Morphological Characterization of Chilli (*Capsicum annuum* L.) Genotypes

ABSTRACT

Chilli, belonging to the Solanaceae family with a chromosome number of 2n = 24, thrives as herbaceous annuals in temperate zones and is propagated by seeds. Its origins are traced to Mexico, Guatemala, and Bulgaria, with the Capsicum genus comprising 30 species, of which five are cultivated: Capsicum annuum L., C. frutescens, C. chinense, C. pubescens, and C. baccatum. Introduced to India by the Portuguese in the 16th century, chillies are globally grown, with India and China as major producers. Despite its economic significance, challenges like diseases and insect infestations impede production and quality. India, a significant player in the global chilli market, accounts for 36 percent of total global chilli exports. Madhya Pradesh has recently shown remarkable growth in chilli production, ranking 3rd in the largest chilli-producing states. Challenges persist in enhancing yields due to factors like the lack of superior cultivars and diseases. Genetic diversity analysis is deemed crucial for crop improvement, aiding in identifying suitable parental combinations and varieties. A study on the morphological characterization of chilli (Capsicum annuum L.) was conducted at Maharajpur Vegetable Farm, Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur. Utilizing 43 genotypes from different regions of Madhya Pradesh, the study aimed to enhance crop improvement programs by understanding genetic diversity. Variability in populations is influenced by both genetic and environmental factors, essential knowledge for effective breeding operations. Aklilu et al. (2016) explored genetic variability, heritability, and genetic advance in 49 hot pepper varieties, finding significant variability in traits like leaf area index and pericarp thickness. Vaishnavi et al. (2018) studied 36 bird's eye chili genotypes, uncovering high genetic variability, heritability, and genetic advance in traits such as plant spread, fruit length, yield, and chemical contents like capsaicin and oleoresin. Yatung et al. (2014) delved into the genetic diversity of 30 chili genotypes (Capsicum annuum L.), identifying significant variability in twelve traits and grouping genotypes into six clusters through cluster analysis.

Keywords: Chilli peppers, Capsicum spp., Genetic diversity, Crop improvement, Morphological characterization, Heritability, Cluster analysis.

INTRODUCTION

Chilli belongs to the family Solanaceae and has a chromosome number of 2n = 24. In the temperate zone, they grow as herbaceous annuals and are propagated byseeds. Chilli is aspice as well as vegetable crop Mexico, Guatemala, andBulgaria are thought to be the chilli's three primary places of origin. TheCapsicum genus contains 30 species, five of which are cultivated (Boslandand Votava *et al.2000*). These five species have mostly been used as
vegetables and spices for thousands of years: *Capsicum annuum* L., *C.frutescens, C.chinense, C. pubescens, and C. baccatum.* Chilli was firstintroduced into India by the Portuguese in 16th century (Krishna De *etal.2003*). The most common variety of capsicum farmed in India is *Capsicumannuum*, but *C. frutescens* and *C. chinense*are also produced in some areas,particularly in the country's north-eastern region and the states of Andhra
Pradesh, Karnataka and Kerala.Initially introduced to India by the Portuguese in the 16th century (Krishna De *et al.*, 2003), chillies are grown globally, with India and China being major producers and exporters. Despite its economic significance, chilli cultivation faces challenges such as diseases and insect infestations, limiting production and quality.

India, a significant player in the global chilli market accounting for 36 percent of total global chilli exports (Aswini *et al*., 2016), Recently Madhya Pradesh shown remarkable growth in the production of chilli and occupies 3rd position in the largest chilli producing states cultivated over 88,675 ha, productivity 2353 kg/ha (Spice board India 2019-20). chilli struggles with enhancing yields due to factors like the lack of

superior cultivars and diseases. Genetic diversity analysis is crucial for crop improvement, aiding in the identification of suitable parental combinations and varieties.

"Studies on morphological characterization of chilli (*Capsicum annuum* L.) was conducted on vegetable farm Maharajpur , Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur. 43 genotypes obtained from different regions of Madhya Pradesh was used as a source material for this study. The list of germplasm is given in the Table below. Deuton et al. (2000) O b s e r v e d s c r e e n e d local pepper germplasm, and noticed differences in plant height, branching behaviour, and other yield factors.

To enhance crop improvement programs, understanding genetic diversity is crucial. Variability in populations is influenced by genetic and environmental factors. A study by (Johannsen et al., 1999) highlighted that variation in a population is due to both heritable and non-heritable factors in segregating populations, whereas variation within pure lines is primarily influenced by environmental factors. This understanding is essential for effective breeding operations.

Aklilu et al. (2016) conducted a study on 49 hot pepper varieties for genetic variability, heritability, and genetic advance. Significant variability was found in traits like leaf area index and pericarp thickness, with high heritability observed in fruiting date, fruit length, plant height, internode length, and fruit diameter. Genetic advance was moderate to high for traits including internode length, number of branches, fruit diameter and weight, pericarp thickness, and leaf area index.

Vaishnavi et al. (2018) studied 36 bird's eye chili genotypes, finding high genetic variability, heritability, and genetic advance in traits such as plant spread, fruit length, yield, and chemical contents like capsaicin and oleoresin.

Genetic diversity in 30 chili genotypes (Capsicum annuum L.). Significant variability was found in twelve studied traits which was examined by Yatung et al. (2014). The genotypes were grouped into six clusters through cluster analysis, with Cluster III having the most (14) and Clusters IV and V having the least (1) genotypes. The highest inter-cluster distance was observed between Clusters II and IV (459.81), and the lowest was between Clusters I and IV (36.04). Cluster III exhibited the highest intra-cluster distance (D2 = 67.66), while Cluster II had the lowest (D2 = 11.19).

Materials and Methods

The current research on chilli variety and variability was carried out in the molecular biology laboratory, Department of Biotechnology Centre, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during the year 2021. The germplasm was initially planted in seed beds in September and later transplanted to the main field in October 2021. The transplantation was carried out following a randomized block design (RBD) with a spacing of 60 cm x 50 cm, and each plot measured 2.40×2.50m².

The study involved observing various morphological and quantitative traits in chili plants. These traits included plant growth habit (spreading, semi-upright, or upright), leaf colour, leaf shape, number of flowers per axil, flower position, fruit set, fruit colour at maturity, intensity of fruit colour, fruit shape, fruit position, days of flowering, days to 50% flowering, plant height, number of primary branches, number of secondary branches, number of fruits per plant, fruit length, average fruit weight, and fruit yield per plot. These observations were made on randomly chosen, tagged plants, and the data were averaged based on five plants per treatment.

The study assessed genetic variability in chili plants using various statistical techniques:

1. The study included statistical analysis techniques like mean, range, variance components calculation, coefficient of variability estimation, heritability assessment, genetic advance determination, and Mahalanobis D^2 analysis for measuring genetic divergence based on morphological traits.

RESULT AND DISCUSSION

TABLE1:- List of Chilligermplasmusedfordiversityanalysis

S.no	Germplasm	Location
1	RHRCH64-1	MPKV,Rahuri
2	LCAS-20	LAM,Guntur
3	DDC-98/1	Dharwad(UHS)
4	RHRCH-10-2	MPKV,Rahuri
5	ACS18-08	AAU,Anand
6	SKAU-89	SKUA&T, Srinagar
7	NDCSel-1	NDUA&T,Ayodhya
8	MPC -5	MadhyaPradesh
9	K-2 check	Karnataka
10	Amritsar	Punjab
11	Guntur	AndhraPradesh
12	Chapata	Telangana
13	JawaharSelection-20181	MadhyaPradesh
14	Teja	AndhraPradesh
15	KashiAnmol	SriLankan
16	MPKHC-1	MadhyaPradesh
17	MPC-6	MadhyaPradesh
18	MPC-7	MadhyaPradesh
19	MPHC-1	MadhyaPradesh
20	G-4	Nashik,Maharashtra
21	MPCTC-1	MadhyaPradesh
22	MPKHC-2	MadhyaPradesh
23	Pusa Jwala	NewDelhi
24	Red top	MadhyaPradesh
25	MPC-10	MadhyaPradesh
26	Kohinoor	MadhyaPradesh
27	MPCTC-2	MadhyaPradesh
28	MPKC-1	MadhyaPradesh
29	MPC-1	MadhyaPradesh
30	MPC-2	MadhyaPradesh
31	MPC-8	MadhyaPradesh
32	MPC-3	MadhyaPradesh
33	MPC-4	MadhyaPradesh
34	JawaharSelection-1	MadhyaPradesh
35	JawaharSelection-18	MadhyaPradesh
36	JawaharSelection-19	MadhyaPradesh
37	JawaharSelection-20182	MadhyaPradesh
38	MPC-9	MadhyaPradesh
39	JawaharSelection-2018HYB	MadhyaPradesh
40	JCS-6	MadhyaPradesh
41	JCS-7	MadhyaPradesh

42	JCS-8	MadhyaPradesh
43	JCS-9	MadhyaPradesh

Table 2 :- Morphologicalcharacterizationofchilligenotypesbasedon DUS guidelines

S.No	Characters	States	No.of genotypes	Score	Frequency in %
1	Plantgrowthhabit	Spreading	1	3	2
		Semiupright	41	5	96
		Upright	1	7	2
2	Leaf colour	Lightgreen	-	1	
		Green	42	2	98
		Purple	1	3	2
3	Leaf shape	Deltoid	-	1	-
		Ovate	-	2	-
		Lanceolate	43	3	100
4	Number.offlowersperaxil	One	40	1	93
		Two	2	2	5
		Threeormore	1	3	2
5	Flower position	Drooping	1	3	2
		Semidrooping	40	5	94
		Erect	2	7	4
6	Fruitset	Low	-	3	-
		Medium	40	5	94
		High	3	7	6
7	Fruitcolour at maturity stage	Yellow	1	1	2
		Orange	-	2	-
		Red	41	3	96
		Purple	1	4	2
		Green	-	5	-
8	Fruit: Intensityof colour	Light	-	3	-
		Medium	43	5	100
		Dark	-	7	-
9	Fruitshape	Elongate	25	1	-
		Almostround	-	2	58
		Triangular	18	3	-
10	Fruitposition	Pendant	1	3	2
		Intermediate	40	5	94
		Erect	2	7	4

Fig . 1 LeafCharacteristics

A.Leafprofileincrosssection(Darkgreen)

B.Leafshape(Lanceolate)

Fig .2 **Plant growthhabit**

A.Semiuprightgrowthhabit

B.Uprightgrowthhabit

C.Branchinghabit

Fig .3 **Flowerposition**

A.Semidroopingflowerposition

B.Erectflower position

Fig .4 **Flowercolour**

A.Whitecolour

B.Purplecolour

Fig .5 **Fruit Position**

A.Erectfruitposition B.Intermediate FruitPosition

Fig .6 **Fruitshape**

A.Triangular

B.Elongate

Fig . 7 **Fruitcolour**

A. Purplecolour

B.Greenandredcolour

C.Yellowcolour

In the morphological characterization of 43 chilli genotypes:**Days to Flower Initiation**: Ranged from 37 to 58 days, with a mean of 45.36 days. High heritability (76%) and moderate genetic advance (20.73%) were observed. **Days 50% Flowering:** Ranged from 51 to 71 days, with a mean of 55.295 days. High heritability (79.3%) and moderate genetic advance (47.39%) were noted. **Plant Height (cm):** Average height was 48.677 cm, with a range of 44.98 cm to 58.27 cm. High genetic advance (48.37%) and high heritability (92.19%) were observed. **Number of Primary Branches**: Ranged from 4.40 to 8.78. High genetic advance (48.88%) and moderate heritability (52.4%) were noted. **Number of Secondary Branches**: Ranged from 2.01 to 5.95, with a mean of 3.612. Moderate heritability (27.89%) and moderate genetic advance (18.95%) were observed. **Number of Fruits per Plant**: Ranged from 39.3 to 103, with a mean of 79.11. High heritability (90.68%) and moderate genetic advance (57.05%) were noted. **Fruit Length**: Ranged from 5.65 cm to 12.40 cm, with a mean of 8.992 cm. High heritability (86.55%) and high genetic advance (56.30%) were observed. **Average Fruit Weight**: Mean weight was 5.364 g, ranging from 4.00 to 10.00 g. High heritability (78.00%) and high genetic advance (36.15%) were observed. **Fruit Yield per Plot (kg)**: Ranged from 0.31 kg to 1.74 kg, with a mean of 1.26 kg. High heritability (97%) and high genetic advance (90.06%) were observed for this trait.

In the study, 43 genotypes were grouped into 6 clusters based on divergence analysis. These clusters were not correlated with geographical distribution. Cluster-1 was the largest, comprising 18 genotypes (MPKC-1,MPC-8, Redtop,MPC-6, Kashi Anmol,MPC-7,JS-18,Tej MPKHC-1,MPHC-8, Amritsar,2018chillivar–1AVTII,MPC-1,G-4,Guntur,MPKHC-2, MPCTC-2,JCS-6.), followed by cluster-2 with 14 genotypes (MPC-3,JS-1,K-2 check,2018chilliHYB-5AVTII, Chapata,MPC-4, Kohinoor,MPC-9,MPC-2,MPC-10, SKAU-89). Cluster-3 had 4 genotypes (JS-19, JCS-7,MPCTC-2,
JCS-8), while cluster-4 and cluster-5 each had 4 genotypes (2018Chillivar–2AVTII,JCS-9, RHRCH-10-2, ACS18-08,LCAS-20). Cluster-6 consisted of 1 genotype (RHRCH64-1).

Table 3 :Contribution of different traits toward clustering in chilli genotype

Source	Timesranked	Contribution%
Daysof flowering	4	0.44%
Daysof50%flowering	1	0.11%
Plantheight (cm)	35	3.88%
No.ofprimarybranches	41	4.54%
No.ofsecondarybranches	23	2.55%
No.offruitperplant	306	33.89%
Fruitlength (cm)	203	22.48%
AverageFruitweight(gm)	281	31.12%
Fruityieldperplot kg	9	1.%

Fig . 8 Dendrogram cluster representation in Hierarchical Tree

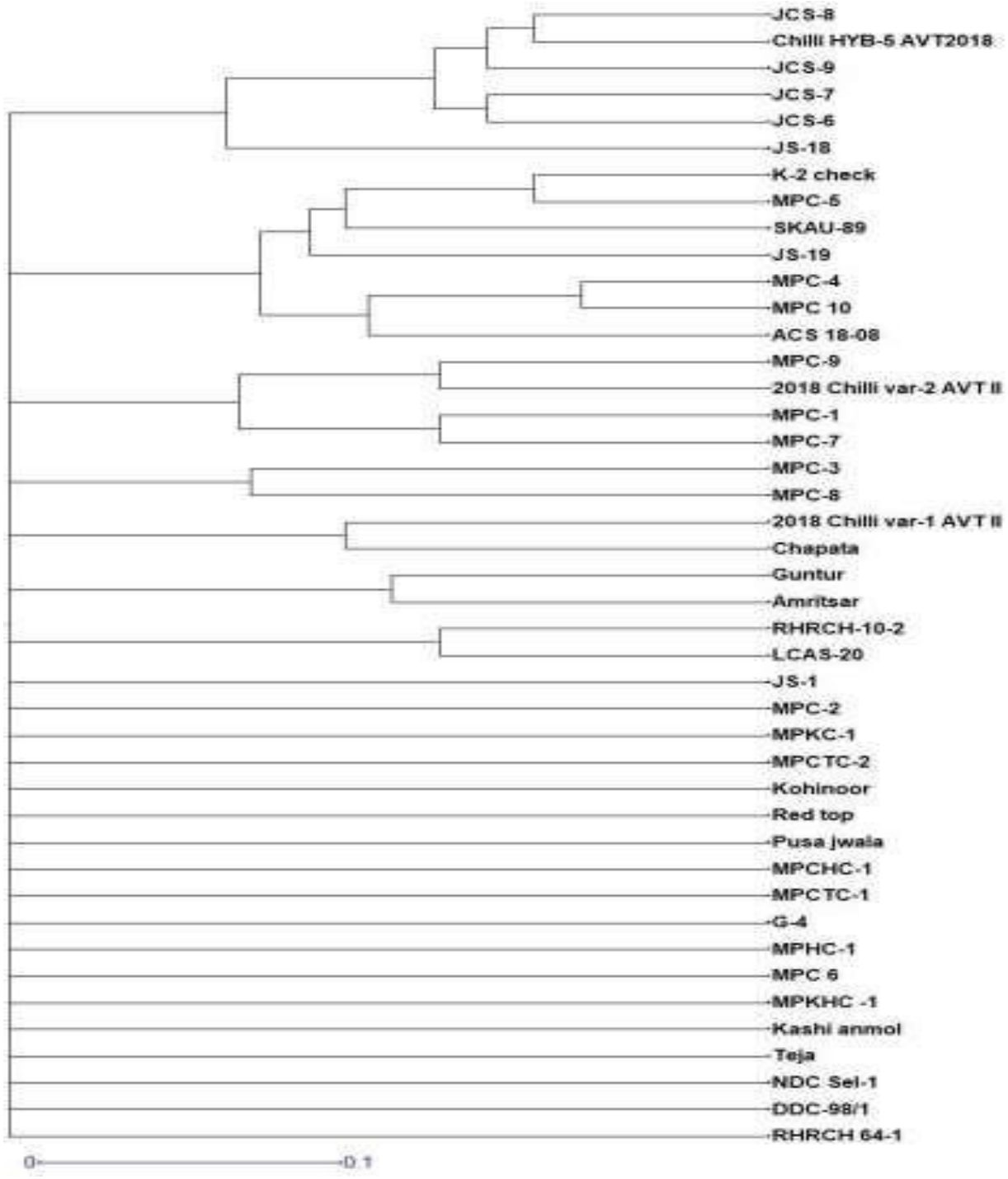
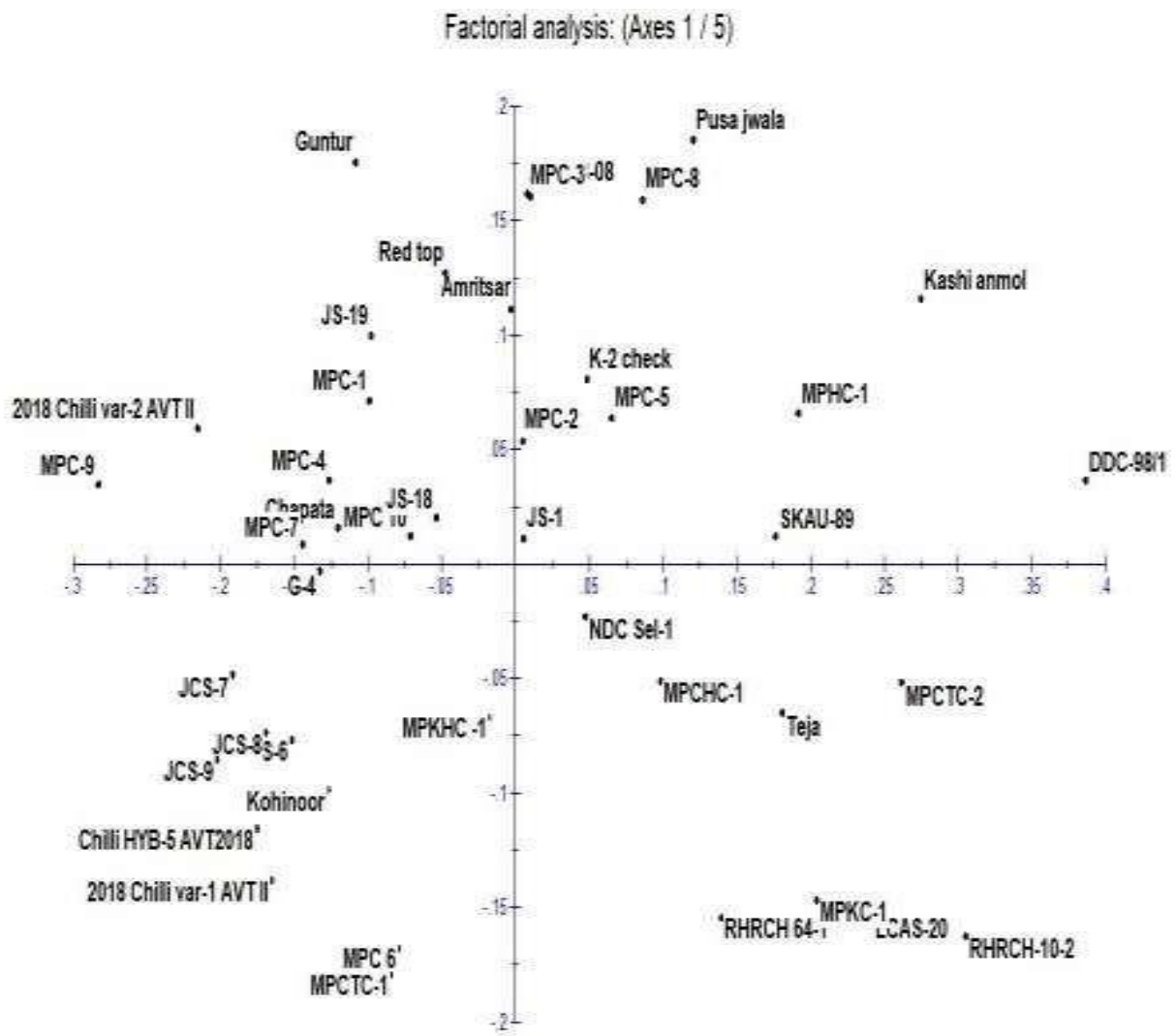


Fig . 9Factorial analysis of dendrogram clusters



In this study, 43 chilli accessions were evaluated to understand the variability in morphological and yield-related traits. The research took place at Maharajpur Vegetable Farm, Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur. Evaluating traits like growth, yield, and quality provides crucial insights into crop performance, crucial for crop improvement programs. Understanding the genetic variability in the population is fundamental for successful breeding initiatives.

In this study, 43 chilli genotypes were evaluated, focusing on traits like primary and secondary branches, flowering patterns, fruit production, plant height, and more. Significant variability was observed in these traits, aligning with previous studies. Qualitative features such as plant growth habit, leaf shape, color, and fruit characteristics were used to categorize the genotypes, consistent with earlier research. Genetic parameters were calculated, indicating moderate to high variation in traits like fruit length, weight, and yield. The study also found high heritability and genetic advance in specific traits, echoing findings from previous research by Krishnamurthy et al. (2013) and Vaishnavi et al. (2018).

The study analyzed genetic diversity in 43 chilli genotypes using Mahalanobis D^2 analysis. Significant variability was observed among the traits studied. Genotypes were grouped into six clusters, with varying inter-cluster distances. The findings align with previous research by Yatung et al. (2014).

CONCLUSION

The analysis of variance in the germplasm indicated significant differences among genotypes for various morphological and yield-related traits, including plant height and secondary branches. These traits exhibited moderate to high Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV), suggesting environmental influence. All traits showed strong GCV and PCV, indicating high heritability and genetic advancement. D2 analysis highlighted genetic variance among the forty-three chilli genotypes.

references

Ajjappalavara, P. S. Genetic Diversity in Chilli (Capsicum annuum L.). Asian Journal of Horticulture, vol. 4, no. 1, 2009, pp. 29-31.

Basu, S. K., De, A. K., & De, A. Capsicum: Historical and Botanical Perspectives. Capsicum: The Genus Capsicum, 2003, pp. 1-15.

Bedaque, P. F., &Griesshammer, H. W. Quartet S Wave Neutron Deuteron Scattering in Effective Field Theory. Nuclear Physics A, vol. 671, no. 1-4, 2000, pp. 357-379.

Casadaban, L., Rauscher, G., Aklilu, M., Villenes, D., Freels, S., & Maker, A. V. Adjuvant Chemotherapy Is Associated with Improved Survival in Patients with Stage II Colon Cancer. Cancer, vol. 122, no. 21, 2016, pp. 3277-3287.

De, A. K. (Ed.). Capsicum: The Genus Capsicum. CRC Press, 2003.

Devi Priya, B., & Thyagarajan, M. An Investigation on Production and Productivity Export Performance of Significant Spices in the Country India. Indian Journal of Science and Technology, vol. 13, no. 48, 2020, pp. 4699-4707.

Fisher, R. A. 061: The General Sampling Distribution of the Multiple Correlation Coefficient. 1928.

Hönninger, C., Paschotta, R., Graf, M., Morier-Genoud, F., Zhang, G., Moser, M., ... & Keller, U. Ultrafast Ytterbium-doped Bulk Lasers and Laser Amplifiers. Applied Physics B, vol. 69, 1999, pp. 3-17.

Johnson, H. W., Robinson, H. F., & Comstock, R. E. Estimates of Genetic and Environmental Variability in Soybeans 1. Agronomy Journal, vol. 47, no. 7, 1955, pp. 314-318.

Li, H., Gyllensten, U. B., Cui, X., Saiki, R. K., Erlich, H. A., &Arnheim, N. Amplification and Analysis of DNA Sequences in Single Human Sperm and Diploid Cells. Nature, vol. 335, no. 6189, 1988, pp. 414-417.

Mullis, K. B., &Faloona, F. A. [21] Specific Synthesis of DNA In Vitro via a Polymerase-catalyzed Chain Reaction. In Methods in Enzymology, vol. 155, Academic Press, 1987, pp. 335-350.

Neocortical origin and progression of gray matter atrophy in nonamnestic Alzheimer's disease. Neurobiology of Aging, vol. 63, 2018, pp. 75-87.

Paran, I., & Van Der Knaap, E. Genetic and Molecular Regulation of Fruit and Plant Domestication Traits in Tomato and Pepper. Journal of Experimental Botany, vol. 58, no. 14, 2007, pp. 3841-3852.

Phillips, J. S., Da Re, F., Dratch, L., Xie, S. X., Irwin, D. J., McMillan, C. T., ... & Grossman, M.

Rao, C. R. Large Sample Tests of Statistical Hypotheses Concerning Several Parameters with Applications to Problems of Estimation. Mathematical Proceedings of the Cambridge Philosophical Society, vol. 44, no. 1, 1948, pp. 50-57.

Rejintal, A., & Aswini, N. Image Processing-based Leukemia Cancer Cell Detection. In 2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), IEEE, 2016, pp. 471-474.

Saghai-Maroof, M. A., Soliman, K. M., Jorgensen, R. A., & Allard, R. Ribosomal DNA Spacer-length Polymorphisms in Barley: Mendelian Inheritance, Chromosomal Location, and Population Dynamics. Proceedings of the National Academy of Sciences, vol. 81, no. 24, 1984, pp. 8014-8018.

Saleem, M. Y., Iqbal, Q., & Asghar, M. Genetic Variability, Heritability, Character Association and Path Analysis in F1 Hybrids of Tomato. Pakistan Journal of Agricultural Sciences, vol. 50, no. 4, 2013.

Sánchez Padilla, L. M., González Pérez, U., Alerm González, A., & Bacallao Gallestey, J. Calidad de Vida Psíquica y Estado de Salud FísicaenelAdulto Mayor. Revista Habanera de CienciasMédicas, vol. 13, no. 2, 2014, pp. 337-349.

Sharmin, A., Hoque, M. E., Haque, M. M., & Khatun, F. Molecular Diversity Analysis of Some Chilli (Capsicum spp.) Genotypes Using SSR Markers. American Journal of Plant Sciences, vol. 9, no. 3, 2018, pp. 368-379.

Votava, E. J., Balok, C., Coon, D., & Bosland, P. W. Brief Communication. Inheritance of Unique Fruit and Foliage Color Mutation in NuMex Piñata. Journal of Heredity, vol. 91, no. 1, 2000, pp. 60-61.

Yatung, T., Dubey, R. K., Singh, V., & Upadhyay, G. Genetic Diversity of Chilli (Capsicum annuum L.) Genotypes of India Based on Morpho-chemical Traits. Australian Journal of Crop Science, vol. 8, no. 1, 2014, pp. 97-102.