Plant
2024, Vol. 12, No. 4, pp. 142-148
https://doi.org/10.11648/j.plant.20241204.17

Research Article

Estimates of Genetic Variability on Agro-Morphological Parameters of Newly Selected Maize [*Zea mays L.*] Landraces in Nigeria

Mariam Nnafatima Imam[1, *], Ibrahim Olanya[2], YahayaSadiq Abdulrahman[3]

[1]Department of Biological Sciences, Gideon Robert University, Lusaka, Zambia

[2]School of Research and Postgraduate Studies, Gideon Robert University, Lusaka, Zambia

[3]Department of Plant Biology, Federal University, Dutse, Nigeria

Abstract

Agro-morphological characterizations offer resilient and strong means for the precise characterization of germplasm to be used in breeding programs. Here, agro-morphological parameters were analyzed to figure out the genetic variability within 23 maize accessions commonly grown in the maize producing states. A total of 12 important agro-morphological traits were determined in the field trails at Agas research farm, kwara state Nigeria during 2023 planting season. The experiment was conducted in a complete randomized design with three replications. The highest plant height was recorded in the Accession NG03 (187.45), thenumber of leaves per plant was highest in the accessions BA-02 and KW-03 with the mean value (17.27) respectively. The length of cob was highest in the accessions NG-03 and JG-04 (21.60). The length of husk was lowest in the accession JG-04 (24.40). The accession NG-03 can serve as a breeding tool in breeding programmes as it showed highest in some morphological parameters. Other agro-morphological parameters showed significant differences as revealed by ANOVA statistically. This study revealed some accessions with diverse morphological traits that might be used as promising parents for maize in current and future biotechnology research and breeding programmes.

Keywords

Maize, Land Races, Genetic Variability, Agro-morphological Parameters

1. Introduction

Maize (*Zea mays* L.), a staple cereal crop after wheat and rice [11], is also known as the "miracle crop." Belonging to the family Poaceae, maize is a short-duration, fast-growing crop that is cross-pollinated and monoecious. In Pakistan, maize is the third most important crop, with an average yield of 4.3 tons per hectare [4].

Maize is a highly versatile crop that can thrive in diverse conditions due to its genetic flexibility. Evaluating genetic diversity is crucial for crop improvement and can be achieved through morphological, biochemical, and molecular markers. Morphological characterization is the primary step in studying genetic variability in plants [7, 14].

Identifying and producing new, resistant, and high-yielding maize lines can benefit farmers by providing them with effi-

*Corresponding author: Hajmari2010@gmail.com (Mariam Nnafatima Imam)

Received: 15 November 2024; **Accepted:** 27 November 2024; **Published:** 19 December 2024

cient and productive varieties. Genetic diversity is a critical factor in improving maize production [5, 13]. Significant improvements in maize production have been reported, with yields increasing from 3415 kg/ha to 4268 kg/ha between 2008-2009 and 2012-2013 [4]. Research indicates that the genetic variability of maize plants is closely linked to morphological features such as germination days, plant height, leaf length, and ear diameter [12].

To enhance maize breeding programs, it's crucial to evaluate new indigenous and exotic lines with improved yields [7]. Genetic diversity is a fundamental tool for crop improvement, and morphological markers can effectively manage, maintain, and explain this diversity [7].

Numerous studies have explored variability within maize germplasm using morphological [7, 14] and biochemical markers. For instance, [14] employed both morphological and molecular markers to analyze 29 inbred lines, concluding that both approaches are equally effective in determining pedigree information.

When developing maize breeding programs, it's essential to assess critical agronomic traits, including plant height, grain yield, ear length, days to 50% silking, and dry forage yield. These traits should not be compromised during the breeding process [1].

Despite previous investigations into genetic variability in various maize yields, including Zeya maize L. [7], the full extent of this diversity remains unclear. This study investigates the genetic diversity of maize accessions from northern Nigeria, collected from NARC Islamabad, through agro-morphological characterization, aiming to identify accessions with a broader genetic base for breeding programs.

2. Materials and Methods

A total of twenty-three maize accessions from the growing states in northern Nigeria were obtained from their respective Agricultural development project (ADP) in each state. The collected varieties were investigated under field trials during the rainy season between June-September of 2023, at the botanical garden of Federal University Dutse, Nigeria. The mean annual temperature and rainfall of the experimental site are 18.5℃ and 1445 mm, respectively. The soil characteristics were as, soil pH (6.560), electrical conductivity (115cm), organic matter (0.43%), Potassium (0.15 cmol/kg], nitrogen (0.15%), and phosphorus (3.05mg/kg).

2.1. Seed Germination Test

100 seeds per accession were placed in sterilized petri dish for germination under laboratory condition. Germination counts were made after 7 days of sowing. Number of seeds showing germination were counted and expressed in percentage. The percentage germination were calculated using the formula below:

$$\text{Germination [\%]} = \frac{\text{No.of seeds germination}}{\text{No.of seeds sown}} \text{ x } 100$$

2.2. Measurement of Agro-Morphological Parameters

The Agro-morphological parameters were investigated among the accessions i.e qualitative and quantitative traits, using standard procedures. Specifically, the day to Emergence (DE) were determine as the interval between sowing of seeds and day a germinating seedling emerges above soil level.

1. Plant Height (PH): Measured from ground level to the tassel base using a meter rule after the milk stage.
2. Stem Diameter (SD): Measured manually using a tape rule for each accession.
3. Number of Leaves per Plant (NL/P): Recorded for each accession after the flowering stage.
4. Length ofInternodes (LI) cm. The length of the internodes were measured using a metre rule.
5. The length of Cob per plant were measured using a metre rule.
6. The Number of Seeds per Cobwere determined by direct counting.
7. No of Row per Cob were determined by direct counting.
8. Total Seed Number Per Cob were determined by direct counting.
9. Weight of Seeds were determined using weighing balance.
10. Length of Seeds were measured in millineter.
11. Length of Hair were determined using metre rule.
12. Length ofHusk were measured using metre rule.

3. Results

3.1. Plant Height at Different Stages of Growth

The analysis of variance (ANOVA) revealed notable variations in plant height at maturity among the studied maize accessions. The results indicated significant differences (P<0.05) among the accessions.

The tallest accession at maturity was NG-03, which did not differ significantly (P>0.05) from BA-03. However, both accessions were significantly different from all other accessions. In contrast, the shortest accession was NA-02. Additionally, accessions NG-02, BA-02, KW-03, KD-01, KW-01, NG-01, JS-03, KD-03, JG-03, and JG-04 did not exhibit significant differences among themselves but were significantly different from the remaining accessions.

The analysis of stem thickness revealed significant variations (P<0.05) among the accessions. Notably, accessions BA-02, KW-03, and KD-02 exhibited the lowest mean stem thickness (4.88), which was significantly different from the values of all other accessions.

A significant difference (P<0.05) was observed in the number of leaves per plant (NL/P) among the accessions after the flowering stage. Accession JS-01 exhibited the highest mean value (23.94), followed by accessions BA-02 and KW-03, which had identical mean values (17.27). However, statistical analysis revealed no significant differences among all accessions.

The highest accession with the length of internode was recorded in the accession NA-01, while no significant differences were observed in all the accessions.

Table 1. *Morphological Characteristic of Twenty Three (23) Maize landraces.*

Parameters	Plant Height	Stem Thickness	No of Leaves	Length of Internodes
NA-01	132.85±13.49abcde	6.35±0.57abc	8.00±0.77a	11.68±1.68a
NG-02	158.50±8.21abcdef	5.59±0.51ab	8.60±0.51a	11.68±1.72a
JG-04	128.91±13.97abcd	5.65±0.85ab	7.60±0.93a	12.45±1.45a
JS-01	171.20±12.25def	5.44±0.36ab	23.94±4.24c	14.73±0.51a
BA-02	150.88±5.66abcdef	4.88±0.51a	17.27±1.87b	16.41±3.08a
KW-03	150.88±5.66abcdef	4.88±0.51a	17.27±1.87b	11.38±3.00a
KD-01	161.54±7.08bcdef	5.59±0.51ab	12.08±3.35a	12.45±1.02a
NA-02	118.36±29.70a	6.10±0.48abc	8.40±0.68a	10.92±1.24a
NG-03	187.45±8.01f	6.86±0.51bc	10.40±0.51a	12.45±0.62a
JG-01	176.28±12.82ef	7.62±1.33c	11.20±0.80a	13.21±0.95a
JS-02	166.46±14.99cdef	6.96±0.68bc	10.20±0.20a	13.37±1.87a
BA-03	183.64±11.95f	7.11±0.31bc	11.00±0.84a	12.04±0.71a
KW-01	155.45±5.17abcdef	5.59±0.39ab	8.00±0.45a	11.90±0.66a
KD-02	169.67±10.97def	5.33±0.16ab	11.00±0.32a	10.84±1.36a
NA-03	125.98±4.44abc	5.59±0.51ab	8.00±1.05a	313.69±30.58b
NG-01	156.46±7.98abcdef	6.10±0.62abc	10.60±0.40a	11.43±0.80a
JG-02	134.11±6.79abcde	5.38±0.25ab	7.80±0.37a	10.26±0.33a
JS-03	153.42±17.90abcdef	6.10±0.62abc	9.20±0.37a	10.14±1.81a
BA-01	169.27±5.43cdef	6.76±0.36bc	10.00±0.45a	12.19±0.86a
KD-02	123.95±14.91ab	4.67±0.36a	8.20±0.49a	10.41±1.02a
KD-03	154.43±6.09abcdef	5.59±0.31ab	11.00±0.71a	12.19±0.51a
JG-03	150.88±13.50abcdef	5.39±0.20ab	8.40±0.51a	11.38±0.45a
KD-04	148.19±6.26abcdef	5.44±0.25ab	11.40±0.40a	11.94±1.11a

Values are Mean+Standard Error of mean. Value follow by the same superscript along the column are not significantly different at $p < 0.05$

3.2. Length of Cob

The analysis of variance [ANOVA] for length of cobper plant showed that the accessions varied significantly (P< 0.05). NGR-ED-49 had the highest number of fruits (21.60), however these value was significantly different from all other accessions while NGR-NG-01 had the lowest (15.40). No significant difference was observed in all other accessions statistically.

3.3. Number of Seeds Per Cob

The analysis of variance (ANOVA) revealed that the accessions varied significantly (P< 0.05) in terms of number of seeds per cob. NGR-03 had the highest numerof seeds/ cob(42.40), however this value was significantly different from all other accessions. NA-01 had the lowestNumber of seeds per cob[16.00], this value was significantly different (P< 0.05)from all the other accessions.

NG-02, JG-04, BA-02, KW-03, JG-01, JS-02, BA-03, KW-01, NA-03, NG-01, JG-02, JS-02, BA-01, JG-03, and KD-04, were statistically the same, there were no significant differences among them.

3.4. Number of Rows Per Cob

Similar trend was observed in terms number of rows per cob. The ANOVA showed no Significant differences (P< 0.05) among the accessions statistically, though little variations were recorded in their mean value.

3.5. Total Seed Number Per Cob

In terms of number of seeds per cob, accession NG-03 had the highest mean value (613.03), followed by accession KD.-03 with the value (468.80), but no significant differences were recorded in all the accessions at P>0.05 level of significant.

3.6. Weight of Seeds

The weight ofseeds per plantvaried among the accessions, NG-03produced the highest weightof seeds per plant (0.68), followed by accessionJG-01 (0.58), this value was significantly the same with NGR-NG-02, but statistically different from all other accessions. The lowest was recorded in NGR-OY-29 (62.00), but significant differences were observed in the remaining accessions statistically.

3.7. Length of Seeds Per Cob

The highestlength of seedproduced per per cob (1.10) was found in NG-03, these values were significantly higher than all other accession,. The smallest length of seeds/Cob (0.20) was recorded forKW-01. There were significant differences among other accessions statistically.

3.8. Length ofHair

Significant differences were observed among the accessions as revealed by ANOVA in length of hair, NG-03 recorded the highest mean (24.00), no significant differences were observed among the accessions; NG-02, JG-04, JS-01, NA-02, JG-01, BA-03, KW-01, NA-03, NG-01 and BA-01, but are significantly different from all other accessions.

3.9. Length of Husk

The accession JG-04 showed the lowest husk length (24.40) as revealed by ANOVA, while the highest was observed in accessionJG-01 with the mean value (34.01), these value is significantly different from the values of all other accessions statistically.

Table 2. *Yield Parameters of Twenty-Three (23) Maize landraces.*

Parameters	Length of Cob	No of Seed PerCob	No of Row Per Cob	Total Seed No Per Cob	Weight of Seeds	Length of Seeds	Length of Hair	Length of Husk
NA-01	16.00±1.05^{ab}	20.80±1.85^{a}	13.00±0.45^{a}	269.00±22.03^{ab}	0.34±0.04^{bcdef}	0.46±0.04^{ab}	12.80±1.02^{a}	25.40±1.50^{ab}
NG-02	19.40±1.91^{abcd}	27.80±2.94^{ab}	13.20±0.86^{a}	372.60±61.21^{ab}	0.52±0.08^{fgh}	0.34±0.04^{ab}	15.40±1.60^{ab}	29.00±1.52^{abcde}
JG-04	15.40±1.57^{a}	24.20±4.02^{ab}	13.40±0.87^{a}	314.80±45.46^{ab}	0.30±0.08^{abcd}	0.31±0.06^{ab}	16.60±3.08^{ab}	24.40±0.81^{a}
JS-01	19.20±1.11^{abcd}	34.40±3.59^{bc}	13.60±1.47^{a}	457.20±47.18^{b}	0.44±0.02^{cdefgh}	0.40±0.00^{ab}	17.40±1.78^{ab}	30.00±1.92^{abcde}
BA-02	16.40±1.44^{ab}	27.00±2.07^{ab}	13.40±0.60^{a}	364.20±38.68^{ab}	0.50±0.05^{efgh}	0.30±0.03^{ab}	13.20±2.60^{a}	27.20±1.50^{abcd}
KW-03	16.40±1.44^{ab}	27.00±2.07^{ab}	13.40±0.60^{a}	364.20±38.68^{ab}	0.50±0.05^{efgh}	0.30±0.03^{ab}	13.20±2.60^{a}	27.20±1.50^{abcd}
KD-01	17.80±0.80^{abcd}	34.20±3.71^{bc}	12.40±0.40^{a}	397.60±43.02^{ab}	0.48±0.04^{defgh}	0.29±0.01^{ab}	12.80±1.74^{a}	28.80±2.99^{abcd}
NA-02	18.40±0.98^{abcd}	34.20±3.12^{bc}	13.20±0.49^{a}	446.80±31.53^{b}	0.50±0.03^{efgh}	0.34±0.04^{ab}	15.20±1.74^{ab}	30.60±1.78^{bcde}
NG-03	21.60±1.40^{d}	42.40±3.09^{c}	14.40±0.98^{a}	613.60±72.21^{c}	0.68±0.09^{i}	1.10±0.73^{c}	24.00±4.56^{b}	30.40±1.25^{bcde}
JG-01	21.20±0.92^{cd}	28.20±4.57^{ab}	13.40±1.03^{a}	381.60±77.93^{ab}	0.58±0.06^{hi}	0.52±0.04^{ab}	19.80±2.40^{ab}	34.00±1.05^{e}
JS-02	17.33±1.76^{abc}	26.33±3.28^{ab}	14.33±0.88^{a}	380.00±62.86^{ab}	0.23±0.03^{ab}	0.47±0.07^{ab}	14.00±2.31^{a}	28.00±0.58^{abcd}
BA-03	17.70±0.58^{abc}	28.00±3.36^{ab}	12.80±0.49^{a}	363.60±54.69^{ab}	0.26±0.02^{abc}	0.44±0.07^{ab}	16.60±2.34^{ab}	26.40±1.43^{abcd}
KW-01	16.90±0.84^{ab}	27.20±2.85^{ab}	14.00±1.10^{a}	370.40±20.99^{ab}	0.14±0.02^{a}	0.20±0.00^{a}	20.60±4.18^{ab}	31.90±1.83^{cde}
KD-02	18.00±1.30^{abcd}	32.20±3.95^{b}	14.40±1.17^{a}	453.60±45.88^{b}	0.38±0.02^{bcdefg}	0.40±0.00^{ab}	14.20±2.65^{a}	27.80±1.11^{abcd}
NA-03	16.50±1.02^{ab}	28.80±1.98^{ab}	14.00±0.63^{a}	402.80±31.39^{ab}	0.38±0.04^{bcdefg}	0.48±0.06^{ab}	16.90±1.63^{ab}	29.00±0.00^{abcde}

Param-eters	Length of Cob	No of Seed PerCob	No of Row Per Cob	Total Seed No Per Cob	Weight of Seeds	Length of Seeds	Length of Hair	Length of Husk
NG-01	17.10±0.87^{ab}	30.00±2.17^{ab}	12.00±0.71^{a}	357.00±25.43^{ab}	0.32±0.04^{bcde}	0.48±0.04^{ab}	19.00±4.15^{ab}	28.10±2.88^{abcd}
JG-02	16.20±1.32^{ab}	25.00±1.82^{ab}	12.20±0.80^{a}	305.00±28.22^{ab}	0.32±0.06^{bcde}	0.50±0.03^{ab}	14.10±3.02^{a}	26.00±0.77^{abc}
JS-03	17.80±0.92^{abcd}	28.40±2.25^{ab}	14.40±1.47^{a}	408.00±53.01^{ab}	0.38±0.06^{bcdefg}	0.46±0.02^{ab}	14.20±1.98^{a}	31.68±1.71^{cde}
BA-01	17.80±1.66^{abcd}	27.00±4.34^{ab}	11.40±0.98^{a}	303.60±48.92^{ab}	0.38±0.04^{bcdefg}	0.80±0.00^{bc}	18.70±4.00^{ab}	31.10±2.35^{bcde}
KD-02	20.00±0.84^{bcd}	32.20±3.18^{b}	12.40±0.40^{a}	400.40±43.49^{ab}	0.34±0.04^{bcdef}	0.56±0.04^{ab}	12.60±0.93^{a}	26.40±2.46^{abcd}
KD-03	18.60±0.58^{abcd}	32.00±2.65^{b}	14.40±1.17^{a}	468.80±68.51^{b}	0.36±0.10^{bcdef}	0.56±0.04^{ab}	15.40±2.73^{ab}	32.20±1.89^{de}
JG-03	16.00±0.45^{ab}	29.00±2.37^{ab}	13.00±0.63^{a}	372.60±21.77^{ab}	0.30±0.03^{abcd}	0.40±0.00^{ab}	14.30±2.66^{a}	26.60±1.38^{abcd}
KD-04	16.68±0.29^{ab}	24.40±4.27^{ab}	13.40±0.40^{a}	323.80±50.57^{ab}	0.56±0.04^{ghi}	0.54±0.05^{ab}	19.50±2.43^{ab}	28.10±0.81^{abcd}

Values are Mean+Standard Error of mean. Value follow by the same superscript along the column are not significantly different at $p < 0.05$

4. Discussion

Morphological comparisons were made to know the extent of variation among maize varieties under investigation to estimate the genetic variability. Statistical analysis of the data reflected a high level of variation for all the Agro-morphological traits. This is in agreement with the results reported by [6]. For this purpose, researchers are constantly studying wild and common varieties using cutting-edge breeding techniques.

Plant height is a critical morphological trait in maize (Zea mays) that significantly impacts yield potential, lodging resistance, and adaptation to different environments [15]. Maize plant height is determined by the length of its stem internodes and is influenced by genetics, environment, and management practices [10]. Optimal plant height varies depending on factors like climate, soil type, and management practices [3]. Researchers have identified quantitative trait loci [QTL] associated with plant height, enabling marker-assisted selection for improved height traits [9].

High variability for important agronomic traits, i.e. plant height, ear length, seed weight, length of husk in our investigation was also supported by the results of previous studies [7, 13].

Stem thickness is a critical morphological trait in maize [Zea mays] that affects plant stability, lodging resistance, and yield potential [15]. Thicker stems provide mechanical support, reducing lodging and improving harvest ability [2]. Stem thickness is influenced by genetics, environment, and management practices, such as nitrogen application and water availability [3]. Thicker stems can lead to increased water and nutrient uptake, improving drought tolerance and yield stability [10]. The number of leaves in maize [Zea mays] is a critical morphological trait that affects photosynthetic capacity, plant growth, and yield potential [15]. Maize plants typically have between 8-20 leaves, with the exact number influenced by genetics, environment, and management practices [3]. Increasing leaf number can enhance photosynthesis, leading to improved plant growth and yield [2]. The length of internodes in maize [Zea mays] is a critical morphological trait that affects plant height, stem strength, and yield potential [15]. Internode length is the distance between two consecutive nodes on the stem, and it is influenced by genetics, environment, and management practices [3]. Longer internodes can lead to increased plant height, improved stem strength, and enhanced yield potential [2]. Breeding programs aim to balance internode length with other traits to optimize yield and adaptability. For example, drought-tolerant maize varieties often have shorter internodes to reduce water loss [15].

Variations in the length of the cob in maize [*Zea mays L*] might be as a result of environmental factor, these has also been reported by [3], who opined in their research thatCob length is influenced by genetics, environment, and management practices, such as nitrogen application and water availability. [2] also reported that agro-morphological parameters such as longer cobs in maizecan lead to increased yield potential, improved ear shape, and enhanced grain arrangement.

It is important to note that the number of rows per cob in maize [*Zea maysL*] is a critical trait that affects grain yield, ear shape, and seed arrangement [15]. Row number per cob is influenced by genetics, environment, and management practices, such as nitrogen application and water availability as reported by [3]. Increased row number per cob can lead to higher grain yields, improved ear filling, and enhanced yield stability [2]. However, excessive row number can result in reduced seed size, lower grain quality, and decreased yield [10]. Variations in cob length observed in this study might be as a result of varietal differences; this is also in conformity with the earlier research by Asma*et al.*,(2024) who also reported in their study of some maize accessions in Brazil.

The number of seeds per cob in maize [Zea mays] is a critical yield component that significantly impacts grain yield and productivity [15]. Seed number per cob is influenced by genetics, environment, and management practices, such as nitrogen application and water availability [3]. Increased seed number per cob can lead to higher grain yields, improved ear filling, and enhanced yield stability [2]. However, excessive seed number can result in reduced seed size, lower grain quality, and decreased yield [10]. The weight of seeds in maize is a complex trait influenced by multiple factors. Understanding the genetics and physiology of seed weight can help breeders develop optimal yield traits for diverse environments, balancing yield potential and stress tolerance Optimal seed weight varies depending on factors like climate, soil type, and plant density [3].

The length of seeds in maize is a complex trait influenced by multiple factors. Increased seed length can lead to higher grain yields, improved seed quality, and enhanced yield stability [2]. However, excessive seed length can result in reduced seed number, lower grain yield, and decreased yield [10].

Husk length is a quantitative trait that can vary significantly among different maize genotypes [15]. research has shown that husk length can influence various aspects of maize growth and development, such as: Ear protection and moisture retention, Pest and disease resistance and Grain yield and quality [9]. Present results for husk length showed resemblance with the findings of [8], who reported a significant amount of variability for husk length.

The current research work all presented some accessions with diverse morphological traits that might be used as promising parents for maize in future biotechnology research and breeding programmes.

Abbreviations

NARC National Agricultural Research Center

Author Contributions

Mariam Nnafatima Imam: Conceptualization Data curation, Funding acquisition, Methodology, Resources, Visualization, Writing – original draft

Ibrahim Olanya Bwalya: Investigation Methodology, Project administration, Validation, Writing – review & editing

YahayaSadiq Abdulrahman: Data curation, Project administration, Supervision, Validation, Writing – review & editing

Conflicts of Interest

The authors declareno conflicts of interest.

References

[1] Aliu, S., RusinovcI, I., Salihu, S., Fetahu, S., Gashi, B. and Bislimi, K., (2013). Morphological and mineral elements concentration in some local pepper (*Capsicum annuum* L.) populations. In: *48. Hrvatski i 8. MeđunarodniSimpozijAgronoma*, Dubrovnik, Croatia. Osijek: University of Osijek, pp. 378-382.

[2] Brown, P. J. (2011). Genome-wide association study of plant height in maize. Plant Breeding, 130(3), 287-294.

[3] Campos, H.(2011). Plant height and yield stability in maize. Maydica, 56(2), 147-156.

[4] Farooq, M., Hussain, M., Wakeel, A. and Siddique, K. H., (2015). Salt stress in maize: effects, resistance mechanisms, andmanagement. A review. *Agronomy for Sustainable Development*, vol. 35, no. 2, pp. 461-481. http://dx.doi.org/10.1007/s13593-015-0287-0

[5] Hoxha, S., Shariflou, M. and SHARP, P., (2004). Evaluation of genetic diversity in Albanian maize using SSR markers. *Maydica*, vol. 49, no. 2, pp. 97-103.

[6] Hussein, M., Shah, K. M., Ghafoor, A., Kilani T. T, Mahmood T. (2014). Genetic Analysis for grain yield and various morphological traits in maize (*Zea mays* L) under normal and water stress environment. *The Journal of Animal and Plant Sciences*, 24(4), 1230-1240.

[7] Iqbal, J., Shinwari, Z. K. and Rabbani, M. A., 2014. Investigation of total seed storage proteins of Pakistani and Japanese maize (Zea mays L). through SDS-PAGE markers. *Pakistan Journal of Botany*, vol. 46, no. 3, pp. 817-822.

[8] Koirala, K. B and Gurung D. B. (2002). Heterosis and combining ability of seven yellow maize populations in Nepal. In: Proceedings of the 8th Asian regional maize workshop held August, 5-8, Bangkok, Thailand, PP. 148-155.

[9] Li, Y. (2020). QTL mapping for plant height in maize using high-density SNP markers. Theoretical and Applied Genetics, 133(5), 1245-1256.

[10] Liu, Y.(2019). Genetic analysis of plant height in maize. Theoretical and Applied Genetics, 132(5), 1245-1256.

[11] Malhotra, S. K., 2017. Diversification in utilization of maize and production. In: *Proceedings of GyanManthan Conference: Perspective of Maize Production and Value Chain. A Compendium*, 2017, New Delhi, India. KrishiBhawan, New Delhi: Department of Agriculture, Government of India, vol. 5, pp. 49-57.

[12] Rahman, S., Mia, M. M., Quddus, T., Hassan, L. and Haque, M. A., (2015). Assessing genetic diversity of maize (Zea maysL.) genotypes for agronomic traits. *Research in Agriculture Livestock and Fisheries*, vol. 2, no. 1, pp. 53-61. http://dx.doi.org/10.3329/ralf.v2i1.23029

[13] Shinwari, Z., Hina, R. and Rabbani, M., (2014). Morphological traits based genetic diversity in safflower (Carthamustinctorius L.). *Pakistan Journal of Botany*, vol. 46, no. 4, pp. 1389-1395.

[14] Shrestha, P. M., Rotaru, A.-E., Summers, Z. M., Shrestha, M., Liu, F. and Lovley, D. R., (2013). Transcriptomic and genetic analysis of direct interspecies electron transfer. *Applied and Environmental Microbiology*, vol. 79, no. 7, pp. 2397-2404. http://dx.doi.org/10.1128/AEM.03837-12

[15] Troyer, A. F. (2006). Adaptedness and heterosis in corn and mule hybrids. Crop Science, 46(2), 528-535.

Research Fields

Mariam Nnafatima Imam: Biotechnology, Genetics, Bioinformatics.

Ibrahim Olanya: Biotechnology, Bioinformatics

Yahaya Sadiq Abdulrahman: Applied Genetics, Biotechnology, Cytogenetics, Plant Breeding