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Jimsonweed (*Datura stramonium* L.) poisoning in horse

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1. Introduction

Plants are one of the most common causes of poisoning in horse (1). *Datura stramonium* L. (jimsonweed, family Solanaceae) is a poisonous plant of concern to the equine family (Equidae; 2). Horses instinctively avoid most toxic plants in pasture, due to their frequently unpleasant odour and taste, but accidental consumption can occur when toxic plants, dry and less fragrant, are admixed into the hay. Fresh jimsonweed individuals have a taste unfavourable to horse (3).

Jimsonweed is also poisonous to other animal species. The poisonous compounds in jimsonweed can harm pig (4,5), cattle (6,7), sheep, goats (7,8), and dogs (9,10). Horses and pigs are particularly vulnerable due to their physiology and anatomy. Other species, such as rats and guinea pigs, have an enzyme called atropine hydroxylase that makes them resistant to poisoning (11).

Tropane alkaloids are the primary active constituents of *Datura stramonium* (2). The main tropane alkaloids in jimsonweed are atropine (including its two enantiomers: S- and R-hyoscyamine), and scopolamine (2).

Tropane alkaloids are anticholinergics, which means that they can inhibit the effects of acetylcholine in the neuromuscular junctions. Tropane alkaloids affect both the central and peripheral nervous system (2). These effects have various consequences and clinical signs such as behavioural changes, restlessness, rarely depression, decreased borborygmi (loss of bowel sounds), a suppressed excretion of urine, xerostomia (reduced secretion of saliva), tachycardia, and rapid breathing (1, 12–15).

It is vital to treat *Datura* poisoning as soon as possible. There are various methods to make a diagnosis, e.g., the check of haematological parameters in blood (16). Different analytical methods are used to indicate the presence of tropane alkaloids in urine including mass spectrometry, gas chromatography, and high-performance liquid chromatography (HPLC) (13,17). Frequent check of feed and pasture for any poisonous plants or contaminants can also be a powerful (and cheap) technique (13). As in any other cases when making a diagnosis, the health history of animal individuals must also be considered (14).

Once the animal is diagnosed, it must be treated right away. Treatments can differ depending on the clinical signs. Prokinetic agents, e.g., laxatives (to enhance gastrointestinal motility), or flunixin (an anti-inflammatory, analgesic, and antipyretic medicine), and intravenous fluids (to correct electrolyte imbalances) are some of the treatment options can be

effective in a variety of mild cases (13). Other treatments include the administration of furosemide (a diuretic medicine), activated charcoal, procaine penicillin (an antibiotic), ascorbic acid, and thiamine to improve liver functions. Pilocarpine can be applied against xerostomia (18).

To prevent and control *Datura stramonium* poisoning in horse, equine owners and veterinarians should be familiar with the plant species growing on pastures and should be able to recognise the most dangerous poisonous plant species. Careful grassland management should be applied with yearly replanted grass species and the prevention of overgrazing. Hay and other forages should always be checked for poisonous plants and contaminants before feeding. Different techniques are used to prevent poisoning, including mechanical (3), chemical (19), and biological controls (20).

Among the mechanical controlling techniques the manual removal of poisonous plant individuals and tilling (to kill the seedlings) can be mentioned (3). A chemical control can be the use of herbicides (19). Biological controls can also be applied, e.g., in crop fields, to control jimsonweed. A natural herbicide, the AAL-toxin, generated by then extracted from the fungus *Alternaria alternata*, can selectively suppress the growth of jimsonweed even in low concentrations (20).

2. Objectives

This work aims to:

I. raise awareness about the consequences of jimsonweed poisoning in horse to owners, members of the equine community, and veterinarians;

II. review and collect information about the cases where jimsonweed poisoning occurred in livestock animals, especially in equine species;

III. collect the most common clinical signs of jimsonweed poisoning in horse, and gather information about the related treatment methods.

3. Materials and Methods

Literature data was obtained from various sources such as Google scholar (https://scholar.google.com/), PubMed (https://pubmed.ncbi.nlm.nih.gov/), and ResearchGate (https://www.researchgate.net/). Scientific handbooks were also checked. Cases of *Datura* poisoning were also collected from scientific papers browsing ScienceDirect (https://www.sciencedirect.com/) and the library of the University of Veterinary Medicine Budapest (Hutÿra Ferenc Library, Archives and Museum).

4. Results

4.1. Taxonomy and morphological description of *Datura stramonium*

The family of *Datura stramonium* L. (jimsonweed) is Solanaceae (nightshade family) (23). This plant is an annual herb with the ability to grow in a height ranging 0.5–2.0 meters. The stems can be green, brownish, or with a purple hue depending on plant age and plant stress driven by, e.g., droughts. Its stem can be hairless or finely hairy. A single jimsonweed stem is always repeatedly divided into two branches (19). Its leaves are dark green or purple while being paler below. The underside veins of leaves can be quite prominent. The leaves can be rounded or broadly triangular, 5–25 cm long and 4–25 cm wide, arranged alternately on the stems. Leaf margins are coarsely, and irregularly toothed or lobed. Leaf stalks can reach 10 cm. A crushed or bruised leaf can cause a foul smell/odour (19).

The flowers are with funnel-shaped, white, fused petals and placed at each fork of the stem (**Figure 1–2**). The seeds are formed in a capsule that opens at maturity. The fruits (capsules) are green when young and turning brown after maturation. Capsules are egg-shaped, 3.0–7.0 cm long and 2.0–3.5 cm wide, and covered by slender, erecting spines (**Figure 3**). Seeds (**Figure 4**) turn from a dark brown to black colour, and are 3–4 mm long and 2–3 mm wide (19).

Figure 1. A booming *Datura stramonium* (24).

Figure 2. *Datura stramonium* leaves with a funnel-shaped flower (24).

Figure 3. Spiky green fruits of *Datura stramonium* (25).

Figure 4. A dry, opened capsule of *Datura stramonium* with black seeds (25).

4.2. History of *Datura stramonium*

Various tribes and indigenous peoples around the world have used toxic plants such as *Datura* species for religious occasions, healing ceremonies, divination and even for witchcraft. More recently, western civilisation's interest in these hallucinogenic plants has been primarily centred on curing mental illnesses like schizophrenia (26). Jimsonweed has been used to treat mental diseases, tumours, infections and even as an aphrodisiac in traditional medicine (26).

The word *Datura* is derived from the early Sanskrit "dustura" or "dahatura", which means "divine inebriation" (29). *Datura* has a variety of street names, including "thornapple", "stinkweed", "locoweed", "augushka", "ditch weed", "devil's snare", "devil's seed", "devil's trumpet", "Korean morning glory", "Jamestown weed", "angel's trumpet" (which refers to *Brugmansia* species), "beelzebub's twinkie", "madhatter", and "crazy tea" (28). Jimsonweed is the preferred common name for *Datura stramonium* that is derived from Jamestown (Virginia state, U.S.A.). Captain John Smith led a group of English colonisers in 1607 at Jamestown. The British soldiers consumed boiled jimsonweed in a salad, resulting in hallucinogenic behaviour (26).

Datura species also had various roles and uses in Asia. The plant was applied to induce visionary dreams, foretelling the future, and revealing the causes of diseases and misfortune.

According to ancient records, the Aztecs in South America were also familiar with *Datura* species. The tribe had a variety of uses for the plant, including using it as an enema, suppository for pain relief in different rituals and to evoke hallucinations (26). Another plant species similar to *Datura stramonium* is *Datura ceratocaula* which was only allowed to be used by priests. Fortune telling and talks with the gods were some of the activities performed while using the plant. It was also used to treat illnesses such as cracked soles, sores, bruises, pustules, and as plasters for ulcers (26).

Datura species were also used for various purposes in medieval Europe, including mind-altering properties, pagan rituals, and special feasts (26). These plants were used to induce hallucinations caused by tropane alkaloids instead of drinking alcohol due to its high cost. Using *Datura* seeds and alcoholic beverages was widespread throughout the Middle Ages. Following the spread of Catholicism throughout Europe, there was a decrease in pagan beliefs, which reduced the use of *Datura* plants in the region (26).

4.3. Geographical range and preferred habitats of jimsonweed

The origin of jimsonweed is still not fully understood, but it probably originated from tropical America (19). *Datura* species are mainly seen in tropical and subtropical areas of the world. However, *Datura stramonium* can also be found in the tropics and subtropics but also widely distributed in the temperate climatic zone. A cosmopolitan species that can be found throughout the world except the arctic regions (29). It can commonly grow in gardens as a weed or planted, as an ornamental plant. **Figure 5** shows the distribution and occurrence of the plant throughout the world. *Datura stramonium* prefers disturbed habitats with nitrogen-enriched soils such as roadsides, railway embankments, wastelands, crop fields, managed pastures, drainage ditches, fallowed landscapes, forest edges, gullies, and riverbeds (19).

There are contrasting theories on the origin and distribution of the plant. However, Mexico and Central America appear to be the origins. This has led to speculations that it was brought to Europe by the explorers of the New World (19). A contradictory belief is that *Datura stramonium* was originated in the Caspian sea and spread south to Africa and east to Asia before being brought to Europe by travellers during the Middle Ages (19). Others believe that the Romani brought *Datura* from India to Europe in the early 15th century (19). Although the English man known as Gerald claimed to have been the first to disperse jimsonweed seeds in England (19).

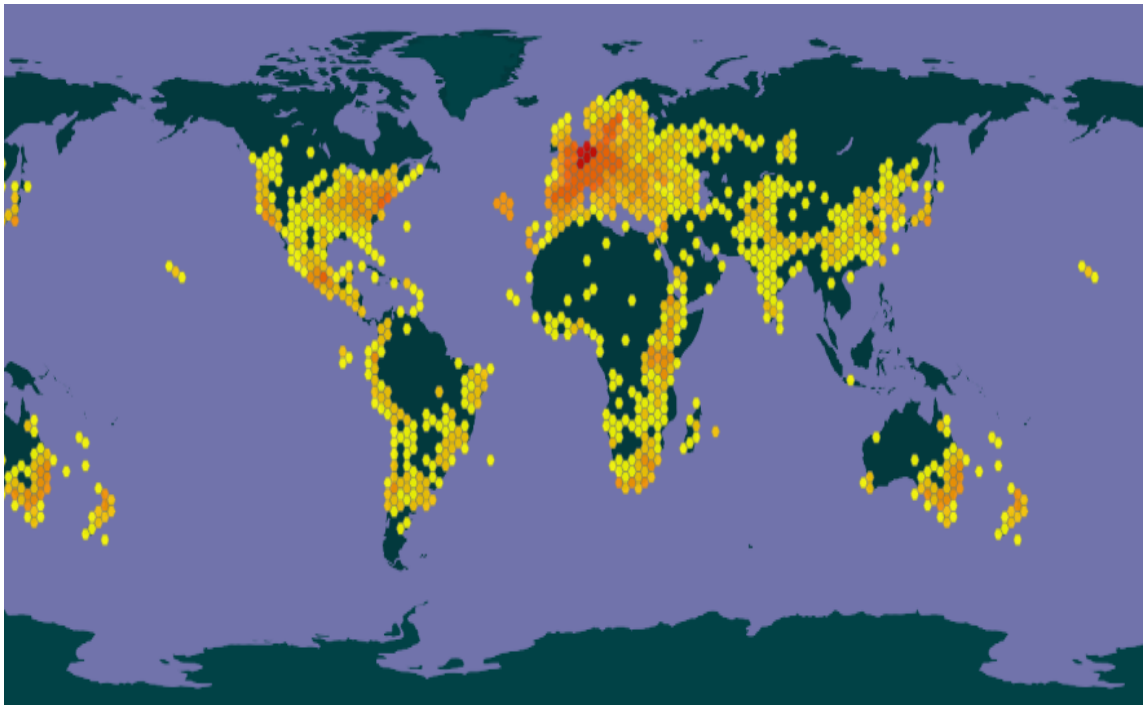

Figure 5. Geographical distribution of *Datura stramonium* between 1600–2022 (29).

4.4. *Datura* toxicity in horse and in other susceptible species

Jimsonweed is of significant concern to most animal species, particularly horses. Horses are hindgut fermenters which means that they ferment their food in the caecum and colon, parts of the large intestine (30). Equine animals are pretty sensitive to tropane alkaloids such as hyoscyamine and scopolamine, which are absorbed through the hindgut. However, the severe effects of gastrointestinal complications are only mentioned in equines (31). Unlike other species, as poultry, rat, rabbit, and guinea pig, that are unique, because they biosynthesize an enzyme called atropine hydroxylase. This enzyme protects them from being affected by tropane alkaloids (11).

Swine is similar to equine in that they are hindgut fermenters and are susceptible to jimsonweed intoxication. Numerous experimental studies were carried out on swine species of different ages and breeds (e.g., 4,5). Swine individuals were fed with different ratios of jimsonweed plant and seeds. This resulted in reduced appetite, reduced weight gain, mydriasis, giddiness, dog-like posture and dry faeces.

Various reports and experiments have occurred where cattle are frequently affected by jimsonweed. The primary way of poisoning occurs due to the contamination of freshly cut maize or silage by jimsonweed seeds (6). The observed symptoms included pulse

acceleration, constipation, dilated pupils, drowsiness, bulging eyeballs, and even death in several occasions (7).

Sheep and goat are both susceptible but at different levels. Kehar and Rau (7) fed two sheep and two goats daily with 10 g/bw kg *Datura stramonium* fruits and leaves but the animals showed no symptoms. A different study was carried out on male desert sheep and Nubian goats by feeding them with jimsonweed plants. After 38 days, the desert sheep died, while the Nubian goats died much later, after 136 days (8).

Plant poisonings caused by jimsonweed are much less common in carnivorous animals than in herbivorous ones (32). The first case of jimsonweed poisoning in a carnivorous species was carried out when a dog experienced mydriasis due to contact with the sap of jimsonweed (9). In another study, a one-year-old dog consumed jimsonweed seeds (10). Its symptoms were hyperaesthesia (excessive physical sensitivity of the skin), high agitation, tachycardia, tachypnoea, and mydriasis, which led circulatory and respiratory failures, and eventually death (10).

4.4.1. Case studies

A case study occurred in Toledo, located in central Spain where fifteen horses were kept. Four horses became intoxicated with jimsonweed plants. Two horses, following treatment, made a full recovery by next morning. Another two horses started displaying clinical signs when one of them made a full recovery and the other died after six hours (1).

In Onderstepoort (South Africa), over a six week period, 18 out of 83 horses were affected after being fed with teff hay containing a mixture of *Datura ferox* and *Datura stramonium* plants. Three horses developed impaction colic in the first week, while two other cases occurred in the fourth week. One of these latter cases was a horse from the first week. Between the fifth and seventh weeks 18 cases occurred where 4 previously affected and 14 new. Out of 11 horses, 7 had their second and 4 had their third incidence with colic. Out of the 18 horses one of the horses died. Following the inspection of the hay it was confirmed that the hay contained *Datura* species (13).

In South Africa, two horses displayed signs of colic, following being fed with a new meal containing sunflower seeds and jimsonweed seeds (25% by volume). The first horse died with severe abdominal distension. The second horse had to be euthanised after failing to respond to treatment (21).

Another case study was carried out in New Zealand where two horses were fed horse meal that was contaminated by jimsonweed seeds. A sample amounting to 994 grams of meal was taken for analysis. The 994 grams of meal contained 562 seeds of *Datura stramonium* with a rate of occurrence of 595 seeds/kg. The seeds were weighed in comparison with the sample. The 562 seeds weighed 4.7 grams which was 0.5% of the weight of the meal. A thoroughbred yearling and a ten-year-old pony were affected. Following the treatment, the feed was changed and both horses made a full recovery (22).

Two horses out of a group of 23 horses were developed colic after fed teff hay that was contaminated by *Datura ferox* and possibly *Datura stramonium*. One of the horses did not respond to the treatment. The horse had surgery for the intestinal atony but had to be euthanised. The other horse responded well to the treatment and made a full recovery. The treatment consisted of 7 ml of flunixin meglumine intravenously and removal of the feed (12).

4.4.2. Clinical signs

When identifying a condition in an animal, clinical indications are crucial and helpful. Numerous authors and researchers have reported that a variety of clinical symptoms can be caused by jimsonweed. The most characteristic symptoms were: anorexia, diarrhoea, hyperexcitability, mydriasis, stagger, overall ill-coordination, sporadic muscle spasms, and rigours (15,33). However, other symptoms that cannot be directly connected to sympathetic predominance were also reported, e.g., abdominal distension leading to colic. Colic can be a secondary symptom due to the suppressed gastrointestinal motility.

A group of 8 mares in Onderstepoort (South Africa) were held on a 5 hectare artificial pasture but were also brought into concrete paddocks and fed teff hay contaminated by *Datura ferox*. One of the mares, a 18 years old one, developed acute severe colic. She showed clinical signs of continuous pain and extreme bilated abdominal distension. Eight days later, a five-year-old mare also showed signs of moderate colic. This mare showed unrest due to the separation of her five-month-old foal. She was alert and showed no discomfort throughout the clinical study. Her temperature was 38.5 °C, with a respiratory rate of 24 breaths per minute. Her pulse rate was 44 bpm. Her mucous membrane colour and capillary refill time were within normal ranges, her borborygmi were normal, and nasogastric intubation revealed no reflux. She also displayed modest bilateral abdominal distension. On rectal examination, the caecum showed signs of mild gas distention (12).

A similar case study occurred in Toledo, Spain. There was 15 horses kept in a stable and were fed barley, fodder, oat straw and lucerne hay. One of the horses had clinical signs of colic with abdominal pain, anxiety and increased borborygmi. The horses' other parameters were checked including its temperature and hydration status which were both normal. While the mucous membranes were reddened (1).

Another case occurred in 1993 in Hungary, where nine horses were fed 60–300 g of *Datura stramonium* seeds, resulting in death. The clinical signs that appeared occurred 6 to 24 hours after ingesting the seeds, resulting in restlessness, colic, laboured breathing, increased heart rate, constipation, dilated pupils and dry oral and nasal mucosae (34).

Another contamination occurred in South Africa where two horses were affected after consuming meal containing sunflower and maize seeds contaminated with jimsonweed seeds (25% in volume). The first horse showed signs of severe colic with impaction. The second horse (a mare) had severe bloat and was depressed. The mare had dry oral and nasal mucosae and bilateral mydriasis. The heart rate was initially 38 bpm but was rechecked the following day and had become tachycardiac which increased to 70 bpm. The respiration rate was 30 bpm and rechecked the following day which decreased to 28 bpm. No gut sounds were heard after auscultation. A rectal exam was carried out with an impacted distal colon palpated. The faeces were dry and had a mucoid coating (21).

4.4.3. Active constituents

Datura stramonium possesses a wide range of pharmacological effects, including antiasthmatic, anticholinergic, acaricidal repellent, antimicrobial, anticancer, anti-inflammatory, larvicidal, mosquito repellent, antifungal, and vibrocidal properties (35). The most important active constituents of *Datura* species are tropane alkaloids. Tropane alkaloids are crucial secondary plant metabolites that are abundant in the members of family Solanaceae. They can be classified into three main compound groups: hyoscyamine/scopolamine, cocaine and calystegines (3). Tropane alkaloids are similar in their structures but they vary in their biological, chemical, and pharmacological characteristics (36). All parts of *Datura stramonium* contain tropane alkaloids and with less importance, tannins, saponins and cardiac glycosides.

Datura stramonium is mainly composed of tropane alkaloids comprising more than 200 compounds in family Solanaceae. The tropane alkaloids consist of a two-ringed structure with a pyrrolidine and piperidine ring that share a single nitrogen atom and two carbon atoms. The

nitrogen atom at the end of the molecule, which defines these compounds as alkaloids, is methylated in this group. The most important tropane alkaloids found in nature are hyoscyamine and scopolamine. Hyoscyamine can be found in the highest concentration in *Datura stramonium* (37).

The tropane alkaloid biosynthetic pathway begins with the amino acids arginine or ornithine and then their intermediate product putrescine. N-methyl-Δ1-pyrrolinium cation is the precursor of each tropane alkaloid. This leads to the branch in the pathway for the production of cocaine, hyoscyamine/scopolamine and calystegine (36). The tropane alkaloids can be distinguished into three groups as described in **Figure 6**. The three major tropane alkaloid groups can be found in different plant taxa. Cocaine comes from the coca alkaloids in the *Erythroxylum coca*. Calysteigins can be found in various plant families, including Convolvulaceae, Solanaceae, Moraceae, and Brassicaceae, which are polyhydroxylated nortropane alkaloids (38).

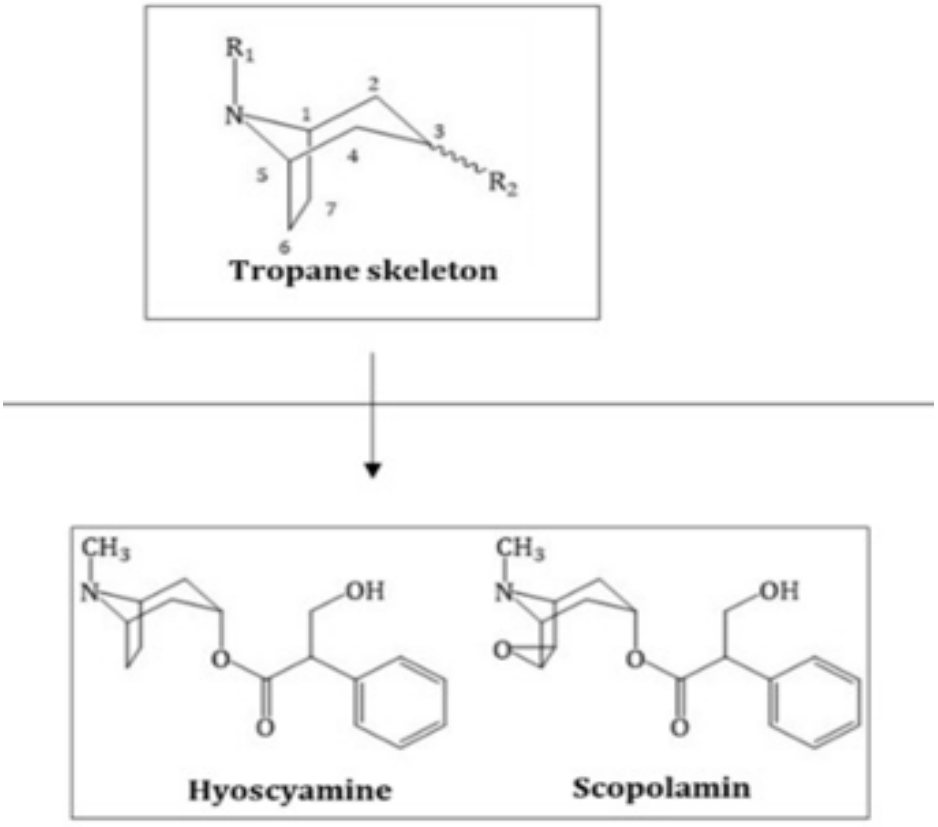

Figure 6. Structure of the tropane skeleton; main groups of tropane alkaloids are derived from this skeleton (28).

Beside tropane alkaloids, *Datura stramonium* produces other compounds as well. Its seed and seed coat contains antinutritive compounds such as phytic acids, tannins and oxalate crystals. Actually, the seed of jimsonweed contains twice the amount of oxalates than the seed coat. Oxalate crystals can be formed by collecting sodium and potassium ions from the blood serum resulting crystal formations in blood vessels or within cells (39). Phytic acids can chelate minerals, which means that they can bind to minerals like zinc and calcium causing mineral deficiencies. Phytic acid can also chelate the vitamin B_3 (niacin). Tannins can inhibit the absorption of minerals, mainly iron and zinc. The suppressed availability of these minerals can lead to anaemia and, among others, dermatitis and alopecia, respectively (39).

4.4.4. Mechanism of action of active constituents

Tropane alkaloids are known to cause anticholinergic effects. Tropane alkaloids bind to all muscarinic acetylcholine receptor types acting as competitive antagonists of acetylcholine (40). Muscarinic cholinergic receptors are located in various organs, leading to multiple consequences and clinical signs. There are five muscarinic cholinergic receptor types, abbreviated as M1 to M5, which are part of the G-protein coupled receptors. The M1 receptors are mainly located in the central nervous system (where they are most abundant in the cerebral cortex, hippocampus, and striatum), autonomic ganglia, the salivary and gastric glands, and the enteric nerves. The M2 receptors can be found widely expressed in the central nervous system, heart, smooth muscle, and at the nerve terminals of the autonomic nervous system (40). The M3 receptors are predominantly found in smooth muscle, glands, heart, and the central nervous system. The M4 receptors are mainly found in the central nervous system (in the forebrain), in different areas than M1 receptors. The fifth and final muscarinic receptor type (M5) can be found in the substantia nigra of the central nervous system, in the ciliary muscle of the eye's iris, and the salivary glands (40).

Neuronal nicotinic acetylcholine receptors (nAChRs) are different; they are not affected by tropane alkaloids (41).

Both atropine and scopolamine are non-selective competitive antagonists of muscarinic cholinergic receptors. Both compounds bind to different muscarinic receptors and at different affinities. Atropine has the highest affinity for subtype M1, followed by M2 and M3 but a weak affinity for M4 and M5 was also reported (42). In contrast, scopolamine has a strong affinity to M1–M4 types (43).

Understanding the absorption, distribution, metabolism, and excretion of plant toxins is critical in treating the animal. Tropane alkaloids are absorbed from the gastrointestinal tract, rapidly distributed into tissues, and excreted via the renal system (37). **Figure 8** shows how tropane alkaloids bind at the muscarinic receptors and act as a competitive antagonist of acetylcholine (34).

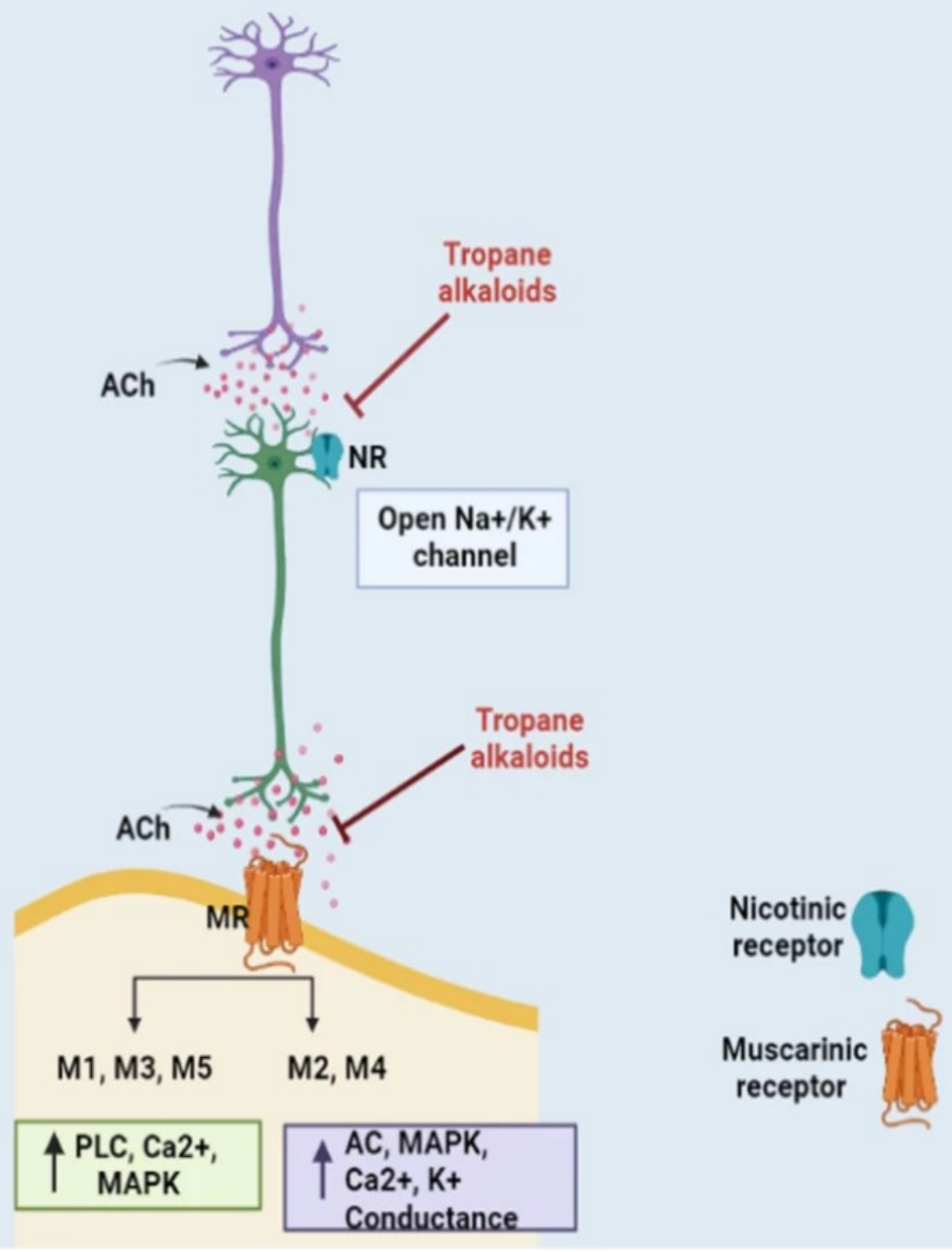

Figure 8. Tropane alkaloids competitively bind to muscarinic receptors and block ACh transmission.
MR: Muscarinic receptor; NR: Nicotinic receptor; ACh: Acetylcholine;
PLC: Phospho-lipase C; AC: Adenylyl cyclase;
MAPK: Mitogen-activated protein kinase (34).

4.4.5. Diagnosis

Diagnosing a horse with jimsonweed poisoning can be difficult for a general practising vet with limited resources. The veterinarian will diagnose the horse by conducting a physical examination followed by asking the owner about the horse's health history and observing the clinical signs and symptoms. A variety of symptoms, including dilation of pupils, muscle twitching, diarrhoea, and frequent urination, can likely be caused by a plant poisoning (14).

One way of diagnosing jimsonweed poisoning is by laboratory testing of the blood parameters. E.g., a case study was conducted in Bulgaria where horses were admitted for consuming freshly harvested maize contaminated by young *Datura stramonium* individuals. There was a total of 34 horses affected which were grouped into three different groups based on the severity of their symptoms. The first group were the horses with typical symptoms. The second group contained horses with atypical symptoms. The third group served as control. Blood samples were taken from the jugular vein for 7 days for haematological studies. Hyperchromasia, erythrocytosis, leukocytosis, neutrophilia and regenerative shift, lymphocytopenia, eosinophilia, increased haematocrit values, and low erythrocyte sedimentation rate were diagnosed. There were no changes that occurred in the mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) (16).

Another way of diagnosing jimsonweed poisoning is the examination of the feed. The majority of cases that occurred were due to the *Datura stramonium* being mixed in with ensilaged feed or in the meal with seeds, with a smaller proportion of cases occurring due to the unpalatableness of the plant. In Onderstepoort (South Africa), 18 horses suffered impaction colic. The hay was sent to be analysed by a botanist to discover the root of the cause. *Datura stramonium* and *Datura ferox* were found in the hay sample. In **Figure 10** *Datura stramonium* plant was identified in the hay bale submitted for analysis (13). After identifying the plant, they were milled and chemically analysed using high-performance liquid chromatography (HPLC) to check the presence of tropane alkaloids (13).

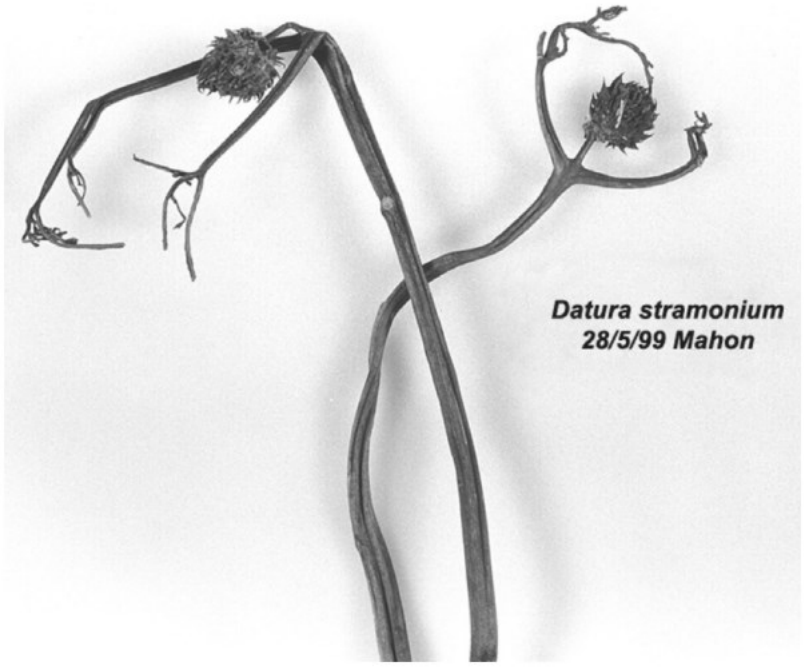

Figure 10. *Datura stramonium* stems with capsules from hay sample (13).

4.4.6. Treatment, prevention, and control

Horse owners must remember that even if they suspect their animal has ingested the plant, they should not attempt to treat or cure them since convulsions can be dangerous and violent. Contact a veterinarian as soon as possible since there are treatments for the dangerous consequences of tropane alkaloids. The owner should take the horse to an equine hospital immediately because treatment at home will not be sufficient (47).

A study in which 18 out of 83 horses had impaction colic. The following steps were applied to treat the animals: prokinetic drugs were administered to enhance gastrointestinal motility, as well as 500 g of laxatives in the form of $MgSO_4$ and 2 l of technical oil daily." Mineral oil (liquid paraffin) is the most frequently used laxative in equine practice and is administered at a dose rate of 10 ml/kg bw via a nasogastric tube. Its effects are considered mild, and it is safe for prolonged use. Water through a nasogastric tube, 5–7 liters, were applied twice daily. Flunixin meglumine at 1.1 mg/kg bw was used as an occasional analgesic. Flunixin is a non-steroidal anti-inflammatory drug which is effective in the control of visceral pain in horses. It is administered to control severe pain and reduce the effects of endotoxins in horses. Neostigmine methyl-sulfate 2.5 mg/ml at 0.005 mg/kg bw was added subcutaneously. Neostigmine directly stimulates intestinal contractions. Cisapride at 0.5 mg/kg bw was administered orally. Cisapride is a substituted benzamide with gastrointestinal

prokinetic properties (15). Polyionic fluid ("Plasma vet") was applied intravenously with an infusion at a rapid rate of 4 ml/kg/hr. Electrolyte solutions provide a stimulus to increase gastrointestinal motility (13,44).

Datura stramonium poisoning occurred in an equine centre in Spain where fifteen horses were fed dried lucerne hay, contaminated with *Datura stramonium*. Initially, one horse exhibited colic signs. The treatment, in this case, included no food and eliminating the lucerne hay. The veterinarian examining the horse prescribed butylscoplamine bromide at 60 mg/day and furosemide at 20 mg per ampoule; 5 ampoules were given in the initial dose before two ampoules were given every hour until the horse urinated. The horse was given 250 ml 40 mg methionine and 20 ml 75 mg. Following these treatment betainglucoronate was added intravenously to help liver functions (1).

Two horses, a thoroughbred yearling and a ten-year-old pony were affected by *Datura stramonium* seeds and treated for the poisoning with antibacterial drugs and electrolyte-supportive therapy. After changing the feed, the appetite and faeces consistency rate returned to normal within four days (15).

A case study (18) in Bulgaria where thirty four horses were fed maize silage contaminated with jimsonweed plants. The horses were grouped into three groups depending on the severity of their symptoms. The first group contained the horses with the most severe clinical signs. The second group contained horses with clinial signs but not as severe. The third group was the control. The treatment for the first group included gastric lavage with 500 g activated charcoal and 300 g $MgSO_4$ in naso-esophageal intubation with 5 l of water. Gas that accumulated in the intestines was released with a long needle. The other medication administered included 3 l Ringer’s solution intravenously, 10 g of ascorbic acid, 1 g of thiamine, 100 ml sodium N-acetyl methionine and 20 ml 20% caffeine-sodium-benzoate. Benzylpenicillin procaine and dihydro streptomycin (antibiotics) intramuscularly. Pilocarpine hydrochloride was administered subcutaneously as an antidote to alleviate sympathetic symptoms.

The treatment of two horses in South Africa which were fed meal that contained sunflower/maize seeds contaminated with jimsonweed seeds included. The first horse died peracutely so didn’t receive any treatment. The second horse (mare) was treated for reflux of the gastric content with serial lavage with forty litres of water. The caecum was trocharised to relieve the bloat. Flunixin (10 ml) (non steroidal anti-inflammatory drug) was given intravenously along with procaine penicillin (20 ml) (antibiotic) intramuscularly. Gastric lavage and nasogastric intubation was repeated the following day. On day three the mare still

had clinical signs. The treatment was repeated including Flunixin (10 ml) and procaine penicillin (20 ml). Cisapride was administered in the rectum to enhance the movement of the gastrointestinal system (21).

The owner's priority should be to keep your horse from coming into further contact with the plant, and it is crucial to remove any plant material in the mouth and flush the mouth with water. As in previous case studies, gastric lavage and activated charcoal reduce toxin absorption into the body. Horses in respiratory distress are given oxygen, and catheterisation prevents atropine accumulation in the kidneys (14).

There are various ways to prevent and control *Datura stramonium* in a pasture. The following management practices can reduce the probability of *Datura stramonium* consumption. Equine owners and veterinarians should familiarise themselves with toxic plants by identifying them at different stages of their growth and knowing their species specific characteristics (45). Another critical area is to know what seasons the plant grows. *Datura stramonium* flowers bloom in April and continue throughout the summer, frequently until October (21). The seeds contain the highest alkaloid content (14).

Equine owners should regularly do field walks, try and identify any poisonous plants growing in the area, and determine where a poisonous plant might grow in the pasture (45). Once the plant has been placed, it should be pulled from the ground wearing gloves and disposed of carefully to prevent it from emerging again (3).

Equine owners should always provide the best forage available. Overgrazing should be avoided at all costs. Dry environmental conditions are favourable to weed species like *Datura* spp. compared to grasses. Keep an eye on fencerows in pull-out lots and sacrifice areas since poisonous plants are frequently found there. Hay and other forages should be substituted in case of low availability of pasture grass (45).

Hay and other forages should be checked regularly for quality and any contaminants. Unlike pasture conditions, horses can struggle to distinguish between poisonous plants in the grass. A botanist or nutritionist should examine the hay after it has been harvested to determine its quality and other impurities (45).

Replanting a percentage of the pasture each year can help reduce the occurrences of weeds and other poisonous plants. However, it is essential to introduce the horses gradually while grazing a new area or freshly planted pasture for any abnormal changes in behaviour or physical changes (45).

Maintaining high standards is another crucial element, whether horses are used for competitions, sightseeing, trail rides, or performances. It is essential to close check on them to ensure they do not ingest anything they should not (45).

Mechanical control is an essential aspect of controlling *Datura stramonium*. Various ways of controlling the plant mechanically include pulling the plant by hand and tilling the ground to kill the seedlings. On the other hand, older plants could regrow from lower nodes that have been cut by tilling (3).

Chemical control can also be effective in preventing the emergence of the plant. Herbicides should be used where suitable. Herbicides are used more frequently on cereals than on pasture used for animals. *Datura stramonium* can be effectively controlled by pre-emergence applications in maize (19).

Biological control has also been used in plant crops to control *Datura stramonium* (2). AAL-toxin is a natural herbicide generated from the fungus *Alternaria alternata*, selectively controls jimsonweed in low concentrations in wheat, tomato, maize, and other dicotyledonous crops. However, it has not yet appeared at the commercialised level and is less likely to be used by an equine (47).

5. Discussion

In my present work I reviewed 47 studies about *Datura* poisoning in various animal species with special attention to horse. The main clinical signs were directly connected to sympathetic predominance e.g., increased heart rate (tachycardia), dilated pupils (mydriasis), abdominal distension (inhibition activity of intestines), sporadic muscle spasms and rigours (inhibition of acetylcholine at the neuromuscular junction), dry oral and nasal mucosae (inhibition of salivation), diarrhoea (due to decreased water uptake in the intestines), anorexia (frequent regurgitation due to suppressed intestinal motility and full stomach), and stagger. Other symptoms, could be derived from, but not directly connected to sympathetic predominance were constipation and impaction colic due to intestinal atony (inhibition of gastrointestinal motility).

Differentiation of early and later symptoms of jimsonweed poisoning helps diagnosing and treating the animal. The early clinical signs were behavioural changes, restlessness, depression, nervousness, colic, diarrhoea, polydipsia (excessive thirst), rapid pulse, rapid breathing, dilated pupils, muscular twitching and spasms, and frequent urination. In contrast, the symptoms of the later or fatal cases were depression, weak pulse, irregular breathing, decreased body temperature, retained urine, convulsions, and coma (14). There is currently not enough research available on chronic cases.

The best prevention methods would be checking the feed/hay for any contaminants, replanting the pasture regularly and frequent field walks to identify any poisonous plants on the pasture. Mechanical and chemical weed controls are widely used against *Datura* species. Controlling the plant mechanically can be carried out by pulling the plant by hand and tilling the ground to kill the seedlings. Chemical controlling methods usually include application of herbicides.

Future research should focus on the development of more accurate clinical tests to diagnose jimsonweed poisoning. Such analytical methods are available but most veterinarians will not have access to these tests due to cost and time. A cost-effective, quick and reliable test that equine owners and veterinarians could use in the future could lead to a reduction in the number of incidences. Furthermore, faster diagnosis could prevent deaths in the future.

6. Conclusions

My first (I) aim was to raise awareness about the consequences of jimsonweed poisoning to owners, members of the equine community and the veterinarians.

In order to reach this aim, I reviewed the available literature about the topic (aim II). I collected 47 scientific reports and concluded that there are several papers on accidental poisonings of horses but only a handful of experimental studies. Most of the case studies reported the consequences of contamination of the feed with jimsonweed seeds or of the hay/silage with the stems and leaves of the plant. Studies demonstrate that horses instinctively avoid grazing fresh *Datura* plants due to their foul smell. Therefore owners should regularly check hay/feed for potential contamination by dry *Datura* plant parts that have less intensive smell/taste.

My third (III) aim concerned symptoms and treatment. The most common clinical signs observed in horse were: suppressed activity of distal colon, mydriasis, hyperexcitability, tachycardia, dryness of the oral and nasal mucosae. The most effective treatments were the removal of the food, intravenous administration of flunixin (a non-steroidal anti-inflammatory medicine), rectal application of Cisapride and butylscopalamine bromide (to enhance gastrointestinal motility), and Pilocarpine to alleviate symptoms.

In conclusion, *Datura stramonium* can affect a wide variety of animal species. Seeing the diverging observations made in case studies it is clear that we need a better understanding of the horse-specific physiological effects of *Datura* poisoning. With this knowledge, we can improve prevention and treatment the poisonous effects of jimsonweed in the future, particularly in equine species which are especially sensitive to *Datura* poisoning.

7. Summary

Jimsonweed is a toxic plant of concern to horses. Horses instinctively avoid jimsonweed due to its unpleasant smell and taste. However, horses can become intoxicated due to the plant being mixed with silage and hay. Jimsonweed is poisonous to other animal species including sheep, goat, pig, and dog.

Tropane alkaloids are the primary active constituents of *Datura stramonium*. The main tropane alkaloids of concern are atropine (including its two enantiomers: S- and R-hyoscyamine), and scopolamine. These tropane alkaloids are anticholinergic, which means that they block the mechanism of action of acetylcholine at the neuromuscular junction. The tropane alkaloids affects both the central and peripheral nervous system. This leads to various clinical signs including behavioural changes, restlessness, decreased borborygmi, tachycardia, irregular breathing, and dryness of the oral and nasal mucosae. For horse, symptoms that cannot be directly associated to the development of sympathetic predominance, were also observed like depression, colic, flatulence or diarrhoea.

There are various methods in diagnosing jimsonweed poisoning including taking a blood sample and checking haematological parameters (8). Different analytical methods are used to diagnose tropane alkaloids from the urine of the animal including mass spectrometry, gas chromatography and HPLC. Checking the feed and pasture for any poisonous plants or contaminants is another vital technique for making a diagnosis. Once the animal is successfully diagnosed it should be treated immediately. Treatment methods can be different depending on the clinical signs present. Prokinetic drugs, laxatives, flunixin, and intravenous fluids are some of the most common treatment methods used. Other treatments include the administration of furosemide, activated charcoal, antibiotics, electrolytes, ascorbic acid, and thiamine for improving liver function. Pilocarpine is used as an antidote to treat the poisoning.

Prevention and control are extremely important. Such measures include careful grassland management, replanting grasslands and avoiding overgrazing. It is also important to check the feed (meal) prior to feeding because silage and hay can be contaminated during their preparation.

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