http://www.pjbs.org

PJBS

ISSN 1028-8880

# Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2020.1220.1226

# Short Communication
# Characterization of Cultivated Eggplant and its Wild Relatives Based on Important Fruit Biochemical Traits

[1,2]Prashant Kaushik

[1]Instituto de Conservación y Mejora de la Agrodiversidad Valenciana, Universitat Politècnica de València, 46022 Valencia, Spain
[2]Nagano University, 1088 Komaki, Ueda, Nagano 386-0031, Japan

## Abstract
**Background and Objectives:** The modern-day eggplant consumers desire varieties with a higher content of chlorogenic acid, but the cultivated varieties of eggplant are with a lower content of chlorogenic acid. Whereas, the wild relatives of eggplant are higher in phenolic acids. Therefore, this study characterized the cultivated eggplant and its wild relatives for the fruit dry matter content, total fruit phenolics and chlorogenic acid content. **Materials and Methods:** Fruits of the accessions of cultivated eggplant, one primary genepool species, nine secondary genepool species and three tertiary genepool species were characterized for dry matter content (%), total phenolics and the fruit chlorogenic acid content (mg $g^{-1}$). The chlorogenic acid content in the fruit flesh was determined by using the High Performance Liquid Chromatography (HPLC). **Results:** Highest content of dry matter content of around 29% was determined for the species *S. tomentosum* and *S. elaeagnifolium*. Whereas, the highest content of total fruit phenolics were determined in the secondary genepool species *S. linnaeanum*. The most top content of chlorogenic acid around 4.5 mg $g^{-1}$ of fruit dry weight was present in the species *S. linnaeanum* and *S. torvum*. Different clustering approaches were able to cluster the primary genepool species with the cultivated eggplant. **Conclusion:** Overall, this work provides important information about the wild relatives of eggplant concerning their dry matter content, total phenolics and chlorogenic acid content. This information can be used to engineer eggplant varieties rich in fruit phenolics.

Key words: *S. linnaeanum*, chlorogenic acid, dry matter, eggplant, phenolics

Citation: Prashant Kaushik, 2020. Characterization of cultivated eggplant and its wild relatives based on important fruit biochemical traits. Pak. J. Biol. Sci., 23: 1220-1226.

Corresp onding Author: Prashant Kaushik, Instituto de Conservación y Mejora de la Agrodiversidad Valenciana, Universitat Politècnica de València, 46022 Valencia, Spain
Nagano University, 1088 Komaki, Ueda, Nagano 386-0031, Japan



Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Vegetables are an essential source of nutraceutical compounds and eggplant (*Solanum melongena* L.) is among the top ten vegetables rich in bioactive compounds[1,2]. The most important compound that provides nutraceutical capacity to eggplant fruit is chlorogenic acid which is phenolic acid that is derived from the cinnamic acid. The phenolics of eggplant fruit are also related to browning and fruit flesh colour associated traits. The improvement of fruit phenolics of eggplant can be performed via various breeding approaches like the conventional, biotechnological and genomics-based approaches[3].

Solanaceae is among the highly diverse families of the plant kingdom and eggplant being a member of family Solanaceae has a large number of wild relatives. Moreover, the wild relatives of eggplant have immensely contributed to the development of modern eggplant varieties on a large number of horizons[4]. Still, there is a constant search for the crucial genes in the wild relatives of eggplant for the genetic improvement of modern cultivated varieties[5]. Eggplant possesses several health-promoting compounds and chlorogenic acid is an important bioactive compound present in the eggplant flesh. Therefore, from the last decade, there is a continuous demand for varieties rich in phenolic acids. Modern eggplant varieties are breed to a specific ideotype and being self-pollinated eggplant has a limited diversity in the farm of cultivated varieties[6].

Recently, we have tested the diversity of eggplant a collection of cultivated eggplant, wild relatives and their interspecific hybrids. But, the relatedness or the clustering of the wild relatives of eggplant-based on fruit phenolics and browning related traits was not performed[7].

Eggplant wild relatives are even useful for improving the yield and quality via the expression of heterosis. Nevertheless, QTL mapping research show promises in interaction consequences for certain developmental, biochemical and architectural traits. The genome interactions in the eggplant hybrid with the wild relative genome resulting in complicated alterations, biochemical, epigenetic and genetic levels[8,9]. Though eggplant has undergone an overwhelming selection strain for the trait notably higher yield, additionally, even when building hybrids for disease as well as insect pest opposition yield is usually not affected[10].

Here were characterized the cultivated eggplant and its wild relatives from all of the three possible genepools of the eggplant, further a relation was established between different genotypes based on the fruit biochemical traits.

## MATERIALS AND METHODS

**Study area:** The study was carried out under open field conditions from January, 2016-2017 at the research farm of Universitat Politècnica de València, Valencia, Spain (coordinates at 39°28'55" N, 0°22'11"W; altitude 7 masl). Furthermore, this work is an extension of a previous study to understand the variation precisely[7].

**Plant material and sample preparation:** Six accessions of cultivated eggplant *S. melongena* and three accessions of the only primary genepool species of the eggplant *S. insanum* were used. Also, thirteen accessions of the nine secondary genepool species namely, *S. anguivi*, *S. campylacanthum*, *S. dasyphyllum*, *S. incanum*, *S. lichtensteinii*, *S. linnaeanum*, *S. pyracanthos*, *S. tomentosum* and *S. violaceum*. Furthermore, six accessions of three tertiary genepool species namely *S. elaeagnifolium*, *S. sisymbriifolium and S. torvum* were also used in the present analysis. Under the open field condition the drip irrigation and fertigation were supplied by distributing 80 g/plant of a 10 N, 2.2 P, 24.9 K plus micronutrients fertilizer (Hakaphos Naranja, Compo Agricultura, Barcelona, Spain) with the irrigation system. Weeds were manually eliminated and no phytosanitary measures were needed. Three samples per accession were used, comprised of five fruits, picked at a commercially ripe stage (physiologically immature). Fruits samples were snap-frozen by using liquid nitrogen and kept at -80°C.

**Characterization for the fruit biochemical traits:** Dry matter content was determined as the percentage of change in weight before and after the lyophilization process. The Folin-Ciocalteu spectrophotometric method was used to measure the total phenolics (mg $g^{-1}$ dw). High Performance Liquid Chromatography (HPLC) on a 1220 Infinity LC System (Agilent Technologies, Santa Clara, CA, USA) was used to determine the CGA content following the manufacturer's instructions. After that, the percentage of peak area for chlorogenic acid was calculated with the chlorogenic acid peak area and a total peak area of other phenolic acids. The polyphenol oxidase activity was determined based on the protocol defined elsewhere[11].

**Data analysis:** The Statgraphics Centurion XVI software (StatPoint Technologies, Warrenton, VA, USA) program was used for the exploratory statistical analysis. In order to determine the relationship among the different accession of cultivated eggplant and its wild relatives, the Unweighted Pair Group Method with Arithmetic (UPGMA) mean clustering method was used. Further, the dendrograms were compared with the help of tanglegram algorithm with the dendextend package in the R environment[12]. Whereas, K-mean clustering was also performed in the R environment as defined elsewhere[13,14].

## RESULTS

**Differences among cultivated eggplant and its wild relatives:** The values for most fruit biochemicals traits were higher in the secondary and the tertiary genepool species (Table 1). The most top content of dry matter content of around 29% was determined for the species *S. tomentosum* and *S. elaeagnifolium* (Table 1). Whereas, the highest content of total fruit phenolics were identified in the secondary genepool species *S. linnaeanum* (Table 1). The most top content of chlorogenic acid around 4.5 mg $g^{-1}$ of dry weight was present in the species *S. linnaeanum* and *S. torvum* (Table 1).

A significant amount of variation was observed in the mean values of all the accessions of the cultivated eggplant and wild species for all of the traits studied in the present investigation (Table 2). Moreover, up to 29% of dry matter content was recorded and chlorogenic acid content of maximum to 4.71 mg $g^{-1}$ was also recorded. The average dry matter content of all of the genotypes was determined to be 17.67% with a coefficient of variation of 34.93% (Table 2), whereas, the chlorogenic acid content in all of the studied accessions ranges from 1.25 mg $g^{-1}$ to the maximum of 4.71 mg $g^{-1}$ with a coefficient of variation 29.77% (Table 2).

**Clustering analysis:** The results of the K-mean clustering of the genotypes are presented in Fig. 1. As expected, the cultivated eggplant and the assessions of the primary genepool species were clustered together (Fig. 1). Different clustering approaches were able to cluster the primary genepool species with the cultivated eggplant. Based on the ward's distance, the genotypes were grouped into four distinct clusters (Fig. 2). As expected, based on the biochemical traits, the genotypes of cultivated eggplant (MEL1 to MEL6) were clustered together (Fig. 2). Interestingly, a secondary genepool species *S. anguivi* and a territory genepool species *S. sisymbriifolium* were grouped together

Table 1: Means for the dry matter (%), phenolics (g $kg^{-1}$ dw) and chlorogenic acid content (mg $g^{-1}$) in the accessions of cultivated eggplant and its wild relatives

| Species | Accession | Dry matter (%) | Phenolics (g $kg^{-1}$ dw) | CGA (mg $g^{-1}$) |
|---|---|---|---|---|
| **Cultivated eggplant** | | | | |
| *S. melongena* | MEL1 | 12.15 | 8.40 | 2.80 |
| | MEL2 | 9.80 | 12.10 | 2.65 |
| | MEL3 | 6.84 | 12.23 | 2.93 |
| | MEL4 | 10.14 | 6.22 | 1.43 |
| | MEL5 | 13.59 | 10.45 | 2.66 |
| | MEL6 | 10.43 | 9.61 | 2.67 |
| **Wild primary genepool** | | | | |
| *S. insanum* | INS1 | 15.74 | 14.63 | 3.97 |
| | INS2 | 14.62 | 16.94 | 3.00 |
| | INS3 | 17.72 | 17.35 | 3.70 |
| **Wild secondary genepool** | | | | |
| *S. anguivi* | ANG1 | 26.21 | 9.57 | 1.25 |
| | ANG2 | 19.48 | 12.39 | 1.42 |
| *S. campylacanthum* | CAM6 | 13.36 | 14.23 | 3.35 |
| | CAM8 | 17.55 | 27.00 | 3.56 |
| *S. dasyphyllum* | DAS1 | 11.81 | 18.83 | 3.58 |
| *S. incanum* | INC1 | 13.97 | 12.09 | 4.06 |
| *S. lichtensteinii* | LIC1 | 20.10 | 26.12 | 3.64 |
| | LIC2 | 22.59 | 17.36 | 3.38 |
| *S. linnaeanum* | LIN1 | 14.09 | 27.56 | 4.25 |
| | LIN3 | 17.35 | 23.07 | 4.71 |
| *S. pyracanthos* | PYR1 | 23.15 | 15.01 | 2.88 |
| *S. tomentosum* | TOM1 | 29.46 | 18.31 | 2.95 |
| *S. violaceum* | VIO1 | 26.67 | 21.75 | 3.24 |
| **Wild tertiary genepool** | | | | |
| *S. elaeagnifolium* | ELE1 | 29.39 | 21.48 | 1.82 |
| | ELE2 | 27.43 | 26.79 | 3.06 |
| *S. sisymbriifolium* | SIS1 | 17.94 | 14.64 | 2.90 |
| | SIS2 | 17.27 | 11.90 | 2.01 |
| *S. torvum* | TOR2 | 15.60 | 18.09 | 4.32 |
| | TOR3 | 20.32 | 19.73 | 4.48 |

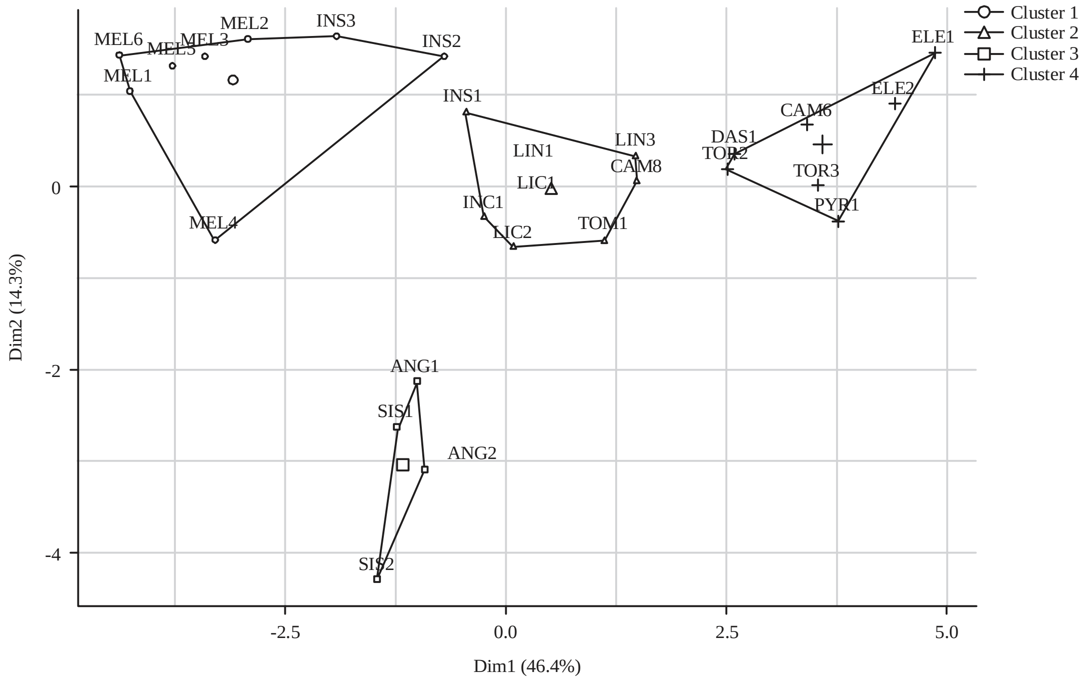


Fig. 1: K-mean clustering of the accessions of the cultivated eggplant and its wild relatives based on their fruit biochemical properties

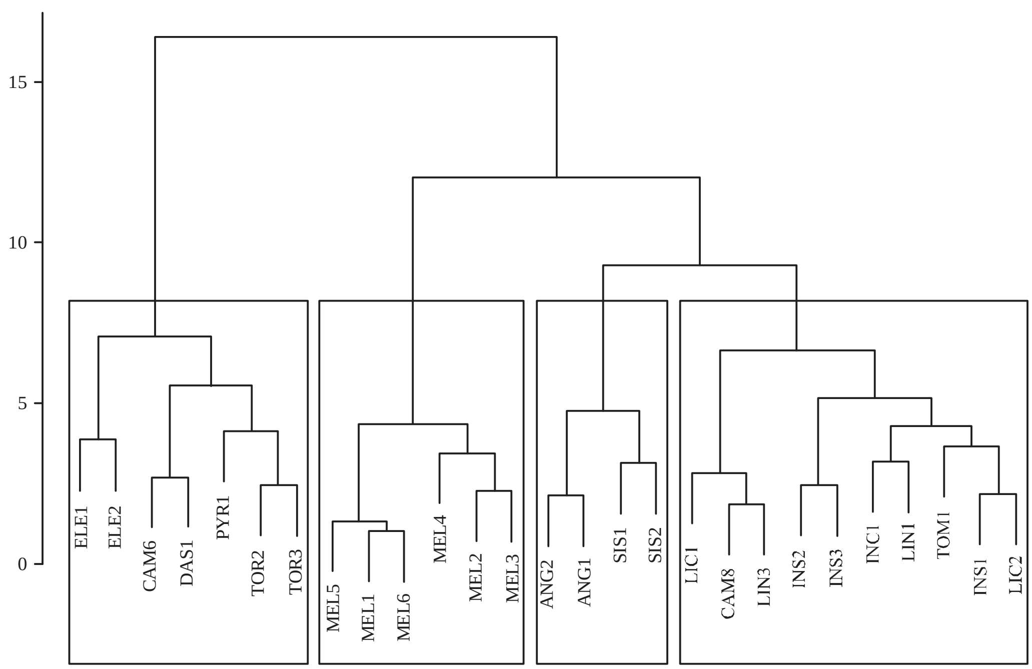


Fig. 2: Unweighted pair group method with arithmetic mean (UPGMA) clustering of the accessions of the cultivated eggplant and its wild relatives

based on their biochemical properties (Fig. 2). Likewise, based on the fruit biochemical properties, the accessions of the only primary species of eggplant *S. insanum* were clustered together in the same cluster with the accession of the secondary genepool species of the eggplant except for *S. anguivi* (Fig. 2). Whereas, the *S. elaeagnifolium* and *S. torvum* from the territory genepool of eggplant were clustered together with three species of the secondary

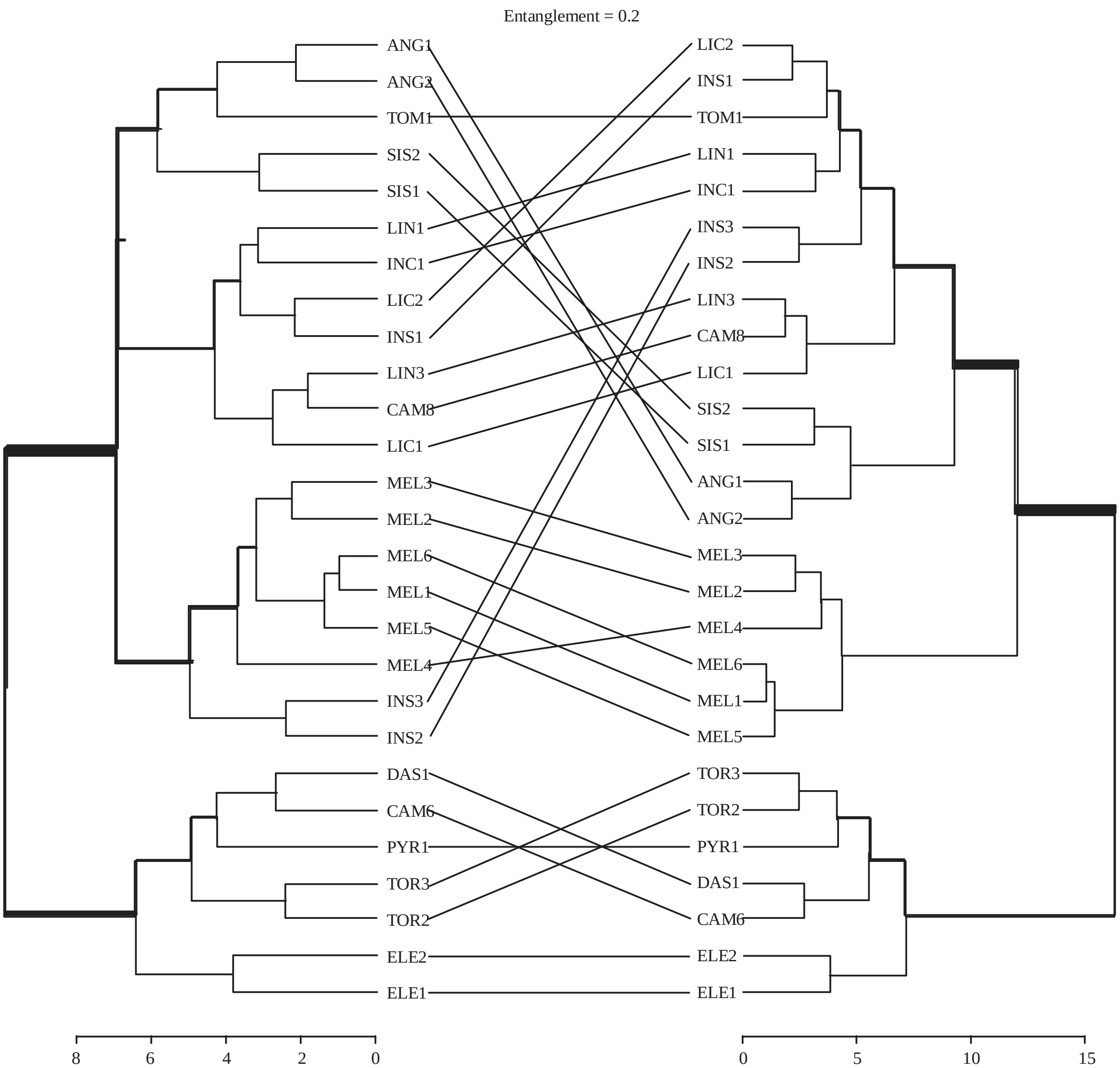


Fig. 3: Tangelgram based relationship among two approaches of clustering used for the accessions of the cultivated eggplant and its wild relatives

Table 2: Summary statistics of the dry matter (%), phenolics (g kg$^{-1}$ dw) and chlorogenic acid content (mg g$^{-1}$) in the accessions of cultivated eggplant and its wild relatives

| Parameters | Dry matter (%) | Total phenolics (g kg$^{-1}$ dw) | CGA (mg g$^{-1}$) |
|---|---|---|---|
| Average | 17.67 | 16.57 | 3.10 |
| Standard deviation | 6.17 | 5.97 | 0.92 |
| Coefficient of variation (%) | 34.93 | 36.04 | 29.77 |
| Minimum | 6.84 | 6.22 | 1.25 |
| Maximum | 29.46 | 27.56 | 4.71 |
| Standard skewness | 0.96 | 0.80 | -0.75 |
| Standard kurtosis | -0.62 | -0.76 | -0.33 |

genepool (Fig. 2). Additionally, the entanglement coefficient was 0.20, overall alignment based on using different methods of clustering (Fig. 3).

## DISCUSSION

Increasing, the content of phenolic acids in vegetables is essential and is usually accomplished by several different means like breeding and selection[15,16]. Here, it was evaluated the cultivated eggplant and its wild relatives intending to identify superior varieties and wild relatives for the improvement of the bioactive profile of eggplant fruit. This tends to pinpoint the phenolic acid compounds present in the eggplant flesh, the glimpse on the variation in cultivated eggplant (together with wild crop relations) providing an opportunity of breeding and biotechnological methods appropriated for obtaining new eggplant varieties with a higher content of phenolic acids[17].

Eggplant is amongst the top vegetables rich in phenolic acids and varieties with enhanced phenolic acid content material are preferred in eggplant buyers. Although, the wild relatives have already been reported owning several-fold higher content of phenolic acids than modern-day eggplant varieties[18]. Hence, this study tested the wild eggplant species in regard to the phenolics composition and fruit flesh colour and browning traits. In eggplant, chlorogenic acid is the predominant phenolic acid inside the fruit flesh. Present study measured the chlorogenic acid content material inside the eggplant applying High Performance Liquid Chromatography (HPLC) as chlorogenic acid is definitely the dominant phenolic acid inside the eggplant's fruit flesh[19]. This holds correct for the cultivated eggplant plus the key genepools species *S. insanum*. Surprisingly, the secondary plus the tertiary genepool species can be the vital donors of genes for the secondary phenolic acids for the cultivated eggplant. This study observed the more substantial content material of total phenolics inside the wild species, additional, some wild species have shown quite a few instances extra content material of total fruit phenolics when compared with the cultivated genotypes.

Related for the morphological traits the interspecific hybrids involving pivotal genepool wild relative behaved like cultivated eggplant for the biochemical traits[6,7]. Though, the interspecific hybrids with secondary and tertiary genepool species have been just like the wild species. Earlier, no important correlations have already been observed involving total phenolics content material or chlorogenic acid content, which suggested that these traits may very well be independent white fruit flesh colour is desirable for many eggplant markets[6]. Wild species of Solanum crops ordinarily have chlorophylls and carotenoids inside the fruit flesh, which as with eggplant lead to significantly less white flesh. Right here, the key genepool species presented improved qualities, using a fruit flesh colour closer to pure white than these of secondary and tertiary genepool species. The association involving target traits is significant for breeding[20].

## CONCLUSION

Results show that wild relatives of eggplant are variable for fruit phenolics, chlorogenic acid content and dry matter content and can be used for improving the phenolics content of cultivated eggplant. Furthermore, this work provides relevant information for improving eggplant with respect to the development of eggplant varieties with a higher content of phenolic acids. In general, we have delivered information and facts about the wild relations of eggplants from a biochemical perspective. We hope this information and facts are going to be practical in achieving a thriving eggplant ideotype with high bioactive fruit phenolics.

## SIGNIFICANCE STATEMENT

Wild relations confirmed more extensive variation for fruit phenolics than cultivated eggplant. The predominant phenolic acid in cultivated eggplant is the chlorogenic acid. This variation identified can be used in the breeding programs to develop eggplant varieties rich in chlorogenic acid.

## REFERENCES

1. Saini I., J. Chauhan and P. Kaushik, 2020. Medicinal value of domiciliary ornamental plants of the Asteraceaefamily. J. Young Pharm., 12: 3-10.
2. Saini, D.K. and P. Kaushik, 2019. Visiting eggplant from a biotechnological perspective: A review. Scientia Horticult., 253: 327-340.
3. Kaushik, P., I. Andújar, S. Vilanova, M. Plazas and P. Gramazio *et al*., 2015. Breeding vegetables with increased content in bioactive phenolic acids. Molecules, 20: 18464-18481.
4. Kaushik, P., J. Prohens, S. Vilanova, P. Gramazio and M. Plazas, 2016. Phenotyping of eggplant wild relatives and interspecific hybrids with conventional and phenomics descriptors provides insight for their potential utilization in breeding. Front. Plant Sci., Vol. 7. 10.3389/fpls.2016.00677.
5. Sinha, S., K. Sandhu, N. Bisht, T. Naliwal, I. Saini and P. Kaushik, 2019. Ascertaining the paradigm of secondary metabolism enhancement through gene level modification in therapeutic plants. J. Young Pharm., 11: 337-343.
6. Kaushik, P., 2019. Genetic analysis for fruit phenolics content, flesh color and browning related traits in eggplant (*Solanum melongena*). Int. J. Mol. Sci., Vol. 20. 10.3390/ijms20122990.
7. Kaushik, P., P. Gramazio, S. Vilanova, M.D. Raigón, J. Prohens and M. Plazas, 2017. Phenolics content, fruit flesh colour and browning in cultivated eggplant, wild relatives and interspecific hybrids and implications for fruit quality breeding. Food Res. Int., 102: 392-401.
8. Singh, H., S. Sethi, P. Kaushik and A. Fulford, 2019. Grafting vegetables for mitigating environmental stresses under climate change: A review. J. Water Climate Change, 10.2166/wcc.2019.177.
9. Kumar A., V. Sharma, B.T. Jain, P. Kaushik, 2020. Heterosis breeding in Eggplant (*Solanum melongena* L.): gains and provocations. Plants., 9: 1-18.

10. Tyagi V., S.K. Dhillon, G. Kaur, P. Kaushik, 2020. Heterotic effect of different cytoplasmic combinations in Sunflower hybrids cultivated under diverse irrigation regimes. Plants., 9: 1-16.
11. Kaushik, P., 2019. Line × Tester analysis for morphological and fruit biochemical traits in eggplant (*Solanum melongena* L.) using wild relatives as testers. Agronomy, Vol. 9. 10.3390/agronomy9040185.
12. Galili T., 2015. Dendextend: an R package for visualizing, adjusting and comparing trees of hierarchical clustering. Bioinf., 31: 3718-3720.
13. Kaushik P., 2020. Classification of Indian States and union territories based on their soil macronutrient and organic carbon profiles. bioArxiv., 10.1101/2020.02.10.930586.
14. Kumar, P., and P. Kaushik, 2020. Evaluation of genetic diversity in cultivated and exotic germplasm sources of faba bean using important morphological traits. bioRxiv., 10.1101/2020.01.24.918284.
15. Aiswarya, C.S., S. Vijeth, I. Sreelathakumary and P. Kaushik, 2020. Diallel analysis of chilli pepper (*Capsicum annuum* L.) genotypes for morphological and fruit biochemical traits. Plants, Vol. 9, No. 1. 10.3390/plants9010001.
16. Kaushik, P., M. Plazas, J. Prohens, S. Vilanova and P. Gramazio, 2018. Diallel genetic analysis for multiple traits in eggplant and assessment of genetic distances for predicting hybrids performance. Plos One, Vol. 13. 10.1371/journal.pone.0199943.
17. Kaushik P., 2019. Application of conventional, biotechnological and genomics approaches for eggplant (Solanum melongena.L). breeding with a focus on bioactive phenolics. Universitat Politècnica de València, 10.4995/Thesis/10251/122295.
18. Kaushik, P., 2019. Standardisation of an agroinfiltration protocol for eggplant fruits and proving its usefulness by over-expressing the SmHQT gene. Preprints, 10.20944/preprints201908.0129.v1.
19. Kaushik, P. and D.K. Saini, 2019. Sequence analysis and homology modelling of SmHQT protein, a key player in chlorogenic acid pathway of eggplant. BioRxiv, 10.1101/599282.
20. Brar N.S., D.K. Saini, P. Kaushik, J. Chauhan, N. K. Kamboj, 2020. Directing for higher seed production in vegetables. ONLINE FIRST, 10.5772/intechopen.90646.