capsicum (*Capsicum annuum* L*.). Aust. J. Exp. Agric.,* 41(1): 93-103.

Ozturk, I. 2020. Root and seedling weight of bread wheat (*Triticum aestivum* L.) genotypes and relation with physiological parameters. *Agriculture Food*, *8*(1).

Paparella, S., Araújo, S.S., Rossi, G., Wijayasinghe, M., Carbonera, D. and Balestrazzi, A. 2015. Seed priming: state of the art and new perspectives. *Plant Cell Reports,* 34(8): 1281-1293.

Serrano, A., De Castro, A.J. and García-Martínez, S. 2020. Assessing seed quality through germination and vigor tests for sustainable crop production. *Agronomy*, 10(4): 567.

Shirin, M., Enayatgholizadeh, M.R., Siadat, E. and Fathi, G. 2008. Comparison of suitable seed vigour of hybrid *Zea Mays* (CV. SC. 704) in the field condition of Ahvaz. *Proceeding of the 10th Congress of Agronomy Plant Breeding,* 330.

Steinbrecher, T. and Leubner-Metzger, G. 2017. The biomechanics of seed germination. *Journal of Experimental Botany*, 68(4): 765-783.

Vivek, B.S. and Krivanek, A.F. 2007. Maize breeding for resistance against stress. *Crop Sci*., 47(S3): 202.

Wang, J., Wang, Z., Mao, H., Zhao, H. and Huang, D. 2013. Increasing Se concentration in maize grain with soil- or foliar-applied selenite on the Loess Plateau in China. *Field Crops Res.,* 150: 83-90.

Xu, M.J., Dong, J. and Zhu, M.Y. 2005. Effects of germination conditions on ascorbic acid level and yield of soybean sprouts. *J. Sci. Food Agric.,* 85(6): 943-947.

Zanuddin, B. and Azrai, M. 2020. Advantages of hybrid corn seed production compared to corn grain. *International Journal of Agriculture System*, 8(1): 44.

Zanuddin, B. and Azrai, M. 2020. Advantages of Hybrid corn seed production compared to corn grain. *International Journal of Agriculture System*, 8(1): 44.