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Potential Assessment of Chrysanthemum Cultivars as Source of Natural antioxidants and Bioactive Compounds

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Abstract

Chrysanthemum blossoms, renowned for their aesthetic appeal, have gained recognition as potential contributors to nutraceuticals, cosmeceuticals, and pharmaceuticals, thereby impacting human health. Phytochemical composition and antioxidative properties of 22 distinct Indian chrysanthemum cultivars was studied. The cultivars viz., Bidhan Protima, Mauve Sarah, Silk Brocate, Diamond Jubilee, and Mahatma Gandhi displayed remarkable levels of phenolic compounds, tannins, saponins, and carotenoids, emphasizing their superior antioxidant capacity. This study also presents the first quantitative determination of total saponin content in *Chrysanthemum morifolium*. Hierarchical analysis categorized cultivars into three groups based on their phytochemical profiles. Correlation analysis underscored the importance of anthocyanins and phenolic compounds in antioxidative attributes. Additionally, variations in carotenoid content unveiled astaxanthin, zeaxanthin, mutatochrome, canthaxanthin, neoxanthin, violaxanthin, and auroxanthin as potential biomarkers in differentiating cultivars. The research elucidates the rich phytochemical diversity of Indian chrysanthemum cultivars, positioning them as invaluable resources for nutraceuticals and pharmaceuticals, with potential benefits for human well-being.

1. Introduction

Chrysanthemum, a member of the Asteraceae family, boasts a vast array of cultivars worldwide, with *C. morifolium* Ramat being the most significant, encompassing over 2300 varieties, including more than 800 originating from India (Kalia, 2015). This flowering plant is extensively cultivated for diverse purposes, such as cut and loose flowers, pot culture, exhibitions, and landscaping, and it ranks among the top ten globally traded cut. Beyond its aesthetic appeal, Chrysanthemum is a repository of potential health benefits within its delicate petals. Chrysanthemum flower extract has garnered attention due to its rich composition of bioactive compounds, encompassing antioxidants, flavonoids, phenolic compounds, and beta-carotene. Primary carotenoids found in Chrysanthemum flowers include lutein, zeaxanthin, β-cryptoxanthin, 13-cis-β-carotene, α-carotene, trans-β-carotene, and 9-cis-β-carotene (Park et al., 2015), conferring a multitude of health advantages and positioning Chrysanthemum flower extract as a subject of interest in natural health remedies. Foremost, the antioxidant properties of the extract are notable, with flavonoids and phenolic compounds combating harmful free radicals, thereby reducing oxidative stress and the risk of chronic diseases (Tian et al., 2019). Notably, a study by Cao et al. (2020) identified catechin as the predominant phenolic compound in Chrysanthemum flowers, underscoring its antioxidative potential. The extract particularly in the form of tea, is known to have calming effect. Chrysanthemum flower extract encompasses a spectrum of potential health benefits, encompassing antioxidative and anti-inflammatory properties, stress relief, and vision enhancement (Wang et al., 2018).

In addition to these benefits, Chrysanthemum flower extract is associated with digestive health, potentially alleviating indigestion symptoms and possessing mild diuretic properties that support a healthy urinary system. In terms of cardiovascular health, the extract exhibits potential in regulating blood pressure, making it relevant for individuals managing hypertension (Shahrajabian et al., 2019).

Furthermore, it may provide relief for allergies and sinus congestion through its potential antihistamine properties, making it a comforting option during allergy seasons.

Given the medicinal significance of Chrysanthemum flower extract, this study aims to compare the qualitative and quantitative content of phenolics, anthocyanins, flavonoids, tannins, carotenoids, alkaloids, and saponins, alongside their antioxidative properties, utilizing spectrophotometric methods across twenty-two distinct Indian Chrysanthemum cultivars. Additionally, it seeks to identify potential biomarkers through variable importance in projection (VIP) plots from Partial Least Squares Discriminant Analysis (PLS-DA) for cultivar differentiation and establish statistical correlations among biochemical compounds in various Chrysanthemum cultivars, providing insights for the further improvement of Chrysanthemum cultivars.

2. Materials and Methods

2.1. Collection of flowers and extracts preparation

The flowers of 22 Indian Chrysanthemum cultivars (Table 1) were collected from the field of ICAR-Directorate of Floricultural Research in Pune. The petals were shade dried for 3–4 days and powdered.

2.2. Quantitative phytochemical assays

2.2.1 Estimation of total phenolic content

Total phenolic content was determined using the Folin-Ciocalteu method following Al Duais et al. (2009) with slight modifications. The total phenolic content was expressed as milligrams of gallic acid equivalent (GAE) per gram.

2.2.2. Estimations of total flavonoid content

With a few minor modifications, the aluminum trichloride method outlined by Zhishen et al. (1999) was used to determine the flavonoid content. The total flavonoid content was expressed as milligrams of Catechin Equivalent (CE) per gram of extract.

2.2.3. Estimation of total carotenoid content

The total carotenoid content was determined using the method outlined by Kamalambigeswari and Rebecca (2016). The concentrations of specific carotenoids were determined by utilizing the λ_{max} values from Britton's 1995 compilation, employing the following formula: Concentration of carotenoids X (µg) = [A x Y (ml) x 10^6] / [$A^{1\%}$ (cm) x 100] ; X (µg/g) = [X (µg)] / [Weight of sample (g)], where A- Absorbance, Y- Volume (ml), $A^{1\%}$ (cm) = Absorption coefficient for a carotenoid (absorbance at a specified wavelength in a 1% solution within a spectrophotometer cuvette with a 1-centimeter light path) which exhibits significant variability when different solvents are used.

2.2.4. Estimation of total anthocyanin content

Total anthocyanin content was determined using a modified spectrophotometric differential pH method (Taghavi et al., 2022). Total anthocyanin content (C) was determined using the equation:

C (mg MY/g DE) = $(A_{520} - A_{700})$ B - $(A_{520} - A_{700})$ A × 463.39 × DF × 10000 / 28000 × L.

Here, A represents the actual absorbance, which is the difference between absorbance values at 500 nm and 700 nm in pH 1.0 and pH 4.5 solutions; 463.39 is the molecular mass of malvidin-3-glucoside; 28000 is its molar absorptivity (ε) at 510 nm in the pH 1.0 solution; DF is the dilution factor, and L is the path length of the cuvette. Results were expressed as milligrams of malvidin-3-glucoside (MY) equivalents per gram of dry extract (mg MY/g DE).

2.2.5. Estimations of total tannin content

The total tannin content was determined using a modified Folin-Denis method (Polshettiwar et al., 2007). The total tannin content was reported as milligrams of tannic acid equivalent per gram of the extract.

2.2.6. Estimation of total alkaloid content

Alkaloid quantification followed the modified titrimetric method of Debnath et al. (2015). The total alkaloid content was calculated as a percentage of gram weight per volume (g % W/V), with the equivalence of 1 ml of 0.1 N HCl ≡ 0.0162 grams of alkaloid.

2.2.7. Estimation of total saponin content

To prepare the sample for estimation, 20 grams of floret powder were mixed with 200 ml of 20% ethanol and heated at 55°C with continuous stirring for 4 hours. After filtration, the residue was re-extracted using another 200 ml of 20% aqueous ethanol. The combined extracts were concentrated to 40 ml at 90°C. The concentrated solution was then subjected to liquid-liquid extraction with 20 ml of diethyl ether, followed by two purification cycles. Upon adding 60 ml of n-butanol to the aqueous phase, two 10 ml washes with 5% aqueous sodium chloride were conducted. The remaining solution was heat-dried until a constant weight was achieved, and the saponin content percentage was calculated following the method by Obdoni and Ochuko (2001).

2.2.8. Anti-oxidant assays

2.2.8.1. DPPH assay: Comparable scavenging methods

Floret extracts were assessed for DPPH radical scavenging ability using an adapted method from Brand-Williams et al. (1995). The percentage of DPPH radical scavenging was calculated using % Inhibition = $[(Abs_{(control)} - Abs_{(test)} / Abs_{(control)}] \times 100$. Plotting percentage inhibition against sample concentration in µg/mL, we determined the IC_{50}, representing the concentration reducing DPPH absorbance by 50%.

2.2.8.2. FRAP assay: Comparable reducing methods

The FRAP assay quantifies the conversion of ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}) in the presence of antioxidants using a previously described method (Suárez et al., 2010). The results were expressed as mmol of trolox per gram of dry floret powder.

2.3. Statistical, PCA and cluster analysis

Statistical analysis was carried out employing MetaboAnalyst 5.0 software to investigate associations among diverse phytochemicals in distinct cultivars and their interrelationships within the dataset. Additionally, a dendrogram was constructed using the Euclidean distance matrix and Ward's minimum variance method to cluster the 22 Chrysanthemum cultivars based on observed dissimilarities in their quantitative phytochemical assays. To assess trait variability, Principal Component Analysis (PCA) was applied to evaluate the contributions of individual traits to the overall variation among genotypes. To ensure data comparability, auto scaling techniques, as outlined by Seisonen et al. (2016), were applied to mitigate unit-related differences for each quantified compound. PCA was executed using the quantified content of selected biochemical compounds as variables. In the quest to identify marker compounds, VIP plots of metabolites were employed within the framework of PLS-DA.

3. Results and Discussion

3.1. Phytochemical and antioxidant potential evaluation

Environmental factors and cultivation practices can significantly influence secondary plant components. To mitigate these influences on phytochemical content, we sourced flowers from 22 Chrysanthemum cultivars grown on the same farm and harvested during the same season.

3.1.1. Total phenol and flavonoid contents

The phenolic content exhibited a considerable range, spanning from 0.83 µg/g GAE to 23.08 µg/g GAE among the 22 Chrysanthemum cultivars (Fig. 1). Among these cultivars, Diamond Jubilee displayed the highest total phenol content (TPC), followed by Silk Brocade and PAU B-43, while Bidhan Sabita had the lowest TPC. On the other hand, the total flavonoid content (TFC) among the same 22 *Chrysanthemum* cultivars ranged from 10 to 555 mg/g CE. The highest TFC was recorded in HYDC-42, followed by Bidhan Protima, with the lowest TFC observed in Bidhan Sabita (Table S1). A correlation analysis revealed a robust relationship between phenol and flavonoid content ($r = 0.38$, $n = 22$).

In our study, Diamond Jubilee, characterized by its deep yellow color, exhibited the highest phenolic content (Fig. 1), followed by Silk Brocade (pink) and PAU-13-46 (pale purple). These findings align with research on total flavonoids and phenolic acids in flowers with purple or pink petals and/or petaloid discs. Conversely, red or white-petaled flowers typically displayed lower levels of flavonoids and phenolic acids (Ryu et al., 2019). The role of flavonoids in influencing flower colors has been extensively investigated across plant species. It is noteworthy that flavonoid glycosides play a role in the formation of purple pigments and protection against radiation damage (Winkel-Shirley, 2002). Furthermore, the

biosynthetic pathway of phenolic compounds is intertwined with anthocyanins, as demonstrated by the accumulation of anthocyanins in a purple sweet potato cell line that produces caffeoylquinic acids (Haslam, 1998). Several studies support the idea that darker-colored fruits or flowers often possess higher antioxidant capacities due to elevated levels of phenolic compounds (Kumari et al., 2022).

3.1.2. Total carotenoid contents

The study of 22 Chrysanthemum cultivars identified 11 distinct carotenoids (Fig. 1), including β-carotene, α-carotene, lycopene, antheraxanthin, astaxanthin, auroxanthin, canthaxanthin, violaxanthin, mutatochrome, neoxanthin, and zeaxanthin. Among these, Mahatma Gandhi, Bidhan Agnidev, and Bidhan Purna cultivars exhibited the highest α-carotene and β-carotene levels, while Mini Jessie and Big Violet had the lowest concentrations of these carotenoids. Notably, Bidhan Agnidev showed the highest content of all other carotenoids. Additionally, Mahatma Gandhi had the highest antheraxanthin content, while Mini Jessie had the lowest levels of α-carotene, lycopene, violaxanthin, neoxanthin, and zeaxanthin. Big Violet displayed relatively low amounts of β-carotene and antheraxanthin, and Mauve Sarah had the lowest mutatochrome content (Table S1). These carotenoid variations result from complex interactions with other natural pigments in the petals and are influenced by factors such as petal color, cultivar, and species.

Carotenoids are a group of organic compounds composed of C40 isoprenoid units, potentially containing epoxy, hydroxy, and keto functional groups. They impart yellow, red, or orange colors to flowers. The carotenoid composition in flower petals is species-specific, unlike the relatively consistent carotenoid profiles in the green tissues of most plants. Non-green tissues exhibit varying qualitative carotenoid compositions, with xanthophyll accumulation in many plants contributing to yellow hues in their flowers. For example, a study on yellow petal Chrysanthemums found lutein, β-carotene, and violaxanthin initially present, with lutein becoming the dominant carotenoid over time (Kishimoto et al., 2006).

A heatmap analysis revealed that Bidhan Agnidev, Mahatma Gandhi, PAU-D-11, Bidhan Gold, Bidhan Lalima, Bidhan Manomi, Bidhan Purna, and Silk Brocate cultivars exhibited the highest presence of all 11 identified carotenoids, forming a distinct cluster (Fig. 4a). In contrast, Big Violet, Mini Jessie, Bidhan Sabita, and Vasantika had lower carotenoid content and were grouped separately. Notably, Bidhan Agnidev showed the highest presence of all carotenoids, while Vasantika had the lowest total carotenoid content.

Furthermore, carotenoids including astaxanthin, zeaxanthin, mutatochrome, canthaxanthin, neoxanthin, violaxanthin, and auroxanthin (Fig. 4b) were identified as potential biomarkers for distinguishing between Chrysanthemum cultivars, based on VIP scores exceeding 1 in the PLS-DA.

3.1.3. Total tannin content

Among the 22 cultivars, the cultivar Mahatma Gandhi has displayed the highest tannin content, followed by Diamond Jubilee Cultivar and Silk Borocate (Fig. 1). In contrast, PAU B-43 had the lowest tannin content (Table S1). Tannins are widely distributed in plants as protectant against grazing animals. They

are also said to work as an antiseptic and are used to treat numerous illnesses. They are typically concentrated in delicate plant parts, such young leaves and flowers, and their concentrations differ between plant species, parts, and environmental factors (Huang et al., 2018). Plants like *Hibiscus rosa-sinensis* and *Limonium delicatulum* showed higher tannin content in aqueous and methanolic extracts of stems and leaves during the flowering stage (Medini et al., 2014). Similar findings were made with extracts from the golden flamboyant plant's leaves and flowers (Muthukumaran et al., 2016).

3.1.4. Total anthocyanin content

In our investigation, we observed that the Mauve Sarah cultivar exhibited the highest anthocyanin content (Fig. 1), followed by Bidhan Protima and Punjab Anuradha, whereas Mini Jessie displayed the lowest anthocyanin levels (Table S1). Furthermore, our findings indicate a close correlation between anthocyanin content and the antioxidant potential of the cultivars, as evidenced by the Pearson's r values presented in Table 2. These results align with numerous prior studies, which have consistently demonstrated that edible flowers are replete with diverse bioactive constituents, prominently including flavonoids, particularly anthocyanins, as well as polyphenols and other compounds (Pires et al., 2018).

3.1.5. Total saponin content

In the case of the 22 Chrysanthemum cultivars under investigation, the saponin content exhibited a range from 0.6–1.5% (Fig. 1). Among these cultivars, Silk Brocade, Diamond Jubilee, Bidhan Sabita, and HYDC 56 displayed the highest saponin percentages, while the Mini Jessie cultivar had the lowest saponin content (Table S1). To the best of our knowledge, this study represents the first quantitative determination of total saponin content in *C. morifolium*.

Saponins, which are surface-active chemicals, find extensive applications in the food, cosmetics, and pharmaceutical industries and also play significant roles in plant ecology (Guçlu-Ustunda and Mazza, 2007). As suggested by Qi et al. (2011), saponins are key components of traditional folk medicines, such as the ginsenosides produced by *Panax* species. Although saponins constitute one of the largest families of plant natural compounds, there is limited understanding of their biological mechanisms. They are typically believed to play significant roles in protecting plants from pathogens, pests, and herbivores due to their antimicrobial, antifungal, anti-parasitic, insecticidal, and anti-feedant properties.

3.1.6. Total Alkaloid content

In the analysis of 22 dried Chrysanthemum floret samples, the highest alkaloid content was identified in Bidhan Gold, closely followed by Vasantika and Bidhan Lalima. The lowest total alkaloid content was observed in the Mauve Sarah cultivar (Table S1). Chrysanthemum's potential as a source of biologically active compounds, including insecticidal pyrethroids and their derivatives from *C. cinerariaefolium*, has been widely reviewed in insect control. Perennial chrysanthemum flower extracts have also been reported to be rich in alkaloids (Husain and Kumar, 2015). In another study, galanthamine, a bioactive alkaloid, was discovered in 97 out of 100 ornamental cultivars of Narcissus, primarily in leaves or bulbs. Among

these, *Narcissus hispanicus* leaves contained the highest content at 0.46% of dry weight, while the 'Yellow Wings' Sanguinine cultivar bulbs contained 0.14% (Torras-Claveria et al., 2013).

In the current study, significant quantities of alkaloids were extracted from Bidhan Gold, Vasantika, and Bidhan Lalima flowers. Further exploration of alkaloid extraction from these flowers could potentially provide a cost-effective and consistent source of this secondary metabolite for the pharmaceutical industry.

3.1.7. Anti-oxidant assays

In this study, we comprehensively evaluated the antioxidant activity of Chrysanthemum florets using two distinct methods: DPPH and FRAP assays.

3.1.7.1. DPPH assay

We assessed DPPH radical scavenging activity and IC_{50} values for 22 Chrysanthemum flower extracts, as detailed in Table S2 and Fig. 1. The extracts exhibited varying inhibitory potential, ranging from 28% (observed in HYDC 42 and Bidhan Sabita) to 98% (PAU B-43). Notably, the cultivar Diamond Jubilee, with the highest phenolic content, displayed the second-highest DPPH radical scavenging activity (96%). This can be attributed to the presence of hydroxyl groups in phenolics, known for their antioxidant properties. Conversely, cultivars like Bidhan Sabita and HYDC 42, with lower total phenolic content, exhibited reduced DPPH radical scavenging activity (28.18%). These results align with prior research, demonstrating a positive correlation between phenolic content and antioxidant activity (Kumari et al., 2022).

The cultivars, Bidhan Agnidev (3.4 µg/g GAE) and Bidhan Rajat (4.0 µg/g GAE), despite of lower phenolic content, still demonstrated significant radical scavenging abilities of 92% and 94%, respectively. This suggests the presence of other bioactive compounds in these cultivars, extending beyond phenolics, consistent with findings in phytochemical and antioxidant studies of Bird of Paradise and other ornamental plants (Orcic et al., 2011).

We further assessed antioxidant properties using IC_{50} concentrations, representing the extract amount required to scavenge 50% of the DPPH radical. The results, summarized in Table S2, showed that Bidhan Lalima had the lowest IC_{50} value (15.03 ppm), followed by Diamond Jubilee (20.36 ppm) and Big Violet (21.93 ppm), indicating their high antioxidant potential. Conversely, Bidhan Agnishika, with the highest IC_{50} value of 84.57 ppm, represented the lowest antioxidant potential.

3.1.7.2. FRAP assay

The FRAP assay revealed that Bidhan Protima exhibited the highest reducing power at 65 mg/g ferrous equivalent, followed by Silk Brocade at 46.86 mg/g and Mauve Sarah at 50 mg/g. The cultivar Ajoy displayed the lowest reducing power, registering only 20 mg/g ferrous equivalent (Fig. 1). These findings are consistent with research indicating that red - colored rose cultivars typically have elevated phenolic content and increased antioxidant activities (Kumari et al., 2022). Bidhan Protima, with the highest

reducing power, also ranked second in total flavonoid content (380 mg/g CE). Silk Brocade exhibited the third-highest reducing capacity and ranked second in total phenolic compound content (22.72 µg/g GAE).

3.2. Statistical Analysis

3.2.1. Correlation between phytochemicals

The Pearson's correlation coefficients presented in Table 2 unveil robust associations among the phytochemical contents. A significant correlation exists between antioxidants and anthocyanins (r = 0.44), as well as between antioxidants and both phenols (r = 0.40) and tannins (r = 0.43) based on the Pearson's correlation coefficient. Furthermore, flavonoid content demonstrated a moderate relationship with the presence of saponins (r = 0.27) and antioxidant activity (r = 0.27). Whilst tannin content exhibited close correlations with phenols (r = 0.45), saponins (r = 0.40), and antioxidants (r = 0.43). Remarkably, a strong relationship was observed between saponins and carotenoids content, with a Pearson's correlation coefficient of 0.58.

3.2.2. Cluster analysis

Based on the Euclidean distance similarity index, a dendrogram was constructed, revealing an initial division of cultivars into two major clusters (Fig. 2c). The first major cluster comprised cultivars Silk Brocade, Mauve Sarah, Bidhan Protima, Diamond Jubilee, and Mahatma Gandhi, which exhibited the highest levels of all biochemical compounds, including antioxidants, assessed in this study. The second major cluster included the remaining cultivars, further subdivided into five sub-clusters. In this cluster, cultivars such as Bidhan Lalima, Bidhan Agnidev, Bidhan Gold, HYDC-56, Bidhan Monami, and Bidhan Purna shared similar characteristics, producing a moderate range of biochemical compounds, with a notable emphasis on carotenoid production. Bidhan Agnishikha, Punjab Anuradha, Mini Jessie, and Vasantika formed another sub-cluster, demonstrating the presence of most studied phytochemicals at lower levels, along with moderate contents of antioxidants. Cultivars PAU-B-43, Big Violet, Bidhan Rajat, and HYDC 42 represented a sub-cluster with lower content of most phytochemicals, except for saponins and flavonoids. Finally, the last sub-cluster consisted of Bidhan Sabita, Ajoy, and Khoka Kingar, which exhibited a moderate range of saponin content and lower levels of other biochemical compounds.

3.2.3. Principal Component Analysis

To assess the data generated from all conducted assays in this study, Principal Component Analysis (PCA) was employed, with data being normalized through auto-scaling. The application of PCA resulted in the generation of two visual representations: scores and loading plots. Variables that cluster together denoted strong positive correlations among them. The scores plot (Fig. 2a) provided a visual representation of the distinctions among accessions, with each test being plotted on a graph where the first two principal components constituted the axes. PC1 explained 32.5% of the total variance, while PC2 elucidated 22.8%, summing up to 55.3%. Further analysis utilizing a bi-plot (Fig. 2b) unveiled the presence of tannin, saponin, carotenoid, and alkaloid in the fourth quadrant. On the other hand, flavonoid, phenol, antioxidant, and anthocyanin were located in the positive first quadrant.

The Variable Importance in Projection (VIP) score, obtained through Partial Least Squares Discriminant Analysis (PLS-DA), identified phenols, saponins, and alkaloids as biomarkers crucial for distinguishing among chrysanthemum cultivars (Fig. 3)

4. Conclusion

In this study, we conducted a comprehensive analysis of phytochemical composition in 22 Indian chrysanthemum cultivars, encompassing flavonoids, phenolic acids, anthocyanins, carotenoids, saponin, and tannin. Notably, significant variations in phytochemical composition were observed among the cultivars. Our investigation unveiled a strong correlation between antioxidant activity, phenol content, and anthocyanins, highlighting their substantial contributions to antioxidant properties. The cultivars HYDC-42, Bidhan Rajat, and Bidhan Protima exhibited notable flavonoid content, while extracts from Mahatma Gandhi, Silk Brocade, and Mauve Sarah displayed heightened antioxidant properties. Vasantika, Bidhan Gold, and Bidhan Lalima showcased high alkaloid production, and Bidhan Protima, Mauve Sarah, Diamond Jubilee, and Punjab Anuradha demonstrated significant anthocyanin production. These findings suggest the potential of these chrysanthemum cultivars as dietary supplements for combating oxidative damage caused by free radicals.

Furthermore, our results imply that these distinctive biochemical compounds can serve as valuable markers for classifying and identifying chrysanthemum cultivars. Additionally, our findings highlight the suitability of chrysanthemum cultivars with substantial content of specific bioactive phytochemicals for applications in functional foods, pharmaceuticals, and horticulture.

Abbreviations

Abbreviation	Full Name
Biological And Chemical	
CE	Catechin Equivalent
DE	Dry Extract
DPPH	2,2-Diphenylpicrylhydrazyl
FRAP	Ferric Reducing Ability of Plasma
GAE	Gallic Acid Equivalent
MY	Malvidin-3-Glucoside
TFC	Total Flavonoid Content
TPC	Total Phenol Content
Trolox	6-Hydroxy-2,5,7,8-Tetramethylchroman-2-Carboxylic Acid
Statistical	
HCA	Hierarchical Cluster Analysis
PCA	Principal Component Analysis
PLS-DA	Partial Least Squares-Discriminant Analysis
VIP	Variable Importance In Projection

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Tables

Tables 1 and 2 are available in the Supplementary Files section.

Figures

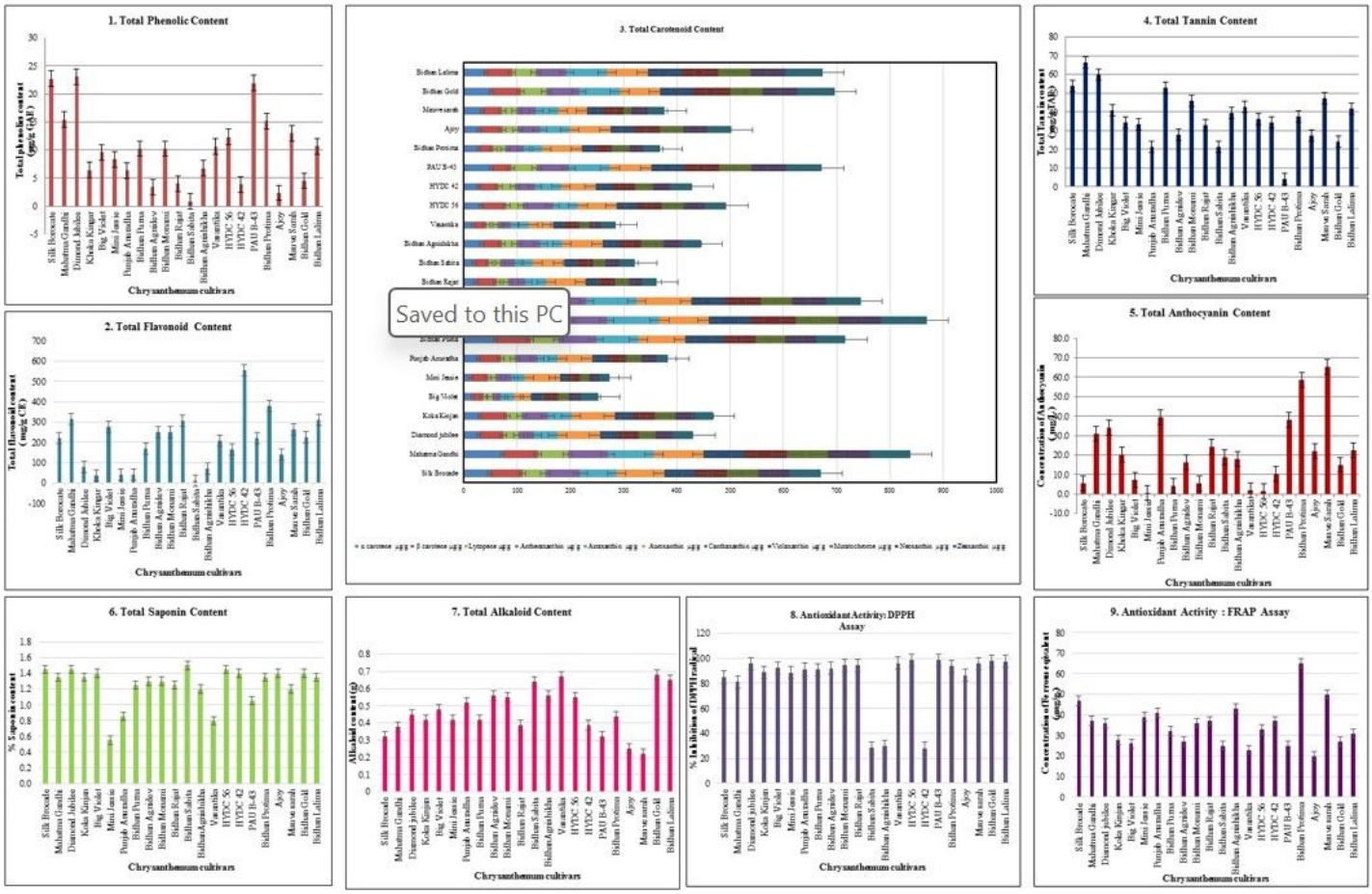


Figure 1

Phytochemical content of Chrysanthemum Cultivars: 1. Total phenolic content of chrysanthemum cultivars; 2. Total flavonoid content of chrysanthemum cultivars; 3. Carotenoids of chrysanthemum cultivars; 4. Total tannin content of chrysanthemum cultivars; 5. Total anthocyanin content of chrysanthemum cultivars; 6. Total saponin content of chrysanthemum cultivars; 7. Total alkaloid content of chrysanthemum cultivars; 8. Percent inhibiting capabilities of floret extracts of chrysanthemum cultivars; 9. Fe^{3+} reducing abilities of floret extracts of chrysanthemum cultivars

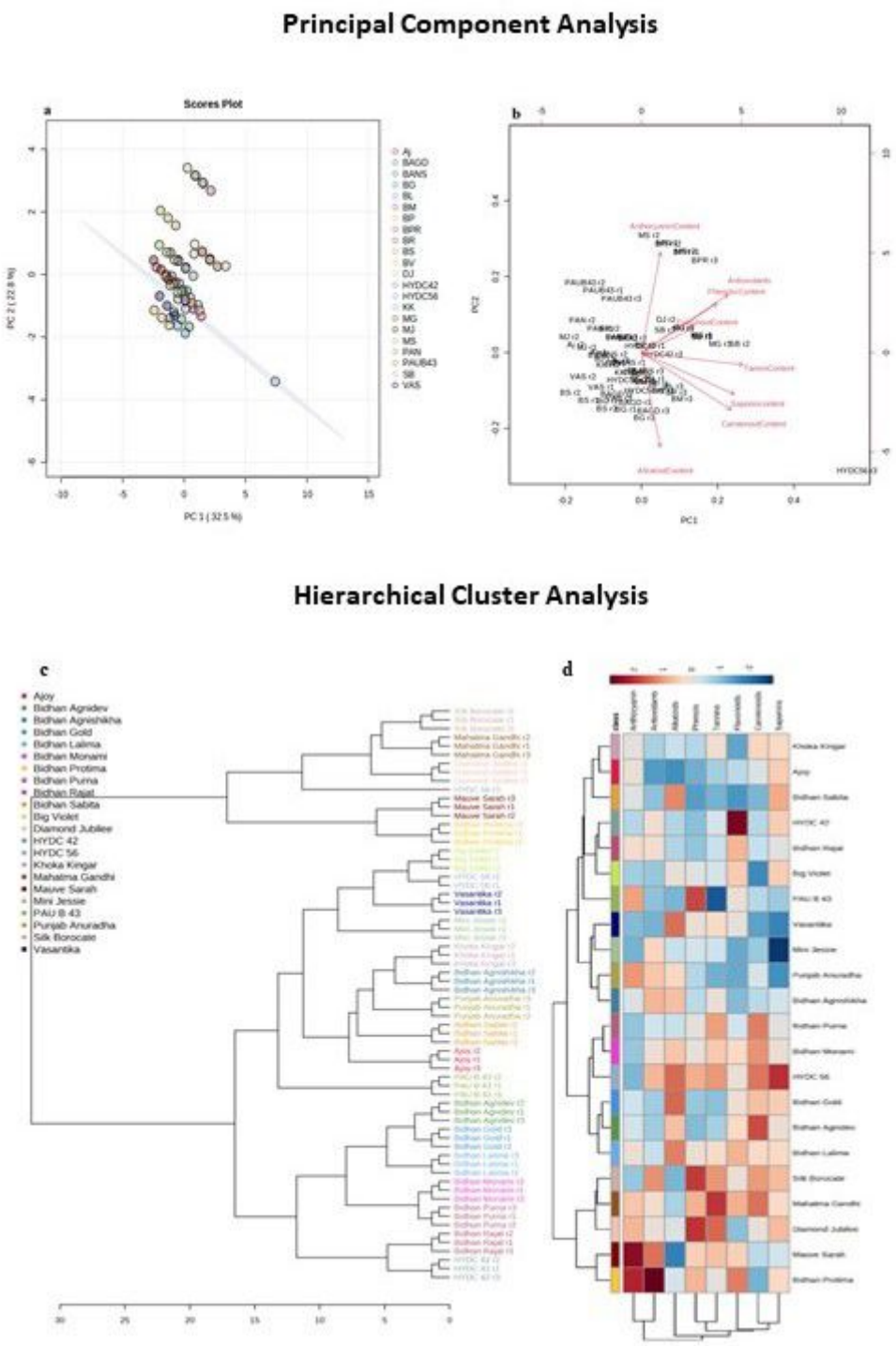


Figure 2

Chemo metric analysis of Chrysanthemum varieties: Principal Component Analysis of data obtained by phytochemical analysis of 22 chrysanthemum cultivars: a - Scores plot and b - Biplot for Total Phenolic Content, Total Flavonoid Content, Total Anthocyanin Content, Total Saponin Content, Total Tannin Content, Total Carotenoid Content, Total Antioxidants and Total Alkaloid Content where the Chrysanthemum cultivars are denoted as SB - Silk Borocate, MG - Mahatma Gandhi, DJ - Diamond Jubilee, KK - Khoka Kingar, BV - Big Violet, MJ - Mini Jessie, PAN – Punjab Anuradha, BP - Bidhan Purna, BAGD – Bidhan Agnidev, BM - Bidhan Monami, BR - Bidhan Rajat, BS - Bidhan Sabita, BANS – Bidhan

Agnishikha, VAS – Vasantika, HYDC56 - HYDC56, HYDC42 - HYDC42, PAUB43 - PAUB43, BPR – Bidhan Protima, Aj - Ajoy, MS - Mauve Sarah, BG - Bidhan Gold, and BL - Bidhan Lalima; and Hierarchical Cluster Analysis (HCA): c - Dendrogram; d - Heatmap obtained on cluster analysis of chrysanthemum cultivars based on their phytochemical content studied

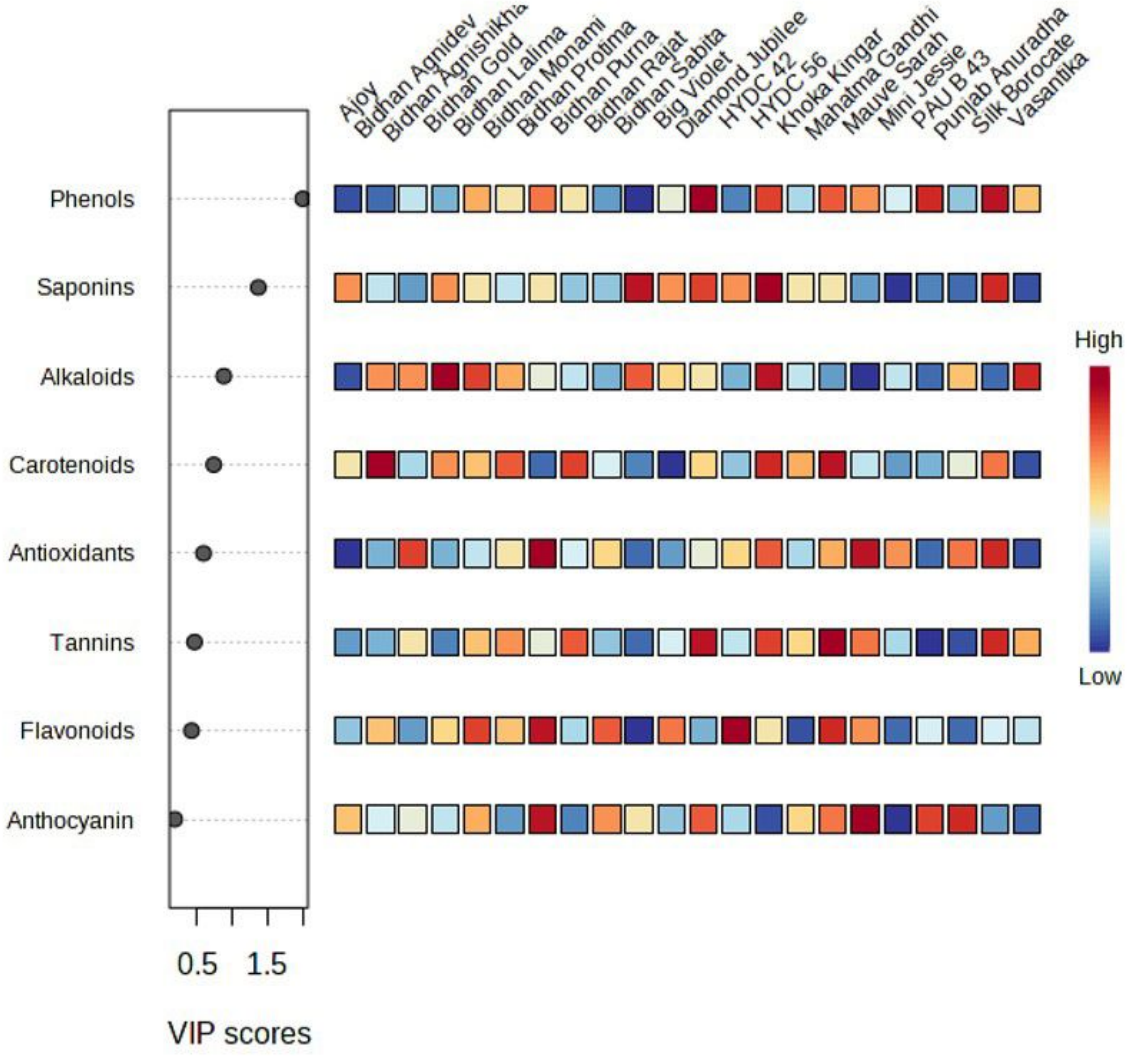


Figure 3

VIP scores obtained through Partial Least Squares Discriminant Analysis (PLS-DA) for the different phytochemicals obtained in 22 Chrysanthemum varieties.

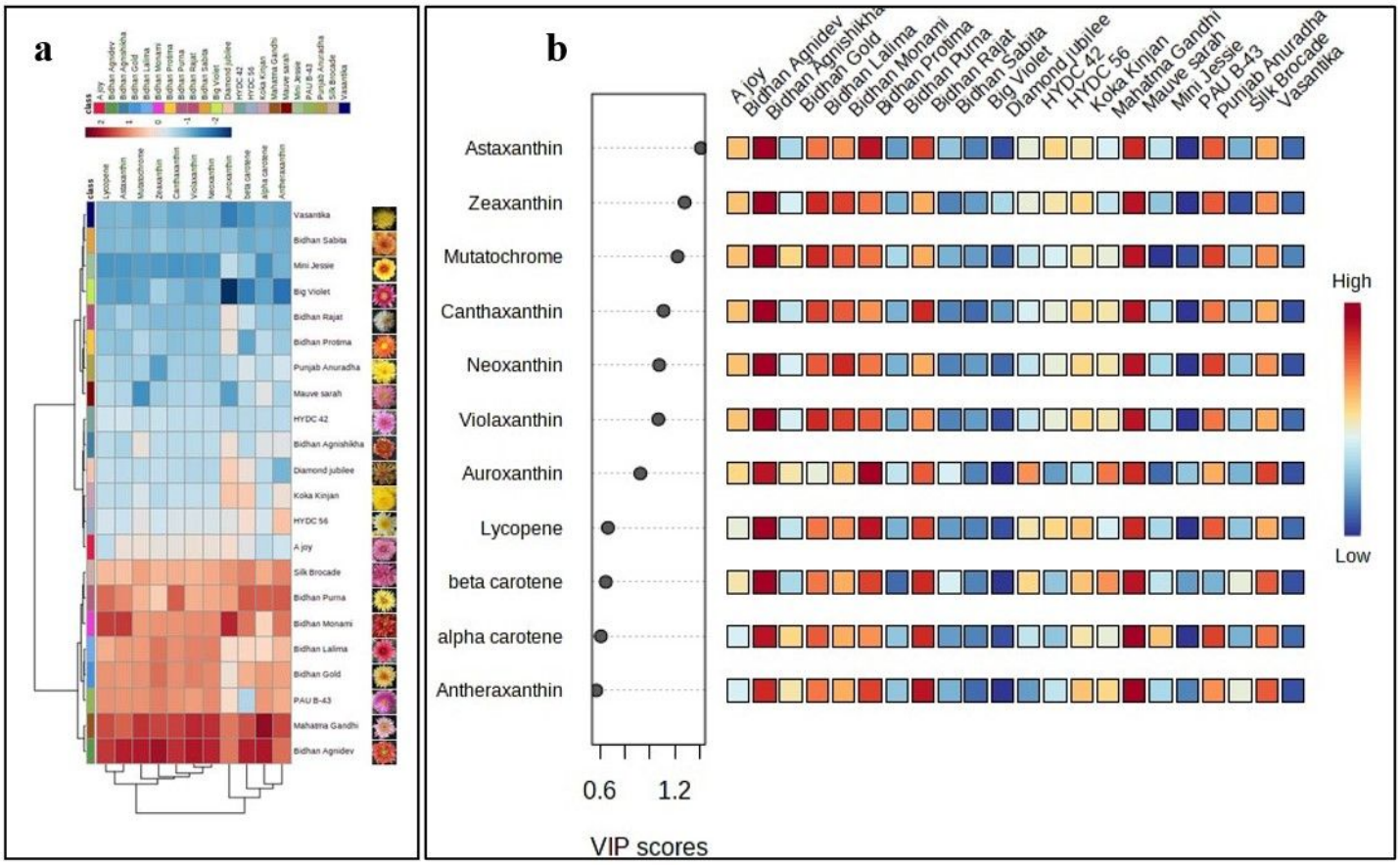


Figure 4

a - Heatmap for 11 carotenoids identified in 22 *Chrysanthemum* cultivars; b – Plot showing VIP scores obtained through Partial Least Squares Discriminant Analysis (PLS-DA) for the different 11 carotenoids identified.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

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