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Research Article

A PRELIMINARY SURVEY AND INVENTORY OF ORNAMENTAL CRASSULACEAN ACID METABOLISM (CAM) PLANTS IN AND AROUND UJJAIN CITY OF MADHYA PRADESH, INDIA

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ABSTRACT
The present research work is selected for a preliminary survey and inventory of ornamental Crassulacean Acid Metabolism (CAM) plants in and around Ujjain city of Madhya Pradesh, India. The work includes the vegetation studies and observation of CAM plants from different sites (gardens, nurseries and residential campuses) in and around Ujjain city. A total of 12 families, 26 genera and 57 CAM plant species are reported in this research work. Plants species are arranged in alphabetical order and family-wise with their botanical name, common name, and family. The present research work has aimed to document, make up the inventory of ornamental CAM plants and find out the diversity of ornamental CAM plants in the given study area so can the study of applications of CAM plants.

Keywords: *Preliminary Survey, Ornamental CAM Plants, Crassulacean acid metabolism, Ujjain City*

INTRODUCTION
The present research work is selected for a preliminary survey and inventory of ornamental Crassulacean Acid Metabolism (CAM) plants in and around Ujjain city of Madhya Pradesh, India. The work includes the vegetation studies and observation of CAM plants from different sites (gardens, nurseries and residential campuses) in and around Ujjain city. The plants that undergoes Crassulacean acid metabolism, a form of photosynthesis in which carbon dioxide is taken up only at night are called CAM plants. CAM Plants use certain special compounds to gather carbon dioxide (CO_2) during photosynthesis. These compounds allow CAM plants to extract more CO_2 from a given amount of air helping them prevent water loss in dry climates. During the night, stomata are open in the CAM plants, allowing CO_2 to enter and be fixed as organic acids that are stored in vacuoles. During the day the stomata are closed (thus preventing water loss), and the carbon is released to the Calvin cycle so that photosynthesis may take place. The CAM plants often show xerophytic features, such as thick, reduced leaves with a low surface area to volume ratio, thick cuticle, and the sunken stomata. Some shed their leaves during the dry season; others store water in vacuoles (Stanley *et al*. 1997). CAM plants are not only good at retaining water but use nitrogen very efficiently. However, due to their stomata being closed during the day, they are less efficient at CO_2 absorption. This limits the amount of carbon available for growth. The CAM plants are adapted to live in arid climates by conserving water. The CAM plants are also good bio-indicator of desertification. Some of CAM plants are grown in home/ office gardens mainly for ornamental purpose (Prerna *et al*. 2015) The ornamental potential of most plants are its good-looking plant parts along with the attractive beautiful flowers and ornamental foliage. Succulent CAM plants are most popular among plant collectors, home gardeners and botanists for a number of reasons with their colorful leaves, special shapes and simple care (Debra 2010, Patel *et al*. 2016). Presently, succulents are used in outdoor and indoor gardening at various places like malls, industries, colleges, hospitals and gardens in the city of Ujjain. CAM plants are highly ignored by taxonomists and researcher in and around Ujjain just because many of them are ornamental. No specific work was done on the ornamental CAM plants for the present study area. In view of the above facts, the present research work has aimed to documentation, make up the inventory of ornamental CAM plants and find out the diversity of ornamental CAM plants in the given study area so can the study of applications of CAM plants. Therefore, the present research work on

ornamental CAM plants in and around Ujjain was undertaken with intensive and extensive floristic exploration studies on the vegetation of the Ujjain area.

MATERIALS AND METHODS

Study area: Ujjain is a district of Madhya Pradesh state in Central India. It is situated on the Malwa plateau in central India and located at – 23.18^0 N and 75.77^0 E. It has an average elevation of 491 meters (1610 ft). Ujjain is situated on the bank of river Kshipra and in a unique geographical location where tropic of cancer passes. There is also a temple of Mahakaleshwar Jyotirlinga, one of the twelve Jyotirlinga shrines to Lord Shiva. It is surrounded by Indore, Dewas, Shajapur, Agar Malwa, Ratlam and Dhar districts.

Field work: A Preliminary Survey of CAM plants in and around Ujjain city of Madhya Pradesh was carried out by visiting different sites. Plant collection was done by standard method (Jain and Rao 1977). During field work the photograph of each CAM plants were taken along with habit, stem, leaves and other floral parts. Field observation and Field data were noted down in the field diary. Collected plant specimens were kept in between the fold of blotting papers, pressed by field press and dried. Dried plant specimens were preserved by dipping the whole specimens in a 2 % saturated solution of Mercuric chloride and absolute alcohol. Dry and preserved plants are mounted on herbarium sheets by adhesive glue and fevicols. Plant specimens were identified with the help of perusal of literature (Hooker, 1872-1897; Cook, 1903; Shah, 1978; Naik, 1998; Verma, Balakrishnan and Dixit 1993; Sing *et al*., 1997; Khanna *et al*., 2001. The plants were also identified through available literature and herbarium in the libraries of Govt. Madhav Science PG college Ujjain, School of studies in Botany, Central library, Vikram University Ujjain. The cited specimens were deposited in the Department of Botany, Govt. Madhav Science PG College Ujjain Madhya Pradesh.

Figure 1: Map of Ujjain

RESULTS AND DISCUSSION

Table 1 shows an inventory of some ornamental Crassulacean Acid Metabolism (CAM) plants having a total of 12 families, 26 genera and 57 species were reported in study area. Based on observations and total number of species, the most represented family was Agavaceae (12 species) followed by Crassulaceae (11 species), Euphorbiaceae (11 species), Cactaceae (9 species), Xanthorrhoeceae (5 species) and

Table 1: Ornamental CAM plant species were reported in and around Ujjain

S.N.	Botanical name of the species	Common name	Family
1	*Agave americana* L.	Century plant, Rambans	Agavaceae
2	*Agave americana var. 'marginata'* Trel.	Yellow margin century plant	Agavaceae
3	*Agave angustifolia* Haw.	Narrow leaved century plant	Agavaceae
4	*Agave attenuata* salm-dyck	Fox tail agave	Agavaceae
5	*Aloe abyssinica* lam.	Gvarapatha, Ghigavar	Xanthorrhoeceae
6	*Aloe vera* (L.) Burm. f.	Gvarapatha, Ghigavar	Xanthorrhoeceae
7	*Aloe 'sean red'* hybrid	Bright star	Asphodelaceae
8	*Ananas camosus* (L.) Merr.	Pineapple	Bromeliaceae
9	*Bryophyllum daigremontianum* (Raym. –Hamet & Perrier) A. Berger	Mother of Thousands	Crassulaceae
10	*Bryophyllum delagoense* (Eckl. & Zeyh.) Druce	Finger plant	Crassulaceae
11	*Bryophyllum pinnatum* (Lam.) Kurz.	Miracle plant	Crassulaceae
12	*Cereus uruguayanus* R. Kiesling	Spiny hedge cactus, Peruvian apple	Cactaceae
13	*Cleistocactus strausii* (Hesse) Backeb.	Silver Torch	Cactaceae
14	*Corynopuntia vilis* (Rose) F.M. Knuth.	Sagebrush cholla	Cactaceae
15	*Crassula subacaulis subsp. erosula* (N.E.Br.) Toelken	Campfire	Crassulaceae
16	*Echinocactus platyacanthus* Link and Otto	Golden barrel cactus	Cactaceae
17	*Euphorbia grandicornis* Goebel ex N.E.Br.	Zig-zag Cactus	Euphorbiaceae
18	*Euphorbia lactea* f. *cristata*	Crested euphorbia	Euphorbiaceae
19	*Euphorbia milii* Des Moul. *'Breonii'*	Crown of thorns	Euphorbiaceae
20	*Euphorbia milii* Des Moul. 'Cristata'	Crested crown of Thorns	Euphorbiaceae
21	*Euphorbia milii* Des Moul.	Crown of thorn	Euphorbiaceae
22	*Euphorbia royleana* Boiss	Danda thor	Euphorbiaceae
23	*Euphorbia tirucalli* L.	Pencil tree, milk bush	Euphorbiaceae
24	*Euphorbia trigona* Mill.	African milk tree	Euphorbiaceae
25	*Furcraea foetida* (L.) Haw.	Green agave	Agavaceae
26	*Furcraea gigantean* var. *mediopicta* Trel.	Mauritius hemp	Agavaceae
27	*Gasteria carinata var. verrucosa* (Mill.) Van Jaarsv.	Deer's Tongue, Ox Tongue	Xanthorrhoeceae
28	Graptopetalum paraguayense (N. E. Br.) E. Walther	Ghost plant	Crassulaceae
29	*Haworthia attenuata (*Haw.) Haw.	Zebra plant	Xanthorrhoeceae
30	*Howorthia fasciata (*Willd.*) Haw.*	Zebra plant	Xanthorrhoeceae
31	*Kalanchoe blossfeldiana* Poelln.	Flaming Katy	Crassulaceae
32	*Kalanchoe fedtschenkoi* f. *variegata* hort	Rainbow Kalanchoe	Crassulaceae
33	*Kalanchoe pumila* Baker	Flower dust plant	Crassulaceae
34	*Kalanchoe thyrsiflora* Harv**.**	Desert Cabbage, paddle plant	Crassulaceae
35	*Opuntia cylindrica* (Lam.) Dc.	Prickly Pear	Cactaceae
36	*Opuntia falcata* Ekman & Werderm.	Tree opuntia	Cactaceae
37	*Opuntia ficus-indica* (L.) Mill.	prickly pear	Cactaceae
38	*Opuntia microdasys* (Lehm.) Lehm. Ex Pfeiff.	Polka-dot Cactus, Bunny Cactus	Cactaceae
39	*Parodiahaselbergii* (F. Haage) F. H. Brand.	Notocactus, small ball cacti	Cactaceae
40	Pedilanthus tithymaloides (L.) poit.	Devil's backbone	Euphorbiaceae
41	Pedilanthus tithymaloides (L.) poit. 'Nanus'	Zigzag plan	Euphorbiaceae
42	Pedilanthus tithymaloides (L.) poit. "variegatus"	redbird-cactus	Euphorbiaceae
43	*Portulaca grandiflora* Hook.	Eleven-o'clock, Sun plant	Portulacaceae
44	*Portulaca oleracea* L.	Green purslane	Portulacaceae

45	*Portulacaria afra* jacq	Elephant food	Portulacaceae
46	*Sansevieria cylindrica* Bojer ex Hook	Cylindrical snake plant	Agavaceae
47	*Sansevieria suffruticosa* N.E.Br.	Cylindrical snake plant	Agavaceae
48	*Sansevieria trifasciata 'Hahnii'*	Bird's Nest, Snake plant	Agavaceae
49	*Sansevieria trifasciata* prain	Mother-in-Law's tongue	Agavaceae
50	Sansevieria trifasciata var. laurentii (De Wild.) N.E.Br.	Snake plant, good luck plant	Agavaceae
51	*Sedum nussbaumeria* Bitter	Golden sedum, stone crops	Crassulaceae
52	*Sedum spectabile* Bor.	Stonecrops	Crassulaceae
53	*Senecio radicans* (L. f.) Sch. Bip.	String of bananas	Asteraceae
54	*Stapelia glanduliflora* Masson	Starfish flowers	Asclepiadaceae
55	*Tradescantia pallida* (Rose) D.R. Hunt	Purple Heart, Purple Queen	Commelinaceae
56	*Vanda roxburghii* R. Br	Rasna, Vandaka	Orchidaceae
57	*Yucca aloifolia* L.	Dagger Plant	Agavaceae

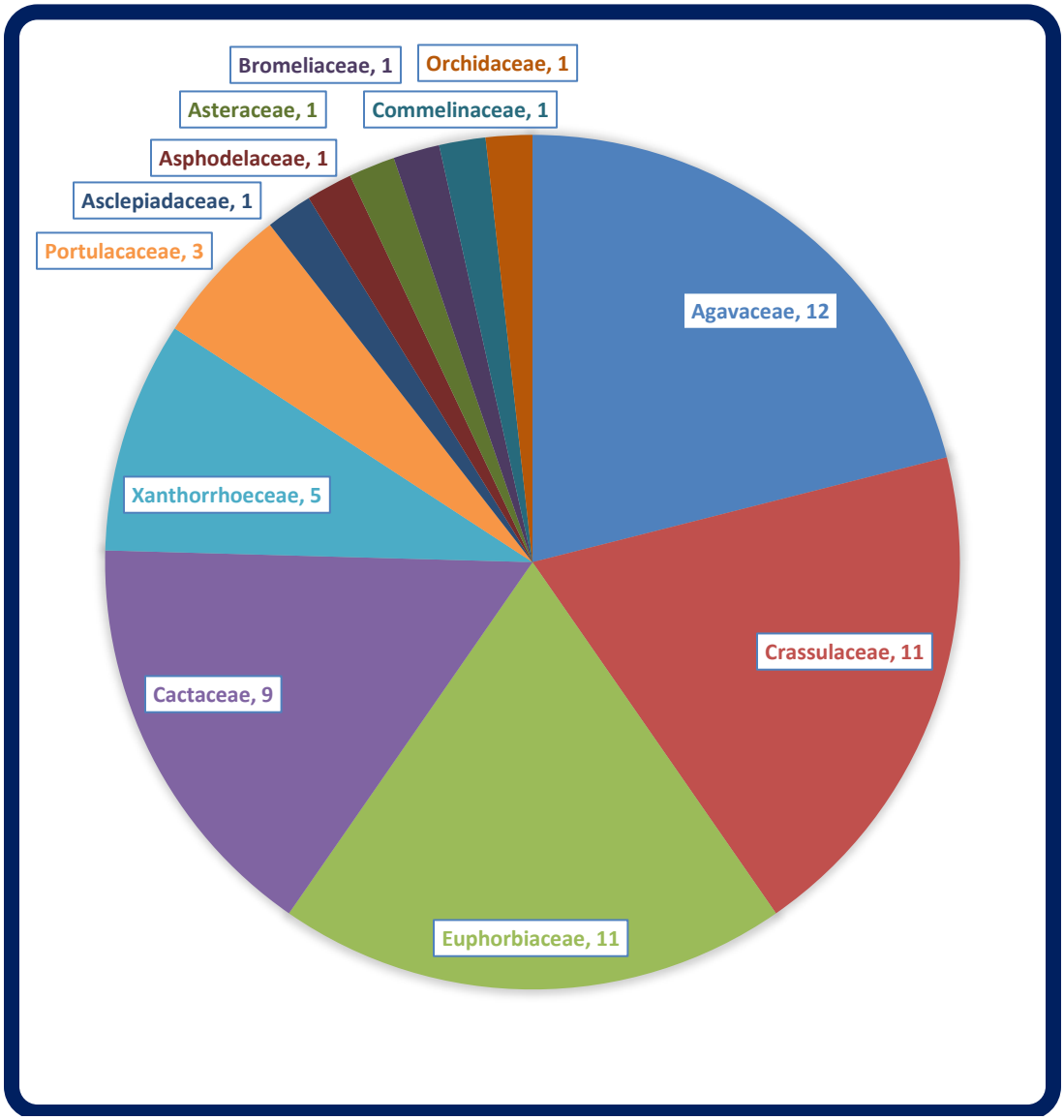

Figure 2: Positions of the families according to their total number of ornamental CAM plant species

Portulacaceae (3 species) (table 3, figure 2). Aditya Kumar, Sayeeda Kousar Bhatti, Chhavi Mangla and Ashok Aggarwal, (2015) have reported 15 species of ornamentally important Plants in his study belonging to 15 genera and 11 families. Similarly, Patel R.M., Qureshimatva U.M., Maurya R.R. & Solanki H.A. (2016) studied and reported 45 genera and 73 species with 1 subspecies, 5 varieties, and 2 cultivated varieties belonging to 15 families. In the present study we have recorded 57 plant species belonging to 26 genera and 12 families.

Table 2: **Total numbers of ornamental CAM plant species in different families**

S. No	Family	Botanical Name	Total No. of Species
1.	Agavaceae	1. *Agave americana* L. 2. *Agave americana var. 'marginata'* Trel. 3. *Agave angustifolia* Haw. 4. *Agave attenuata* salm-dyck 5. *Furcraea foetida* (L.) Haw. 6. *Furcraea gigantean* var. *mediopicta* Trel. 7. *Sansevieria cylindrica* Bojer ex Hook 8. *Sansevieria suffruticosa* N.E.Br. 9. *Sansevieria trifasciata* 'Hahnii' 10. *Sansevieria trifasciata* prain 11. *Sansevieria trifasciata* var. laurentii (De Wild.) N.E.Br. 12. *Yucca aloifolia* L.	12
2.	Asclepiadacea	*1. Stapelia glanduliflora* Masson	1
3.	Asphodelaceae	*1. Aloe 'sean red' hybrid*	1
4.	Asteraceae	*1. Senecio radicans* (L. f.) Sch. Bip.	1
5.	Bromeliaceae	*1. Ananas camosus* (L.) Merr.	1
6.	Cactaceae	1. *Cereus uruguayanus* R. Kiesling 2. *Cleistocactus strausii* (Hesse) Backeb. 3. *Corynopuntia vilis* (Rose) F.M. Knuth 4. *Echinocactus platyacanthus* Link and Otto 5. *Opuntia cylindrica* (Lam.) Dc. 6. *Opuntia falcata* Ekman & Werderm. 7. *Opuntia ficus-indica* (L.) Mill. 8. *Opuntia microdasys* (Lehm.) Lehm. Ex Pfeiff. 9. *Parodia haselbergii* (F. Haage) F. H. Brand.	9
7.	Commelinaceae	*1. Tradescantia pallida* (Rose) D.R. Hunt	1

8.	Crassulaceae	1. *Bryophyllum daigremontianum* (Raym.-Hamet& Perrier) A. Berger 2. *Bryophyllum delagoense* (Eckl. & Zeyh.) Druce 3. *Bryophyllum pinnatum* (Lam.) Kurz. 4. *Crassula subacaulis subsp. erosula* (N.E.Br.) Toelken 5. Graptopetalum paraguayense (N. E. Br.) E. Walther 6. *Kalanchoe blossfeldiana* Poelln. 7. *Kalanchoe fedtschenkoi* f. *variegata* hort 8. *Kalanchoe pumila* Baker 9. *Kalanchoe thyrsiflora* Harv**.** 10. *Sedum nussbaumeria* Bitter 11. *Sedum spectabile* Bor.	11
9.	Euphorbiaceae	1. *Euphorbia grandicornis* Goebel ex N.E.Br. 2. *Euphorbia lactea* f. *cristata* 3. *Euphorbia milii* Des Moul. *'Breonii'* 4. *Euphorbia milii* Des Moul. 'Cristata' 5. *Euphorbia milii* Des Moul. 6. *Euphorbia royleana* Boiss 7. *Euphorbia tirucalli* L. 8. *Euphorbia trigona* Mill. 9. *Pedilanthus tithymaloides* (L.) poit. 10. *Pedilanthus tithymaloides* (L.) poit. 'Nanus' 11. *Pedilanthus tithymaloides* (L.) poit. "variegatus"	11
10.	Xanthorrhoeceae	1. *Aloe abyssinica* lam. 2. *Aloe vera* (L.) Burm. F. 3. *Gasteria carinata var. verrucosa* (Mill.) Van Jaarsv. 4. *Haworthia attenuata (*Haw.) Haw. 5. *Howorthia fasciata* (Willd.) *Haw.*	5
11	Portulacaceae	1. *Portulaca grandiflora* Hook. 2. *Portulaca oleracea* L. 3. *Portulacaria afra* jacq	3
12.	Orchidaceae	1. *Vanda roxburghii* R. Br	1

Table 3: Positions of families according to their total number of ornamental CAM plant species

S. No	Family	Number of Plant Species	Position of the Family
1	Agavaceae	12	1
2.	Crassulaceae	11	2
3.	Euphorbiaceae	11	3
4.	Cactaceae	9	4
5.	Xanthorrhoeceae	5	5
6.	Portulacaceae	3	6
7.	Asclepiadaceae	1	7
8.	Asphodelaceae	1	7
9.	Asteraceae	1	7
10.	Bromeliaceae	1	7
11.	Commelinaceae	1	7
12.	Orchidaceae	1	7

***Aloe vera* (L.) Burm.f.**

***Euphorbia lactea* f. cristata**

***Venda roxburghi* R.Br.**

***Aloe'sean* red' hybrid**

Echinocactus platyacanthus

***Euphorbia milii* Des Moul.**

***Portulaca grandiflora* Hook.**

***Furcraea gigantea* "mediopicta"**

Kalanchoe thyrsiflora

***Haworthia attenuata* (Haw.)**

***Euphorbia trigona* Mill.**

Graptopetalum paraguayense

Photoplate 1: Photographs of study site with Ornamental CAM plants

CONCLUSION

The main aims of this research work were to make up the inventory of ornamental CAM plants and find out the diversity of CAM plants in the given study site so can the study of applications of CAM plants. The present work gives information on up-to-date Nomenclature, a brief description, habit and habitat, and locality of ornamental CAM plants. The ornamental CAM plants are produced and cultivated mainly for their aesthetic value; thus, the propagation and improvement of quality attributes are important economic goals for the ornamental CAM plant's industries. Conservation of ornamental flowering species is also one of the alternate methods to maintain their diversity (Kumar *et al*. 2015). It is essential to know wild ornamental CAM plant species. The ornamental CAM plant inventory of the Ujjain area provides unique information on the ornamental CAM plant floristic diversity which will serve as a ready reference for Scientists and researcher scholars. We can retain biodiversity in ornamental CAM plants only if we can maintain CAM phytodiversity. We can make special efforts to grow some of the endangered ornamental CAM plant species for conserved and propagation in our botanical gardens, nurseries, residential campuses, and houses. The present study highlights the knowledge of ornamental CAM plants that are generally grown in every home/office garden for beauty and ornamental purpose. Through the present study we hope to convey that, the various species, which are documented from the study area, are possessing ornamental potentialities in their attractive habit and flowers. We hope that this work will help the researchers, students and local people, who are interested in ornamental CAM plants.

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