



Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.027>

EVALUATION OF CHILLI (*Capsicum* SPP.) GERMPLASM LINES FOR QUALITY TRAITS: PUNGENCY AND EXTRACTABLE COLOUR

Gaganashree K.P.^{1*}, O. Sridevi¹, Sumangala Bhat¹, P. U. Krishnaraj² and R.V. Hegde³

¹Department of Genetics and Plant Breeding, University of Agricultural Sciences Dharwad, Karnataka, 580005, India

²Department of Agricultural Microbiology, University of Agricultural Sciences Dharwad, Karnataka, 580005, India

³Department of Vegetable Sciences, University of Agricultural Sciences Dharwad, Karnataka, 580005, India

*Corresponding author E-mail: kpgagana@gmail.com

(Date of Receiving-14-05-2026; Date of Revision-18-07-2026; Date of Acceptance-03-08-2026)

ABSTRACT

Chilli (*Capsicum annuum* L.) is an important spice cum vegetable crop of the family *Solanaceae* that is cultivated worldwide for its economic, nutritional and pharmaceutical importance. The most important quality traits of chilli fruits are pungency and color which are responsible to classify chilli as a commercial spice crop in international spice trade. Pungency is attributed to a group of alkaloids known as capsaicinoids, while the fruit's color is due to carotenoid pigments. Therefore, breeding programs prioritize these traits for improvement. Seventy germplasm lines were evaluated during *kharif* 2023 for pungency and extractable color using a colorimetric method. Capsaicin content in dry chilli fruits was expressed as a percentage, and color content was measured in ASTA units. The analysis of variance revealed highly significant differences for both the traits, suggesting considerable variability within the germplasm for future breeding efforts. Total extractable color ranged from 50.61 to 172.41 ASTA units. A total of six germplasm lines showed higher extractable color than check Byadgi Dabbi (BD). Capsaicin levels ranged between 0.22% to 2.31% with none of the genotypes showing more pungency than Bhut Jalokia (BJ). Accession 3, 76 and 25 recorded high capsaicin next to BJ. Both color and pungency exhibited high GCV (20.07 and 42.55), PCV (20.34 and 44.20), high estimates of heritability coupled with genetic advance over mean. These results indicate scope for improvement of these two quality traits through selection of best lines which enable chilli breeders to develop a variety having high capsaicin content coupled with rich in color fruit type which happens to be the most desirable genotype of chilli.

Key words: Pungency, Extractable color, ASTA units, Quality traits, Capsaicin, Carotenoids.

Introduction

Chilli (*Capsicum* spp.) is a globally cultivated crop valued for its use as a fruit, vegetable, and spice. As reported by FAOSTAT, 2024, approximately 44.8 million tons of dry and green chilies were produced worldwide. The *Capsicum* genus consists of over 30 species, including five domesticated species: *Capsicum annuum*, *C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens* (Lee *et al.*, 2016).

Traditionally, pepper fruits have been used as appetite stimulants, flavour enhancers, and remedies for conditions such as parasitic infections, rheumatism, muscle pain, coughs, sore throats, and to promote wound healing.

These health benefits are largely attributed to their antioxidant properties (Carvalho *et al.*, 2015; Badia *et al.*, 2017; Takemura *et al.*, 2021). Due to these properties, chilli is being utilized for a wide range of food processing, medicine development, pest and animal control and even in law enforcement which make this crop of immense importance nowadays.

Pepper is abundant with various bioactive compounds and essential minerals, including vitamins (notably C and E) and colored pigments like β -carotene, zeaxanthin, violaxanthin, β -cryptoxanthin, lutein, capsanthin, and capsorubin. It also contains phenolic compounds such as capsaicinoids and flavonoids (Antonio *et al.*, 2018; Baenas

et al., 2019). The levels of these compounds can vary significantly depending on factors such as the genotype and cultivation methods [Carvalho *et al.*, 2015; Fayos *et al.*, 2019; Baenas *et al.*, 2019]. Among these, pungency (capsaicin) and extractable color (Carotenoids) are two important components of the fruit which are responsible to classify chilli as a commercial spice crop in international spice trade.

Pungency is a key economic trait in peppers and has been extensively studied. The pungency in peppers is attributed to capsaicinoids, a group of secondary metabolites unique to the *Capsicum* genus. Capsaicinoids consist of various compounds, among which capsaicin and dihydrocapsaicin accounting for about 90% of the total capsaicinoid content in pepper fruits (Wahyuni *et al.*, 2013). These compounds have been shown to offer potential health benefits, such as pain relief, anti-inflammatory effects and anticancer properties, making them valuable for both the food and pharmaceutical industries (Aza-González *et al.*, 2011).

Peppers are typically classified into two groups: pungent (hot peppers) and non-pungent (sweet peppers) based on capsaicinoids content. The Bhut Jolokia pepper was once considered the hottest pepper, with a pungency of one million Scoville Heat Units (SHU). However, other varieties with significantly higher SHU, such as the Trinidad Butch, T Scorpion and Trinidad Moruga Scorpion, have since been discovered (Bosland *et al.*, 2012). In 2013, the Carolina Reaper, a cross between the Really Nastily Hot and Naga Viper cultivars, became the hottest pepper, reaching 2.2 million SHU. More recently, Ed Currie bred Pepper X, which now holds the title of the world's hottest pepper with a staggering 3.18 million SHU (Buchanan., 2020).

Color is yet another important quality parameter in chilli valued for its vast demand in food as well as cosmetic industries. Red color of chilli is mainly due to the presence of carotenoid pigments namely capsanthin and capsorubin. These carotenoid pigments added to food and processed meat as well as beverages to impart attractive color (Cirlini *et al.*, 2019). Hence, it is considered to be a best substitute of synthetic color used in food and cosmetic industries. The extractable color of chili peppers measured as total pigment content, is commonly assessed using the American Spice Trade Association (ASTA) method 20.1. This method is based on the absorbance of a chili pepper solution in acetone at 460 nm (ASTA, 1985).

Pungency and extractable color are two traits that significantly affect consumer preferences and are

important considerations for breeders developing new varieties to meet the specific desires and preferences of consumers and producers (Venkatesh *et al.*, 2023). The present study deals with the evaluation of diverse germplasm lines for pungency and extractable color using colorimetric technique. The final aim of the work is to assess the high-quality fruits of the considered experimental germplasm lines and guarantee the products for industrial applications.

Materials and Methods

Plant Materials, Location, Experimental Design

The present study was conducted during *kharif*-2023 using seventy germplasm lines including checks [Byadgi Dabbi (BD), Bhut Jalokia (BJ), DC1007, ABL-S] grown in augmented block design in Botanical Garden, University of Agricultural Sciences, Dharwad which is located 15° 29' N latitude, 74°59' E longitudes at an altitude of 689m above mean sea level.

Sampling and sample preparation

Fresh fruits were randomly collected at maturity from the different plants, discarding the fruits evidently damaged. All the selected fruits were sun dried for two weeks, after that dried at hot air oven at 65 °C for 48 hrs. The dried fruits were finally milled to powder, sieved and stored in dry place.

Extraction and Estimation of the extractable color

The extractable color was determined using colorimetric method given by FAO, WHO 1984. Briefly, 0.1 g of chilli pepper powder was extracted with 10 ml of acetone was added, closed tightly with the stopper. The contents were kept for 16hrs at room temperature in dark and shaken intermittently on a mechanical shaker. The sample was then filtered using whatman filter paper

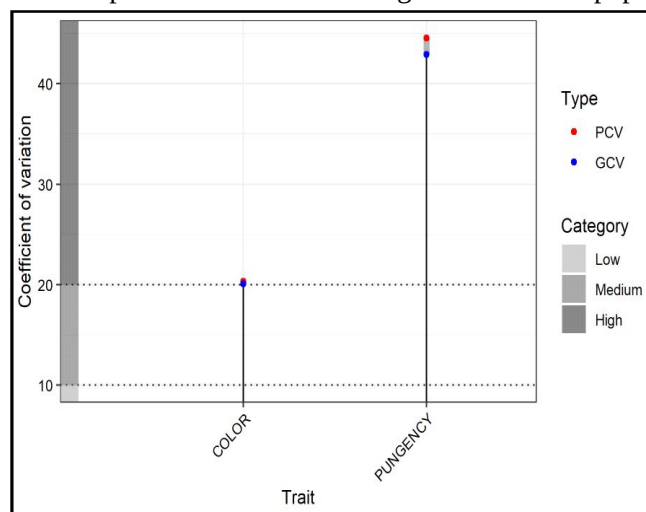


Fig. 1: Graphical Representation of Phenotypic and Genotypic Co-efficient of Variation.

Table 1: Descriptive Statistics for pungency and color.

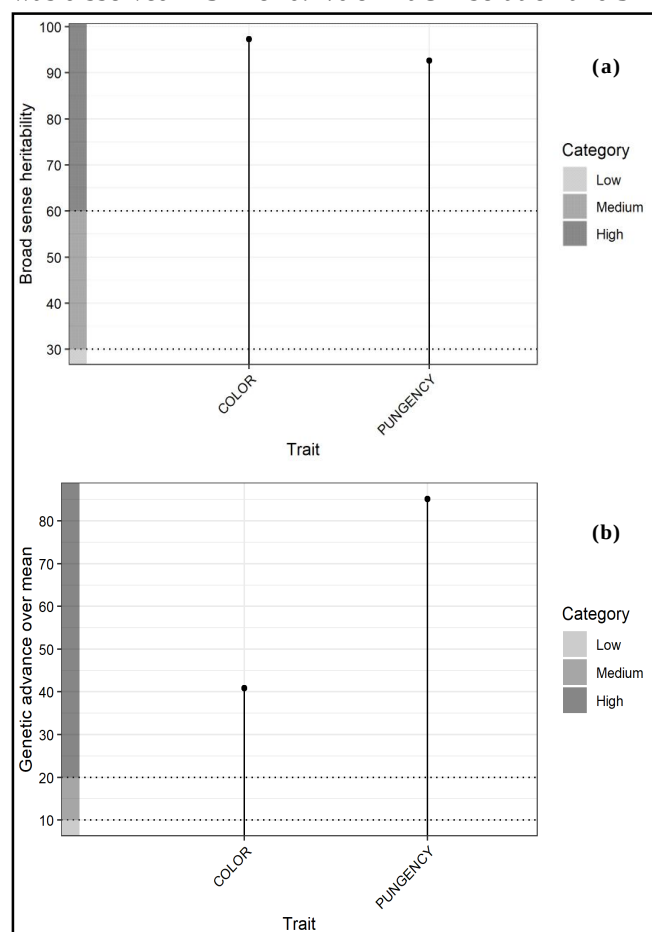
Traits	Mean	Min	Max	Range
PUNGENCY	0.69	0.10	2.31	2.11
COLOR	121.47	50.61	172.41	121.8

grade 41 and final volume made upto 100ml using distilled water. All the extractions were performed for three biological replicates. The absorbance at 460 nm of the resulting solution was measured using UV-VIS Spectrophotometer (Thermo scientific Evolution 201) at 25 °C using pure acetone as blank.

$$\text{ASTA units} = \frac{\text{Absorbance at 460nm} \times 16.4}{\text{weight of sample in grams}}$$

Extraction and Estimation of capsaicin content

Determination of Capsaicin content was done by colorimetric method as described by Bajaj *et al.*, (1980). About 0.5g dry chilli powder was weighed 10ml dry acetone was added into the glass stoppered test tube and kept on mechanical shaker for 3hrs for extraction. Then, samples were centrifuged at 10000rpm for 10min and 1ml of the clear supernatant was taken into a test tube and evaporated to dryness in a hot water bath. The residue was dissolved in 5ml of 0.4% of NaOH solution and 3ml

**Fig. 2:** Graphical representation of: a) Broad sense heritability, b) Genetic Advance over Mean.**Table 2:** Analysis of Variance of Augmented Block Design.

SOURCE	Df	Mean.Sq pungency	Mean.Sq color
Treatment (ignoring Blocks)	69	0.36**	1096.97**
Treatment: Check	3	6.20**	11538.01**
Treatment: Test	65	0.10**	610.60**
Treatment: Test vs. Check	1	0.23**	1387.80**
Block (eliminating Treatments)	5	0.01 ^{ns}	18.95 ^{ns}
Residuals	15	0.01	16.30

^{ns} P > 0.05; * P ≤ 0.05; ** P ≤ 0.01

of 3% phosphomolybdic acid was added. The contents were shaken and left undisturbed for 1hr. After 1hr the solution was quickly transferred into centrifuge tubes to remove any floating debris, and then centrifuged at 5000rpm for 15min. The clear blue coloured solution was directly transferred into the cuvette and absorbance was read at 650nm along with a reagent blank. A standard graph was prepared using 0-200 µg pure capsaicin. Simultaneously 0.2, 0.4, 0.6, 0.8 and 1ml of working standard solution were taken into new test tubes and proceeded as mentioned above. Percent capsaicin

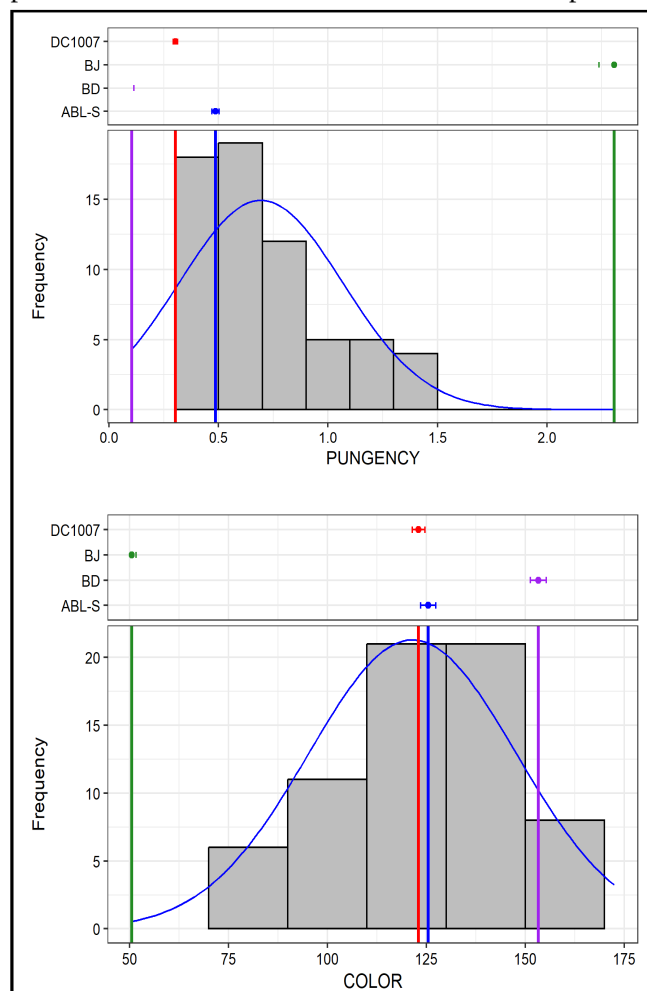
**Fig. 3:** Frequency distribution of germplasm lines for pungency and extractable color.

Table 3: Variability Parameters for the traits Pungency and Color.

Traits	GCV	CA	PCV	CA	BSH	GA
PUNGENCY	42.89	High	44.56	High	High	High
COLOR	20.07	High	20.34	High	High	High
CA: Category; BSH: Broad sense heritability, GA: Genetic advance over mean						

calculated using the formula mentioned below;

$$\% \text{ Capsaicin} = \frac{\mu\text{g capsaicin} \times 100 \times 100}{1000 \times 1000 \times 1 \times 0.5}$$

Statistical Analysis

The Analysis of Variance for augmented block design was carried out to see the significant difference between the genotypes for both the traits *i.e.*, pungency and color, cluster analysis was carried out using R statistical software utilizing R version 4.3.1.

Results and Discussion

ANOVA and Variability parameters:

Analysis of variance showed highly significant variation at 1% and 5% level of significance for both the quality traits indicating that there is a much variability among this germplasm to take up further breeding programme (Table 2). The present investigation depicted that the total extractable color ranged from 50.61 to 172.41 ASTA units. A total of six germplasm lines showed higher extractable color than check BD. Capsaicin levels ranged between 0.22% to 2.31% with none of the genotypes showing more pungency than BJ (Table 1) whereas, accession 3, 76 and 25 recorded high capsaicin next to BJ.

Both color and pungency exhibited high Genotypic Co-efficient of Variation (GCV) *i.e.*, 20.07 and 42.55, Phenotypic Co-efficient of Variation (PCV) *i.e.*, 20.34 and 44.20 respectively (Table 3). According to Deshmukh

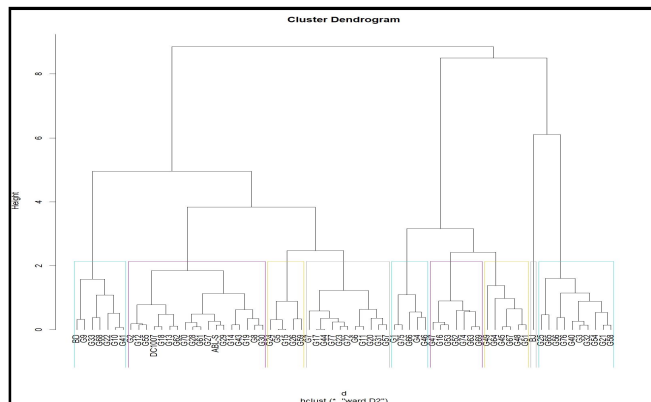


Fig. 4: Dendrogram of the cluster analysis using Ward's method and the Euclidean distance from the morphological characterization for pungency and color of 70 accessions of chilli (*Capsicum* spp.).

Table 4: Cluster size, means and genotype list.

Cluster	Cluster size	Pungency mean	Color-cl. mean	Genotypes
C1	11	0.78	124.84	G7, G17, G44, G77, G23, G72, G6, G11, G20, G31, G57
C2	1	2.31	50.61	BJ
C3	10	1.24	139.05	G25, G65, G56, G40, G76, G3, G32, G54, G21, G58
C4	7	0.25	160.17	BD, G9, G33, G68, G22, G10, G41
C5	7	0.58	103.66	G47, G16, G53, G52, G74, G63, G69
C6	18	0.39	127.24	G2, G12, G55, DC1007, G18, G13, G62, G70, G28, G61, G27, ABL-S, G29, G14, G43, G19, G8, G30
C7	6	0.60	75.267	G49, G64, G45, G67, G48, G51
C8	5	1.00	95.306	G1, G75, G66, G4, G46
C9	5	0.68	154.81	G24, G5, G15, G26, G59

et al., (1986) GCV and PCV values greater than 20% are considered as high, and values between 10 to 20% regarded as medium, while values less than 10% are considered to be low. Thus, from the present findings estimates for PCV and GCV were observed high for color and pungency (Fig. 1). The evaluation of the genotypes revealed a great deal of diversity, which can be used to further improve the genotypes for high pungency and color in chilli. Higher values of GCV and PCV for color and pungency in chilli was also reported by many researchers (Mishra *et al.*, 2001; Janaki *et al.*, 2015; Maurya *et al.*, 2015; Meena *et al.*, 2016; Yogeshkumar *et al.*, 2018 and Sushmitha *et al.*, 2019).

The GCV combined with the higher heritability projects better estimates of the amount of advance to be expected from selection (Burton and Devane, 1953). The

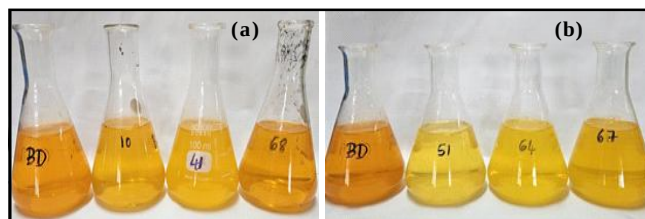


Fig. 5: Representative pictures of genotypes with a) highest and b) lowest extractable color content in ASTA units using colorimetric method.

Table 5: Intra and Inter Cluster Distance Average.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0.537	1.441	6.854	3.172	2.580	1.386	2.050	2.521	3.470
C2		0.000	5.988	2.107	2.315	1.180	1.077	1.235	2.160
C3			0.658	3.968	4.545	5.562	5.013	5.131	4.740
C4				0.610	1.835	2.021	1.238	1.258	1.408
C5					0.528	1.385	1.559	2.378	3.026
C6						0.552	1.001	1.782	2.704
C7							0.716	0.954	1.811
C8								0.595	1.091
C9									0.540

values for heritability in broad sense ranged above 90% for both color and pungency. The heritability estimates greater than 80% was noted as very high, values from 60-79% were considered high, values from 40-59% were medium and less than 40% were regarded as low heritability values (Singh, 2001). The prediction of genetic progress would only be possible when heritability combines with genetic advance, because the presence of both additive and epistatic effects in broad sense heritability (Johnson *et al.*, 1955). The genetic advance over mean under selection indicates the improvement of traits in genotypic value for the new population, under one cycle of selection intensity as compared with base population (Singh, 2001). Therefore, the results showed that there were very high estimates of heritability coupled with genetic advance over mean for both traits indicate scope for selection. Higher estimates of broad sense heritability coupled with genetic advance over mean was also reported by Kumari *et al.*, (2010), Janaki *et al.*, (2015), Yogeshkumar *et al.*, (2018) and Sushmitha *et al.*, (2019). Frequency distribution of germplasm lines for color and pungency is presented in Fig. 3. It was noted that for the trait pungency the distribution was right skewed which is mainly due to the presence of extremely high pungent genotype BJ and for color the distribution was normal.

Performance of germplasm lines and cluster analysis for pungency and extractable color

Table 6: List of germplasm lines with high capsaicin content compared to check BD, BJ.

Genotypes	G3	G25	G32	G65	G76	BD	BJ
Pungency (Capsaicin%)	1.288	1.311	1.285	1.273	1.333	0.10	2.31

Table 7: List of germplasm lines with high extractable color content compared to check BD, BJ.

Genotypes	G10	G25	G33	G41	G68	BD	BJ
Color (ASTA \Units)	170.88	162.30	160.33	169.19	167.06	153.25	50.61

Multivariate hierarchical clustering was carried for both quality characters. Distance between all pairs of genotypes was calculated using squared Euclidean distance method and genotypes were clustered based on Ward's method. From the dendrogram, it can be concluded that the genotypes were mainly classified into 9 different clusters (Fig 4). Each cluster are having varied cluster mean for pungency and color among which members of Cluster III showed relatively higher pungency and color content. The Cluster II (Bhut Jalokia) was distinct from other accessions with extremely high capsaicin content and lowest ASTA value for color which indicated that this genotype is considerably unique among all the other accessions under study (Table 4).

Intra and inter cluster distances are presented in Table 5. The maximum intra-cluster distance was found in cluster VII, followed by cluster III and cluster IV. The inter-class distance was highest between Cluster I and III, followed by Cluster II and III. The more considerable the inter-cluster distance, the more distinct and well-separated the clusters. Ramana, 2018 also used hierarchical cluster analysis for 44 genotypes which were grouped into 7 clusters whereas, higher contribution to the total divergence for quality traits were reported for total extractable colour followed by capsaicin content. These findings are in line with earlier reports of Gobinath *et al.*, (2014); Jyothi *et al.*, (2008); Kumar *et al.*, (2008); Danojeviæ, D. and Medic-Pap, S. (2018).

Among seventy germplasm lines, G3, G25 and G76 had higher capsaicin content next to BJ i.e., 1.288%, 1.311% and 1.333% respectively (Table 6). A total of six accessions G10, G22, G25, G33, G41 and G68 showed higher extractable color than check BD (Fig. 5a) (Table 7).

Conclusion

Pungency and color are the two economically important quality traits which has huge export value and global market demands specially in chilli processing industries. On the basis of information obtained from the present study, it indicates that there is an existence of greater amount of variability with high phenotypic and genotypic coefficient of variation, heritability in broad sense and genetic advance as percent of mean which can be efficiently utilized for further improvement of chilli genotypes by choosing effective breeding program based on genetic makeup of these traits and to develop a variety having high capsaicin content coupled with rich in color fruit type which happens to be the most desirable genotypes of chilli.

Acknowledgements

The authors are thankful to DST-INSPIRE for providing financial assistance for conducting our research and University of Agricultural Sciences, Dharwad for providing the facilities, infrastructure for carrying out the present study. We wish to present our special thanks to Molecular Biology Laboratory, Department of Genetics and Plant Breeding and Microbial Genetics Laboratory, Department of Agricultural Microbiology for giving access to many instruments, resources and guiding me throughout the research.

Conflict of interests: The authors have declared no conflict of interests exist.

References

- American Spice Trade Association (1985). *Official analytical methods*. American Spice Trade Association.
- Antonio, A.S., Wiedemann L.S.M. and Junior V.V. (2018). The genus *Capsicum*: A phytochemical review of bioactive secondary metabolites. *RSC Advances*, **8(45)**, 25767–25784.
- Aza-González, C., Núñez-Palenius H.G. and Ochoa-Alejo N. (2011). Molecular biology of capsaicinoid biosynthesis in chili pepper (*Capsicum* spp.). *Plant Cell Reports*, **30**, 695–706.
- Badia, A.D., Spina A.A. and Vassalotti G. (2017). *Capsicum annuum* L.: An overview of biological activities and potential nutraceutical properties in humans and animals. *Journal of Nutritional Ecology and Food Research*, **4(2)**, 167–177.
- Baenas, N., Belovic M., Ilic N., Moreno D.A. and García-Viguera C. (2019). Industrial use of pepper (*Capsicum annuum* L.) derived products: Technological benefits and biological advantages. *Food Chemistry*, **274**, 872–885.
- Bajaj, K.L. (1980). Colorimetric determination of capsaicin in *Capsicum* fruits. *Journal of the Association of Official Analytical Chemists*, **63(6)**, 1314–1316.
- Bosland, P.W., Coon D. and Reeves G. (2012). ‘Trinidad Moruga Scorpion’ pepper is the world’s hottest measured chile pepper at more than two million Scoville heat units. *HortTechnology*, **22(4)**, 534–538.
- Buchanan, M. (2020). Some like it hot. *Nature Physics*, **16(1)**, 112–112.
- Burton, G.W. and DeVane D.E. (1953). Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal*, **45(10)**, 478–481.
- Carvalho, A.V., de Andrade Mattietto R., de Oliveira Rios A., de Almeida Maciel R., Moresco K.S. and de Souza Oliveira T.C. (2015). Bioactive compounds and antioxidant activity of pepper (*Capsicum* sp.) genotypes. *Journal of Food Science and Technology*, **52**, 7457–7464.
- Cirlini, M., Luzzini G., Morini E., Folloni S., Ranieri R., Dall’Asta C. and Galaverna G. (2019). Evaluation of the volatile fraction, pungency and extractable color of different Italian *Capsicum annuum* cultivars designed for food industry. *European Food Research and Technology*, **245(12)**, 2669–2678.
- Danojeviæ, D. and Medic-Pap S. (2018). Different multivariate analysis for fruit traits in sweet pepper breeding. *Genetika*, **50(1)**, 121–129.
- Deshmukh, S.N., Basu M.S. and Reddy P.S. (1986). Genetic variability, character association and path coefficients of quantitative traits in Virginia bunch varieties of groundnut. *Indian Journal of Agricultural Sciences*, **56**, 816–821.
- Doyle, J.J. (1991). DNA protocols for plants. In G. M. Hewitt, A. W. B. Johnston, & J. P. W. Young (Eds.), *Molecular techniques in taxonomy* (283–293). Springer.
- Food and Agriculture Organization. (2024). *FAOSTAT*. Food and Agriculture Organization of the United Nations.
- FAO/WHO Joint Expert Committee on Food Additives. (1984). *Specifications for identity and purity of food colours: Prepared by the 28th session of the Joint FAO/WHO Expert Committee on Food Additives, Rome, 19–28 March 1984*. Food and Agriculture Organization & World Health Organization.
- Fayos, O., Ochoa-Alejo N., de la Vega O.M., Savirón M., Orduna J., Mallor C., Barbero G.F. and Garcés-Claver A. (2019). Assessment of capsaicinoid and capsinoid accumulation patterns during fruit development in three chili pepper genotypes (*Capsicum* spp.) carrying *Pun1* and *pAMT* alleles related to pungency. *Journal of Agricultural and Food Chemistry*, **67(44)**, 12219–12227.
- Gobinath, P., Zachariah T.J., Shiva K.N., Leela N.K., Jayarajan K. and Geoffrey K. (2014). Cluster analysis based on biochemical constituents in paprika-like chillies (*Capsicum annuum* L.). *Indian Journal of Horticulture*, **71(2)**, 164–169.
- Janaki, M., Naram N.L., Venkataramana C. and Paratpa R.M. (2015). Selection of promising genotypes for qualitative traits in chilli (*Capsicum annuum* L.). *Plant Archives*, **15(1)**, 441–446.
- Johnson, H.W., Robinson H.F. and Comstock R.E. (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy Journal*, **47(7)**, 314–318.
- Jyothi, P., Jagdish S., Ajay V., Singh A.K., Mathura R. and Sanjeet K. (2008). Evaluation of chilli (*Capsicum annuum* L.) genotypes for some quality traits. *Journal of Food Science and Technology*, **45(5)**, 463–465.
- Kumar, K.V., Reddy V.C., Reddy K.S., Babu J.S., Kumar P.R. and Srinivasulu R. (2008). Multivariate analysis in paprika chilli (*Capsicum annuum* L.). *Indian Cocoa, Arecanut and Spices Journal*, **32(3)**, 86–89.
- Kumari, S.S., Jyothi K.U., Srihari D., Sankar A.S. and Sankar C.R. (2010). Variability and genetic divergence in paprika (*Capsicum annuum* L.). *Journal of Spices and Aromatic Crops*, **19(1–2)**, 71–75.
- Maurya, A.K., Kushwaha M.L. and Singh B.K. (2015). Genetic studies in chilli (*Capsicum annuum* L.). *The International*

- Journal of Science and Technology*, **3(8)**, 289–292.
- Meena, M.L., Kumar N., Meena J.K. and Rai T. (2016). Genetic variability, heritability and genetic advance in chilli (*Capsicum annuum* L.). *Bioscience Biotechnology Research Communications*, **9(2)**, 258–262.
- Mishra, A., Sahu G.S. and Mishra P.K. (2001). Variability in fruit characters of chilli (*Capsicum annuum* L.). *Capsicum and Eggplant Newsletter*, **20**, 107–109.
- Ramana, C.V. (2018). Multivariate analysis in paprika (*Capsicum annuum* L.). *Electronic Journal of Plant Breeding*, **9(4)**, 1308–1321.
- Singh, B.D. (2001). *Plant breeding: Principles and methods* (6th ed.). Kalyani Publishers.
- Sushmitha, A., Allolli T.B., Ganiger V.M., Ajjappalavar P.S., Evoor S., Gopali J.B. and Kareem A. (2019). Assessment of genetic variability, heritability and genetic advance for growth, yield and quality traits of Byadgi Dabbi genotypes of chilli (*Capsicum annuum* L.). *Journal of Pharmacognosy and Phytochemistry*, **8(5)**, 944–947.
- Takemura, M., Sahara T. and Misawa N. (2021). Violaxanthin: Natural function and occurrence, biosynthesis, and heterologous production. *Applied Microbiology and Biotechnology*, **105(16)**, 6133–6142.
- Venkatesh, J., Lee S.Y., Back S., Kim T.G., Kim G.W., Kim J.M., Kwon J.K. and Kang B.C. (2023). Update on the genetic and molecular regulation of the biosynthetic pathways underlying pepper fruit color and pungency. *Current Plant Biology*, **35**, 100303.
- Wahyuni, Y., Ballester A.R., Sudarmonowati E., Bino R.J. and Bovy A.G. (2013). Secondary metabolites of *Capsicum* species and their importance in the human diet. *Journal of Natural Products*, **76(4)**, 783–793.
- Yogeshkumar, H.J., Ajjappalavara P.S., Megharaj K.C., Patil H.B., Revanappa M.S. and Gollag S.G. (2018). Genetic variability, heritability and genetic advance for growth, yield and quality components of Byadgi Dabbi ecotypes of chilli (*Capsicum annuum* L.). *International Journal of Chemical Studies*, **6(3)**, 879–881.