

ORIGINAL RESEARCH ARTICLE

Profile and consequences of intentional plant intoxication in Morocco: a retrospective study over a 13-year period

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ABSTRACT

Inappropriate use of plants represents a significant public health risk that is often underestimated. This study aims to determine the profile and consequences of intentional plant intoxication in Morocco over a 13-year period. This study was based on a retrospective analysis of cases of intentional plant intoxication reported to the Moroccan Poison Control and Pharmacovigilance Centre (MPCPC) between 1 January 2010 and 31 December 2022. The significance level was set at 5%. During the study period, the MPCPC recorded 189 cases of intentional herbal intoxication, representing 9.37% of all herbal intoxications occurring during this period (2016 cases). The average age of the patients was 29.77 years, with the majority being young adults (68.25%), adolescents (14.28%) and children under 15 (7.93%). The sex ratio (M/F) was 0.41 (71.04% female). Suicide attempts were the main cause of poisoning (87 cases), with *Atractylis gummifera* being the most commonly implicated plant (17 cases). Twenty-two cases were related to abortions, mainly caused by *Peganum harmala* (45.45%), drug addiction (16 cases), of which *Datura stramonium* was the most incriminated plant (5 cases), and plant mixtures (63.63%) were the most commonly used in criminal activities (11 cases). The route of administration was mainly oral (162 cases). Digestive, neurological and cardiac disorders, renal failure, rhabdomyolysis and liver damage were reported. The outcome was favourable in 103 cases, fatal in 4, including a 9-year-old girl who ingested *Rumex divers*, with sequelae in 2 cases and unknown in 80 cases. Calculation of the p-value revealed that several variables were highly significant. Inappropriate use of plants poses a significant risk to public health. It is essential to raise awareness of the dangers associated with these plants and to emphasise the importance of appropriate psychiatric support in cases of intentional intoxication.

Keywords: intentional poisoning; toxic plants; inappropriate use; public health; Morocco

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1. Introduction

Plant poisoning is a public health problem due to its frequency and severity^[1,2]. The incidence of plant poisoning is estimated to be about 1.5% in France, 5% in Belgium, 6.5% in Italy, 7.2% in Switzerland and 6% in Turkey^[3]. The number of deaths remains difficult to establish and is probably underestimated because of the difficulty of carrying out analytical work on the subject^[3]. The number of deaths remains difficult to establish and is probably underestimated, as it is difficult to

carry out analytical work on the subject^[4]. However, about forty plants (genus or species) are responsible for 95% of the deaths from plant poisoning published in the literature^[5].

Poisoning is defined as an interaction between a foreign chemical and a biological system that results in damage to a living organism^[6]. A plant is considered toxic if it contains one or more substances that are harmful to humans or animals and if its use causes more or less serious or even fatal disorders^[7,8].

The use of plants can have different motives: accidental, linked to dietary habits, linked to traditional medicine, or linked to a voluntary search for intoxication with the aim of suicide or homicide^[9]. Before the age of five, intoxication is generally accidental, but it is important to rule out the possibility of maltreatment. After the age of five, the possibility of intentional poisoning must be systematically considered^[10].

In 2013, WHO estimated that 300,000 people die each year as a result of poisoning^[11]. The majority of these deaths occur in low- and middle-income countries and are associated with intentional pesticide poisoning^[12,13].

In Morocco, reports of poisoning to the Moroccan Poison Control and Pharmacovigilance Centre (MPCPC) show that the use of plants is far from negligible and is practised in an irrational, anarchic and uncontrolled manner^[14].

In fact, Morocco's geographical location, climatic data and soil diversity favour a significant floristic biodiversity in the country^[15,16]. These heterogeneous ecological conditions favour the proliferation of more than 42,000 plant species belonging to 150 families and 940 genera^[17]. Morocco is thus considered one of the Mediterranean countries with the most diverse plant potential. This floristic diversity provides a range of medicinal plants that people can use in a variety of circumstances^[18,19]. However, although plants are an essential part of traditional therapy, their inappropriate use can sometimes have serious or even fatal consequences. According to MPCPC statistics, plants rank first among the most lethal poisons^[20].

Plant poisoning in Morocco represents 5.1% of all poisoning cases reported to the MPCPC between 1980 and 2008, of which 33.4% are intentional. According to the same study, the mortality rate of plants is one of the highest for a toxic product in Morocco, with a mortality rate of 7.3%, of which 66.7% of fatal cases were observed in children^[21]. Previous studies by the same centre (MPCPC) showed that plants were involved in 3-5% of all poisonings, but resulted in a relatively high mortality rate, estimated at 17%^[22,23]. Thus, overuse of plants can lead to acute and chronic poisoning, sometimes fatal^[22]. These are all the more serious when the use is intentional. A study carried out in the Fès-Boulemane region between 1980 and 2007 showed that 19.3% of deaths were related to plants and 83.3% of voluntary poisonings were suicide attempts^[24].

Furthermore, one study estimated the average direct cost of treating poisoning in Morocco to be US\$157, or 60% of the country's monthly national minimum wage. Total direct medical costs accounted for 80%, compared with 20% for direct non-medical costs^[25]. The average length of stay for intoxicated children was 2.15 ± 1.87 days, ranging from a few hours to 10 days^[25].

These statistics show that the inappropriate use of plants represents a significant public health risk, which is often underestimated. The severity of plant poisoning depends on many factors: the type of plant, the part consumed, the quantity, whether it was consumed on an empty stomach or not, age and circumstances^[21]. Depending on the circumstances, these poisonings can be accidental, when the type of exposure to plants is classical, or the result of a therapeutic or professional error, a dietary error or an adverse reaction; or deliberate, when the exposure is deliberate with malicious intent, especially in the subcircumstances of suicide attempts, abortion, drug addiction or criminal acts.

It is therefore necessary to regularly monitor the epidemiology of this type of poisoning, especially as data on this problem are still scarce. Few studies have been carried out on plant poisoning in Morocco, and none specifically on intentional plant poisoning. However, a better understanding of the consequences of

intentional plant ingestion can improve patient management and avoid confusing assessments in health care settings. The aim of this study is to investigate the characteristics and consequences of intentional plant exposure in Morocco over a period of 13 years.

2. Materials and methods

This is a retrospective, descriptive study of cases of plant poisoning reported to the MPCPC between 1 January 2010 and 31 December 2022. Data were collected by the Toxicovigilance Unit of the Moroccan Poison Control and Pharmacovigilance Centre (MPCPC) using two information systems: Toxicovigilance and Toxicological Information.

The data were then entered into a national database and analysed using Excel and Epi Info 3.3.2 software. From this database, all cases of plant poisoning corresponding to the study period were selected. These represent the general cases of plant poisoning, classified in a general table. From this table, only intentional poisonings were selected to form our study sample.

The aim of this study was to gain a better understanding of the characteristics of intentional plant exposures. To this end, the following variables were included: patient demographics, plant involved, exposure characteristics, route of intoxication, symptoms and outcome of intoxicated patients. The analytical study also identified the risk factors associated with this type of intoxication.

The scientific name of the plant was given according to the international binomial nomenclature, which consists of two Latin words (genus then species). The term "mixture" refers to preparations based on a combination of plants, either powdered or combined with honey or oil.

Age groups were classified according to the WHO International Programme on Chemical Safety (IPCS) guidelines: newborn (<4 weeks), infant (4 weeks - <12 months), toddler (1-4 years), child (5-14 years), adolescent (15-19 years), adult (20-74 years), elderly (>75 years)^[26].

The severity of intoxication was assessed using the Poisoning Score Severity (PSS) scale^[27]. The following grading system was used. Grade 0 (no signs or signs unrelated to intoxication); Grade 1 (signs resolved spontaneously); Grade 2 (marked or moderate signs, treatment required); Grade 3 (severe intoxication with vital risk); Grade 4 (fatal intoxication).

Symptomatology was classified according to the WHO Adverse Reaction Terminology (ART)^[28].

Differences are considered significant if the p-value $p < 0.05$.

3. Results

During the study period, MPCPC recorded 189 cases of intentional plant poisoning, representing 9.37% of all plant poisoning cases during the same period (2016 cases). The results for the variables studied are as follows:

✓ Indicators related to intoxicated persons

The average age of the patients was 29.77 years, mostly young adults (68.25%), adolescents (14.28%) and children under 15 years (7.93%) (**Figure 1**).

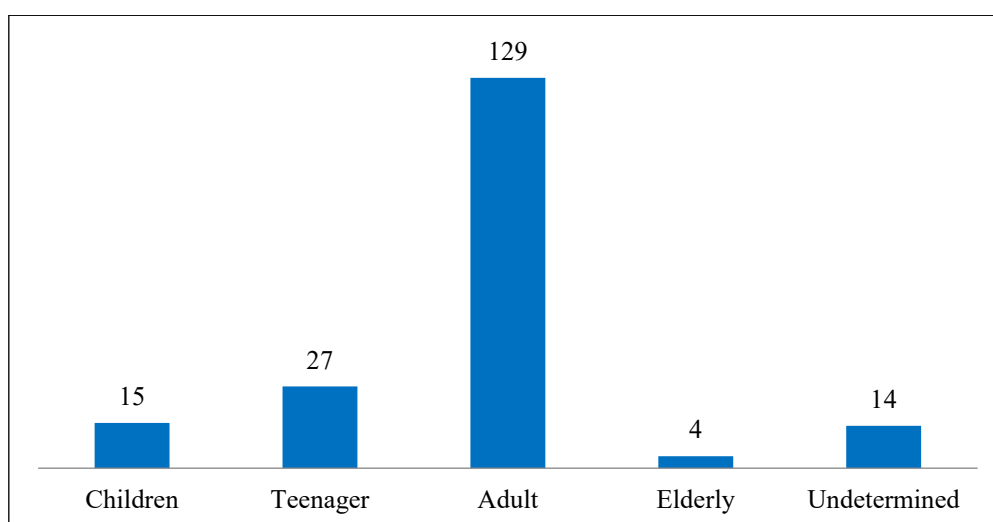


Figure 1. Distribution of intentional plant poisoning by age group, MPCPC, 2010-2022.

The sex ratio (M/F) was 0.41, indicating that women constitute the majority of victims of intentional poisoning, with a percentage of 71.04% versus 28.96% for men.

✓ **Poisoning indicators**

The majority of these incidents transpired in urban areas (80.24%).

The preponderance of these incidents occurred within the residential domicile (91.62%).

The majority of these incidents were considered to be isolated cases (74.6%). The initial severity of intoxication was determined to be moderate (with pronounced signs) in 52.94% of cases, severe in 16.67%, and unclassifiable in 85.29% (**Table 1**).

The predominant route of administration was oral, as evidenced by the 162 cases depicted in **Figure 2**.

Of the 157 patients for whom symptomatology was specified, 51.59% were symptomatic (**Table 2**). The patient exhibited multiple organ system involvement, with various systems affected simultaneously. The observed organ systems included the digestive system, neurological system, cardiac system, renal failure, rhabdomyolysis, and liver damage.

The results were favorable in 103 cases (94.5%), fatal in 4 cases (yielding a specific case-fatality rate of 3.67%), and left sequelae in two cases, while the outcome remained unknown in 80 cases (**Table 2**).

Table 1. Distribution of intentional plant intoxications by environment, location, type and gradation, MPCPC, 2010-2022.

Poisoning environment	Number of cases	Percentage (%)	p-value
Rural	33	19,87	<0,001
Urban	133	80,24	
Unspecified	23	-	
N active	166	100	
Place of intoxication	Number of cases	Percentage (%)	
Home	153	91,62	<0,001
Public place	12	7,18	
Professional environment	1	0,6	
School	1	0,6	
Unspecified	22	-	
N active	167	100	

Type of intoxication	Number of cases		Percentage (%)	p-value
Collective	2		1,08	<0,001
Isolated	183		98,92	
Unspecified	4		-	
N active	185		100	
Gradation	Initial grading (Number of cases)	(%)	Final grading (Number of cases)(%)	p-value
0 : No signs	20	(19,61)	26 (20,8)	<0,001
1 : Signs spontaneously regressive	11	(10,78)	17 (13,6)	
2 : Pronounced signs	54	(52,95)	72 (57,6)	
3 : Severe intoxication with vital risk	17	(6,67)	6 (4,8)	
4 : Death	0	(0)	4 (3,2)	
Unclassifiable	87	-	64 -	
N active	102	100	125 100	

Table 1. (Continued)

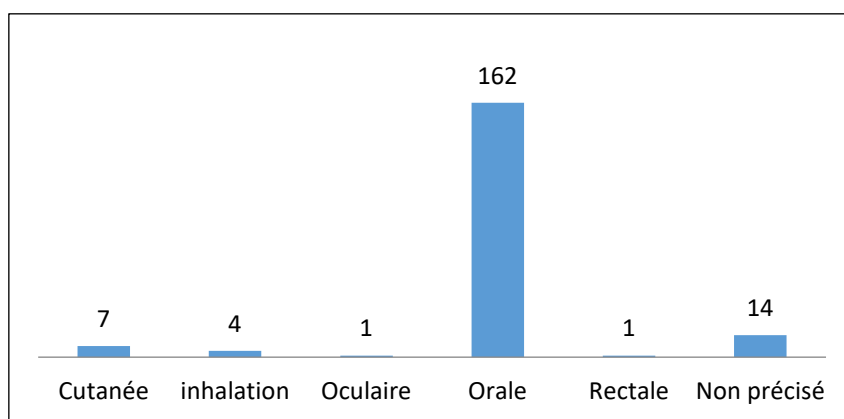


Figure 2. Distribution of intentional herbal intoxication cases by route of administration, MPCPC, 2010-2022.

Table 2. Distribution of intentional herbal intoxications by type of risk, symptomatology and evolution of intoxication cases, MPCPC, 2010-2022.

Type of risk	Number of cases	Percentage (%)	p-value
Definite intoxication	25	21,37	<0,001
High risk	38	32,48	
Moderate risk	53	45,3	
No risk	1	0,85	
Not specified	72	-	
N active	117	100	
Symptomatology	Number of cases	Percentage (%)	p-value
Symptomatic	81	51,59	<0,001
Asymptomatic	76	48,41	
Unspecified	32	-	
N active	157	100	
Evolution	Number of cases	Percentage (%)	p-value
Favorable	103	94,5	<0,001
Sequelae	2	1,83	
Death	4	3,67	
Unknown	80	-	
N active	109	100	

Statistical analysis revealed significant disparities (p much lower than 0.05) in the following variables: environment, location and type of intoxication, gradation, type of risk, symptomatology and evolution.

With regard to the subcircumstance of intentional plant use, when identified, the distribution of cases showed that it involved four classes: suicide attempts, abortions, drug abuse and criminal acts (**Figure 3**).

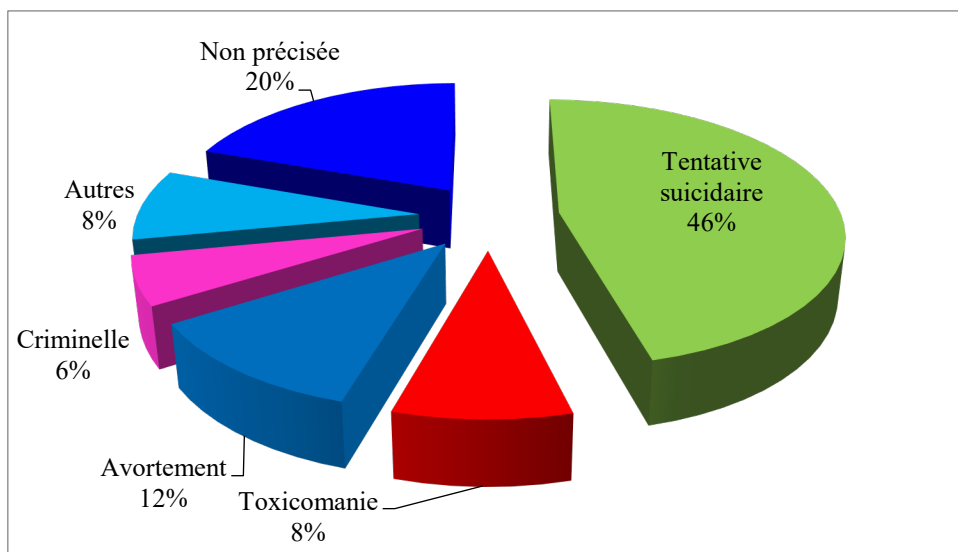


Figure 3. Distribution of intentional intoxication cases by subcircumstance, MPCPC, 2010-2022.

✓ Indicators relating to intoxicated persons

Suicide attempts were the main reason behind intentional intoxication (87 cases), with *Atractylis gummifera* the most incriminated plant (17 cases) (**Figure 4**).

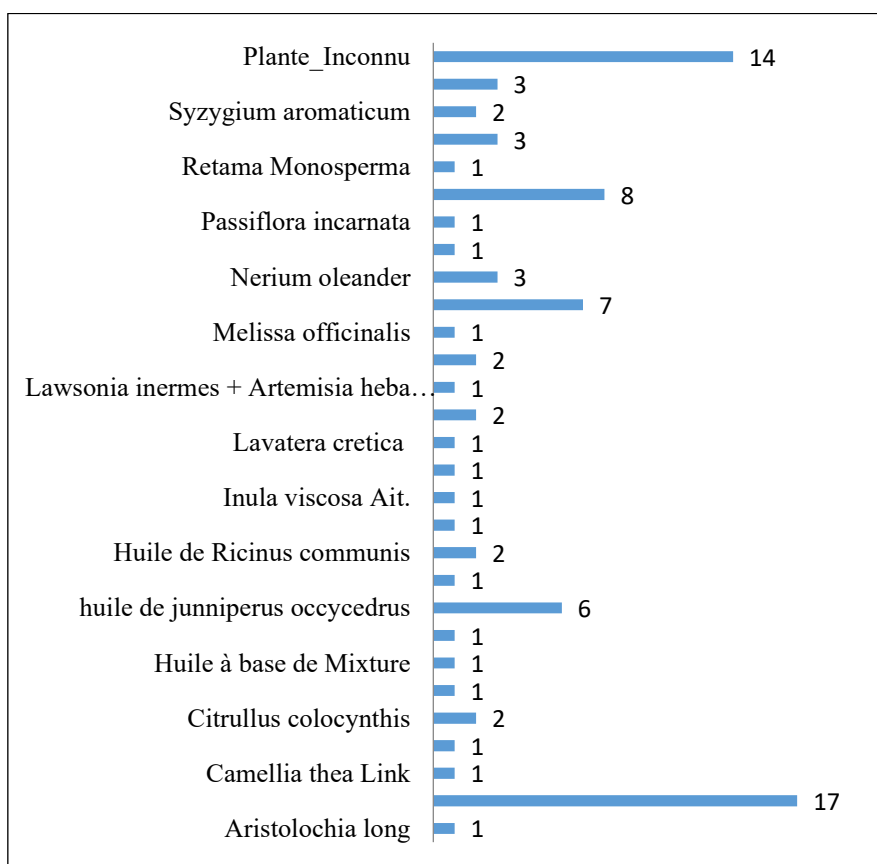


Figure 4. Graphical representation of plants implicated in suicidal attempts, MPCPC, 2010-2022.

A total of 22 cases of abortion were documented, with *Peganum harmala* identified as the primary substance utilized in 45.45% of cases (**Figure 5**). The analysis revealed that 16 cases were associated with drug addiction, with *Datura stramonium* identified in five instances, as depicted in **Figure 6**. In criminal acts, plant mixtures (63.63%) were the most commonly used (**Figure 7**).

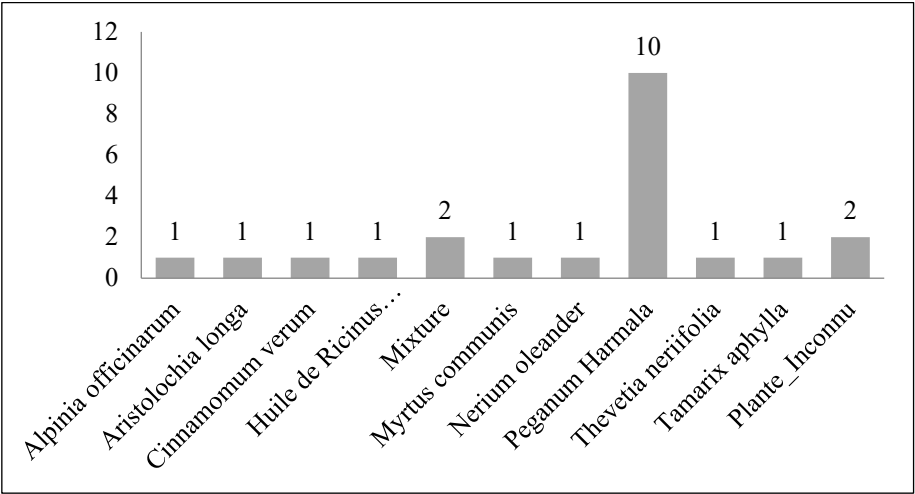


Figure 5. Plants involved in intoxications following abortions, MPCPC, 2010-2022.

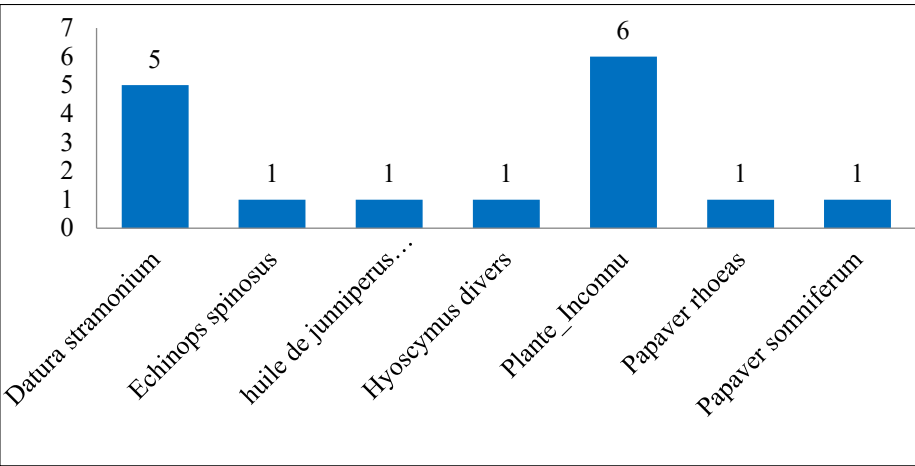


Figure 6. Plants involved in drug poisoning, MPCPC, 2010-2022.

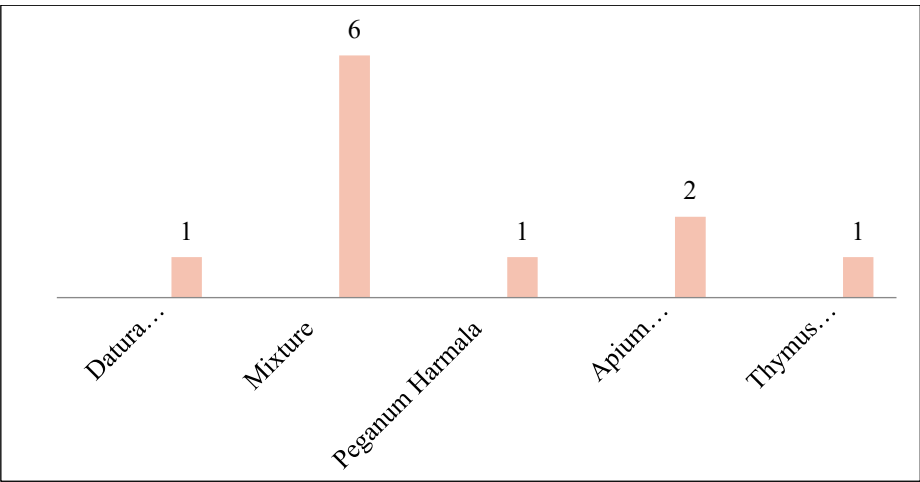


Figure 7. Plants involved in criminal intoxication, MPCPC, 2010-2022.

✓ **The following indicators pertain to fatalities**

A total of four cases were fatal, predominantly affecting females residing in rural areas (75%), including a 9-year-old girl who ingested *Rumex divers*, a woman who ingested *Peganum harmala*, and a third individual who ingested *Atractylis gummifera*. The plant utilized in the fourth case could not be identified. The duration of intoxication exhibited a range from 24 to 96 hours. It is noteworthy that the utilization of the oral route and home use were observed in all four patients who were hospitalized, although the duration of hospitalization remained unclear in 50% of cases.

The clinical picture, when specified, was characterized by its severity, with involvement of multiple organs and vital functions (**Table 3**).

Table 3. Characteristics of cases of death due to intentional use of MPCPC plants, 2010-2022.

	Death 1	Death 2	Death 3	Death 4
Gender	Female	Female	Not specified	Female
Age (years)	40	23	Non précisé	9
Environment	Rural	Rural	Urban	Rural
Year of intoxication	2018	2013	2015	2017
Place of intoxication	Home	Home	Home	Home
Substance	Abortion	Suicide attempt	Suicide attempt	Unspecified
Duration of intoxication	48(H)	24(H)	Non précisé	96(H)
Plants used	<i>Peganum Harmala</i>	<i>Atractylis gummifera</i>	Plant_Unknown	<i>Rumex</i> ?
Route of use	Oral	Oral	Oral	Oral
Initial grading	3: Severe intoxication with vital risk	Unclassifiable	Unclassifiable	Unclassifiable
Type of risk	Certain poisoning	High risk	Not specified	High risk
Symptomatology	Symptomatic	Symptomatic	Asymptomatic	Asymptomatic
Symptoms	-Abdominal pain -Gastrointestinal system disorders -Acute renal failure -Urinary tract disorders -Rhabdomyolysis -Osteo-muscular system disorders -Hypertension -General cardiovascular system disorders, -Peripheral cyanosis.	Hypotension	Unspecified	Unspecified
Hospitalization	yes	yes	yes	yes
Length of hospitalization	Unspecified	1 day	Unspecified	02 days

4. Discussion

To our knowledge, this is the first study in Morocco devoted exceptionally to the intentional use of plants over a 13-year period. The aim of the present study was to identify: the characteristics of intoxicated patients; the type, subcircumstances, severity, symptoms and evolution of intoxication; the characteristics of the most incriminated plant.

During the study period, intentional plant intoxications involved 189 cases, representing 9.37% of all plant-related intoxications occurring during this period (2,016 cases). These results are in line with Rhalem's

study, which found that, out of a total of 1,826 reports of plant poisoning, intentional use involved 157 cases (9.3%)^[21].

According to the WHO, intoxication is cellular or tissue damage, functional impairment or death caused by the inhalation, ingestion, injection or absorption of a toxic substance. According to the same source, a toxic substance is any substance which, when inhaled, ingested or absorbed through the skin, can cause significant acute or chronic health risks, or even death^[26].

The ingested substance may be directly toxic or may become so depending on the quantity present in the victim's body^[29].

However, the toxic dose depends on several factors: the concentration of glycosides present in the plant, the quantity ingested, the age and state of health of the victim^[30].

✓ Indicators relating to intoxicated persons

The results of this study show that voluntary intoxication through the use of plants is linked to various circumstances. They mainly affect young adults, but also other age groups, including children, both sexes, and involve plants known for their toxicity or commonly used by the Moroccan population. The results of this study show that voluntary intoxication through the use of plants mainly affects young female adults. These results are in line with those of Ait el cad'i's study of intoxications from all causes in Morocco over a 5-year period. According to the latter, voluntary intoxication is associated with the female sex in 35 cases (67.3%)^[31]. Similarly, Achour's study of *Peganum harmala* intoxication found that the average age of patients was 24.4 ± 16.8 years, with a clear female predominance (167 females versus 33 males)^[32]. However, according to a MPCPC study, plant poisoning predominantly affects males, with a sex ratio (M/F) of 1.58^[21]. One study revealed that although women are more likely than men to commit suicide, men are more exposed to death due to the violent means used^[33].

✓ Signs of intoxication

Severity analysis showed that signs of intoxication were initially pronounced (grade 2) in 52.95% of cases, and in 57.6% of cases in the final stage. However, in 16.67% of the cases, severe intoxication with vital risk (grade 3) was present initially, and in 4.8% of the cases it was present in the final stage. This study emphasizes that extreme grades, such as grade 0 (19.61% initially and 20.8% in the final stage), representing the absence of signs or signs unrelated to intoxication, and grade 4, corresponding to death (0% initially and 3.2% in the final stage), are lower than grade 2. However, the severity of plant intoxication depends on many factors: the type of plant, the part consumed, the quantity, whether it was taken on an empty stomach or not, age and circumstances^[21].

While most accidental exposures do not result in serious intoxication, causing only nausea and vomiting^[30], voluntary use of plant parts is more serious and more complex to manage medically, as the patient ingests a "set of active plant molecules" that varies depending on the part of the plant ingested. The composition and quantity of these molecules vary by species, location, individual, and time of intoxication. One study reported that drought conditions during plant growth can increase the risk of toxicosis^[34].

In this study, the route of administration was primarily oral in 162 cases. This observation is corroborated by the findings of other studies. For instance, Wangny's study demonstrated that voluntary intoxications were associated with the oral route in 93% of cases^[35]. In pregnant women who utilized herbal remedies at various stages of pregnancy, the oral route predominated (73.21%), followed by the vaginal route (20.53%)^[36].

The patients in this study presented symptoms (51.59% of them) affecting several organs, and the observed symptomatology was extremely polymorphic. However, the majority of patients exhibited signs of digestive and neurological disorders. Consistent findings were documented by Hami^[20]. The suspicion of toxic plants can be made on the basis of the toxidrome presented by the patient. However, it is important to note that

certain plants have been observed to induce a range of associated toxicoses. Consequently, a patient may exhibit damage to multiple systems within the body^[37].

A number of clinical classifications have been proposed for plant toxins to facilitate rapid patient recognition and management. These toxins have been classified into four groups: cardiotoxic toxins, neurotoxic toxins, cytotoxic toxins, and gastrohepatotoxic toxins^[13]. A study of the therapeutic use of plants in pregnant women in the Guelmim-Oued Noun region of southern Morocco revealed that complications occurred in 58.79% of cases, with the primary complication being acute fetal distress (30.71%), post-partum hemorrhage (20.47%), hyperkinesia of meconium-tinged amniotic fluid (13.38%), neonatal asphyxia (12.60%), neonatal death (3.15%), premature rupture of membranes (2.36%), and perineal tears (1.58%)^[38].

Conversely, the predominant causes of intentional poisoning in this study were subcategories of four classes: suicide attempts (46%), abortions (12%), drug addiction (8%), and criminal acts (6%). In Rhalem's study, among the 157 cases of voluntary intoxication, suicide attempts accounted for 4.79% (75 cases), drug addiction 1.79% (28 cases), abortions 1.47% (23 cases), and criminal or malicious intoxication 0.77% (12 cases)^[37]. In Rebgui's study, among the 27.5% of voluntary intoxications, suicide attempts accounted for 83.3%^[24]. According to the toxicovigilance report for 2022 from the Moroccan Poison Control Center (MPCPC), voluntary intoxications, all causes combined, accounted for 25.32% (844 cases out of a total of 4,225 intoxication declarations in 2022, excluding scorpion stings and envenomations). A study of voluntary intoxications revealed that the suicidal subcircumstance predominated with 789 cases (23.7%), those linked to drug addiction concerned 25 cases (0.8%), criminal acts 6 cases (0.2%), and abortions 1 case (0.12%)^[39]. From 1980 to 2008, the MPCPC documented 4,287 cases of plant intoxication, constituting 5.1% of the total cases. The utilization of flora in suicide attempts was documented in 12.8% of cases^[21].

✓ Indicators relating to toxic substances

In the present study, *Atractylis gummifera* was identified as the most frequently implicated plant in suicide attempts, with a total of 17 cases documented. *Atractylis gummifera* is an endemic species of the Mediterranean region, found in all regions of Morocco except Marrakech, the Anti-Atlas, and desert or arid areas^[15]. Moreover, it is widely available without a prescription from herbalists and traditional markets^[15]. It has been determined that all parts of the plant contain toxic principles, namely atractyloside (potassium atractyloside) and carboxyatractyloside (gummiferin)^[24]. These substances act as poisons, selectively disrupting the redox reactions that are critical for oxidative phosphorylation, the process by which ATP is produced within the inner membrane of mitochondria^[40]. In the most severe cases, additional complications may arise in the respiratory, cardiovascular, and hepatic-renal systems^[40], in addition to digestive and neurological disorders^[20]. The majority of cases are fatal^[41].

The primary symptoms associated with the ingestion of *Atractylis gummifera* include gastrointestinal distress (nausea, vomiting : bilious, h e m o r r a g i c and vomiting), neurological disorders (these can go as far as coma, accompanied by contractures, decerebrate rigidity, trismus, collapse, congestion, hypersalivation with apnea in the final stage), hematological disorders (including purpura and hemorrhages (digestive, and pulmonary, urinary), neurovegetative disorders (hypothermia), as well as, in the most severe cases, respiratory, cardiovascular and hepato-renal complications, a deep hepatic coma, with death most often occurring during a tetaniform crisis^[42]. According to Larrey's study, intoxication by *Atractylis gummifera* manifests as abdominal pain, vomiting and acute hepatitis combining both hepatocyte necrosis and microvesicular steatosis^[43]. The course is often fatal^[20,40,43].

A total of 22 cases involving abortion were documented, with *Peganum harmala* L. identified as the primary drug utilized in 45.45% of the cases. However, it is noteworthy that this plant has also been employed in instances of suicide and intentional criminal activity. *Peganum harmala* L., also known as "harmel," "bender tiffin," "rue sauvage," "rue verte," or "rue de Syrie," is one of the most widely used plants in traditional

medicine for ritual, magical, prophylactic, and, above all, therapeutic purposes^[15,44]. It has been identified in significant concentrations within the sub-desert regions of North Africa, including Tunisia, Algeria, Libya, and Egypt, as well as in specific areas of Mediterranean Europe^[45]. In Morocco, harmal poisoning is not an infrequent occurrence; it accounts for 4.6% of all plant poisoning cases received at the country's Poison Control Centre^[21]. Harmal poisoning is most often secondary to therapeutic use; however, the use of this plant during pregnancy can be particularly serious^[46]. Moroccan women who are pregnant have been observed to utilize the seeds of the plant in two distinct practices. Firstly, the seeds are used in the process of inducing abortion. Secondly, the seeds are used to facilitate the process of childbirth. It is important to note that the use of this plant in such practices can result in severe consequences, including fatality. This observation has been documented by Achour in 2012b^[46]. A case of intoxication by *Peganum harmala* L. occurred in a pregnant woman who presented with disorders of consciousness, uterine contractions, oliguria, renal failure, liver damage, deterioration of consciousness, and spontaneous expulsion of the fetus. Notably, she exhibited persistent sequelae, including cerebellar ataxia and peripheral polyneuropathy^[47]. A study documented 200 cases of *Peganum harmala* L. intoxication, with therapeutic circumstances accounting for 32.5% of cases, followed by suicide (28.5%) and abortion (13.5%). The patients' clinical picture was dominated by neurological, digestive, and cardiovascular signs, with 34.4%, 31.9%, and 15.8%, respectively. A total of seven deaths were reported, resulting in a case-fatality rate of 6.2%^[32]. Another study documented the case of a 20-year-old woman who was found to be intoxicated by *Peganum harmala* L. Upon admission, the patient exhibited symptoms of shock, agitation, vomiting, altered consciousness, anemia, thrombocytopenia, acute nephropathy, elevated transaminases, and the presence of plasma hCG. Cerebral CT revealed multiple areas of cerebral ischemia with subarachnoid hemorrhage, while thoraco-abdominal-pelvic CT showed enlargement of the uterus and localization of internal hemorrhage^[48]. The prognosis is generally favorable, although excessive use of high doses of *Peganum harmala* L. can lead to a fatal outcome^[32].

In this series, drug addiction was implicated in 16 cases, with *Datura stramonium* being the most frequently implicated substance (5 cases). The plant in question belongs to the Solanaceae family. This plant is also referred to as "devil's herb" or "angel's trumpet." It is a wild plant that contains high levels of anticholinergic alkaloids, similar to those found in atropine and scopolamine. In Africa and Asia, it is employed as a medicinal plant to treat asthma or coughs^[49]. However, its flowers and seeds have been utilized for their hallucinogenic properties, with its alkaloids exhibiting an atropinic effect^[50]. Its consumption has increased among adolescents and young adults in an addictive context due to its hallucinogenic effects^[51,52]. There have been documented cases of voluntary and involuntary intoxication with *Datura Stramonium*, particularly among adolescents and children^[53]. The consumption of *Datura stramonium* has been demonstrated to induce a variety of symptoms, including, but not limited to, dry mouth, bilateral mydriasis, blurred vision, dizziness, ataxia, and constipation. In some cases, hallucinations or agitation may also occur. These symptoms manifest within thirty minutes of ingestion and can persist for up to forty-eight hours^[52].

Currently, there is no validated, easily executable biological work-up to confirm the diagnosis, which is instead based on a thorough interview and physical examination. The predominant differential diagnosis is anticholinergic syndrome induced by drug intoxication^[52]. Furthermore, a study documented a series of 1,186 cases of *Datura* exposure, as reported by French poison control centers. Of these, 643 (54.2%) were considered deliberate, including 486 in the context of drug addiction and/or recreational use. The lethal risk associated with these intoxications is primarily attributable to the fact that these plants induce hallucinations and can therefore lead to self-mutilation^[54]. In 2020, the Centre antipoison Grand-Est reported cases of severe intoxication following the ingestion of *datura* leaves in July of that year. Four members of the same family prepared and consumed a meal that contained *datura* leaves, which they mistook for horny tetragon leaves harvested from their vegetable garden. The subjects rapidly exhibited symptoms of severe intoxication,

necessitating admission to the intensive care unit^[55]. The prognosis can be fatal, especially in children and in cases of massive intoxication for autolytic or addictive purposes^[56].

In the context of criminal acts, herbal mixtures were the most prevalent (11 cases), accounting for 63.63% of the observed cases. Mixtures are preparations based on several ground plants and other products mixed with honey. The products utilized are frequently a "mix" of plants whose knowledge, preparation, and consumption requirements are not fully mastered. Consequently, these plants may contain potent chemical compounds that are responsible for adverse effects and toxicity^[57]. Indeed, the toxic effect could lead to synergistic action and fatal consequences. The formulation is a combination of active ingredients derived from multiple plant sources. However, a single plant may contain a variety of active ingredients (totum), each exhibiting a distinct action. Consequently, these active constituents exert their effects on multiple organs within the same patient, resulting in a manifestation of multi-visceral failure. The lack of awareness among clinicians regarding these conditions, their rapid evolution, and their high frequency give rise to medico-legal problems that can only be resolved by identifying the causative agent post mortem.

In Morocco, however, there is still no official, codified pharmacopoeia. The existing legislative framework in this area is deemed to be deficient. The entities engaged in the sale of these "natural" products are not subject to any regulatory oversight. The right to sell goods freely, both in traditional brick-and-mortar stores and online, is a fundamental tenet of economic freedom^[14]. This policy facilitates widespread access to these plants, irrespective of the end user's intentions.

In 53 cases, the specific identity of the plant could not be ascertained. In all cases, the process of identifying plants is often arduous. Fresh samples are required; these should be as complete as possible and include leaves, branches, fruit, and flowers, among other components. The plants utilized in this process are frequently subjected to desiccation or compression, which can pose significant challenges in terms of identification. It has been observed that relatives often exhibit reluctance to engage in collaborative efforts, which may be attributed to a reluctance to face potential reproach when a toxic etiology is invoked^[58]. The corpus of botanical knowledge is often transmitted through family traditions and is characterized by the variability of vernacular plant names^[58]. Moreover, the identification of consumed plants is challenging, primarily due to the extensive array of vernacular names that exist throughout the kingdom^[15]. In certain instances, the same nomenclature is applied to different plants depending on the geographical location^[15]. However, the plants involved in cases of intoxication vary according to the flora and socio-cultural habits of each country, as demonstrated by studies such as that by WY Ng and that by Slaughter^[59,60].

✓ **Death indicators**

In this series, the outcome, when specified, was fatal in four cases, the majority of which were female, and three of which were rural. The prolonged duration of intoxication, ranging from 24 to 96 hours, could be attributed to the remote geographical location of health facilities. This, in turn, contributes to the high mortality rate observed in cases of intoxication.

The following list enumerates the plants responsible for the aforementioned mortalities: *Peganum harmala*, *Atractylis gummifera*, and *Rumex divers* (25% each) were identified, while the fourth plant remained undetermined. A study documented that 7.3% of cases reported to the MPCPC involved death from plants^[21]. A retrospective study of 241 cases of plant poisoning was carried out between 1980 and 2007 in the Fès-Boulemane region. The findings indicated that the outcome was fatal in 19.3% of cases^[24]. In France, the Lille toxicovigilance network reported a rate of plant-related deaths that was less than 1% of all reported cases^[61]. In Rebgui's study, *Atractylis gummifera* was identified as the causative agent in 68% of the documented poisoning cases, resulting in 30 fatalities, within the Fès-Boulemane region of Morocco^[24].

In Hami's study, the severity of this intoxication was confirmed by a high in-hospital mortality rate. A study by Hami (2011) revealed that of the 182 patients for whom the outcome was known, 98 died (54%).

According to the data from the MPCPC, 68 cases of death from *Atractylis gummifera* were reported during the period from 1992 to 2008^[62]. In comparison with earlier MPCPC studies, the number of cases of death by this plant was 98^[62]. This finding serves to underscore the high toxicity of the plant in question. In the MPCPC annual report for 2022, the distribution of poisoning case reports by type of product revealed a predominance of drug poisoning (39%), with plant-related poisoning accounting for only 1.3%. However, the specific plant-related lethality was the highest: 3.64% versus 0.3% for drug-related lethality, while the general national lethality was 0.71%^[39]. Combe's study indicates that intentional intoxications from plants are less prevalent than drug intoxications. These cases are more complex for medical teams to manage, as the description of the species involved is often brief and imprecise, making identification challenging. Additionally, the purported dose ingested is frequently difficult to estimate^[30].

A single instance of fatality was associated with *Peganum harmala* L. However, the intraperitoneal injection of aqueous extracts at varying doses into male mice resulted in severe manifestations of toxicity, including somnolence, hypoactivity, anorexia, social isolation, bradycardia, respiratory distress, excitation, and ultimately, death. The findings indicate that the highest administered dose, designated as the 100% lethal dose (LD 100), results in the demise of all subjects. This dose is determined to be 10 g/kg for *Peganum harmala* L. In contrast, the maximum tolerated dose is recorded as 1 g/kg^[63].

In this study, a case of death linked to the genus *Rumex* was recorded in a 9-year-old girl with suicidal intent. *Rumex*, also referred to as "sorrel," "patience," "doche," or "parellel," is a genus of dicotyledonous herbaceous perennials classified within the Polygonaceae family. These plants are characterized by their remarkable hardiness and tendency to invade new environments, often reaching heights of 50 to 120 centimeters. It has been established that docks contain oxalic acids and potassium salts in very high concentrations^[64]. The consumption of oxalate by cattle is possible due to its metabolism by rumen microbes. However, even in these animals, the ingestion of substantial quantities of oxalate can result in intoxication. Indeed, in the event of massive ingestion of the plant, these acids can be the cause of renal failure, with hypersalivation and acute hypocalcemia, since oxalate, by combining with the calcium in the blood, forms calcium oxalate crystals which can obstruct the blood vessels of the kidneys and, ultimately, lead to death^[65].

For humans, the toxicity of foliage is mild, but symptoms of intoxication resulting from excessive ingestion can include tremors, salivation, and diarrhea. Furthermore, it has been demonstrated that this condition increases the risk of developing kidney stones. Upon absorption, these substances have the potential to bind with calcium present in the blood, resulting in the formation of crystals that can cause damage to the kidneys and lead to renal dysfunction. Furthermore, mineral deficiencies have been observed in association with this condition. As indicated by the Encyclopedia of Plants (2024)^[66], the consumption of *Rumex* has been demonstrated to carry a heightened risk for individuals who are pediatric, afflicted by renal calculi, rheumatism, arthritis, or other pathological conditions.

The findings of this study demonstrate that the extent of the phenomenon is often underestimated, as these plants are utilized in a variety of contexts and by diverse age groups. Furthermore, the extensive diversity of these plants results in a high degree of symptomatology polymorphism, contingent on the specific toxicant involved. This polymorphism is typically accompanied by substantial severity.

Furthermore, this study paves the way for additional research endeavors concerning the rational utilization of toxic plants in Morocco. These properties can be leveraged in the medical field and as alternatives to chemical substances in the agricultural field for environmental protection.

5. Conclusion

Intentional intoxication by plants constitutes a grave public health concern in Morocco. The results of the study may have implications for the therapy and prevention of this type of intoxication. In light of these findings, the following recommendations are made:

The objective is to raise awareness of the dangers associated with herbal intoxication. It is imperative to address the prevailing silence surrounding this particular type of intoxication and to provide support to those at risk of experiencing it. One potential strategy is to establish anonymous listening services, such as hotlines and psychological and social helplines, to offer assistance and guidance to individuals in need.

It is imperative to promote health education initiatives aimed at mitigating the risks associated with this particular type of intoxication. Furthermore, it is essential to incorporate explicit sequences on herbal intoxication into existing teaching programs.

It is imperative to underscore the significance of adequate psychological assistance for individuals who have been subjected to, or are at risk of, intentional plant poisoning.

The objective is to establish a local database comprising monographs and toxic profiles of medicinal plants. This database is to be readily accessible to parents and health professionals.

Finally, it is recommended that a national strategy be implemented in Morocco to address the issue of plant poisoning, with the objective of reducing the risk irrespective of the intended context of use.

Conflict of interest

The authors declare no conflict of interest.

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