Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v2024i1.1267
Biol. Clin. Sci. Res. J., Volume, ***2024****: 1267*
Original Research Article

IDENTIFICATION OF CLIMATE RESILIENT GENOTYPES ON BASE OF PHYSIO-MORPHIC AND YIELD RELATED TRAITS IN MAIZE (*ZEA MAYS L.*)

AHMAD K[*1], ULLAH A[2], ISLAM B[3], KHAN MA[4], QADIR MS[5], SALEEM S[6], AHMAD I[7], REHMAN ZU[8], ASLAM M[7], HUSSAIN S[9]

[1]Ali Akbar Group Pvt Ltd Multan, Pakistan
[2]Department of Plant Breeding and Genetics, College of Agriculture, University of Sargodha, Pakistan
[3]Department of Plant Breeding and Genetics, Bahauddin Zakria University, Multan, Pakistan
[4]Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan
[5]Sunway Agro Chemicals & Seed Multan, Pakistan
[6]Maize Sorghum & Millet Program, National Agricultural Research Centre, Islamabad, Pakistan
[7]Pesticide Quality control Laboratory, Multan, Pakistan
[8]Maize and Millets Research Institutes, Sahiwal, Pakistan
[8]Department of Agronomy, Faculty of Agriculture Sciences, University of Layyah, Pakistan
**Corresponding author`s email address:* khalilpbguaf@gmail.com

(Received, 04th August 2024, Revised 25th October 2024, Published 31st October 2024)

Abstract: *The impact of climate change on maize production is a growing concern. Changes in temperature, precipitation patterns, and the increased frequency of extreme weather events can significantly affect maize yields. Recognizing the importance of developing climate-resilient maize varieties, an experiment was conducted in 2022 to identify such genotypes. Ten commercial maize varieties were planted with three different sowing dates in the spring season: January 15th, January 30th, and February 15th. The results indicated that Sahiwal Gold and Malka 2016 were climate-resilient and produced high grain yields compared to other varieties across the three sowing dates. The findings concluded that the January 15th sowing date was the most effective, with genotypes producing the highest yields. Physio-morphic traits such as relative water content, chlorophyll content, days to tasseling, days to silking, plant height, and yield related traits ear length, and 100-kernel weight supported the plants in producing grain yield per hectare under changing climatic conditions. The variety Pop-1 was found to be susceptible to climate change, resulting in the lowest grain yield. The selected genotypes will be valuable in breeding programs aimed at developing climate-resilient maize varieties.*

Keywords: Climate Change, Maize Production, Climate-Resilient Varieties, Grain Yield, Physio-Morphic Traits, Relative, Breeding Programs

Introduction

Maize, known as corn in North America, is a cereal grain first domesticated by indigenous peoples in southern Mexico about 9,000 years ago. The botanical name for maize is Zea mays, a species of the grass family Poaceae. This plant's history is deeply intertwined with the development of human civilization in the Americas, where it became a staple food crop for many cultures, notably the Maya and the Aztecs. Following the Columbian Exchange, maize spread globally and now plays a pivotal role in agriculture worldwide. As a versatile crop, maize is used for a plethora of purposes: as food for humans and feed for animals, and in industry for the production of biofuels, starch, and oil. The importance of maize cannot be overstated. It is the most widely grown grain crop throughout the world. Globally, maize is a critical food security crop and is more widely produced than rice or wheat, making it an essential component of global food systems. Its adaptability to diverse climates and soils makes it a valuable crop for farmers worldwide. In addition to its direct consumption, maize is a key ingredient in many processed foods and is also a significant source of fodder for livestock. The global maize production reached significant heights, a record output of 1.234 billion tonnes, marking a 6.1% increase from the previous year (FAO, 2023). This remarkable growth in maize production is attributed to various factors, including technological advancements, yield improvements, and area expansion. The United States led the charge as the largest producer, contributing approximately 389.7 million metric tons to the global count. China and Brazil followed, securing their positions as top maize producers on the world stage. In Pakistan, the maize production outlook for 2023 was particularly positive. The country produced 10.3 million tonnes, which was 17% above the average, reflecting substantial sowings and high yields. However, the impact of climate change on maize production is a growing concern. Changes in temperature, precipitation patterns, and increased frequency of extreme weather events can significantly affect maize yields. Studies have shown that while moderate warming and increased carbon dioxide levels can potentially enhance maize growth, extreme heat poses a severe risk, reducing yields and threatening food security. For instance, high temperatures can reduce pollen viability, leading to decreased kernel formation and smaller harvests. Moreover, changes in rainfall patterns can lead to either drought stress or excessive waterlogging, both of which are detrimental to maize crops. The impact of climate change on agriculture is a pressing issue worldwide, and Pakistan's maize production is no exception. Recent studies have highlighted the vulnerability of the agricultural sector to climatic variability, particularly in regions like Punjab and Khyber Pakhtunkhwa, where maize is a significant crop. Research using the autoregressive distributed lag (ARDL) approach on data from 2000 to 2020 indicates that meteorological factors such as air temperature and evapotranspiration play a crucial role as well. In Punjab, for instance, maize production is negatively affected by rising air temperatures, which is a concern given the province's central role in Pakistan's maize output. In addition to local studies, global research corroborates these findings, indicating that climate change exerts significant pressure on crop production due to more frequent extreme weather events. According to climate change scenarios, agricultural productivity will be drastically reduced, limiting the ability of many regions to make the technological advances necessary for future food security (Cairns *et al*., 2012). Millions of impoverished maize consumers may face hunger and food insecurity unless farmers produce climate-resilient cultivars that boost yields (Lobell *et al*., 2008). Knowing the importance of developing climate resilient maize varieties, an experiment was planned in 2022 to identify climate resilient maize genotypes.

Methodology

The study was conducted in Multan area during spring season of 2022. Ten maize commercial varieties were tested for climate resilience. The experiment was conducted on three dates of sowing 15 January, 30 January and 15 February 2022. The standard agronomic practices were performed equally. The experiment was laid out in factorial under RCBD with three replications. Each genotype was sown in 2 rows of 4 meters with a spacing of 60 cm between rows and 20 cm between plant to plant. The weather data was recorded Table 1. The physio-morphic and yield related traits recorded at the time of anthesis and maturity. The data were recorded for the days to 50% tasseling (DT, days): expressed as number of days from planting to the day when 50% of the plants had tassels in each sub-plot, days to 50% silking (DS, days): expressed as the number of days from planting to the day when 50% of the plants are in silk emergence stage. **Relative water contents,** to obtain an accurate measurement of relative water content (RWC), fully expanded younger leaves from each treatment were gathered. After the surface of the leaf had been carefully dried with tissue paper, it was first wrapped in polythene bags and then transported to the laboratory. To determine the fresh weight of the leaf, samples of the leaf were weighed (FW). After that, the samples were placed in plastic tubes that contained distilled water and allowed to sit in the dark for an entire night. The following morning, these leaves were delicately swollen with tissue paper to determine the turgid weight, and the results were recorded (TW). After that, a hot air oven was used to dry the leaves at a temperature of 70◦C until the weight remained the same. After that, dried leaves were weighed to record their dry weight (DW). The RWC was determined by applying the formula presented below according to Schonfeld *et al.* (1988) as follow:

$$RWC (\%) = (FW - DW) / (TW - DW) \times 100$$

The SPAD502 chlorophyll meter was used to test chlorophyll content at four developmental stages: anthesis, 14, 28, and 42 days post-anthesis (Minolta Co., Ltd., Osaka, Japan). The portable apparatus uses the absorbance of two light wavelengths (650 and 940 nm) flowing through intact leaves to estimate the amount of chlorophyll present. All plants were tested for chlorophyll content even if there were no competing plants in the immediate vicinity of the samples. The highest ear's ear leaf was used to take the measurements. The base, middle, and midway between the midrib and the leaf border were all measured (Gekas *et al*., 2013). For each individual plant, the readings were repeated three times, and the average of those values was recorded. Days to 50% tasseling (DT, days): expressed as number of days from planting to the day when 50% of the plants had tassels in each sub-plot. Days to 50% silking (DS, days): expressed as the number of days from planting to the day when 50% of the plants are in silk emergence stage.Plant height (PH,cm): ten guarded plants from each entry were selected at maturity and plant height was measured with a meter rod in centimeters from the ground level to the base of the tassel and the average height was calculated. Ear height (EH, cm): measured from the ground level to the upper bearing node of the same plants used in measuring plant height. Ear length (EL, cm): length of the ear (cm) measured from 10 random ears/plot. 100-kernel weight (HKW, g): taken randomly from grains of the same 10 ears after shelling (g) adjusted at 15.5% grain moisture. The 100-kernel weight was also determined from the same sample according to Tollenaar and Lee (2006). Grain yield was measured and adjusted to 15.5% grain moisture then converted to grain yield in kg/ha.

Results & Discussion

The results of three sowing dates and mean data recorded for morphological, physiological and yield related traits presented in Table1, Table 2 and Table 3. The commercial varieties screened for climate resilience indicated that for relative water contents in sowing date 1 the 15th January Sahiwal Gold had the highest percentage. The ability to retain water varies among different varieties, with some being more resilient to climate conditions. Malka 2016 exhibited good water retention at 75.17%, slightly outperforming Sahiwal Gold. YHD-444 showed moderate water retention at 68.44%. MMRI-Yellow had a slightly lower retention rate at 63.61%, while Gohar-19 demonstrated lower water retention at 55.14%, making it potentially less suitable for dry environments. Golden struggled in drought conditions with a retention rate of 47.53%. Sultan's water retention was similar to Golden's at 44.24%. Pearl exhibited relatively low water retention at 41.16%. Both Neelam and Pop-1 had the lowest relative water contents at 40.43% and 40.19%, respectively. Relative Water Content (RWC) in plants is affected by several key factors. Soil Moisture is one of the most important and critical factor amount of water in the soil is crucial. Adequate moisture keeps RWC high, while drought reduces (Adebayo *et al*., 2014). Different plants and their varieties have unique abilities to retain water. Some are better adapted to dry conditions and can maintain higher RWC. Plants can modify their internal osmotic pressure to hold onto water, helping them stay hydrated during drought.

Factors like temperature, humidity, and light affect RWC. High temperatures and low humidity can increase water loss, lowering RWC. The regulation of stomata (tiny openings on leaves) influences water loss. Plants that effectively manage stomatal openings can preserve higher RWC. Features such as leaf size, thickness, and surface area affect water retention (Abdelsalam *et al*., 2022). Smaller, thicker leaves with a waxy surface generally lose less water, maintaining higher RWC. Chlorophyll is a pigment in plants that plays a crucial role in photosynthesis. Chlorophyll absorbs light mainly in the blue and red parts of the spectrum and reflects green light, making plants appear green. This absorbed light is vital for photosynthesis. The energy from the absorbed light is used to transform carbon dioxide and water into glucose and oxygen. Glucose is crucial for the plant's energy and growth. During photosynthesis, glucose is created, which the plant uses for growth, development, and reproduction (Afzal *et al*., 2020). It can also be stored as starch for future energy needs. A byproduct of photosynthesis is oxygen, which is essential for the respiration of most living organisms. Chlorophyll provides the energy needed for cell division and growth, helping create new cells and allowing plants to expand (Gholamin *et al*., 2015). Sahiwal Gold (35.8) had highest chlorophyll contents, indicating excellent photosynthesis and plant health. Malka 2016 (33.8) had high chlorophyll, just below Sahiwal Gold, suggesting good photosynthetic efficiency. Neelam and Pop-1 had (23.5) and (19.3) chlorophyll contents respectively indicating even less photosynthetic capacity (Ali *et al*., 2011). Different maize varieties have unique growth rates. Some mature early, while others take longer to reach the tasseling stage due genotypic effect (Goma *et al*., 2011). But the abiotic factors also played role, high temperature speed up growth and reduce the days needed for tasselling (Gupta *et al*., 2020). Conversely, cooler temperatures can delay this process. The length of daylight impacts tasseling. Maize can mature faster in longer days, depending on the variety (Huge *et al*., 2021). Sahiwal Gold had taken the longest (72.2 days) to tassel, indicating a longer vegetative growth period followed by Malka 2016 slightly quicker than Sahiwal Gold (71.1 days) but still slow to mature. Pop-1 had also tassels at the same time as YHD-444 and Neelam (70.2 days), indicating similar growth. Early-tasseling genotypes like Golden and Gohar-19 are better for regions with shorter growing seasons, while later-tasseling genotypes like Sahiwal Gold and Malka 2016 are suited for areas with longer growing seasons (Hussain *et al*., 2021). Sahiwal Gold had the longest time to silk, (73.1 days) indicating a lengthy vegetative growth before flowering followed by Malka 2016 (73.2 days) similar to Sahiwal Gold, also takes a long time to silk, suggesting a prolonged vegetative phase benefiting from extended vegetative growth that can lead to higher biomass and yield (Anjum *et al*., 2011). Early Silking genotypes included Golden (70.1 days) and Gohar-19 (70.2 days) had fast transition from vegetative growth to flowering (Kandil *et al*., 2020). Moderate Silking Genotypes MMRI-Yellow (71.5 days, Pearl (72.5 days) and Neelam (72.6 days) with moderate silking times. Silks are the female reproductive parts, begin to appear from the husks a few days after the male flowers (tassels) have emerged and started releasing pollen (Araus *et al*., 2012). Silks grow quickly from the base of the ear toward the tip, with each ovule (potential kernel) developing its own silk (Shabbir *et al*., 2021). The elongated silks are designed to catch pollen from the tassels. Pollination happens when the pollen from the tassels lands on the silks. Each silk is linked to an ovule, and when pollen lands on a silk, it germinates and creates a pollen tube that grows down to the ovule, which is essential for fertilization (Arora *et al*., 2002). Once the pollen tube reaches the ovule, fertilization occurs, resulting in the formation of kernels (Zhu *et al*., 2021). Each successful fertilization forms one kernel on the cob. After fertilization, kernels start to develop while the silks remain active and can receive more pollen for about a week, maximizing the chances of fertilization. The number of kernels per ear is primarily set during the silking stage, making successful pollination and fertilization crucial for achieving high yields (Bahar *et al*., 2021). The silking stage is critical for the reproductive success of maize. Lack of water can limit silk growth and lead to dryness, reducing successful pollination. High Temperatures can speed up silk emergence but may also dry out the silks, harming pollen viability and pollination success (Bahrami *et al*., 2014). Factors like soil salinity and extreme weather can disrupt silk development and function. Any stress, during this period can severely impact pollination and kernel development, thereby affecting overall crop yield. To overcome these challenges, it is important to manage irrigation, provide adequate nutrients, control pests, and choose stress-tolerant maize varieties, ensuring effective silking and maximizing yield (Bates *et al*., 1973). Sunlight, enhancing photosynthesis and biomass production. Height correlates with overall biomass; taller plants typically produce more leaves and stems. But it is vital for tall plants to be sturdy enough to avoid falling over, balancing height with structural strength. Taller plants with extensive root systems can access more soil nutrients, promoting better growth and yields (Cakir, 2004). Sahiwal Gold (206.1 cm) was tallest genotype, which captures more sunlight for better photosynthesis and higher potential yields. Malka 2016 (205.2 cm) was slightly shorter than Sahiwal Gold but still tall, enabling effective light capture and strong yield potential. Pop-1 remained the shortest but still maintain sufficient height for effective light capture and growth. Sahiwal Gold and Malka 2016, with greater height, are likely to yield more due to better light capture and biomass production. Sahiwal Gold (20.8 cm) longest ear length, likely to yield the most kernels. Pop-1 (18.9 cm) shortest ear length, likely yielding the least. Longer ears generally indicate higher yield potential (Cao *et al*., 2022). Improving ear length is a significant goal in maize breeding to enhance productivity. Resource Utilization, longer ears can better utilize resources like light and nutrients, leading to greater biomass and grain production (Dodd, 2003). Selecting for longer ear length in breeding programs can lead to the development of higher-yielding maize varieties, as seen in genotypes like Sahiwal Gold and Malka 2016. Heavier kernels contribute more to the total grain mass, thereby increasing yield. Breeding for higher kernel weights can enhance yield, leading to more productive maize varieties (El-Naggar *et al*., 2020). Heavier kernels often indicate better resource use by the plant, such as nutrient uptake. Larger, heavier kernels are typically preferred in the market due to their better quality and processing traits. Kernel weight is a major component of grain yield (Gao *et al*.,

[Citation Ahmad, K., Ullah, A., Islam, B., Khan, M.A., Qadir, M.S., Saleem, S., Ahmad, I., Rehman, Z.U., Aslam, M., Hussain, S. (2024). Identification of climate resilient genotypes on base of physio-morphic and yield related traits in maize (*ZEA MAYS L.*). *Biol. Clin. Sci. Res. J.,* **2024***: 1267*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1267]

2015). Heavier kernels contribute more to the total grain mass, directly impacting yield (Fan *et al*., 2016). Selecting maize genotypes with higher 100-kernel weights, such as Sahiwal Gold and Malka 2016, is likely to yield better results due to their larger kernels. Understanding and optimizing kernel weight is crucial for developing high-yield maize varieties (Fernandez *et al*., 1992). Sahiwal Gold (9100 kg/ha top performer with the highest yield, attributed to optimal ear length, high kernel weight, and efficient resource use followed by Malka 2016 (8877 kg/ha) slightly lower yield than Sahiwal Gold, still very high, benefiting from good ear length and kernel weight. Pop-1 (4261 kg/ha) had the lowest yield, indicating significant limitations in growth traits and resource utilization (Gamalero *et al*., 2012). High-Yielding Genotypes Sahiwal Gold and Malka 2016 are top choices for maximizing yields due to their favorable traits. Moderate-Yielding Genotypes YHD-444, MMRI-Yellow, and Gohar-19 show reliable productivity with a good balance of traits. Lower-Yielding Genotypes Pearl, Neelam, and Pop-1 have lower yields and may require special management to improve their performance.

In Second date of sowing 30th January, the performance of different commercial varieties effected due to increase in temperature during the end of February and early March 2022. Sahiwal gold maintained the relative water contents to 70.53%, chlorophyll contents 25.1, Days to tasselling 72.2 days to silking 73.1, plant height 198.1, ear length 19.1 cm, 100 kernel weight 295.1 g and grain yield 6800 kg/ha. The grain yield although affected by climate change but still Sahiwal gold had shown the resilience and produced the highest value among other commercial varieties. The Pop-1 had the lowest grain yield 2150 kg/ha badly affected by the climate change. The 3rd date of sowing 15th February 2022 all varieties badly effected due to climate change. The highest value of gain yield was observed in Sahiwal gold 3975 kg/ha and lowest value was observed in Pop-1 1250 kg/ha. The graphical comparison of varieties for grain yield kg/ha at different date of sowing is presented in Fig 1.

Table 1: Mean Values of Maize Varieties of Morphological, Physiological, Yield and Yield Related Traits Under 1st Date Of Sowing 15 January

Sr.No	Genotypes	RWC%	CC	DT	DS	PH (CM)	EL (CM)	HKW(g)	GY kg/ha
1	Sahiwal Gold	84.83	35.8	72.2	73.1	206.1	20.8	315.2	9100
2	Malka 2016	75.17	33.8	71.1	73.2	205.2	20.1	310.2	8,877
3	YHD-444	68.44	32.2	70.2	72.1	201.2	19.8	305.1	8367
4	MMRI-Yellow	63.61	30.1	69.4	71.5	199.1	19.5	303.2	8500
5	Gohar-19	55.14	28.2	68.2	70.2	198.5	19.3	298.2	8100
6	Golden	47.53	25.1	68.0	70.1	198.1	19.1	295.1	7800
7	Sultan	44.24	26.8	68.2	70.2	197.8	19.0	291.2	7454
8	Pearl	41.16	24.5	69.1	72.5	194.4	19.2	290.0	6000
9	Neelam	40.43	23.5	70.2	72.6	190.1	18.9	288.2	6175
10	Pop-1	40.19	19.3	70.2	72.8	185.0	18.1	285.2	4261

RWC:Relative water contents, CC:Chlorophyll contents, DT:Days to Tasselling, DS:Days to Silking, PH:Plant Height, EL:Ear length, HKW:100 kernel weight, GY:Grain yield

Table 2: Mean Values Of Maize Varieties Of Morphological, Physiological, Yield And Yield Related Traits Under 2nd Date Of Sowing 30 January

Sr.No	Genotypes	RWC%	CC	DT	DS	PH (CM)	EL (CM)	HKW(g)	GY kg/ha
1	Sahiwal Gold	70.53	25.1	68.0	70.1	198.1	19.1	295.1	6800
2	Malka 2016	62.24	26.8	68.2	70.2	197.8	19.0	291.2	6150
3	YHD-444	60.16	24.5	69.1	72.5	197.4	19.2	290.0	6000
4	MMRI-Yellow	55.43	23.5	61.2	63.6	197.1	20.1	288.2	5175
5	Gohar-19	51.59	19.3	59.2	62.8	197.0	18.9	285.2	4261
6	Golden	48.2	24.1	55.2	58.1	190.1	18.5	278.2	3475
7	Sultan	43.1	25.8	54.1	57.2	188.2	17.9	270.1	3175
8	Pearl	41.2	22.5	52.2	54.2	185.3	17.1	250.1	2850
9	Neelam	40.1	22.5	51.2	53.1	184.2	16.5	238.1	2550
10	Pop-1	39.1	21.2	50.2	52.6	180.1	16.2	230.2	2150

RWC:Relative water contents, CC:Chlorophyll contents, DT:Days to Tasselling, DS:Days to Silking, PH:Plant Height, EL:Ear length, HKW:100 kernel weight, GY:Grain yield

Table 3: Mean Values Of Maize Varieties Of Morphological, Physiological, Yield And Yield Related Traits Under 3rd Date Of Sowing 15 February 2022.

Sr.No	Genotypes	RWC%	CC	DT	DS	PH (CM)	EL (CM)	HKW (g)	GY kg/ha
1	Sahiwal Gold	56.2	23.1	55.2	58.1	190.1	18.5	268.2	3975
2	Malka 2016	55.1	24.8	54.1	57.2	188.2	17.9	260.1	3675
3	YHD-444	45.2	22.5	52.2	54.2	185.3	17.1	255.1	3050
4	MMRI-Yellow	41.1	22.5	51.2	53.1	184.2	16.5	251.1	2850
5	Gohar-19	39.1	21.2	50.2	52.6	180.1	16.2	248.2	2450
6	Golden	37.2	21.1	49.5	50.1	175.1	16.5	245.1	2175

[Citation Ahmad, K., Ullah, A., Islam, B., Khan, M.A., Qadir, M.S., Saleem, S., Ahmad, I., Rehman, Z.U., Aslam, M., Hussain, S. (2024). Identification of climate resilient genotypes on base of physio-morphic and yield related traits in maize (*ZEA MAYS L.*). *Biol. Clin. Sci. Res. J.*, **2024***: 1267*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1267]

7	Sultan	35.2	20.1	48.1	48.2	172.2	16.4	243.2	1850
8	Pearl	34.1	20.2	47.2	46.2	168.1	16.1	240.1	1650
9	Neelam	33.2	22.1	46.5	45.1	165.2	15.8	238.2	1500
10	Pop-1	31.2	21.2	45.5	44.1	162.2	15.5	235.1	1250

RWC:Relative water contents, CC:Chlorophyll contents, DT:Days to Tasselling, DS:Days to Silking, PH:Plant Height, EL:Ear length, HKW:100 kernel weight, GY:Grain yield

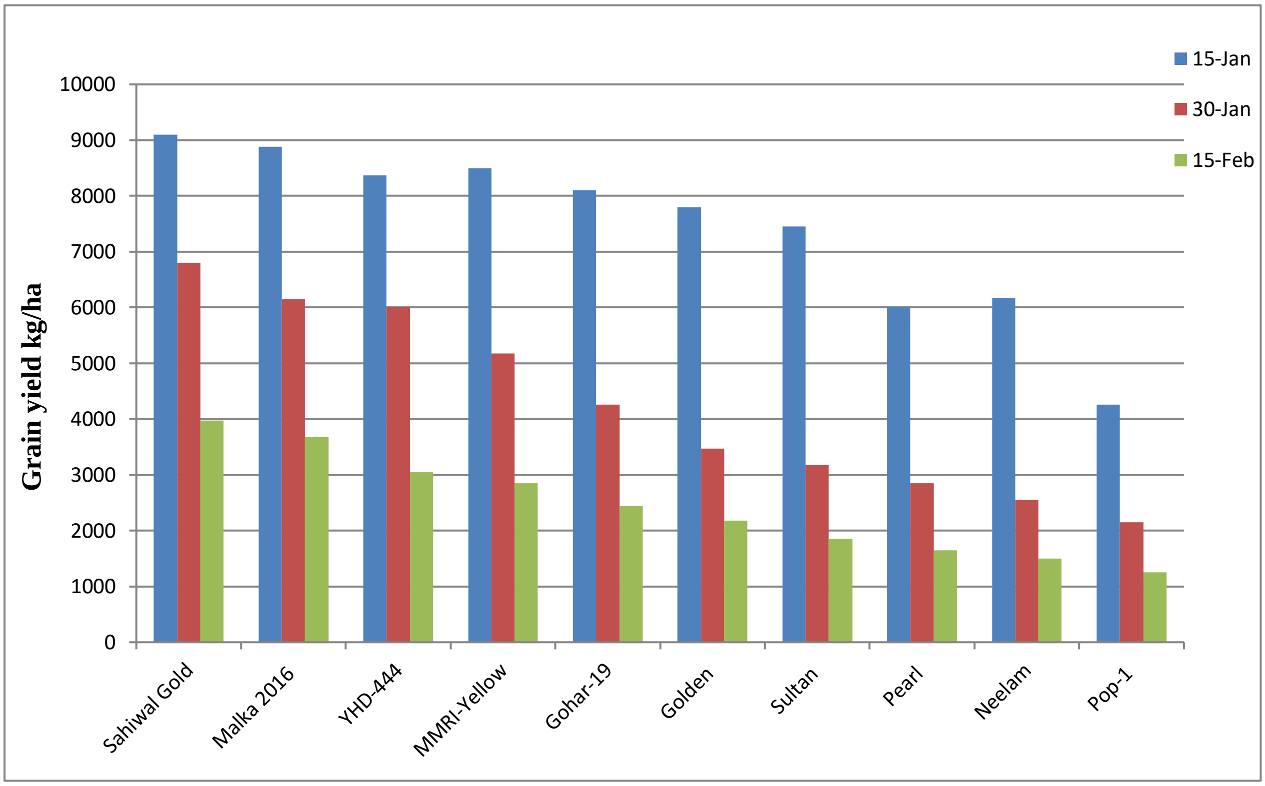

Fig. 1: Mean Comparison Of Maize Genotypes For Grain Yield Kg/Ha At 15 January, 30 January and 15 February 2022.

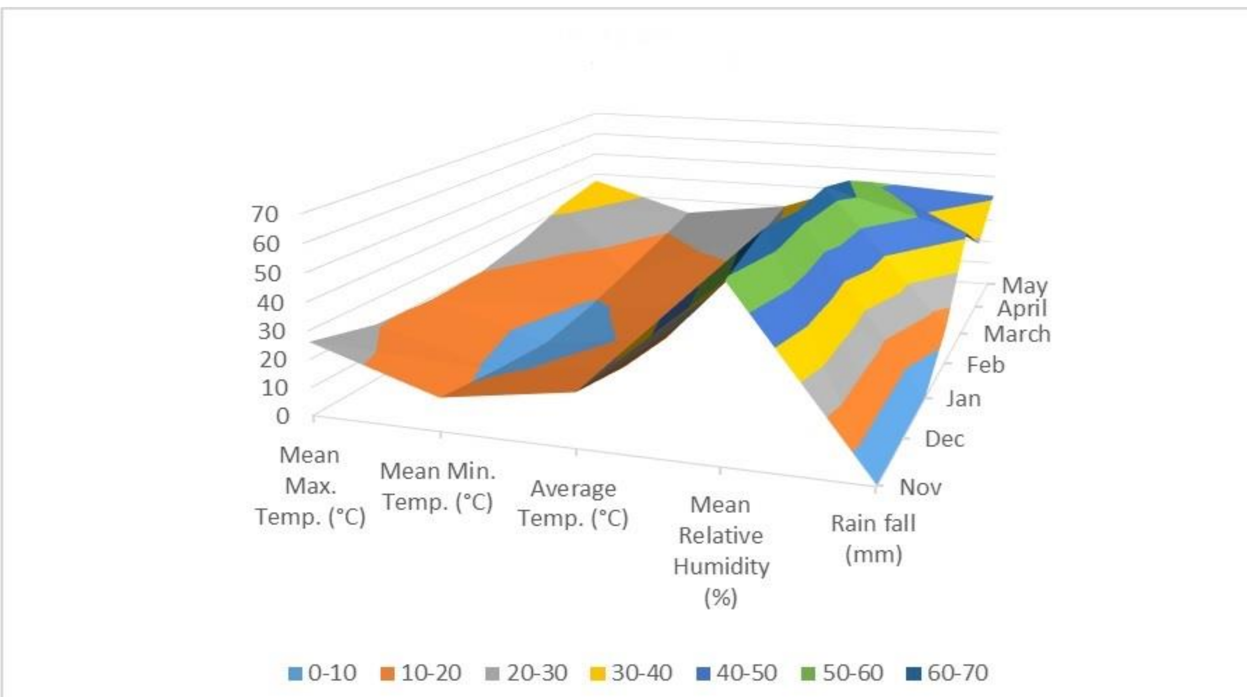

Fig 2. METEOROLOGICAL DATA RECORDED AT MULTAN DURING THE CROPPING SEASON OF SPRING MAIZE 2022.

[Citation Ahmad, K., Ullah, A., Islam, B., Khan, M.A., Qadir, M.S., Saleem, S., Ahmad, I., Rehman, Z.U., Aslam, M., Hussain, S. (2024). Identification of climate resilient genotypes on base of physio-morphic and yield related traits in maize (*ZEA MAYS L.*). *Biol. Clin. Sci. Res. J.*, **2024***: 1267*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1267]

Fig. 3: Crop Comparison of Maize Genotypes At 15 January, 30 January And 15 February 2022 And Effect Of Climate Change On Maize Plant.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate
Approved by the department Concerned.

Consent for publication
Approved

Funding
Not applicable

[Citation Ahmad, K., Ullah, A., Islam, B., Khan, M.A., Qadir, M.S., Saleem, S., Ahmad, I., Rehman, Z.U., Aslam, M., Hussain, S. (2024). Identification of climate resilient genotypes on base of physio-morphic and yield related traits in maize (*ZEA MAYS L.*). *Biol. Clin. Sci. Res. J.,* **2024***: 1267*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1267]

Conflict of interest

The authors declared absence of conflict of interest.

Author Contribution

References

Abdelsalam, N. R., Balbaa, M. G., Osman, H. T., Ghareeb, R. Y., Desoky, E.- S. M., Elshehawi, A. M., et al. (2022). Inheritance of resistance against northern leaf blight of maize using conventional breeding methods. Saudi J. Biol. Sci. 29, 1747–1759. doi: 10.1016/j.sjbs.2021.10.055

Adebayo, M., Menkir, A., Blay, E., Gracen, V., Danquah, E., and Hearne, S. (2014). Genetic analysis of drought tolerance in adapted× exotic crosses of maize inbred lines under managed stress conditions. Euphytica 196, 261–270. doi: 10. 1007/s10681-013-1029-5

Afzal, I., Imran, S., Javed, T., and Basra, S. M. A. (2020). Evaluating the integrative response of moringa leaf extract with synthetic growth promoting substances in maize under early spring conditions. South Afr. J. Bot. 132, 378–387. doi: 10.1016/j.sajb.2020.04.025

Ali, Z., Basra, S. M. A., Munir, H., Mahmood, A., and Yousaf, S. (2011). Mitigation of drought stress in maize by natural and synthetic growth promoters. J. Agric. Soc. Sci. 7, 56–62

Anjum, S. A., Wang, L. C., Farooq, M., Hussain, M., Xue, L. L., and Zou, C. M. (2011). Brassinolide application improves the drought tolerance in maize through modulation of enzymatic antioxidants and leaf gas exchange. J. Agronomy Crop Sci. 197, 177–185. doi: 10.1111/j.1439-037X.2010.00459.x

Araus, J. L., Serret, M. D., and Edmeades, G. (2012). Phenotyping maize for adaptation to drought. Front. Physiol. 3:305–305. doi: 10.3389/fphys.2012.00305

Arora, A., Sairam, R. K., and Srivastava, G. C. (2002). Oxidative stress and antioxidative system in plants. Curr. Sci. 82, 1227–1238. Arzu, K., Onder, O., Bilir, O., and Kosar, F. (2018). Application of multivariate statistical analysis for breeding strategies of spring safflower (Carthamus tinctorius L.). Turkish J. Field Crops 23, 12–19.

Bahar, A. A., Faried, H. N., Razzaq, K., Ullah, S., Akhtar, G., Amin, M., et al. (2021). Potassium-induced drought tolerance of potato by improving morpho-physiological and biochemical attributes. Agronomy 11:2573. doi: 10. 3390/agronomy11122573

Bahrami, F., Arzani, A., and Karimi, V. (2014). Evaluation of yield-based drought tolerance indices for screening safflower genotypes. Agronomy J. 106, 1219–1224. doi: 10.2134/agronj13.0387

Bates, L. S., Waldren, R. P., and Teare, I. D. (1973). Rapid determination of free proline for water-stress studies. Plant Soil 39, 205–207. doi: 10.1007/BF00018060

Cairns, J. E., Sonder, K., Zaidi, P. H., Verhulst, N., Mahuku, G., Babu, R., et al. (2012). Maize production in a changing climate: impacts, adaptation, and mitigation strategies. Adv. Agronomy 114, 1–58. doi: 10.1016/B978-0-12-394275- 3.00006-7

Cakir, R. (2004). Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Res. 89, 1–16. doi: 10. 1016/j.fcr.2004.01.005

Cao, Y., Cai, H., Sun, S., Gu, X., Mu, Q., Duan, W., et al. (2022). Effects of drip irrigation methods on yield and water productivity of maize in Northwest China. Agric. Water Manag. 259:107227. doi: 10.1016/j.agwat.2021.107227

Dodd, I. C. (2003). Hormonal interactions and stomatal responses. J. Plant Growth Regul. 22, 32–46. doi: 10.1007/s00344-003-0023-x

El-Naggar, M. E., Abdelsalam, N. R., Fouda, M. M., Mackled, M. I., Al-Jaddadi, M. A., Ali, H. M., et al. (2020). Soil application of nano silica on maize yield and its insecticidal activity against some stored insects after the post-harvest. Nanomaterials 10:739. doi: 10.3390/nano10040739

Fan, W., Zhao, M., Li, S., Bai, X., Li, J., Meng, H., et al. (2016). Contrasting transcriptional responses of PYR1/PYL/RCAR ABA receptors to ABA or dehydration stress between maize seedling leaves and roots. BMC Plant Biol. 16:1–14. doi: 10.1186/s12870-016-0764-x

FAOSTAT, F. (2023) "Agriculture organization of the united nations statistics division," in Economic Social Development Department (Rome). Available online at: http//faostat3.fao.org/home/E (accessed Febraury 15, 2022).

Fernandez, G. C. (1992). "Effective selection criteria for assessing plant stress tolerance," in Proceeding of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress, (Shanhua, Taiwan), 257–270.

Gamalero, E., and Glick, B. R. (2012). Ethylene and Abiotic Stress Tolerance in Plants. Berlin: Springer. doi: 10.1007/978-1-4614-0815-4_18

Gao, J., Zhang, R. H., Wang, W. B., Li, Z. W., and Xue, J. Q. (2015). Effects of drought stress on performance of photosystem II in maize seedling stage. Ying Yong Sheng Tai Xue Bao 26, 1391–1396.

Gekas, F., Pankou, C., Mylonas, I., Ninou, E., Sinapidou, E., Lithourgidis, A., et al. (2013). The use of chlorophyll meter readings for the selection of maize inbred lines under drought stress. World Acad. Sci. Eng. Technol. 7, 815–819.

Gholamin, R., and Khayatnezhad, M. (2011). The effect of end season drought stress on the chlorophyll content, chlorophyll fluorescence parameters and yield in maize cultivars. Sci. Res. Essays 6, 5351–5357. doi: 10.5897/AJMR1 1.964

Gomaa, M., Kandil, E. E., El-Dein, A. A., Abou-Donia, M. E., Ali, H. M., and Abdelsalam, N. R. (2021). Increase maize productivity and water use efficiency through application of potassium silicate under water stress. Sci. Rep. 11, 1–8. doi: 10.1038/s41598-020-80656-9

Gupta, A., Rico-Medina, A., and Caño-Delgado, A. I. (2020). The physiology of plant responses to drought. Science 368, 266–269. doi: 10.1126/science.aaz7614.

Huqe, M. A. S., Haque, M. S., Sagar, A., Uddin, M. N., Hossain, M. A., Hossain, A., et al. (2021). Characterization of Maize Hybrids (Zea mays L.) for Detecting Salt Tolerance Based on Morpho-Physiological Characteristics. Ion Accumulation and Genetic Variability at Early Vegetative Stage. Plants 10:2549. doi: 10.3390/ plants10112549

Hussain, H. A., Men, S., Hussain, S., Chen, Y., Ali, S., Zhang, S., et al. (2019). Interactive effects of drought and heat stresses on morpho-physiological attributes, yield, nutrient uptake and oxidative status in maize hybrids. Sci. Rep. 9, 1–12. doi: 10.1038/s41598-019-40362-7

Kandil, E. E., Abdelsalam, N. R., Mansour, M. A., Ali, H. M., and Siddiqui, M. H. (2020). Potentials of organic manure and potassium forms on maize (Zea mays L.) growth and production. Sci. Rep. 10, 1–11. doi: 10.1038/s41598-020-65 749-9

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., and Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. Sci. 319, 607–610. doi: 10.1126/science.1152339

Schonfeld, M. A., Johnson, R. C., Carver, B. F., and Mornhinweg, D. W. (1988). Water relations in winter wheat as drought resistance indicators. Crop Sci. 28, 526–531. doi: 10.2135/cropsci1988.0011183X002800030021x

Shabbir, R., Javed, T., Afzal, I., Sabagh, A. E., Ali, A., Vicente, O., et al. (2021). Modern biotechnologies: Innovative and sustainable approaches for the improvement of sugarcane tolerance to environmental stresses. Agronomy 11:1042. doi: 10.3390/agronomy11061042

Tollenaar, M., and Lee, E. (2006). Dissection of physiological processes underlying grain yield in maize by examining genetic improvement and heterosis. Maydica 51:399.

Zhu, X., Xu, K., Liu, Y., Guo, R., and Chen, L. (2021). Assessing the vulnerability and risk of maize to drought in China based on the aquacrop model. Agric. Syst. 189:103040. doi: 10.1016/j.agsy.2020.10 3040

[Citation Ahmad, K., Ullah, A., Islam, B., Khan, M.A., Qadir, M.S., Saleem, S., Ahmad, I., Rehman, Z.U., Aslam, M., Hussain, S. (2024). Identification of climate resilient genotypes on base of physio-morphic and yield related traits in maize (*ZEA MAYS L.*). *Biol. Clin. Sci. Res. J.*, **2024**: *1267*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1267]