Datura contamination of hay as the suspected cause of an extensive outbreak of impaction colic in horses

T W Naudé[a*], R Gerber[b], R J Smith[c] and C J Botha[a]

ABSTRACT

Datura poisoning of horses is extensively reviewed. An outbreak of intractable impaction colic affecting 18 of 83 horses was stopped by withdrawing dried tef hay contaminated with young *Datura* plants. The dried, botanically identified *Datura stramonium* and *D. ferox* contained respectively 0.15 % mass/mass (m/m) hyoscyamine as well as 0.16 % m/m hyoscine (scopolamine) and only hyoscine at a concentration of 0.11 % m/m. Immature, unidentifiable plants resembling *D. stramonium,* contained 0.14 % m/m and 0.12 % m/m of the 2 respective tropane alkaloids. The outbreak was characterised by protracted and repeated colic attacks due to impaction of the large colon and/or caecum without any other anti-muscarinic signs. Comparative analyses of single specimens of dried seed of the 2 species collected from both fertilised and waste areas revealed that young South African *Datura* spp. had levels of tropane alkaloids comparable to those in the well-known toxic seed and were, consequently, equally toxic. The inherent danger of tef hay being contaminated with *Datura* is emphasised. To our knowledge this is the 1st field case of poisoning in horses ascribed to the vegetative parts of *Datura* spp.

Key words: atropine, *Datura ferox, Datura stramonium,* hay contamination, horses, hyoscine, hyoscyamine, impaction colic, scopolamine, tropane alkaloids.

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Fig. 1: ***Datura stramonium* L.** (courtesy of SANBI).

Fig. 2: ***Datura ferox* L.** (courtesy of SANBI).

INTRODUCTION

Datura stramonium L. (common thorn apple, gewone stinkblaar, Fig. 1) and *D. ferox* L. (large thorn apple, grootstinkblaar, Fig. 2) are the 2 cosmopolitan weed species of this genus of the Solanaceae commonly encountered in South Africa. The former probably originated from Central and South America (where the common name is Jimson weed) and the latter from Asia[10]. They are annual herbs associated with disturbed soil and occur widely in South Africa as invaders in annual crops, waste areas and river beds. These 2 species are mainly differentiated by the spines on the upright, oval fruit capsules: in the former these slender spines are up to 10 mm long whereas in the latter the stout, spreading spines are up to 30 mm in length.

[a]Section of Toxicology, Department of Paraclinical Sciences, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort, 0110 South Africa.

[b]Department of Companion Animal Medicine, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort, 0110 South Africa.

[c]Phytex Australia (Pty) Ltd., P.O. Box 543, Castle Hill, NSW 2154, Australia.

*Author for correspondence.
E-mail: theuns.naude@up.ac.za

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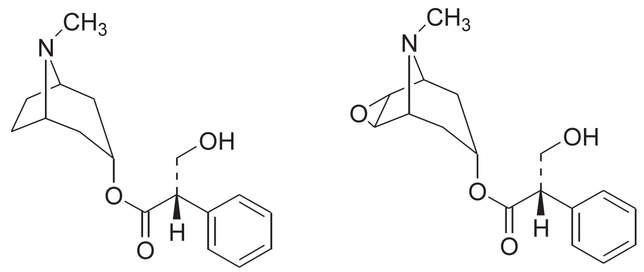
D. inoxia Mill. (= *D. meteloides,* = *D. wrightii,* downy thorn apple, harige stinkblaar) is the 3rd locally occurring weed of this particular genus. As the common name implies it is characterised by being soft, grey velvety and by a globose, hanging capsule densely covered with slender spines. It is much less common locally and has mainly a far western and northern distribution[10].

The toxic principles in *Datura* spp. are the tropane alkaloids of which atropine (*dl*-hyoscyamine) and scopolamine (hyoscine) (Fig. 3) are the major components of *D. stramonium*[17] and scopolamine that of *D. ferox* (Springhall and Seawright 1972, cited by Everist[8]). Pharmacologically active *l*-hyoscyamine occurs in the plant but during chemical isolation this can change to the *dl*-racemate (atropine) with only about half the antimuscarinic potency[1,5]. In this publication the terms scopolamine for hyoscine and atropine for hyoscyamine will be used for these 2 substances. These 2 tropane alkaloids are esters of the aromatic tropic acid and the respective bases, tropine and scopine. The intact esters are essential for pharmacological activity.

Datura spp. are annual weeds ripening with the grain crops they invade. The characteristic finely-pitted, kidney-shaped seeds[11] have the same specific gravity as grain kernels and, consequently, do not separate well from grain during sifting. It is, therefore, a frequent contaminant of grain, including maize, which is widely used as stock feed. South African legislation (Foodstuffs, Cosmetics and Disinfectants Act, Act 54 of 1972) stipulates an



l-Hyoscyamine
(Atropine = *dl*-hyoscyamine)

Scopolamine

Fig. 3: **Hyoscyamine and scopolamine: esters of the aromatic tropic acid** (right) **and the respective bases, tropine and scopine** (left).

allowable limit of *Datura* seed in grain for human consumption as 1 seed/10 kg maize, 3 seeds/400 g ground nuts and 5 seeds/400 g soya beans. Grain rejected for this reason usually finds its way into stock feed and further sifting to clear such seed for human consumption often results in the heavily contaminated siftings being used as stock feed[12]. The seed of local *D. stramonium* has an alkaloid content of 0.36 % the chief component being atropine. The alkaloids are also contained in the malodorous leaves ('stinkblaar') at a level of 0.5-0.54 % dry matter base (DMB)[17] but is never-the-less frequently grazed by ruminants in South Africa (T. W. Naudé and T.S. Kellerman, Onderstepoort, pers. obs.). The only recorded cases of stock poisoning by this plant in South Africa was in the horse and this was due to grain-contaminated seed[17]. The vegetative part of the plant as such has, consequently, to date been regarded as of relatively minor toxicological importance[12].

Atropine and related parasympatholytic compounds are competitive antagonists of the actions of acetylcholine and other muscarinic agonists and compete for common binding sites on the muscarinic receptor[1,17]. In humans, atropine at therapeutic doses has virtually no detectable effect on the CNS, whereas scopolamine, which more readily crosses the blood–brain barrier, causes CNS depression manifested as drowsiness, amnesia and fatigue. Euphoria is also encountered. The acute toxic effects commonly seen with the tropane alkaloids are mydriasis and cycloplegia, dry mucous membranes and tachycardia. At higher doses, central nervous excitation becomes more prominent, resulting in restlessness, irritability, disorientation, hallucination and delirium. At still larger doses, stimulation is followed by depression leading to circulatory and respiratory failure after a period of paralysis and coma[5]. Although humans are very susceptible to poisoning, atropine has an exceptionally wide therapeutic index in humans, fatalities being rare even in instances of gross over-dosage or poisoning.

Datura poisoning, especially following ingestion of the seed, is often seen in humans[5,17]. In animals it is rare and the only credible cases have been reported in the horse where 3 outbreaks occurred after ingestion of grain heavily contaminated with *Datura* seed[3,16,18]. The clinical signs and course of intoxication varied rather widely. In the 1st case[16], 1 horse died from acute gastric dilatation and rupture whereas the 2nd had to be euthanased due to unresponsive paralytic ileus. As this incident had occurred in South Africa, it is assumed that the seed involved was probably a mixture of that of *D. stramonium* and *D. ferox*. In the 2nd case[3], 15 animals from a group of 34 were affected and 11 died, 2 as long as 6 days after withdrawal of the incriminated feed, cracked maize containing 'an unusually large number of Jimson weed (*D. stramonium*) seeds'. The signs recorded were anorexia, hyperexcitability, staggers, muscular spasms, frequent urination, mydriasis with impaired vision progressing to convulsive seizures, rigor and coma preceding death. There is no mention of gastrointestinal complications. In the 3rd case[18], 2 horses were fed a meal containing 0.5 % *D. stramonium* seed. They exhibited depression, mydriasis, anorexia, tachycardia, polydipsia and polyuria, fever and a brown foetid diarrhoea. Both recovered after supportive treatment.

Only 2 cases of experimentally produced *Datura* intoxication were found. Barney and Wilson[3] fed a horse '2 quarts' (*c.* 2.2 ℓ) of cracked maize containing 'an unusually large number of Jimson weed seeds' on a daily basis for an unspecified number of days. Inappetance, hyperexcitability and mydriasis appeared on the 8th day. On the 10th day staggering and muscle spasms were exhibited and the animal died on the same day. Again the authors do not refer to any clinical signs associated with colic.

Galey *et al.*[9] dosed 4 adult mares with air-dried *D. meteloides* (= *D. inoxia*) vegetative plant material containing *c.* 550 mg scopolamine and 370 mg *l*-hyoscyamine (740 mg as atropine)/kg at 0.0125, 0.025, 0.1 and 0.5 g/kg. Clinical signs consisting of severe gastrointestinal atonia, tachycardia, sweating and colic, were seen at only the highest dose of 0.5 g/kg, equivalent to 0.275 mg scopolamine and 0.185 mg atropine/kg (in addition to the other unquantified related tropane alkaloids in the plant). Clinical signs were evident 2 hours after dosing and had not resolved by 72 hours after dosing. Urine alkaloid concentrations peaked within 1–2 hours after dosing and at low dosages were mostly absent after 12–24 hours. The $t_{1/2}$ of scopolamine and atropine were 1.7 and 2.3 hours, respectively.

Atropine is widely used in veterinary practice, especially for the treatment of poisoning by organophosphorus and carbamate cholinesterase inhibitors[1]. However, even when used as a preanaesthetic or mydriatic in the horse, the potential detrimental effects on intestinal activity should, however, be considered[1,16]. In the horse it is also used for the treatment of chronic obstructive pulmonary disease but with the proviso that it must be used with care as it may produce ileus and abdominal pain[14].

Similarly, Ducharme and Fubini[7] found that the horse was especially sensitive to gastrointestinal atony on administration of atropine and concluded that it was contraindicated for the relief of intestinal spasm and may in fact lead to severe gastrointestinal complications. After experimental i/v injection of clinically normal ponies ($n = 5$) at 0.044 mg/kg and 2 weeks later again at 0.176 mg/kg, intestinal motility was decreased after 30 minutes and the horses had stopped eating, exhibited abdominal pain and were quiet and depressed at both dose levels. With the low dose they resumed eating after 1–2 hours but after the higher dose, which also caused caecal distention, they only resumed eating 2–7.5 hours later and intestinal motility had only gradually returned to normal by 12 hours.

In an equine study on myoelectrical and mechanical intestinal activity in clinically normal ponies ($n = 4$), atropine at 0.044 mg/kg caused a marked decrease in jejunal and pelvic flexure motility for more than 2 hours and had increased pelvic flexure sphincter tone, possibly indirectly by decreasing parasympathetic tone[2].

In ruminants microbial degradation of atropine, scopolamine and related tropanes (most probably by hydrolysis of the ester bond) presumably takes place in the rumen as the toxic dose *per os* for cattle is estimated by Nelson *et al.*[13] to be

2.49 mg/kg/day of hyoscyamine (thus probably 5 mg/kg/day of atropine) with an additional 0.5 mg/kg/day of scopolamine in *Datura stramonium* seed.

The poisoning was also self-limiting as ruminal atony and anorexia prevent further intake until the blood levels of alkaloids are reduced to allow normal intestinal function. In contrast, the toxic oral dose for the horse (*vide infra*) is 0.1 mg/kg of *l*-hyoscyamine (equal to 0.2 mg atropine/kg). Of all species the serious consequences of gastrointestinal complications are only mentioned in equines[1]. In humans the gastrointestinal tract is, in contrast to the horse, rather insensitive to the effect of atropine. Only 1 report of paralytic ileus was traced and was due to protracted, excessively high, constant infusion of atropine (2600 mg over a 30-day period) to control excessive bronchial secretion after an organophosphorus suicide attempt[4].

In calculating the toxicity of atropine found in plant analyses, it must be remembered that in the plant, atropine (*dl*-hyoscyamine) would be in the active *l*-form and, consequently, approximately twice as potent as commercially available atropine sulphate[5].

In contrast to atropine, scopolamine is only rarely used in veterinary medicine[1].

HISTORY OF OUTBREAK

Eighty-three riding horses (belonging to different owners) were kept at a well-managed riding school which had been established 7 years earlier. During April 1999 a spate of impaction colic, a condition which had not been diagnosed there previously, suddenly occurred. Over a 6-week period 18 horses were affected, one of which died.

It transpired that a new consignment of hay, received from the usual supplier had been fed to the horses. Impaction colic occurred in 3 horses during the 1st week they had access to this hay. No cases occurred during the following 2 weeks and then 2 more cases occurred in the 4th week, 1 of which had also been affected during the 1st week. During the 5th to 7th weeks, however, no fewer than 18 cases occurred affecting 14 previously unaffected horses as well as 4 that had been affected before and had apparently recovered.

The attending veterinarian referred a number of affected animals to the Equine Clinic of the Department of Companion Animal Medicine at the Faculty of Veterinary Science, Onderstepoort, where a tentative diagnosis of atropine intoxication was made as some *Datura* plants were found in the hay submitted with the animals. Following an *in loco* inspection the suspect hay was withdrawn after it had been fed for 7 weeks.

During the week following the withdrawal there were, however, still 11 cases of impaction colic. One case developed signs of colic the day following withdrawal, 2 on the 3rd day and 8 on the 5th day. Only 1 of these horses had not been affected previously and all had had colic attacks during the last 2 weeks prior to withdrawal of the hay. Of these 11 horses, 7 had their 2nd and 4 their 3rd attack of colic.

After withdrawal, 4 further cases were readmitted to the hospital at the stable's request as these animals were regarded a showing signs of colic (unwillingness to drink and aberrant *habitus*). On clinical examination, however, nothing abnormal was detectable but they were kept under observation for a few days and then returned to the riding school. The withdrawal thus terminated the occurrence of colic. Repeated attacks on the farm were initially probably due to re-exposure to *Datura*-contaminated hay.

A commercial ration, Epol Rider Cubes (Epol (Pty) Ltd.), was fed as concentrate, and water, which was also used for the household purposes, came from a borehole. Standard inoculation against horse sickness and equine influenza, routine external parasite control with pyrethroids and diazinon were maintained and deworming depended on the individual owner's choice. Sawdust was used for bedding and had been obtained 3 times a week from the same firm for some time.

Apart from a rather overgrazed 11 ha camp with natural grazing, which on inspection revealed no poisonous plants that could be related to the colic, all feed was purchased. Baled *Eragrostis curvula* hay was regularly obtained (250 bales at a time) from the same supplier. With the last 2 consignments he had, however, been unable to supply only *Eragrostis curvula* and had supplied some tef (*Eragrostis tef*) hay in stead. The outbreak was clearly related to feeding of these 2 consignments of hay.

EXAMINATION OF HAY AND CUBES

The 2 last consignments were examined for contaminating plants. Six bales of each, irrespective of whether it was *Eragrostis curvula* or tef, were selected at random and the stable hands were requested to collect all material other than grass for further inspection.

The second-last batch was of poorer quality than the last. An occasional patch of very slight mouldiness was observed during sorting. The following dried foreign plant material was identified: several maize stalks; stems of a large, hard grass (possibly *Hyparrhenia tamba*, blue thatch grass) and tufts and roots of various veld grasses; *Nidorella* spp.; *Cucumis* spp.; numerous pieces of *Cyperus esculentus* (nutsedge or 'uintjies'); 2 leaves of what could possibly have been either tulip (*Moraea* spp.) or *Gladiolus* spp. Additionally, *Datura* spp. were present and comprised some 30 small to large pieces of young, brownish stems (diameter 1–2 cm) which could initially not be identified as such. Fortunately, 2 of these stems with young fruit were present and were positively identified as *D. stramonium* (M. Welman, Botanical Research Institute, Pretoria, pers. comm., 1999) thus enabling identification of the remaining material

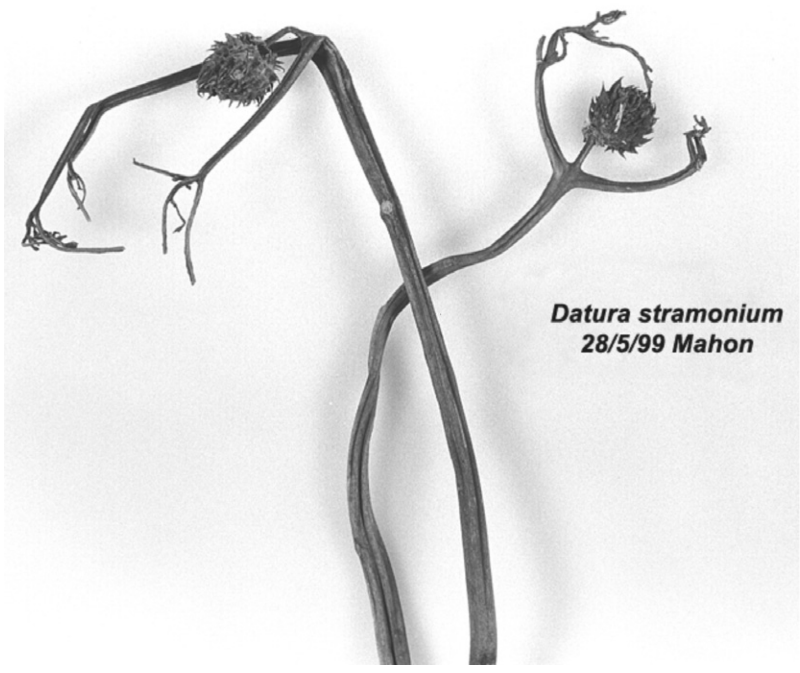


Fig. 4: **Immature, but botanically identifiable *Datura stramonium* (note dark stem) from hay.**

by comparison (Fig. 4).

The last batch was of better quality and contained only the following: many specimens of *Cyperus esculentus,* a number of *Verbena bonariensis,* a few *Conyza bonariensis* and 1 unidentified species. No *Datura* plants were found in these 6 bales.

On a 2nd *in loco* inspection, 2 bales of tef and *Eragrostis curvula* each and 1 of apparently veld grass (mainly *Setaria* spp.) were very carefully taken apart layer by layer and the following were found:

The 2 bales of *Eragrostis curvula* contained no annual weeds and only a small amount of veld grass. The bale of grass (consisting mainly of *Setaria* with some tef in it) contained, apart from some *Cyperus esculentus,* nothing else of importance.

One of the tef bales was contaminated with a large number of *Cyperus esculentus* specimens, some annual *Eleusine* and *Setaria* grass spp. and a few maize stalks. The other bale, on the contrary, contained grass root tufts, *Hyparrhenia tamba, Eleusine* and *Setaria* spp., *Oenothera tetrapta, Cyperus esculentus* and 3 *Datura* plants. The careful opening of the bales had enabled recovery of the young dried, pressed, intact, entire plants with leaves, 1 of which could, due to the presence of the typical young fruit, be positively identified as *D. ferox* (Fig. 5). From the positive identification of *D. stramonium* from the previously inspected bales, the other 2 plants appeared to be *D. stramonium* (Fig. 6).

Both the positively identified *D. stramonium* and *D. ferox* plants as well as the botanically sterile suspect entire plants taken from the hay, were milled and chemically analysed for tropane alkaloid content. In order to compare these analyses with that of the well-known toxic seed, material collected from waste areas as well as fertilised lands in the Onderstepoort vicinity were also subjected to chemical analysis.

A 25 g sample of the Epol Rider Cubes fed to the horses was crushed at the laboratory and the ground material examined by stereo-microscope for the presence of the typical black, finely pitted testas (outer coverings) of *Datura* seed[11]. Stereo-microscopic examination of the ground concentrate cubes revealed no shells resembling those of *Datura* seed. In view of the fact that these cubes were also used widely by other stables without any problem, it was not subjected to chemical analysis.

COLIC MANAGEMENT AND TREATMENT

Sixteen horses were referred to the Onderstepoort Equine Clinic over a period of 18 days. On admission the clinical parameters important in judging the severity of colic, namely pulse, respiratory rate, temperature, mucous membrane colour and capillary refill time, were usually normal. Borborygmi were somewhat reduced but not absent and on rectal examination the most significant findings were varying degrees of impaction of the caecum and/or pelvic flexure of the colon. In some no impaction was palpated but their faeces were very dry. Furthermore, the usual signs of colic, namely pawing, sweating and rolling were generally only mild to moderate. Nasogastric intubation revealed no reflux.

Fig 5: **Immature *Datura ferox*** (note paler stem) **from hay.**

Clinicopathological findings were also within normal limits and no dehydration was observed. In addition, fluid obtained by abdominocentesis from some horses revealed no abnormalities.

The owner's observation of decreased water intake could only be confirmed in 1 case during hospitalisation where water was given *ad libitum,* whereas feed was withdrawn in cases of severe impaction.

Treatment was administered according to the severity and extent of the signs of colic and rectal findings. Therapy included water by nasogastric tube (5-7 ℓ b.i.d to t.i.d.), laxatives *per os* ($MgSO_4$ 500 g and/or technical oil, 2 ℓ daily); the prokinetic agents neostigmine methylsulphate (Fresenius), 2.5 mg/mℓ at 0.005 mg/kg s.c. and cisapride ('Prepulsid' Jansen-Cilag 20 mg tablets) at 0.5 mg/kg *per os* t.i.d.; polyionic fluid ('Plasma Vet', Adcock-Ingram) i.v. infusions at a rapid rate (4 mℓ/kg/h) and flunixin meglumine ('Finadyne', Schering-Plough AH) i.v. at 1.1 mg/kg as analgesic, when required.

Treatment was continued until all signs of discomfort were absent and rectal examination revealed resolution of the impaction. Most of the animals needed repeated treatment over several days until all signs of discomfort had disappeared. Then tef and lucerne were reintroduced in small amounts several times a day and gradually increased.

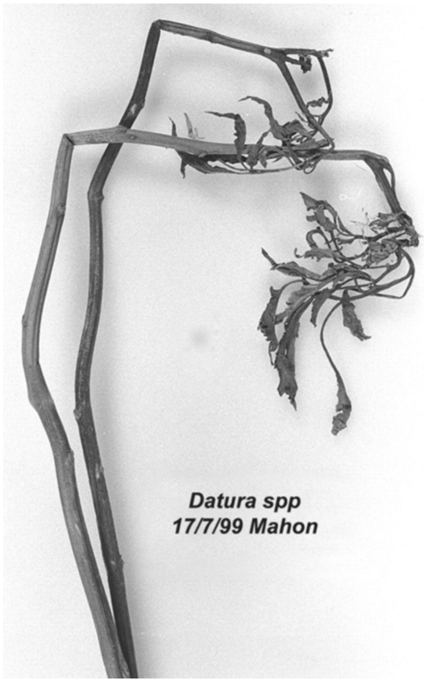


Fig. 6: **Immature, botanically unidentifiable *Datura* spp.** (note paler stem left, and darker right, of entire plants found pressed in hay)**.**

Six horses discharged from the Clinic had to be readmitted a few days later. All responded well to treatment except for 1 which had undergone surgery for severe large colon impaction which was unresponsive to conservative treatment. Five days later it had to be euthanased due to recurrence of the same problem.

ANALYTICAL RESULTS

Tropane alkaloid analysis

These HPLC results are reflected in Table 1.

Extraction procedure: the samples were ground (coffee grinder) and extracted (in

Table 1: **Chemical analyses of *Datura* plant specimens for tropane alkaloids.**

Description of dried, milled specimen	*l*-Hyoscyamine* content (g/kg)	Scopolamine content (g/kg)
Botanically unidentifiable *Datura* spp. from hay	1.4	1.2
Botanically identified *Datura stramonium* from hay	1.5	1.6
Botanically identified *Datura ferox* from hay	Nil	1.1
Botanically identified *Datura stramonium* seed from fertilised land	1.9	0.3
Botanically identified *Datura stramonium* seed from waste area	1.5	0.7
Botanically identified *Datura ferox* seed from fertilised land	Nil	1.2
Botanically identified *Datura ferox* seed from waste area	Nil	0.7

*Atropine = *dl*-hyoscyamine.

duplicate) with 0.1 % H_2SO_4. The resulting solution was filtered and the alkaloids extracted into dichloromethane at pH 10. The dichloromethane was removed and the residue redissolved in the mobile phase (see below) and analysed.

Chromatographic conditions: the system used consisted of a Waters 600 controller and 610 Fluid unit with a Waters 486 tunable UV detector and a Rheodyne injector (fitted with a 20 $\mu\ell$ loop). The analysis was performed using a Phenomenex Luna™ 5 μ C18 (2) column (4.6 ×150 mm) with absorbance at 210 nm. The mobile phase was methanol:50 mM NaH_2PO_4:triethylamine (25:74:1), adjusted to pH 3.0 ± 0.1 with H_3PO_4, was used at a flow rate of 1 mℓ/min.

Cardiac glycoside test: the few leaves, possibly resembling cardiac glycoside containing tulp (*Moraea* spp.), was tested by digoxin-specific fluorescent polarisation immuno assay[6] with negative results.

DISCUSSION

The signs encountered during the outbreak were characterised by only gastrointestinal colic manifested as retarded motility. The usually expected signs of muscarinic receptor blockage, amongst others mydriasis, tachycardia, sweating and dry mucous membranes, were not recorded. Furthermore, stimulatory central nervous system signs were absent and animals were, in fact, very docile.

Nevertheless, this spate of impaction colic was attributed to *Datura* intoxication. This was confirmed by withdrawal of the contaminated hay which resulted in the termination of colic incidence. Although 5 more cases (of which 1 had to be euthanased) occurred 3–4 days after withdrawal of this hay and had to be admitted to the Academic Hospital for treatment, it transpired that all these cases had been affected earlier and that these were most probably relapses from previous exposure. One of these horses exhibited an abnormal *habitus* 6 days before withdrawal of the hay and was hospitalised for suspected colic but was discharged the following day. The same animal was, however, readmitted 3 days after withdrawal of the suspect hay with severe, recalcitrant impaction colic and eventually had to be euthanased after 8 days, that is, 11 days after the last possible exposure to toxic plant material. It is possible that in this horse the condition had been aggravated by additional factors, since it was the only case with severe clinical signs and a fatal outcome. A certain way to have confirmed the diagnosis would have been determination of horse urine tropane alkaloid levels but there was not access to this facility at the time.

Affected animals were depressed and docile, which is in contrasts to the hyperexcitability, muscular spasms, rigor and convulsive seizures described by Barney and Wilson[3], but in accord with what is described by Williams and Scott[16] and Ducharme and Fubini[6]. Colic is the dominant sign described by other authors[9,16] and it is possible that the nervous signs mentioned by Barney and Wilson[3] could have been due to peracute colic, although spasms, rigor and seizures are not characteristic of colic.

Galey *et al.*[9] calculated the $T_{1/2}$ of scopolamine and atropine in the horse, after a subtoxic dose of *Datura,* to be respectively 1.7 and 2.3 hours. These substances were virtually eliminated after 24 hours. F D Galey (University of California, Davis, pers. comm., 1999), however, is of the opinion that tropanes behave erratically in the horse and any substantial exposure should be treated with extreme care. Despite the short half-lives following low doses it seems that the residence time at higher levels is prolonged and it is surmised that once atony sets in the atony seems to be intractable. This could explain why the 1 horse had to be euthanased 11 days after the last possible exposure. In another more recent clinical case of *Datura* intoxication, a horse developed acute colic with mydriasis and tachycardia. It was successfully treated and exhibited only mydriasis the next day but no further colic and both atropine and scopolamine was still present in its urine 96 hours later (R Gerber, T W Naudé, Onderstepoort, and S de Kock, SA Jockey Club, unpubl. data, 2000). It is, therefore, postulated that the horses during the outbreak under discussion might have had just transient signs of mydriasis, etc., or that this was overlookde and that only the long-term effects on the gastrointestinal tract were noticed.

Galey *et al.*[9] determined that 0.5 g *Datura inoxia* plant material/kg (equivalent to 0.185 mg *l*-hyoscyamine and 9.275 mg scolpolamine/kg) induced colic. At 0.01 % [equivalent to respectively 0.037 mg/kg *l*-hyoscyamine (0.074 mg/kg atropine) and 0.055 mg/kg scopolamine] there were no clinical signs of intoxication[9].

On the other hand Ducharme and Fubini[7] found atropine sulphate to cause colic at 0.044 mg/kg (equivalent to only 0.022 mg/kg of *l*-hyoscyamine) and marked atony lasting 12 hours at a dose of 0.176 mg/kg. The latter would be equivalent to only 0.088 or *c.* 0.1 mg *l*-hyoscyamine/kg (the active component occurring in the plant).

In the present case the material ingested by the horses contained an average of 1450 mg *l*-hyoscyamine and 1300 mg scopolamine/kg (Table 1). In terms of *l*-hyoscyamine only, the equivalent dose of plant material containing 0.1 mg of *l*-hyoscine and which could thus have resulted in colic would have been only 0.069 g or 69 mg/kg.

No data are available on the dose of scopolamine that may result in colic. Its role, and that of the other minor tropanes in *Datura* spp., can only be surmised to be additive and aggravating.

Apart from atropine, xylazine also decreases the myoelectrical and mechanical activity of the distal portion of the equine jejunum and the pelvic flexure of the colon[2] and fatal drug-induced, refractory impaction colic in the equine can be related to the use of amitraz[14].

From a pharmacological point of view, neostigmine is the drug of choice to treat atropine poisoning but it must be used with circumspect in the horse since administration can cause severe signs of colic and may even lead to rupture of a severely impacted large intestine. However, it did not have any dramatically beneficial effect in this outbreak. Mild cases receiving the drug recovered as well as those not receiving it. Adams *et al.*[2] found in their study on the effect of drugs on the myoelectrical and mechanical activity of the jejunum and pelvic flexure of the equine colon, that whilst neostigmine increased the propulsive activity of the pelvic flexure and regularly resulted in defecation, it had no effect on the motility of the jejunum. As the dose of neostigmine used in this case was slightly higher than that usually employed, the treated horses were walked after injection to obviate possible side-effects. There were none and thus higher doses of neostigmine could possibly have been used.

According to Goodman and Gillman[5] physostigmine is regarded as the drug of choice to treat atropine intoxication in humans. It rapidly abolishes delirium and coma and should seriously be considered as an alternative cholinergic. It is, in contrast to neostigmine, not ionised and, consequently, readily passes tissue barriers[5]. It might possibly overcome the recalcitrant, perceived gut receptor blockage. As it is rapidly metabolised in humans, repeated doses at short intervals may be necessary.

The hay derived from the perennial *Eragrostis curvula* was free of *Datura* and contamination was limited to the tef hay. Tef is sown annually and *D. stramonium* and *D. ferox* are annual weeds and it must, consequently, be expected that tef (and any other annual grasses) would easily be contaminated with these poisonous weeds. Tef should routinely be sprayed with broad-leaf herbicides a few weeks before the hay is cut in order to ensure freedom from noxious weeds (A. Lawrence, tef farmer, Greylingstad, pers. comm., 2002).

Tef hay is more expensive and generally regarded as superior to and preferred to *Eragrostis curvula* for horses. It must, however, be free from noxious weeds. Its use for equines subsequent to this incident, as well as another outbreak of colic at Onderstepoort ascribed to *Datura* (R Gerber, T W Naudé. Onderstepoort and S. de Kock, SA Jockey Club, unpubl. data, 2000), prompted its temporary discontinuance as roughage for horses at the local veterinary faculty. There does not appear to be any danger to ruminants fed contaminated tef[12].

It is most difficult once *Datura* has been found in a few bales of hay of a particular consignment, to attempt to exactly quantify the extent of contamination as it is impractical to examine every bale. Problems may either be due to only 1 or 2 bales or most of the bales may be contaminated. Manual removal of all toxic plants, in order to render contaminated bales safe, is impractical. This procedure is both very labour-intensive and, due to the brittle nature of the fragile dried young plants, actually impossible. Such hay should certainly not be used for equines.

The danger of *Datura* seed particularly to equines[12,15] and humans[16] has long been recognised in South Africa. Old references to the toxicity of vegetative parts of *Datura* exist[16] but have until recently been largely ignored as such intoxication in stock was not diagnosed. Cattle frequently browse *Datura* without any deleterious consequences (T W Naudé, T S Kellerman, Onderstepoort, pers. obs., 2000) which further contributed to the assumption that young, green *Datura* plant material was not of toxicological significance in stock. Owing to its offensive smell, fastidious feeders, such as the horse, will most probably not ingest the fresh plant at all. On the other hand, horses that are stable fed with dry hay, are forced to eat what is available. Dried, young *Datura* in hay has lost most of its odour and although horses will reject the thicker stems of the plant (T W Naudé, Onderstepoort, pers. obs. 2000), the brittle, fine tops and leaves of immature plants baled with the hay, becomes so intermingled on opening the bale, that the animals cannot avoid eating it.

Only single specimens of *D. stramonium* and *D. ferox* were chemically analysed (Table 1) and deductions and generalisation about the tropane alkaloid content of these species must, therefore, be guarded. The fact that only scopolamine was found in both the botanically identified *D. ferox* plant from the hay and from the seed specimens, is in accordance with Everist[8]. The unidentified young plants taken from the hay (Fig. 5) and which were most probably mainly what the horses had taken in, appears from the chemical analyses to have been, or to have mainly been, *D. stramonium.* The concentrations of the 2 main tropanes in the young plant approximates that of ripe seed and for *D. stramonium* the scopolamine content of the leaves was considerably higher.

The cost of veterinary treatment for this outbreak to the riding school amounted to R39 600 and the loss in condemned hay to a further R8300. The value of the horse that had to be euthanased is not included.

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REFERENCES

1. Adams H R 1995 Cholinergic pharmacology: Autonomic drugs In Adams H R (ed.) *Veterinary pharmacology & therapeutics* (7th edn). Iowa State University Press, Ames
2. Adams S B, Lamar C H, Masty J 1984 Motility of the distal portion of the jejenum and pelvic flexure in ponies: effect of six drugs. *American Journal of Veterinary Research* 45: 795–799
3. Barney G B, Wilson B J 1963 A rare toxicity syndrome in ponies. *Veterinary Medicine* 48: 419–421
4. Beards S C, Kraus P, Lipman J 1994 Paralytic ileus as a complication of atropine therapy following severe organophosphate poisoning. *Anaesthesia* 49: 791–793
5. Brown J H, Taylor P 2001 Muscarinic receptor agonists and antagonists In Hardman J G, Limbird L E, Gilman A G. (eds) *Goodman & Gilman's the pharmacological basis of therapeutics* (10th edn). McGraw-Hill, New York
6. Cheung K, Hinds J A, Duffy P 1989 Detection of poisoning by plant-origin cardiac glycosides with the Abott TD_x analyser. *Clinical Chemistry* 35: 295–297
7. Ducharme N G, Fubini S L 1983 Gastrointestinal complications associated with the use of atropine in horses. *Journal of the American Veterinary Medical Association* 182: 229–231
8. Everist S L 1974 *Poisonous plants of Australia* Angus & Robertson, London and Sydney
9. Galey F D, Holstege D M, Francis T, Hyde W, Jack R 1996 Residues of *Datura* species in horses. In Auer D E, Houghton E (eds) *Proceedings of the 11th International Conference of Racing Analysts and Veterinarians, Queensland, Australia,* 333–337
10. Henderson L 2001 *Alien weeds and invasive plants. A complete guide to declared weeds and invaders in South Africa.* Plant Protection Research Handbook No. 12, Agricultural Research Council, Pretoria
11. Henderson M, Anderson J G 1966 *Common weeds in South Africa.* Botanical Survey Memoir No. 37, Department of Agricultural Technical Services, Republic of South Africa
12. Kellerman T S, Coetzer J A W, Naudé T W 1988 *Plant poisonings and mycotoxicoses of livestock in southern Africa.* Oxford University Press, Cape Town
13. Nelson P D, Mercer H D, Essig H W, Minyard J P 1982 Jimson weed seed toxicity in cattle. *Veterinary and HumanToxicology* 24: 321–325
14. Pearson E G, Riebold T W 1989 Comparison of bronchodilators in alleviating clinical signs in horses with chronic obstructive pulmonary disease. *Journal of the American Veterinary Medical Association* 194: 1287–1291
15. Roberts M C, Argenzio A 1986 Effects of amitraz, several opiate derivatives and anticholinergic agents on intestinal transit in ponies. *Equine Veterinary Journal* 18: 256–260
16. Schulman M L, Bolton L A 1998 *Datura* seed intoxication in two horses. *Journal of the South African Veterinary Association* 69: 27–29
17. Watt J M, Breyer-Brandwijk M G 1962 *The medicinal and poisonous plants of southern and eastern Africa* (2nd edn). E S Livingstone, Edinburgh & London
18. Williams S, Scott P 1984 The toxicity of *Datura stramonium* (thorn apple) to horses. *New Zealand Veterinary Journal* 32: 47