Allergenic and Toxic Compounds in Ornamental Plants – A review

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Abstract

Various biosynthesised compounds from ornamental plants can be harmful to man, throughout a plant's entire life cycle or only during certain moments, present in all of its organs or restricted only to some. Interdisciplinary research regarding plant toxins and allergens are being conducted worldwide, aiming to prevent the production of diseases. The research aimed to phytochemically classify vegetal compounds with toxic and allergenic characteristics found in ornamental plants, to identify the main pathogenic pathways through which these compounds act and to come up with recommendations regarding valorification of these plants. The study focuses on ornamental plants in both spontaneous and cultivated flora, in protected or unprotected spaces, commonly met in Romania. The current review includes vegetal allergens in the toxic vegetal substances group, from the perspective of modern definitions of toxicity. Based on phytochemical criteria, a classification of toxic vegetal compounds (including allergens) was achieved. Common native toxic ornamentals from our habitat are tabulated. Some non-native species were included on the basis of their high presence as house plants. Correlated to the commercial practices in Romania, the risks for ambient health were identified, both at the work place, at home and in the public space. Ornamentals can be dangerous to man's health. The majority of toxic and allergenic substances (excluding pollens) are secondary metabolism compounds. Given these risk factors to health, it is necessary to impose health and safety regulations at work, to inform the general population regarding potential negative effects and to commercialize plants with labels which should contain warnings about the risk of diseases or the aggravation of existing ones.

Keywords: *allergenicity, biosecurity, ornamental plants, pathogenicity, toxicity*

INTRODUCTION

Plants have evolved the strategy to produce bioactive natural products as a means of defence against herbivores and pathogenic agents. Some of them produce toxins that can severely damage or kill an herbivore (Wink, 2009). In order to be effective, the defence compounds must be able to interfere with molecular targets of cells, tissues or organs in an herbivore. These toxic principles may cause serious problems to the human body or even death (Wink, 2009; Bernhoft, 2010; Gilbert, 2013).

Ornamental flowering plants could be dangerous in special circumstances related to the plant, way of exposure and potential victim (Piiirila, 1994; Crosby, 2004). Usually, undesired effects are registered by accident. Hazardous ornamentals

can be harmful through protective structures (Capon, 2011), pollens (Goldberg *et al.*, 1998) and chemical compounds (Gaillard and Pepin, 1999; Lewis, 2003; Wink, 2009). Toxicity, by and large as Kingsbury (2013) underlined, involves an interrelationship among dose, absorption, detoxification and excretion. The words "harmful" or "health problems" are anthropocentric. Quality and accessibility of information are central to effective management of all these problems, to prevent and reduce undesired happenings.

Interdisciplinary researches regarding plant toxins and plant allergens are being conducted worldwide (Huntington, 1999; Nelson, 2003; Crosby, 2004; Gilbert, 2004; Prisăcaru and Burlacu, 2005; Wink, 2011; Lăncrăjan, 2012; Rozas-Munóz *et al.*, 2012; Chadwick *et al.*, 2013; Fraga, 2013).

The aims of these researches are to prevent the occurrence of diseases, to increase economical uses of plants and plants products and to ensure biosecurity in human environment.

This review aims to phytochemically classify the allergenic and toxic compound from Romanian ornamental plants, to identify the main pathways of defined substances, to evaluate hazardous plant risk for human health and to create a local databases of common hazardous ornamentals. In compiling the review article, an extensive literature review was performed by searching internet resources: ISI Web of Science, Medline, Pub Med, Scopus, Google Scholar. Initial searching of these databases was done using specific keywords: 'plant', 'poisoning', 'poison', 'toxicity', 'allergenicity', 'secondary metabolites' to identify relevant articles and books. Further information was obtained from book chapters, relevant new reports and international databases. A focus on selected studies was combined with systematic methods of study-selection and results exploration (Philip, 2009) in order to present the most current researches for the present topic and to develop personal classification and local databases.

DEFINITION OF TOXIC PLANTS AND TOXIC COMPOUNDS IN PLANTS

Poisonous plants, generally accepted, are those which cause health problems or even death if a quantity of its stem, leaves, flowers, seeds, fruits, roots is ingested (Ionel *et al.*, 2000; Khajja *et al.*, 2011; Lăncrăjan, 2012). Some other plants are normally harmless but its may become toxic in condition of long term exposure or ingestion of high doses of vegetal parts or plant products. Research emphasized (Gaillard and Pepin, 1999; Lewis, 2003; Nelson, 2003; Wink, 2009; Bernhoft, 2010; Jack *et al.*, 2013; Kingsbury, 2013; McGovern and Barkley, 2013) that healthy problems can occur through different ways of exposure: ingestion, inhalation, contact (dermal, mucosal or eye contact). From these perspective, toxic plant, through its chemical compounds "kills, injuries or impairs an organism" (Crosby, 2004). Ornamental toxic plants are beauty plants, possible dangerous for humans, used in ornamental purposes but with different economic uses. These plants are daily companions for florists and horticulturists, being an underestimated occupational hazards (Piiirila, 1994; Goldberg *et al.*, 1998; Nelson, 2003;

Crosby, 2004; Le Coz *et al.*, 2011). Ornamentals are large scale used but are not properly labelled from a healthy perspective as Kingsbury (2013) has mentioned.

It has considered that a poison is a substance which, when administrated, inhaled, ingested, touched, is capable to damage or suppressed the normal function of an individual. Poisons cause undesirable effects in living organism. The term of toxic relate to poisonous or deadly effects on the body by breathing, eating, absorbtion or direct contact with a chemical (GHS United Nations, 2011). Natural poisons are produced by species of bacteria, fungi, protists, plants and animals. Plant poisons are bioactive phitochemicals produced as "secondary metabolites" (Wink, 2009; Bernhoft, 2010; Mogoşanu *et al.*, 2012). The major poisonous principles found among plants are organic compounds belonging to different chemical classes. These compounds elicit pharmacological or toxicological effects in man and animals depending on specific factors (Ciulei *et al.*, 1993; Gavrilescu, 2008; Mogoşanu *et al.*, 2012; Lăncrăjan, 2012). Bioactive natural products have important role in plant evolution and different biological effects (Kumar *et al.*, 2005; Iason *et al.*, 2012; Chadwick *et al.*, 2013; Tamilselvan *et al.*, 2014). Secondary metabolites have a broad range of biological activities: antimicrobial effects, antihelmintic properties, analgesic and anti-inflammatory actions, antihyperlipidic activity, effects on plant growth, insecticidal, insect antifeedant properties, mammalian antifeedant properties, acute mammalian toxicity, cytotoxic and antitumor properties. The level of efficacy cannot be generalized. Each compound has individual properties and therapeutic and economical significance.

CLASSIFICATION OF TOXIC COMPOUNDS IN PLANTS AND MECHANISM OF ACTION

A logical way to group poisonous plants is by their poisonous principle, which cause toxic reaction when ingested by humans and animals (Lewis, 2003). As Sekhar *et al.* (2012) have considered, there is a huge variety of plant poisons and it is difficult to organize "the myriad plant toxins in an understandable manner". Plant toxins can be classified based on their structural and chemical properties or according to the organ

system in the human body, which they affect. There are also classifications where plant toxins are described based on their mechanism of action, human fatal effect or forensic criteria. Different points of view are commonly met regarding the vegetal allergens and their definition as toxic substances. The relevant researches are reviewed in this paper.

Wink has conducted relevant researches regarding secondary metabolites, their importance, diversity and evolution. The author chemically classified secondary metabolites (2009) into two major groups: with nitrogen (alkaloids, non-protein amino-acids, amines, cyanogenic glucosides, glucosinolates, alkalamides) and without nitrogen (monoterpenes, sesquiterpenes, diterpenes, triterpenes, saponins, steroids, tetraterpenes, phenylpropanoids, coumarins, lignans, flavonoids, tannins, polyacetylenes, fatty acids, waxes, polyketides, carbohydrates, acids). Wink also reviewed plant toxins on the basis of important mechanism of action. Poisons are classified in three categories according to their oral toxicity, determined in rat experiments: class Ia – extremely hazardous (5mg or less per kg body weight); Ib – highly hazardous (5 to 50 mg/kg body weight); class II – moderately hazardous (50 to 500 mg/kg body weight) and class III – slightly hazardous (500 mg and more per kg body weight), as cited by Wink (2009) and Khajja *et al.* (2011). Toxins, which fall into the classes Ia, Ib and II interfere with central functions in an animal. The most poisonous substances are neurotoxins which affect the nervous system followed by cytotoxins and metabolic poisons that disturb the liver, heart, kidneys, respiration, muscles and reproduction (Wink, 2009). Poisonous plants of Europe were tabulated, with some details on their toxins and toxicology. Wink approached toxins of skin and mucosal tissues and their biochemical mode of action. The author included in that category phorbol esters, furanocoumarins, glycoside as ranunculin (precursor of protoanemonin) and calcium-oxalate needles.

Gilbert (2004) has focused on the toxicity of some of the better-known plants, organised by organ/system affected: skin, gastrointestinal, cardiovascular, nervous systems, liver and reproductive effects. Skin symptoms were explained through either an allergic antibody-mediated response or through direct-acting

chemicals. Crosby (2004) classified major skin allergenic vegetal compounds. Bernhoft (2010) categorised secondary metabolites on the basis of main chemical groups: glycosides, flavonoids and proanthocyanidins, tannins, mono and sesquiterpenoids and phenyl propanoids, diterpenoids, resins, lignans, alkaloids, furocoumarines and naphthodianthrones, peptides. The author mentioned medical uses of these compounds. Vegetal examples were cited. Sekhar *et al.* (2012) classified plant toxins on their structural and chemical properties: alkaloids, glycosidal toxins, tannins, proteins, volatile etheric layers, photosensitizing substances, antivitaminases, phytoestrogens, enzyme inhibitors. The author discussed chemical effects more than structural and chemical classes. This type of classification is met to other authors also (Zanoschi *et al.*, 1981; Ionel *et al.*, 2000).

Gaillard and Pepin (1999) have reviewed the main toxic plants responsible for human deaths throughout the world. Forty genera and species were reported. The authors have appreciated that the total number of deaths is difficult to establish. From ornamental plants the following were included: *Aconitum*, *Colchicum*, *Convallaria*, *Datura*, *Diffenbachia*, *Nerum oleander*, *Polygonatum*, *Ricinus*. Lewis (2003) elaborated a chemical classification of vegetal toxin on the main groups: glycosides, alkaloids, lectines, resins, element and nitrate absorption. Khajja *et al.*, (2011) have reviewed more than 50 Indian poisonous plant species according with forensic traits: toxic parts, toxic constituents, fatal dose and fatal period.

There are great number of international books, research articles and databases which refers to poisonous plants (Huntington, 1999; Frohne and Pfänder, 2005; Johnson and Johnson 2006; Harmful garden plants in Western Australia, 2009; Dauncey, 2010; Burrows and Tyrl, 2013; McKenzie, 2012; FDA Poisonous plants database, 2014), allergic contact dermatitis to plants and plants extracts (Jovanovic and Poljacki, 2003; Al Aboud, 2011; McGovern and Barkley, 2013), guidelines for designing spaces with low allergy impact (Cariñanos and Casares-Porcel, 2011) or to gardening with asthma (Esch *et al.*, 2001). All these references have discussed name and description of plant, poisonous parts and clinical symptoms. Comprehensive reports on plant

secondary metabolites have been elaborated by pharmacognosists: chemical description, laboratory determinations, medical uses, toxicology of plant constituents (Ciulei *et al.*, 1993; Mogoşanu *et al.*, 2012).

It is fact that virtually any substances can be harmful at specific concentration and specific conditions. Exposure could be anywhere in public spaces, work environment or private homes and gardens (Finkle, 2013).

Apart from internal organs, the skin and mucosal tissues of animals and humans can also be affected by several toxins. This is done through either an allergic antibody – mediated response or through direct-acting chemicals. For an allergenic type of response, it is not the first contact that produces the reaction, but rather the next. Although not a direct protection for the plant, pollens cause an allergic response in many people (Crosby, 2004; Gilbert, 2013).

POISONOUS AND ALLERGENIC COMPOUNDS IN ORNAMENTALS

On the basis of reviewed data we consider that vegetal toxic compounds include poisonous and also allergenic bioactive chemicals. This approach is in accordance with the research of Gilbert (2004) and Crosby (2004). Chemical classification based on structural and chemical properties, in our opinion, is the best way to centralize and understand the secondary metabolites. These traits allow to better organize identification of these principles from vegetal extracts.

Ornamentals haven't been toxicology evaluated as single groups of plants. These plants are beauty but can be hazardous for people. Information about their risk potential for health is important in managing potential problems. Ornamentals are daily companions, inside or outside, in private or public spaces. Poisonous compounds in ornamentals are tabulated (tab.1): chemical class, type of compounds and typical vegetal elicitors are mentioned. Irritant and allergenic compounds in ornamentals are tabulated (tab.2). Chemical compounds, typical elicitors and class of dermatotoxicity and possible sensitization are mentioned.

Floral species usually produce and accumulate a mixture of secondary metabolites with possible additive or even synergetic properties and activi-

ties. In Table 3, common toxic ornamentals from our habitat (poisonous and allergenic) are tabulated, with some details of their toxins and toxicology. Some non-native plants, even shrubs in their area of origin, were included on the basis of their high presence as house plants. Allergenic and poisonous weeds without ornamental characteristics were not included in the paper, despite their allergenicity (*Ambrosia* sp., *Artemisia* sp. etc.) or their toxicity (*Atropa belladonna*, *Conium maculatum* etc.).

Our classifications should be of use to botanists, chemists, horticulturists, health professionals, pharmacognosists. Romanian poisonous ornamental plant databases is subject of interest for landscape architects and landscape engineers, horticulturists, floral designers, enthusiasts in gardening and those with a concern for threats to human health in the environment.

Common toxic ornamental plants databases include general data: scientific and family name, common name, hazardous plant parts, toxicity class, hazardous active principles, class of symptoms. There are also some specific information we considered be of practical importance: human exposure, plant uses, human fatal dose and fatal period (if reported), occupational risk factor (if known). Sixty native ornamental plants (Şelaru, 2007) and ten nonnative ornamental houseplant were analysed. These centralised data could be a starting point for a national databases (poisonous plant information system).

OCCURRENCE AND FUNCTION OF SECONDARY METABOLITES IN PLANTS

Plants have involved the strategy to produce bioactive natural products as a means of defence against herbivores and microbes (Wink, 2009). Biosynthesis, transport and storage of secondary metabolites are usually complex processes in plants (Wink, 2009; Capon, 2011; Iason *et al.*, 2012).

In some species, the poisonous constituents occur throughout the whole plant. In others they are concentrated in one or more parts (Ciulei *et al.*, 1993; Mogoşanu *et al.*, 2012; Wink, 2009). The biosynthesis of secondary metabolites differ in terms of quantitative level, grade of toxicity, chemical structures, depending on the geographical and climate conditions (temperature, humidity, light), characteristics of soil, agrotechniques

Tab. 1. Notable poisonous compounds in ornamentals

Chemical compounds		Typical elicitors (example)
Class	Type	
1. Alkaloids		
True alkaloids	tropane alkaloids (hyoscyamine, atropine, scopolamine)	<i>Atropa belladonna</i> , <i>Datura stramonium</i> , <i>Hyoscyamus niger</i>
	pyridine alkaloids (ricinine) and piperidine alkaloids (coneine)	<i>Ricinus communis</i> <i>Conium maculatum</i>
	pyrrolizidine alkaloids (senecionine)	<i>Senecio</i> sp.
	quinolizidine alkaloids (lupinine)	<i>Lupinus</i> sp.
	isoquinoline alkaloids (curare/morphine, codeine) and amaryllis alkaloids (galantamine, nivalidine, narcissine)	<i>Capsicum</i> sp./ <i>Papaver</i> sp. <i>Galanthus nivalis</i> <i>Narcissus poeticus</i>
Protoalkaloids	indole alkaloids (harmine, ergotamine, vincamine)	<i>Passiflora</i> sp., <i>Ipomoea</i> sp., <i>Vinca</i> sp.
	colchicine, colchamine	<i>Colchicum autumnale</i> , <i>Gloriosa superba</i>
Pseudoalkaloids	capsaicin, dihydrocapsaicin	<i>Capsicum annum</i>
	diterpenes alkaloids (aconitine/delphinine)	<i>Aconitum</i> sp./ <i>Delphinium elatum</i>
2. Peptides (as lectines)	ricin, abrin	<i>Ricinus communis</i>
	crotine	<i>Croton</i> sp.
	snow-drop lectine	<i>Gallanthus nivalis</i>
3. Glycosides		
Cardiac (steroidal) glycosides	digoxin, digitoxin	<i>Digitalis purpurea</i> , <i>D. lanata</i>
	convalatoxin	<i>Convallaria majalis</i>
	adonitoxin	<i>Adonis vernalis</i>
	oleandrine	<i>Nerium oleander</i>
	proscillaridin A	<i>Scilla maritima</i>
Thioglycosides (glucosinolates)	hellebrim, hellebrigenin	<i>Helleborus niger</i>
	gluco-tropeolin	<i>Tropaeolum majus</i>
Cyanogenic glycosides	sinigroside	<i>Brassica</i> sp.
	aroin	<i>Arum</i> sp.
Saponins	tigonin	<i>Digitalis lanata</i>
	gitonin	<i>Digitalis purpurea</i>
	triterpene saponins	<i>Primula</i> sp.
	saponariosides A, B	<i>Saponaria officinalis</i>
Antraquinone glycosides	antron, anthranol, aloin A, B	<i>Aloe</i> sp.
Hydroquinone glycosides	arbutin	<i>Bergenia crassifolia</i>
Alcoholic glycosides	salicin, salicilin derivatives	<i>Primula</i> sp.
4. Aromatic compounds (other than glycosides)		
Phenols and derivatives	hydroquinone and derivatives	<i>Calluna</i> sp.
	salligenin	<i>Primula</i> sp.
Benzopyran and derivatives	coumarins and chromones	<i>Angelica arhangolica</i> , <i>Citrus</i> sp.
	flavonoids (flavan, flavone, isoflavone, catechins etc.)	Amarantaceae, Asteraceae, Euphorbiaceae, Iridaceae
Tannins	catehic, galic	<i>Geum urbanum</i> , <i>Potentilla erecta</i>
Antraquinones and derivatives	hypericin	<i>Hypericum perforatum</i>
5. Allyl derivatives	allicin	<i>Allium</i> sp.
6. Isoprenoides	monoterpenes, diterpenes, triterpenes, tetraterpenes, sesquiterpenes (luian, ambein, artegla A etc.)	<i>Inula helenium</i> , <i>Euphorbia</i> sp.
7. Other classes	amines, acids, essential oils etc.	<i>Citrus</i> , <i>Rosa</i> , <i>Dieffenbachia</i>

Tab. 2. Irritant and allergenic compounds in ornamentals

Chemical compounds		Typical elicitors (example)	Class of Dermato-toxicity	Sensitization
Class	Example			
Esters of diterpene polyols	phorbol esters	<i>Euphorbia</i> sp. (<i>E. pulcherima</i>)		
Organo sulphur compounds		simalbin, gluconapin, simgrin	<i>Brassica</i> sp.	
	Glucosinolates	glucoibrin, glucoibervirin	<i>Tropaeolum majus</i> , <i>Matthiola incana</i> , <i>Iberis sempervirens</i>	
	Allyl derivatives	allicin (diallyl thiosulfinate) and analogs	<i>Allium</i> sp.	Irritant contact dermatitis (ICD)
				No
Lactones	protoanemonin	<i>Anemone</i> sp., <i>Ranunculus</i> sp., <i>Caltha palustris</i> , <i>Pulsatilla vulgaris</i>		
Amines and amides	capsaicin	<i>Capsicum annuum</i>		
Calcium oxalate	calcium oxalate crystals (sand, aggregate, sharp needles)	<i>Dieffenbachia</i> sp., <i>Anthurium andreaeanum</i> , <i>Zantedeschia aethiopica</i> , <i>Narcissus</i> sp. (bulbs)		
Urushiods	resorcinol	<i>Phyllodendron</i> sp.		
Quinones and hydroquinones	primin	<i>Primula</i> sp. (<i>P. obconica</i>)		
Lactones	alantolactone, arteglin A, carabron, niveusin A, tulipalin A, tuliposid A	<i>Inula helenium</i> , <i>Dendranthema</i> sp, <i>Primula</i> sp., <i>Arnica longifolia</i> , <i>Helianthus annuus</i> , <i>Tulipa</i> sp., <i>Alstroemeria</i> sp.	Allergic contact dermatitis (ACD)	Yes
Essential oils (complex mixtures with aliphatic and alicyclic compounds)	geraniol, hydroxycitronellal, γ -methylionone, limonene	<i>Geranium</i> sp., <i>Rosa</i> sp., <i>Viola odorata</i> , <i>Citrus</i> sp.		
Furocoumarins (benzopyran derivatives)	angelicin, bergapten, psoralen, pimpinellin	<i>Angelica arhangelica</i> , <i>Citrus</i> sp.	Photo-toxicity (PT)	No
Polyhydroxy quinone	hypericin	<i>Hypericum perforatum</i>		
Terthienyls	α -therhienyl	<i>Tagetes patula</i>		

Tab. 3. Common Allergenic and Poisonous Ornamental Plants

Scientific name, Family	Common name	Hazardous plant parts	Toxi- city class	Main hazardous active principles	Expo- sure	Use	Human fatal dose, fatal period/ occup. disease	Class of symptoms
<i>Aconitum napellus</i> and related species, Ranunculaceae	Monkshood	All parts, especially tubers	Ia	Aconitine, aconine, hyaconitine, mesaconitine and other terpene alkaloids	IN	M	1-2 mg aconitine or 1-2 g root	NR (PNS) DG
<i>Adonis vernalis</i> , <i>A. estivalis</i> and related species, Ranunculaceae	Pheasant eye	All parts, especially aerial parts	Ib	Adonitoxin and other cardiac glycosides, aconidine	IN	M O	Fatal dose not reported	CV DG RE
* <i>Agave americana</i> , Agavaceae	Century plant	Leaves	II SKI PT	Saponins and Ca ⁺⁺ oxalate	DC IN	O A	Fatal dose not reported	DT HT
<i>Allium giganteum</i> , <i>A.</i> <i>ursinum</i> , <i>A. vineale</i> and related species, Liliaceae	Giant allium, bear garlic, wild garlic	All parts	SKI SKA	Allylsulfides	DC	M, C, AB, U	Occupational dermatitis reported	DT
* <i>Alstroemeria aurantiaca</i> , Liliaceae	Peruvian lily	All parts	SKA	Tulipoid A	DC	O	Occupational dermatitis	DT
<i>Anagallis arvensis</i> , Primulaceae	Scarlet pimpernel	All parts, especially roots	II	Cucurbitacin B, arvenin I and arvenin II triterpene saponens oxalates	IN	O M	Substantial ingestion	DG NR RE
<i>Anemone nemorosa</i> , <i>A.</i> <i>ranunculoides</i> , <i>A. coronaria</i> and related species, Ranunculaceae	Windflowers	All parts	II SKI	Ranunculin is converted enzymatically to protoanemonin (lactone)	IN DC	O M	Fatal dose not reported	OG NR (CNS) RE DT
<i>Angelica archangelica</i> , Umbelliferae	Angelica	Aerial parts	PT	Furocoumarins	IN, DC	M, A, O, C	Fatal dose not reported	DT
* <i>Anthurium andreanum</i> , Araceae	Anthurium	Leaves	SKI	Ca ⁺⁺ oxalate	DC IN	O	Occupational dermatitis	DT
<i>Aquilegia vulgaris</i> and other species, Ranunculaceae	Cohimbine	All parts, especially seeds	II	Cyanogenic glycoside	IN	A M AB	Ingestion of seeds has been fatal to children	NR RS
<i>Arnica montana</i> , <i>A. fulgens</i> , Asteraceae	Arnica	Aerial parts	SKA	Carabron (sesquiterpenlactone)	DC	M, O, C	Fatal dose not reported	DT (ACD)
<i>Arum maculatum</i> , <i>A.</i> <i>italicum</i> , <i>A. palaestinum</i> , Araceae	Cuckoopint	Aerial parts, berries, roots	Ia SKI	Aroin, cyanogenic glycosides, saponins, Ca ⁺⁺ oxalate raphides, formic acid	IN DC	M O	Substantial ingestion	CV, NR, T, OG, DT

<i>Caltha palustris</i> , Ranunculaceae	Marsh marigold	All parts	II SKI	Ranunculin, triterpene saponins, magnoflorine	IN DC	O	Strong irritant to skin	DG, RE, MU, DT
* <i>Capsicum annuum</i> and related species, Solanaceae	Bell peppers	Fruits	II SKI	curara, capsaicin, dicumarol	IN DC	O, A, M	0,15 mg/kgc curara	NR, RS
<i>Cheiranthus cheiri</i> , Brassicaceae	Wallflower	All parts, especially seeds	II	Cheirotoxin, cheiroid A and other cardenolides	IN	O	Not reported	CV, DG, RS
<i>Chrysanthemum cinerariaefolium</i> , Asteraceae	Pyrethrum daisy	Aerial parts, including flowers	SKA	Pyrethrosin	DC	O, M, AB	Occupational dermatitis reported	DT (ACD)
<i>Chrysanthemum coronarum</i> , Asteraceae	Garland chrysanthemum	Aerial parts including flowers	SKA	Ambrosin Chrysanthemin A, B	IN DC IH	O, C, M, A, AB	Occupational dermatitis reported	DT (ACD) RS
* <i>Citrus</i> sp., Rutaceae	Citrus	Juice, oil	PT	Bergapten (furanocoumarine)	IN, DC	O, A, C, M, U	Occupational photo-dermatitis reported	DT (PT)
<i>Colchicum autumnale</i> , Liliaceae	Autumn crocus, meadow safron	All parts, especially seeds and bulbs	Ia	Colchicine and related alkaloids	IN	M O	6-20 mg colchicin 5 g seeds (similar to arsenic)	DG, RE, CV, RS
<i>Consolida regalis</i> , <i>C. ajacis</i> , <i>C. orientalis</i> and related species, Ranunculaceae	Larkspur	All parts, especially seeds	Ia SKI	Delcosine, lycocotnine, delpheline and other terpenoid alkaloids	IN DC	O AB M	Substantial ingestion	NR PSI DG, CV, RS, DT
<i>Convallaria majalis</i> , Liliaceae	Lilly of the valley	All parts, flowers, fruits	Ib	Convallatoxin and other cardenolides, saponins	IN	O, A, C, U	Not reported, but extremely toxic	CV DG
* <i>Croton tiglium</i> and related species, Euphorbiaceae	Purging croton	Leaves, seeds and oil	Ia	Diterpen esters, crotin-a toxal-bumine, crotonic acid, crotonoside, tiglinic acid	IN DC	O	4-6 seeds 1-2 ml oil (6h to 3 days)	NR DT
* <i>Cyclamen persicum</i> , Primulaceae	Cyclamen	All parts, especially bulbs	II	Cyclamin and other triterpene saponins	IN	O	Not reported	DG, CV, RS
<i>Datura stramonium</i> , <i>D. innoxia</i> , Solanaceae	Thornapple	Flowers, leaves, seeds and roots	Ia	Hyoscyamine, scopolamine, atropine	IN	O, M, AB	0,6-1 g (24 h)	NR PSI (hallucinogen)
<i>Delphinium</i> sp, Ranunculaceae	Candle larkspur	All parts	Ib SKI	Delphinine, methyllycaconitine and other terpenoides alkaloids	IN DC	O, M AB	Substantial ingestion	GI, RE, GE, RS, CV, DT
<i>Dendranthema grandiflorum</i> , Asteraceae	Chrysanthemum	Aerial parts	SKA	Arteglasin A (epoxy lactone)	DC IH	O, A, C	Occupational dermatitis	DT

<i>*Dieffenbachia</i> sp., Araceae	Dumbcane	Leaves	SKI EI MI	Ca ⁺⁺ oxalate, proteases	IN DC EC	O	Extremely irritant if ingested/chewed	DT DG, ET
<i>Digitalis purpurea</i> , <i>D. lanata</i> and related species, Scrophu- lariaceae	Foxglove	All parts, es- pecially roots, la- veas	la	Purpurea glycoside A, B, E, lana- tosides, digitoxin, digoxin, digi- talin, digitonin, gitoxin	IN	O, M, AB, U	15-30mg digitalin 4 mg digitoxin (1h to 24h)	CV DG NR (CNS)
<i>Equisetum palustre</i> <i>Equisetum hyemale</i> <i>Equisetum fluviatile</i> <i>Equisetum ramossissimum</i> Equisetaceae	Marsh horse- tail	Aerial parts	II	Palustrine, palustridine, other alkaloids, thiaminase, saponins	IN	O	Not reported	Antivamine B ₁ , NR (PNS), GI
<i>Eranthis hyemalis</i> , Ranuncu- laceae	Winter aco- nite	All parts, espe- cially tubers	Ib	Eranthin A, B and other cardiac glycosides	IN	O M	Substantial inges- tion	CV, DG, NR
<i>Erysimum crepidifolium</i> , <i>Erysimum diffusum</i> Brassicaceae	Wall flowers	All parts, espe- cially seeds	Ib	Erysimoside helveticoside and other cardiac glycosides	IN	O	Substantial inges- tion	GI, NR (CNS), CV
<i>*Euphorbia marginata</i> , <i>E. lath- yris</i> , <i>E. helioscopia</i> and related species, Euphorbiaceae	Euphorbia	All parts, espe- cially latex and seeds	II SKI EI	Phorbol esters in latex, triterpe- noids * <i>E. pulcherrima</i> without phor- bol esters (less toxic)	IN DC EC	O AB U	Extremely irritant	DG, CV, RE, NE, DT ET
<i>Fritillaria imperialis</i> , Liliaceae	Crown impe- rial	Especially bulbs	II SKA	Imperiline and other steroid al- kaloids, tuliposide A, tulipalin A (SQ)	IN DC	O	Not reported	NR, DG, RE, CV, DT (ACD)
<i>Galanthus nivalis</i> , Amarylli- daceae	Snow drop	Mainly bulbs	II	Galanthamine, lycrene and other alkaloids	IN DC	O	Substantial inges- tion	NR (PNS) DG
<i>Glaucium flavum</i> Papaveraceae	Yellow horn- poppy	All parts	II	Glaucine, magnoflorine, protopi- ne, other isoquinoline alkaloids	IN	O M	Substantial inges- tion	NR, PSI, GE, DG
<i>Helianthus annuus</i> , Asteraceae	Sunflower	Flower, aerial parts	SKA	Niveusin A (sesquiterpenlac- tone)	DC IH	A, O, C, U	Occupational der- matitis	DT (ACD) RS
<i>Helleborus viridis</i> , <i>H. niger</i> and other related species, Ranunculaceae	Hellebore	All parts, espe- cially aerals	la SKI	Cardiac glycosides (bufadien- olides), hellebrin, steroid sap- onins (helleborin), ranunculo- side, alkaloids (celliamine)	IN	O M	Substantial inges- tion	CV DG NR DT
<i>Hellenium autumnale</i> , Aster- aceae	Elena's flow- ers	Aerial parts	SKA	1-0metil, 1-4,5dihidro-niveusin A	DC	O	Fatal dose not re- ported	DT (ACD)

<i>Heracleum mantegazzianum</i> , Apiaceae	Giant hog-weed	All parts	II	8-methoxypsoralen and other furanocoumarins	IN	DC	O	Fatal dose not reported	DT (PT) MU DG
<i>Hypericum perforatum</i> , Hypericaceae	St. John's wort	Aerial parts, especially flowers; oil	PT SKA	Hypericin, protohypericin, chironones and hydrochironones	DC	DC	A, O, M, U	Occupational disease	DT (PT) ACD
<i>Ipomoea coerulea</i> , I. <i>tricolour</i> ; Convolvulaceae	Morning-glory	Seeds	Ib	Indolic alkaloids (ergotamine, ergotoxine)	IN	IN	O	Fatal dose not reported	NR
<i>Iris germanica</i> , Iridaceae	Purple flag	Seeds, rhizomes	SKA	20-primin relatives; irisquinone	DC	IN	A, O, M, C, U	Substantial ingestion	DT (ACD) DG
<i>Leucojum vernum</i> , <i>Leucojum aestivum</i> Amaryllidaceae	Spring snowflake	Bulbs and aerial parts	II	Lycorine, galanthamine, tazettine and other alkaloids	IN	IN	O	Not reported	NR (PNS) DG
<i>Lupinus polyphillus</i> , and related species, Fabaceae	Lupin	All parts, especially seeds	Ib II	Lupanine, sparteine, anagyrine and related quinolizidine alkaloids	IN	IN	O M	Fatal dose not reported	DG, T, GE CV, NR
<i>Narcissus pseudonarcissus</i> and related species, Amaryllidaceae	Daffodil	All parts, especially bulbs	Ib-II SKI SKA	Lycorine, haemanthamine, narcissine, tazettine and other isoquinoline alkaloids; Ca ⁺⁺ oxalate crystals	IN	DC	O	Occupational dermatitis reported	DG RS DT (ACD)
<i>*Nerium oleander</i> , Apocynaceae	Oleander	All parts, seeds, nectar, honey, leaves	Ia	Oleandrin and several other cardenolides (neriodorin, neriodorein, karabin)	IN	IN	O	15-20 g roots (24-36 h) > 4 seeds	CV, DG, NR, RS
<i>Nuphar lutea</i> Nymphaeaceae	Nuphar	All parts	II	Nupharine, desoxynupharidine and other simple quinolizidine alkaloids	IN	IN	O	Not reported	NR (PNS) PSI CV
<i>Nymphaea alba</i> Nymphaeaceae		All parts	II	Nupharine, nymphaeline, aporphine	IN	IN	O	Not reported	NR (PNS) PSI, CV
<i>Ornithogalum umbellatum</i> , Liliaceae	Star-of-Bethlehem	All parts, especially bulbs and flowers	Ib	Convallatoxin and other cardenolides in bulbs, prasinolide G and other steroid glycosides	IN	IN	O	Not reported	CV DG NR

<i>Oxalis acetosella</i> and related sp. Oxalidaceae	Wood sorrel	All parts	II SKI	Ca ⁺⁺ oxalateas	IN DC	Death reported	DT, DG CV, NR
<i>Papaver rhoeas</i> , <i>P. somniferum</i> and other poppy species, Papaveraceae	Papaver	All parts, especially latex (immature seed capsule); flowers, seeds	II	Isoquinoline alkaloids; protopine, berberine, rhoeadine	IN	2g opium 0.2g morphine	NR DG
<i>Paris quadrifolia</i> , Melanthiaceae	Herb True Knot	All parts, especially fruits	II-III	Pariden, aristophen and other steroidal saponins	IN	Not reported	NR (CNS) DG, RE, RS
<i>Phalaris arundinacea</i> , <i>P. aquatica</i> , <i>P. canariensis</i> , <i>P. minor</i> , <i>P. tuberosa</i> , Poaceae	Reed grass	Aerial parts	III	Trypstatamine derivatives, gramine, DMT, bufotenin	IN	Not reported	NR PSI (hallucinogenic, psychedelic)
<i>*Philodendron</i> sp. Araceae	Phylodendron	All, especially leaves and stem	MI SKI EI	Calcium oxalate	IN DC EC	Reported in children	RE, DG, DT, ET
<i>Polygonatum multiflorum</i> , <i>P. odoratum</i> , <i>P. verticillatum</i> , Liliaceae	Solomon's seal	All parts, especially fruits	II-III	Acetidine2carboxylic acid, steroid glycosides	IN	Only high doses	DG CV NR (CNS)
<i>Primula</i> sp., <i>P. obconica</i> , Primulaceae	Primrose	All parts, especially flowers	II SKA	Primuline A; primula saponin A; priverogenol; primin (quinone) and related hidro-quinones; Phenols (resorcinols), ethers	IN DC	Substantial ingestion ; occupational dermatitis reported	CV DG DT (ACD)
<i>Pulsatilla pratensis</i> , <i>P. vulgaris</i> , Ranunculaceae	Pasque flower	All parts	II SKI	Ranunculin, protoanemonin, saponins	IN DC	Substantial ingestion	GI, RE MU, DT
<i>Ranunculus acris</i> , <i>R. bulbosus</i> , <i>R. multifidus</i> , <i>R. sceleratus</i> , Ranunculaceae	Buttercup	All parts	Ib-II SKI	Ranunculin is enzymatically converted to the active protoanemonine (lactone)	IN DC	Extremely irritant	DT, DG, CV, RE, RS
<i>Rhododendron ponticum</i> , <i>Rhododendron ferrugineum</i> Ericaceae	Rhododendron	All parts, nectar (honey)	Ib	Rhododendron andromedotoxin triterpens arbutin	IN	Not reported	DG NR (CNS) RS
<i>Ricinus communis</i> , Euphorbiaceae	Castor bean	Seeds, oil	Ia	Ricin (a lectine), ricinine (pyridine alkaloid), ricinolic acid (fatty acid)	IN	6 mg of ricin, 10 seeds for adults or 6 seeds for children	Multisystemic organ failure; DG RE NR CV
<i>Scilla bifolia</i> , <i>S. maritima</i> , Liliaceae	Squill	All parts, especially bulbs and seeds	Ib	Saponins, proscillaridin A and other bufadienolides, scillarine	IN	Not reported	CV DG

<i>Sedum acre</i> , Crassulaceae	G o l d m o s s stonecrop	All parts	II	Sedamine, sedinine, other piper- idine alkaloids	IN	O	Not reported	DG, NR, RS
<i>Senecio jacobaea</i> , <i>S. latifolius</i> and other ragwort species, Asteraceae	Ragwort	All parts, especially flowers	II SKA	Senecionine and other pyrrolizidine alkaloids	IN	M O	Not reported	HT MU, NR DG, DT
<i>Solidago</i> sp. Asteraceae	Golden rods	Pollen	RA	Diterpenes	IN, IH, DC	O, M, A, U	Not reported	RS (pollen allergy) DT DG
<i>Tagetes patula</i> , Asteraceae	French marigold	Leaves, flowers	PT SKA	Carotenoids, flavons (α -terthienyl), lactones	DC	A, AB, O, U, M	Not reported	DT (APT)
<i>Trollius europaeus</i> , Ranunculaceae	Globe-flower	All parts	Ib-II SKI	Ranunculin, protoanemonin	DC IN	O	Not reported	DT, DG, CV, RE, RS
<i>Tropaeolum majus</i> , Tropaeolaceae	Garden nasturtium	Seeds, aerial parts	I	Glucosinolates	IN DC	A, O, M, AB, U	Substantial ingestion	NR DG, DT, RE
<i>Tulipa</i> sp., Liliaceae	Tulip	Bulb	SKA	Tulipalin A (hemiterpene lactone)	DC	O	Occupational dermatitis ("tulip fingers")	DT (ACD)
<i>Vinca minor</i> , <i>V. major</i> , Apocynaceae	Periwinkle	Aerial parts	III	Indolic alkaloids (vincamine)	IN	O M AB	Substantial ingestion	NR DG
<i>Viola odorata</i> Violaceae	Violet	Aerial parts, rhizomes and seeds	II, III	Flavonoids, saponins, alkaloid (odoratine), volatile oil	IN	O, C M, A	Not reported	GI, CV NR, RS

Toxicity class: Ia-extremely hazardous, Ib-high hazardous, II-moderately hazardous, III-slightly hazardous, SKI-skin irritant, SKA-skin allergy,

PT-phototoxicity, MI-mucosal irritant, EI-eye irritant, RA-respiratory allergy

Exposure: IN-ingestion, DC-dermocontact, IH-inhalation (of dried aerial parts or smoke from burned parts), EC-eye contact

Use: M-medicinal, A-alimentary, C-cosmetics, O-ornamental, AB-biologic agriculture (including pesticides), U-other uses (colouring, oils, industrial products), H-homeopathy

Class of symptoms: DG-digestive, NR-neurological (CNS-central nervous system, PNS-peripheral nervous system), PSI (psychoactive), HT (hepatotoxicity),

RS-respiratory, GE-genito-reproductiv, CV-cardio-vascular, RE-renal, T-thermoregulation, MU-mutagenic and carcinogenic,

DT-dermatotoxicity, ACD-allergic contact dermatitis, ET-eye toxicity

Other: occup. disease - occupational disease

* Non native plants (houseplants/cut flowers)

(water supply, fertilization, time of harvesting), plant age, species and sometimes depending on the microbiological invasions (bacteria, viruses, fungi) (Kumar *et al.*, 2005; Hansen and Wold, 2010; Nasim *et al.*, 2010; Adeyemi, 2011; Fraga, 2013).

Sahoo *et al.*, (2012) have evaluated the variations in the total amount of secondary metabolites during different seasons in India, in five important valuable medicinal plants. The results revealed that maximum amount of secondary metabolites (total alkaloids and phenols) were observed during summer, while minimum in rainy season. Growth parameters including plant height, herb fresh and dry weights were reduced significantly with increasing water stress levels in a study conducted by Azhar *et al.*, (2011). In the same study, total phenolic contents and chlorophyll contents increased under water stress conditions. Seasonal variation in the production of secondary metabolites and antimicrobial activity were observed in two Brazilian plant species (Chaves *et al.*, 2012). Growth regulators had significant effects on the secondary metabolite production (Karaliya and Parić, 2011). After addition of plant growth regulators to the medium (BA, IBA) elicitation of phenolic compounds was recorded and the same treatment showed a decrease in monomeric anthocyanins.

Species of plants vary in their content of toxic compounds owing to unpredictable extrinsic and genetic factors (Kingsbury, 2013; Azeez and Ibrahim, 2013).

PLANT POISONING

Human fatal cases are the fact of about 40-50 genera throughout the world (Gaillard and Pepin, 1999). Usually, undesired effects are registered by accident. Poisoning by plant is underestimated worldwide.

It is interesting to note that the plants most commonly enquired about at Poison Control Centres in Switzerland and the United States are only 5 genus (*Euphorbia*, *Dieffenbachia*, *Pyracantha*, *Ilex* and *Philodendron*) and they are the common causes of poisoning in both areas (Frohne and Pfänder, 2005). The Swedish Poison Information Centre (PIC) received 4514 inquiries about children exposed to plants in 2008. Ornamentals commonly involved were: *Convalaria majalis*, *Digitalis purpurea*, *Spathiphyllum wallissi*, *Euphorbia pulcherrima*, *Crassula sp.*, *Epipremum*

aureum, *Dieffenbachia sp.*, *Zamioculcas zamifolia* (Spillum and Muan, 2010). In New Zealand National Poison Centre 15 plants are commonly reported (child and adult enquiries). Ornamentals involved are: *Zantedeschia aethiopica*, *Euphorbia sp.*, *Spathiphyllum sp.*, *Agapanthus sp.*, *Iris foetidissima*, *Colocasia esculentum*, *Narcissus sp.*, *Nerium oleander*, *Digitalis purpurea* (Slaughter *et al.*, 2012).

SUMMARY AND PERSPECTIVES

As mentioned in the previous sections, ornamental plants may be hazardous for human health through vegetal constituents (irritant, allergenic or poisonous). It is important to know these plants and their biochemical products in order to avoid intoxication or skin exposure in humans (especially children), pets or livestock.

Toxic plants or their compounds are also used for different purposes. Secondary metabolites are source in the production of several valuable products (agrochemicals, biopesticides, colours, flavours, fragrances, food additives and pharmaceuticals). The commercial value of plant secondary metabolites have been the main reason for the enormous research effort put into understanding and manipulating their biosynthesis and the cultivation of specific plants including ornamentals. Several investigation have shown that there is a large genetic variation for concentration of these substances and this variation can be exploited.

We think that more effort should be invested in research on toxic compounds of ornamental plants. The risk to health impose health and safety regulations at work, the need to inform population and the evaluation of natural remedies and cosmetic products from plants through an poisonous and allergenic perspective. Many ornamentals represent a valuable source of highly biologically active compounds and could have greater economic uses. A national poisonous plants databases will allow people to access information, to avoid undesired effects and to increase biosecurity in human environment.

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