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Plant poisoning – an emerging problem in equine medicine?

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Summary: The incidence of plant poisoning in horses seems to have increased, but there are only a few reports discussing this issue. This study was performed to assess the number of plant intoxications treated in an equine clinic in Germany between 2011 and 2020 and to relate them to weather conditions (temperature, sunshine duration, precipitation). The analysis included a Poisson count regression. Forty-two cases were included. Plant poisoning roughly doubled in hot and dry years 2018 (n = 8) and 2019 (n = 9) compared to previous years. An increase of the average annual temperature by 1 °C resulted in more than a doubling of intoxication cases relative to colic cases (IR 2.466, CI 1.52–4.98, p = 0.001). Longer sunshine duration resulted in a significant increase in cases (p = 0.013). *Berteroa incana* and *Robinia pseudoacacia* were the most common intoxicants. Climate change is a growing problem and leads to the overgrowth of plants that prefer warm and dry conditions, including poisonous plants, such as *B. incana* and *Senecio jacobeae*. If the grass on a pasture is scarce, horses eat plants that are normally unpalatable. Moreover, hay quality and its contamination with toxic plants might be an issue. Our hypothesis was confirmed as the number of plant intoxications in our region increased since 2018. Furthermore, our study tentatively indicates that weather conditions may influence the number of poisonings but also the species of toxic plants responsible for such poisonings. Awareness should be raised among equestrians that the number of certain plant intoxications threatens to increase in the future if climate change progresses. Further investigations are needed to test the hypothesis in a geographically wider area.

Keywords: plant, intoxication, poisoning, weather, climate change

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Introduction

Certain plants produce secondary metabolites (e.g. tannins, cyanides, glycosides, alkaloids) to defend themselves against other plants, insects, microorganisms and animals[1,2]. Highly toxic plants, such as *Taxus baccata* (common yew) can be lethal to a horse after an ingestion of merely 200 g of leaves[3]. Less toxic flora, however, is more common in equine neighbourhoods and usually requires an ingestion of larger amounts to cause toxic effects. Although 72 % of all intoxications in equines were caused by toxic plants, according to *Kupper* et al. (2010)[4], horses generally avoid them.

Nevertheless, there are reports suggesting that plant poisoning has recently become a relevant problem in equine medicine[5,6]. Many factors may contribute to this phenomenon, including weather conditions leading to quantitative and qualitative changes on pastures. When the amount of grass is scarce due to heat and drought, horses may try to eat plants and tree parts that are normally unpalatable[1]. Moreover, while many plants remain toxic after transformation into hay or silage[7,8], they become more palatable and difficult to sort out for equids[9].

In order to test the hypothesis that the incidence of plant poisoning in horses increases with extreme weather conditions in the study region

1) the number of cases seen in a referral hospital in the catchment area of Berlin and Brandenburg between 2011 and 2020 was reported,
2) the incidence of plant intoxication was compared to the incidence of colic cases, and
3) the incidence of plant intoxication was related to weather conditions.

Materials and methods

The electronic data of all horses admitted to the equine clinic in Berlin with suspicion of plant intoxication between January 2011 and December 2020 were collected. Additionally, the number of colic patients admitted during the same period were extracted and served as a reference population.

Plant intoxication was defined as a case, in which poisoning with a certain plant or tree parts was suspected, if there was a temporal relationship between digestion/contact and onset of disease, if the horse developed clinical signs/abnormal laboratory findings that met the toxicologic profile of the plant or tree, available information was reliable, and no other causative agent was identified. Furthermore, the probability of plant intoxication was evaluated, based on adjusted causality assessment protocol[10]. The cases were classified as "probable" if they fulfilled the following criteria:

1. associative connection based on timing between plant digestion or contact and the onset of clinical signs,
2. clinical signs matching the toxicological profile of the suspected plant,
3. positive toxicology results/hay analysis or exclusion of equally plausible explanations (based on typical laboratory or pathological findings, clinical symptoms in other horses, improvement after removing the plant from a diet or antidote administration),
4. sufficient and reliable data.

All cases fulfilling criteria 1, 2 and 4, but without further analyses (and, therefore, with another potential diagnosis) were classified as "possible". The cases were allocated to the category "unlikely" if the plant in question was proven not to be the causing agent (e.g. negative toxicology results, no specific laboratory or pathologic findings, other confirmed diagnosis). Additionally, if crucial information was missing or data were considered unreliable, the cases were categorized as "unassessable".

Furthermore, selected weather condition data from the ten-year study period were obtained from the online database published by the National German Meteorological Service[11] for Berlin/Brandenburg and Germany overall. The mean air temperature at 2 m above ground (°C), sum of the sunshine duration (hours) and sum of the precipitation height (i.e. the total rainfall depth; in mm, equals l/m^2) were collected for each year.

Data analysis included descriptive statistics and a Poisson count regression. Overdispersion was excluded using the test by *Gelman* and *Hill* (2007)[12]. The number of colic patients was used as an offset to adjust for changes due to higher patient volume. Results are reported as relative incidence ratios with 95 % confidence intervals. A significance threshold of

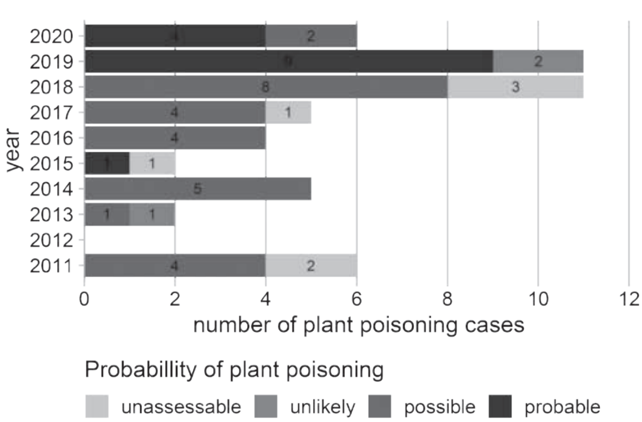

Fig. 1 Probability of presented plant intoxications. Stacked bar chart showing the number of plant intoxications divided according to their probability between 2011 and 2020. | *Wahrscheinlichkeit der vorgestellten Pflanzenvergiftungen. Gestapeltes Balkendiagramm, das die Anzahl der Pflanzenintoxikationen, aufgeteilt nach ihrer Wahrscheinlichkeit, zwischen 2011 und 2020 zeigt.*

0.05 was used. All statistical analyses were performed using R version 4.02 (R Foundation Vienna). Power calculation was performed using G*Power 3.1[13].

Results

A total of 54 cases (53 horses; one was presented twice) with a suspicion of plant poisoning were admitted to the clinic during study period. Two cases suspected of botulism were excluded, since the disease is not caused by a plant toxin. Further 10 cases, categorized as "unlikely" (n = 3) and "unassessable" (n = 7), were also excluded as they did not match our definition of plant intoxication. Fourteen of the remaining 42 cases included in this study were classified as "probable" and 28 were deemed "possible" (Fig. 1). *Berteroa incana* (hoary alyssum) was the most common cause and responsible for 14 poisonings (14/42), followed by *Robinia pseudoacacia* (black locust) (12/42). *Acer pseudoplantanus* (sycamore maple tree) (4/42) and *T. baccata* (4/42) caused four cases each. *Heracleum* spp. (hogweed) and other phototoxic plants caused three intoxications (3/42), while *Thuja occidentalis* (white cedar) was associated with two of them (2/42). Furthermore, there were single cases of intoxication with *Senecio jacobeae* (tansy ragwort), *Hedera helix* (common ivy) and *Rumex* spp. (dock and sorrel). Most plant poisoning cases occurred during spring (16/42) and summer (16/42). The case fatality rate due to plant poisoning was 14.3 % (6/42) (Tab. 1).

A total of 2929 colic cases were admitted during the same period and their number per year did not increase simultaneously with the number of plant intoxications during the study period (Tab. 1). However, the proportion of plant poisoning cases to the colic cases increased in years with high mean air temperature (2015, 2018–2019), long sunshine duration (2011, 2018–2020) or a low sum of precipitation height (2018) (Tab. 1).

Table 1 The number of plant poisoning cases between 2011–2020, their proportion to colic cases and case fatality rate. | *Anzahl der Pflanzenvergiftungen zwischen 2011–2020, Verhältnis zu Koliken und Fallsterblichkeit.*

Year	Plant poisoning cases	Colic cases	Proportion of poisoning cases to colic cases	Case fatality rate
2011	4	226	1.8 %	0 %
2012	0	303	0 %	0 %
2013	1	242	0.4 %	0 %
2014	5	287	1.7 %	40 %
2015	1	278	0.4 %	0 %
2016	4	347	1.2 %	0 %
2017	4	302	1.3 %	0 %
2018	8	326	2.5 %	12.5 %
2019	9	307	2.9 %	22.2 %
2020	6	311	1.9 %	16.7 %
Total	42	2929	1.4 %	14.3 %

Detailed case description

An evident rise in the number of intoxications with *B. incana* was noted especially in 2019 (5/14) and 2020 (3/14). As toxicologic examination is not available, the diagnosis was based on confirmed plant consumption or positive hay examination and typical clinical signs: lameness or laminitis (9/14), swelling of extremities (6/14), fever (3/14) and gastrointestinal disorders (colic symptoms, diarrhoea, haemorrhagic colitis) (5/14). Furthermore, similar finding reported in horses kept together supported the diagnosis. Two affected horses were euthanized (severe laminitis resulting in exungulation, haemorrhagic colitis).

Horses intoxicated with *R. pseudoacacia* were admitted mainly at the beginning of the year (9/12). Toxicology confirmed the intoxication in one horse and the remaining eight cases were deemed "possible". Seven horses showed only gastrointestinal disorders (7/9), while two had additionally neurological signs (2/9). Only one horse with "possible" intoxication did not make a recovery.

A. pseudoplantatus caused intoxication in four horses during the autumn (3/4) and spring (1/4). Hypoglycin A was detected in one case classified as "probable" and the remaining three were deemed "possible" (3/4). Myoglobinuria (2/4), sweating (2/4), stiff gait (2/4), recumbency (1/4), dysphagia and ptyalism (2/4) were commonly observed. One pony was submitted to the clinic twice with the same symptoms and was euthanised during the second visit.

Ingestion of *T. baccata* caused four intoxications and half of them were fatal (2/4). The patients showed a highly disturbed general condition, including sweating, tachypnoea, lethargy, anorexia and colic signs. Three "possible" cases from the same stable were presented in 2014 after having access to the tree for a week. Only one of these horses recovered and *T. baccata* leaves were found post-mortem in the stomach of the others.

Phototoxic plants were suspected to cause photodermatitis (3/3) and ocular changes (2/3), including uveitis and corneal oedema[14]. Hay analysis confirmed the presence of *Pastinaca sativa* subsp. *sylvestris* (wild parsnip) and, subsequently, seven other horses in different stables were identified after being fed hay from the same source[14].

A "possible" case of seneciosis was presented with weight loss and severely elevated liver enzyme activities. *S. jacobeae* was identified on the pasture few years before, but the liver biopsy was not performed.

A horse with acute *Rumex* spp. intoxication was presented three days after intra-articular corticosteroid administration and was reported to selectively consume the plant during walks. It showed ataxia, ptyalism, muscle tremors and diarrhoea at home and developed tetany spams, diaphragmatic flutter and atrial flutter at admission. Clinical signs resolved completely after calcium supplementation.

"Possible" cases of intoxication with *H. helix* and *T. occidentalis* were presented in autumn. Affected horses were presented with gastrointestinal disorders, including impaction (3/4) and paralytic ileus (1/4).

Relation to the weather conditions

Hotter and dryer conditions generally increased the number of intoxication cases (Fig. 2). Each increase of the average annual temperature by 1 °C resulted in more than twice the

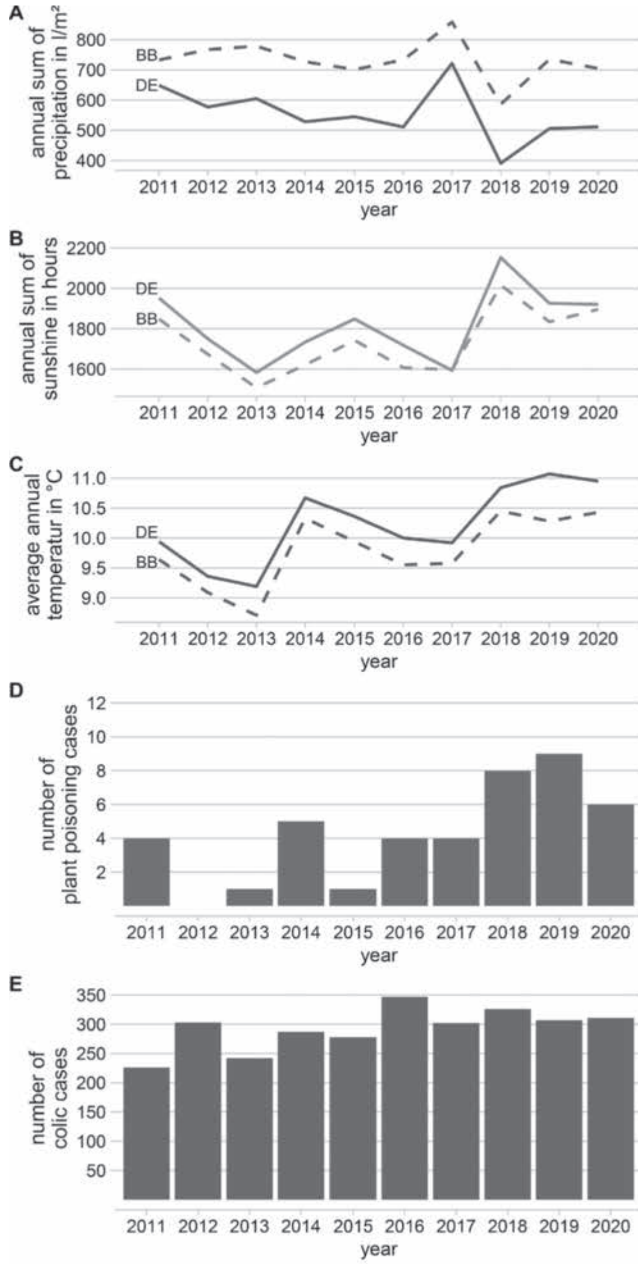

Fig. 2 Weather conditions. Weather conditions in Berlin-Brandenburg district (BB - - -) and Germany (DE ——): annual sum of precipitation height (A), annual sum of sunshine duration (B) and annual average temperature (C) compared with the number of plant poisonings (E) and colic cases (D) admitted to the clinic in each year during the study period. Data basis: Deutscher Wetterdienst – Climate Data Center (2021), gridded data reproduced graphically, own elements added. | *Wetterbedingungen. Witterungsverhältnisse im Bezirk Berlin-Brandenburg (BB - - -) und in Deutschland (DE ——): Jahressume der Niedereschlagshöhe (A), Jahressume der Sonnenscheindauer (B) und Jahresdurchschnittstemperaur (C) im Vergleich zur Anzahl der Pflanzenvergiftungen (E) und der Kolikfälle (D), die in jedem Jahr des Untersuchungszeitraums in die Klinik eingeliefert wurden. Datengrundlagen: Deutsche Wetterdienst – Climate Data Center (2021), eigene Elemente hinzugefügt.*

number of intoxication cases relative to colic cases (IR 2.466, CI 1.52–4.98, p = 0.001). Mean annual temperatures for the period of the study ranged from 9.19 to 11.07 °C. The increase in the annual sum of sunshine duration by 100 h correlated to an increase of 24 % in intoxications (IR 1.24; 1.05–1.48; p = 0.013). Regarding precipitation, the increase of the annual sum by 50 l/m^2 correlated to a slight reduction of intoxication cases (IR 0.85; 0.71–1.02; p = 0.077). The post hoc power calculations for the Poisson regressions showed a Power of β = 99.9 % for mean annual temperature, annual sum of sunshine duration β = 90.8 % and annual sum of precipitation β = 51.3 %.

Discussion

Toxic plants in the study

Highly toxic plants are not common on horse pastures in Brandenburg[15], what was confirmed by the relatively low case fatality rate in this study (Tab. 1) and the lack of reports of fatal poisonings in this area in the literature. However, mild and moderately toxic flora was widespread[15] and was responsible for most of the poisonings.

A poisoning with *B. incana* seems to be an emerging problem in Germany[8], which is in accordance with our finding of being the most common cause of intoxication. *Rühl* (2019)[15] showed that the plant was present on 56.5 % of horse pastures in the south of Brandenburg and found that it often accounted for more than 25 % of all plants in those areas. *B. incana* is very robust[8,16,17] and resistant to ultraviolet radiation[18]. Warm and dry summers facilitate its spread and it seems to be replacing the heat-sensitive flora[8,16,19]. It also remains toxic after drying[8,17], which explains winter cases. Pastures and meadows with controlled grazing, regular fertilization and regular swathing are generally less affected by *B. incana*[8,15,17,19]. However, early swathing[8] and inappropriate timing of fertilizer application might be additionally responsible for the widespread existence of the plant[16,17,19].

Despite isolation of few glucosinolates, that potentially increase the vascular permeability and cause typical oedemas[8,17,19–21], the toxin of *B. incana* remains unknown. The lack of this hallmark clinical signs in many horses in this study might be due to the owner's management (bandaging and cooling the limbs, administration of anti-inflammatories) or delay in referral to the clinic (clinical signs due to laminitis usually persist longer than swellings). On the other hand, in few horses presented with colitis, colic signs could have preceded the swelling formation.

Similar to the findings of *Kupper* et al. (2010) [4] ingestion of *R. pseudoacacia* or its parts, was one of the most common types of intoxication in this study. The tree is invasive and resistant to extreme weather conditions[22], thus, it accounts for 60 % of the tree stock in dry regions of Brandenburg and Saxony-Anhalt in Germany[23].

The tree concentrates its toxins mostly in the seeds and bark[21,24,25], however, the wood (e.g. shavings, fence posts) may also lead to intoxication after ingestion[25]. The exposure in this study was usually due to a change in husbandry, e.g. after bringing a horse to a new paddock or leaving a cut down tree on the pasture. Only in two cases temporary neurological symptoms, such as muscle trembling and excitation were observed[24,25]. Unfortunately, the level of ammonia in the blood was not measured to confirm intestinal hyperammonaemia[25–27]. Less commonly described pathologies, such as haemolytic anaemia and acute kidney failure, were also presented in this study[24,25,28].

The ingestion of *A. pseudoplantatus* seeds in the autumn, or, less often, seedlings in the spring, is a common cause of equine atypical myopathy in Europe[29]. Hypoglycin A is the main toxin causing acute rhabdomyolysis[30]. The case fatality rate is high, thus, prevention is crucial[31]. *Gonzalez-Medina* et al. (2019)[32] reported that common preventative methods, such as mowing and herbicides, did not affect the concentration of toxin within two weeks after application. Moreover, seedlings and seeds remain toxic after transformation to hay or silage[32]. A paddock vacuum cleaner to collect samaras from affected areas can be successfully utilised but is time-consuming[32]. The wide spread of *A. pseudoplantatus*[33] and ineffective preventive methods contribute to a high occurrence of the disease in Europe[29].

Surprisingly, most of the owners in this study (3/4) reported no tree next to the pasture, however, it was present in the neighbourhood. The intoxication in these cases could be explained by the wind spreading the seeds for long distances[34,35]. Consequently, a noticeable increase in the number of cases was found in 2017, were high humidity and wind were reported.

T. baccata, T. occidentalis and *Hedera helix* belong to evergreen florae commonly grown as ornamental plants in Europe[36]. They attract horses when other food is scarce, as was the case in all patients in this study. Furthermore, feeding horses with garden leftovers is a highly hazardous practice as the leaves and fruits of these plants remain toxic after drying up[37,38].

T. baccata contains cardiotoxic taxine alkaloids, which lead to acute hypotension, bradycardia, arrythmia and sudden cardiac death[37]. Stress caused by transport or therapy attempts often leads to the collapse of a patient, as was the case in two horses included in this study[21,37]. As clinical symptoms develop within a few hours of ingestion, detection of the plant material in the stomach post-mortem supports the diagnosis of *T. baccata* intoxication.

T. occidentalis containing monoterpene thujone was assumed to be responsible for paralytic ileus in one case[37,38]. *H. helix* contains flavonoids and saponins that cause irritation of the mucous membranes after ingestion[38,39] (Institut für Veterinärpharmakologie und -toxikologie, 2021a, *Yu* et al. 2015), which could explain the ptyalism in one included case. However, two horses developed impactions untypical of intoxication with *T. occidentalis* or *H. helix*. Probably small amounts of the plant material caused irritation of the mucus membranes, so that it discouraged horses from drinking and eating, resulting in impaction.

Primary photosensitivity occurs due to the ingestion of plants containing fur(an)ocoumarins. There are a lot of phototoxic plants in Germany, including *Hypericum perforatum* (St. John's wort), *P. sativa* subsp. *sylvestris*, *Heracleum sphondylium, H. mantegazzianum* and *H. sosnowskyi* (the common, giant and Sosnowskyi hogweed respectively)[1,14,40]. The latter four contain very high concentrations of toxin and can lead to skin or eye lesions even after a brief direct contact[1,14,40], what was reported in this study.

P. sativa subsp. *sylvestris* prefers warm and dry conditions so its occurrence increases[14]. Furthermore, *H. mantegazzianum* and *H. sosnowskyi* are commonly known invasive plants and since they pose a threat to humans, the "Giant Alien" program was introduced in Europe in 2002 to manage them[41]. The authors describe cutting the plant or its roots as the most efficient method of management, however, manual eradication becomes very labour-intensive when plant colonies become bigger. Therefore, less effective methods such as mechanical mowing, chemical control or sheep grazing (preferably black-coated) are recommended[41]. Consequently, the occurrence of primary photodermatitis threatens to increase in the future due to climate warming and ineffective preventive measures against phototoxic plants.

Many horse owners assume that poisoning with plants containing pyrrolizidine alkaloids, e.g. *S. jacobeae*, is a very common problem[42]. Indeed, it is often encountered on the extensive meadows of south Brandenburg[15]. The plant is also highly resistant and its number increases after drought[43]. However, hardly any intoxication cases have been reported in recent years in this study. This might be due to the introduction of intensive control measures after the hepatotoxicity of *S. jacobeae* became well-known[3,44,45]. Mowing and herbicides have proven quite successful in limiting the weed on meadows[15], however, pulling the plant out by hand remains the best eradicative method[44]. On the other hand, the occurrence of seneciosis could be falsely low, since not many horses are presented for further diagnostic examinations unless advanced clinical signs of liver failure are present[1,3,42,43,46]. The delay between the digestion of the plant and clinical signs appearing may lead to a lack of suspicion of seneciosis by the owners. Furthermore, the veterinarian's recommendation of a liver biopsy to check for megalocytes, which is a reliable method to diagnose seneciosis[42,43,45], is often rejected by horse owners.

Rumex spp. is not highly toxic but has been found on 82.6% of pasture areas in the south of Brandenburg and was the most common toxic plant encountered[15]. Although not palatable, its wide distribution can attract horses and some of them might develop a taste for it, as did the horse in this study. *Rumex* spp. contains high concentrations of oxalates and their consumption may cause calcium deficiency[47]. Common clinical signs, including failure to thrive, swelling of the head bones and lameness, occur due to nutritional secondary hyperparathyroidism after the chronic ingestion of oxalate[47,48]. Acute intoxication after *Rumex* spp. digestion, as seen in this study, is rarely described[49] but could explain the acute hypocalcaemia found in this case, which responded well to supplementation. Nevertheless, reported intra-articular corticosteroid administration could have been partially responsible for the clinical signs developing in this patient as they reduce calcium absorption[50,51].

Incidence and distribution of plant intoxications over the study period

We observed roughly a doubling of case numbers especially during the extremely hot and dry years of 2018 (n = 8) and 2019 (n = 9) in comparison to 2016 (n = 4) and 2017 (n = 4). However, a proper diagnosis of the plant intoxication and recognition of actual cases remains challenging. Toxicology tests are infrequently performed due to relatively long processing times and high costs, especially if no specific plant is suspected. Moreover, tests are not available for some common poisonous plants (e.g. *B. incana*). Furthermore, the clinical signs are rarely specific, and the anamnesis might be misleading as many horse owners are not aware that their animal could have ingested a toxic plant. On the other hand, many people are convinced that their horse has been poisoned without having any proof, as was the case in three horses excluded from this study due to a confirmation of an alternative diagnosis ("unlikely" group). Moreover, differences in veterinarian qualifications seem to contribute to the information found in medical record.

The number of confirmed plant poisonings ("probable" group) increased significantly in 2019 (Fig. 1). We cannot fully exclude that part of this increase was related to an easier access to diagnostic tests (toxicology, hay analysis) or the increased awareness of horse owners and veterinarians.

There is a well described tendency that plant intoxications occur more often during the spring and autumn. Many toxic plants grow earlier than the desirable grass in spring and survive longer on the pastures in the late autumn[52]. Moreover, toxic plants are often not palatable in the summer due to their bitter taste or largely woody texture, but seedlings and young plants might be well-accepted in the spring, for example, *B. incana*[45]. Additionally, the toxin concentration is often highest when plants begin to flower, i.e. *B. incana*[45], *Trisetum flavescens* (yellow oatgrass) [7] or in seedlings, such as *A. pseudoplantatus*[32]. The increase of occurrences of plant intoxications in the autumn could be explained by a lack of alternative food when the grass on the field is scarce.

Plant intoxications occurred during all seasons in our study, but most of them were admitted during the spring and summer. An obvious increase in the number of cases in the autumn could not be observed, which may be due to a low total case number, but the seeds of *A. pseudoplantatus*, *Rumex* spp. and ornamental plants caused disorders in our study in this season. Cases that presented during the winter were due to the consumption of hay containing toxic plants or after eating the bark of a *R. pseudoacacia*. Summer drought and heat could have led to an overgrowth of sensitive florae by robust toxic plants and occasional intoxications in horses.

Factors influencing the composition of the flora in pastures

This study shows that an increase in the mean annual temperature and annual sunshine duration is positively correlated to the number of plant intoxications in equines in the study region. However, there are plants with different weather preferences or toxicity time for which this correlation was not valid.

The incidence of atypical myopathy, for example, increased only when the amount of precipitation increased.

Climate change seems to be a key factor influencing the composition of florae. It has led over the last few decades to an overgrowth of plants that prefer warm and dry conditions, including poisonous *B. incana*, *S. jacobeae*, *Hypochaeris radicata* (catsear), *T. flavescens*, *P. sativa* subsp. *sylvestris* and *R. pseudoacacia*[22,53]. Some of them, for example, *S. jacobeae* and *H. mantegazzianum*, count as noxious and invasive weeds[41,45].

Extensive agricultural practice generally leads to a wider range of toxic plants on meadows[54]. Moreover, extremely extensive organic farming has become very popular recently and there have been reports of poisoning in horses, for example, with *T. flavescens*, after consuming hay harvested from those areas[7]. Contrarily, practices typical for intensive farming, including mowing and herbicides, usually harm toxic plants. Unfortunately, extremely intensive agricultural practices also lead to the development of herbicide resistance in some areas[6]. Furthermore, the intense use of nitrate-based fertilizers can lead to the spreading of certain toxic plants, for example, *Solanum nigrum* (black nightshade)[6] and cause nitrate accumulation in others, for example, wheat[55].

Furthermore, many horse keepers ignore the problem and have limited knowledge of toxic plants[52]. *Rühl* (2019)[15] describes the neighbourhood of agricultural and residential areas as a risk factor, as many ornamental plants can mix with the florae on the pasture or pose a direct risk of being eaten by a horse.

Other reasons for the increasing incidence of plant intoxications

Losing a primitive instinct to avoid toxic plants due to domestication may have also contributed to the rising number of poisonings[52]. Nowadays, horses often do not have an opportunity to learn from older animals[52,56] and they are exposed to a limited number of plants. If they are put into an unfamiliar environment or if it changes, equines might encounter and eat toxic plants to which they have not developed negative associations[56], for example, leaving cut down *R. pseudoacacia* on a pasture.

Supplementing additional roughage on pastures when the grass is heat-burned may theoretically decrease the number of plant intoxications in the autumn as horses would have an alternative. Unfortunately, extreme weather conditions lead to poor hay harvests and rising prices, as seen in 2018 and 2019[57]. Furthermore, both, extremely extensive and intensive management of meadows can be a source of hay including toxic plants[6,7]. As a cheap alternative, green waste from gardens might be fed to equines and, subsequently, cause a severe intoxication or even death as many decorative plants and trees are highly toxic[3,6,53].

Limitations of the study

Despite precise inclusion and categorization criteria and mainly due to the retrospective nature of this study, the correct assessment of the number of plant intoxications were difficult. It cannot be fully excluded that the rising occurrence was partially due to improvement in diagnostics. However, the growth in the number of cases was not linear as it would be expected if intoxications were just being diagnosed more frequently. The power of the Poisson regression for temperature and sunshine duration was satisfying, despite the biggest limitation being a small number of cases. Furthermore, most of the cases were severe enough to be referred to the hospital, hence, it remains unknown how many and what type of intoxications are treated overall in the area. A survey among general practitioners would be highly informative.

In addition, this study only covered a limited area of catchment (two states in northern Germany). Extending the study to the remaining states or even larger scales could be attempted in future investigations. Since climate change is a global problem, the relations found in this study might be more universal.

Conclusions

Our hypotheses were confirmed in this study as the number of plant intoxications and the proportion to the number of colic cases in our region have increased since 2018. Furthermore, our study tentatively indicates that weather conditions may influence the number of poisonings and may affect the species of toxic plants responsible for them. Awareness should be raised among horse keepers and veterinarians that the number of certain plant intoxications threatens to increase in the future if climate change progresses and if special precautions are not applied. Special attention should be paid to the management of *B. incana* and selected phototoxic plants. Furthermore, avoiding the toxic trees (mainly *R. pseudoacacia* and *A. pseudoplantatus*) and ornamental plants occurring next to the pasture is an important issue. Further investigations are needed to test the hypothesis in a geographically wider area and on a larger group of horses.

Conflict of interest statement

All authors declare that they have no conflicts of interest.

Animal welfare statement

No ethical approval was required as this is a retrospective study.

Statement of informed consent

The authors declare that written informed consent was obtained from all horse owners as a part of the treatment agreement signed by the owners upon admission.

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