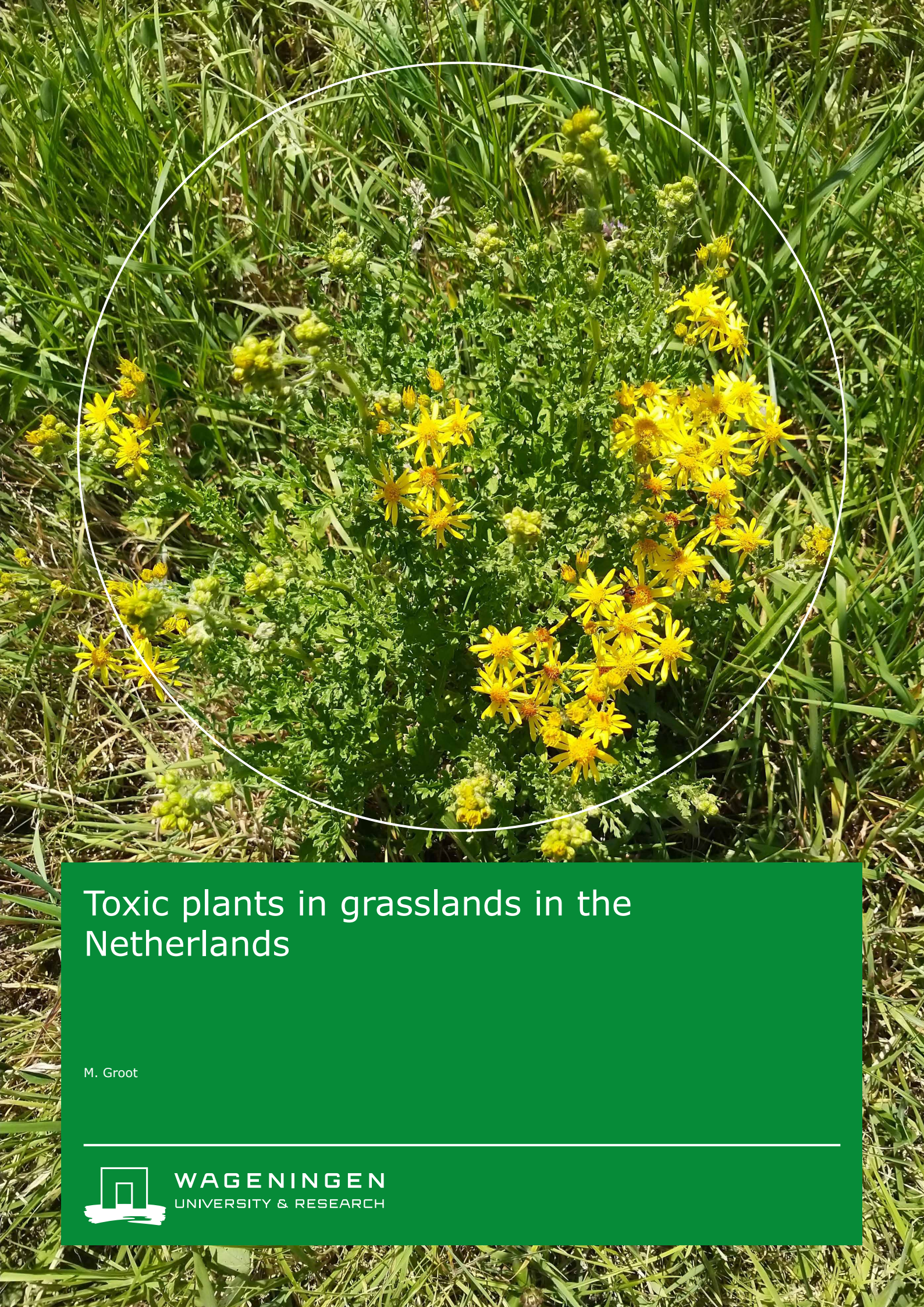

Toxic plants in grasslands in the Netherlands

M. Groot

WAGENINGEN
UNIVERSITY & RESEARCH

Toxic plants in grasslands in the Netherlands

M. Groot

This research has been carried out by Wageningen Food Safety Research, institute within the legal entity Wageningen Research Foundation subsidised by the Dutch Ministry of Agriculture, Nature and Food Quality through the Knowledgebase Program 34: Circular and Climate Neutral;[KB-34-007-010], Program 35: Food Security and Valuing Water; [KB-35-007-002].

Wageningen, September 2022

WFSR Report 2022.020

WAGENINGEN
UNIVERSITY & RESEARCH

Groot, M., 2022. *Toxic plants in grasslands in the Netherlands.* Wageningen, Wageningen Food Safety Research, WFSR Report 2022.020. 24 pp.; 0 fig.; 0 tab.; 47 ref.

Project number: 1297384401
BAS-code: KB-35-007-002
Project title: Nature Based Solutions
Project leader: M. Groot

This report can be downloaded for free at https://doi.org/10.18174/576217 or at www.wur.eu/food-safety-research (under WFSR publications).

P.O. Box 230, 6700 AE Wageningen, The Netherlands, T +31 (0)317 48 02 56, E info.wfsr@wur.nl, www.wur.eu/food-safety-research. WFSR is part of Wageningen University & Research.

WFSR report 2022.020

Distribution list:
- Marjolein Sterk
- Annemarie Groot
- Wijnand Sukkel
- Lotte Caarls

Contents

Summary

Within the framework of the Knowledgebase Program 34 (Circular and Climate Neutral), this literature review presents information about toxic herbs in Dutch pastures that can negatively affect health and production in dairy cows. For dairy cattle there is growing interest in herbal pastures, both to increase biodiversity, soil health and to support animal health. In this review the focus is on the effects of pasture herbs that can negatively affect animals health.

To achieve this a literature review was performed using the following method: based on an existing database of plants in grassland, PubMed, Scopus and some handbooks on veterinary phytotherapy a literature search was performed for negative effects of the pasture plants on health in cattle. Since pastures may be surrounded by trees or shrubs, or located near villages, some trees and garden plants are also included. Many garden plants are poisonous for cattle, and feeding pruning waste may lead to severe intoxications. Finally, these plants are listed with their common and botanical name, their constituents, their biological action and target tissues according to literature.

Most toxic plants are avoided in the meadow by livestock due to their bitter taste or smell. In hay and silage however these characteristics may been lost and the plants may be eaten and lead to intoxication. Main plant toxins are saponins, tropane-, pyrrolizidine-, and piperidine alkaloids, furanocoumarins, protoanemonin and oxalic acids.

Reports of intoxication of cattle by meadow herbs are scarce and most are old publications. In North- and Eastern Germany meadow saffron (*Colchicum autumnale* L.), cowbane (*Cicuta virosa* L.), sweet clover (*Melilotus alba* MED.), sheep's sorrel (*Rumex acetosella* L.), bracken (*Pteridium aquilinum* KUHN) and St. John's wort *(Hypericum perforatum* L.) were mentioned and in France intoxication by water-dropwort (*Oenanthe crocata*) in cattle was described.

Ruminants are better able to detoxify secondary metabolites than monogastric animals due to the variability of the ruminal flora which can adapt to the feed. The metabolism of ruminants may adapt on some groups of compounds which can be detoxified, decomposed or metabolised before actual absorption takes place. In some cases endemic animals can cope with certain toxic crops which are toxic for animals in non-endemic areas. Some groups of compounds have only limited impact on the health of cattle, due to detoxification, such as protoanemonin which is detoxified during drying.

In the Netherlands there is a trend to increase the groundwater levels especially for rewetting peat meadow areas. A high groundwater level not only puts a brake on subsidence but also on greenhouse gas emissions. But it has to be taken into account that several poisonous plants thrive on wet meadows, like Marsh horsetail (*Equisetum palustre*), Hemlock (*Conium maculatum*), Hemlock water dropwort (*Oenanthe crocata*), Cowbane (*Cicuta virosa*), meadow saffron (*Colchicum autumnale*) and comfrey (*Symphytum officinale*).

In dry periods herbs appear to be more resilient than grasses and may be the only vegetation left to eat. This may also lead to intoxication when toxic herbs like ragwort (*Senecio Jacobaea*) remain.

In conclusion toxic plants may occur in biodiverse herbal meadows and need monitoring, especially when water management is changed. Cases of intoxication of cattle by meadow herbs are scarce, but rewetting peat meadows may pose a risk. Garden pruning waste, or garden plants surrounding pastures may also form a risk.

Conclusions

- Most poisonous plants are only eaten when there is nothing else to eat.
- In hay or silage poisonous plants may lose their smell and taste and may be eaten.
- If a plant is poisonous depends on the amount eaten, growth stage and the adaptation of the ruminal microflora.
- Especially in wet areas there is more risk of poisonous plants like Marsh horsetail (*Equisetum palustre*), Hemlock (*Conium maculatum*), Hemlock water dropwort (*Oenanthe crocata*), Cowbane (*Cicuta virosa*), meadow saffron (*Colchicum autumnale*) and comfrey (*Symphytum officinale*).
- Extended dry periods may lead to reduction of grasses and only herbs left to eat.

Recommendations

- In biodiverse pastures check the composition of the meadow regularly for poisonous plants, especially when pastures are rewetted.
- Careful inspection of hay and silage and removal of toxic plants from pastures.
- When poisonous plants are invasive, they should be controlled and the cattle prevented to graze affected areas or moved to another pasture.

1 Introduction

Cattle are exposed to various herbs through feed and roughages. Most flowering plants produce a wide range of biologically active compounds, as secondary metabolites for defence against various stressors. Plant toxins can be considered as subset of these secondary metabolites, consisting of saponins, tropane-, pyrrolizidine-, and piperidine alkaloids, furanocoumarins, protoanemonin and oxalic acids (van Raamsdonk et al., 2015). Clinical signs of poisoning in cattle may vary from mild gastrointestinal disturbances to sudden death. Diagnosis is based on the combination of clinical signs and the history of exposure of the animals to the plant and chemical detection of toxins in liver, urine or blood (Anadon et al., 2012). Meadow grasses can also be invaded by toxic fungi such as Fusarium species (Fink, 2010). In this review we do not consider this group of toxins.

For dairy cattle there is growing interest in herbal pastures. Herbal pastures are characterized by biodiversity in plant species (such as herbs) rather than English Rye grass being the sole grass species. This biodiverse diet can contribute directly to the health of the animal and, indirectly, through its plant secondary metabolites and its better mineral supply (Pirhofer-Walzl et al., 2011). Biodiversity in the diet is mirrored in the biodiversity of the gut and rumen microbiome, leading to more resilient animals (Caroprese et al., 2020). Biodiverse pastures also have deeper root systems, more diverse soil life, better water retention capacity and are more draught resistant (Koorevaar and Geerts, 2016) which makes them very valuable in combatting the effects that climate change has on grazing systems. In 2020 we made a spreadsheet with an overview of plants in grasslands, their main components, health effects and potential toxic effects and literature. In this review the focus is on the effects of grassland plants that can negatively affect animals health. Since pastures can be surrounded by shrubs, trees and hedges, or located near villages some trees and toxic garden plants are also included. Feeding pruning waste may lead to severe intoxications.

2 Materials and methods

The plants mentioned in this review are based on a spreadsheet with meadow plants, biological actions and health effects composed by Davide Angelucci in 2020, and some additions from literature. Literature was searched for the mentioned plants on negative effects on production and health in cattle via Pubmed and Scopus and handbooks on veterinary phytotherapy (Wynn and Fougere, 2007; Brendick-Worm and Melzig, 2020). Plant databases used for biological activities and constituents were Liber Herbarum II from Erik Gotfredsen and Dukes Phytochemical and Ethnobotanical databases, and the CliniPharm CliniTox database. Search terms were cattle, toxicity, toxic effects, alkaloids and the botanical name of the plant.

Negative effects include loss of production, gastrointestinal effects, effects on kidneys or liver, skin, reproduction and neurological effects.

3 Results

3.1 Intoxication by plants

Cattel may graze in nature reserves, which may harbour toxic plants. Toxic plants can also be found on the edge of the meadow, or the meadow may border on trees that may be toxic at some point. Mostly animals do not eat toxic plants because most taste bitter. But when there is a lack of food, they sometimes do it anyway and in hay or silage many plants lose their characteristic smell and taste and toxic plants can be eaten (Driehuis et al., 2018). Reports of intoxication of cattle by meadow herbs in Eastern Germany (Schrader et al., 2001) mention meadow saffron (*Colchicum autumnale* L.), cowbane (*Cicuta virosa* L.), sweet clover (*Melilotus alba* MED.), sheep's sorrel (*Rumex acetosella* L.), bracken (*Pteridium aquilinum* KUHN) and St. John's wort *(Hypericum perforatum* L.). Older data from France mention intoxication by water-dropwort (*Oenanthe crocata*) in cattle and pigs in wet meadows (Ander et al., 1976). In general reports of intoxication of ruminants by toxic meadow plants are scarce. Intoxication by garden pruning like oleander or laurel may also occur (Ceci et al., 2020; Kennedy et al, 2020). Many garden plants are highly toxic. In the oleander case 13 of 50 Fleckvieh died and in the laurel intoxicated animals 22 of 36 dairy-cross yearlings died. Yew (*Taxus baccata*) is also notorious for its toxicity to grazing animals (Cortinovis and Caloni, 2015; Handeland et al., 2017).

3.2 Plant toxins

Different plant toxins can be present in several plant species (van Raamsdonk et al., 2015; Driehuis et al., 2018; Cortinovis and Caloni, 2015).

Protoanemonin is a toxin from some genera of the family of the Ranunculacae, as the major buttercup species, *Ranunculus repens*. Other sources are: *Ranunculus acris, Ranunculus flammula, Caltha palustris, Ranunculus sceleratus, Ranunculus bulbosus, Ranunculus sardous* and *Anemone nemorosa.*
Protoanemonin is an irritant and can cause blistering of the mucous membranes. High doses may lead to anorexia, salivation, weakness, convulsions, breathing difficulty and even death (Lingenfelter et al., 2022).

Furanocoumarins exposure comes from plants belonging to the family of Apiaceae (Umbelliferae), such as parsnip (*Pastinaca sativa*). Other sources are *Heracleum sphonylium, Angeli sylvestris, Eryngium campestre, Peucedanum plaustre, P. carvifloia, Pimpinella Saxifraga, P. major, Apium nodiflorum, A. graveolens*.
Furanocoumarins are fat soluble and penetrate the skin fats. They bind to DNA and proteins when activated by ultraviolet light. Binding to DNA can lead to cell death (apoptosis) and it increases the chance of mutations. Binding to proteins creates an allergenic complex (gddiergezondheid.nl).

Oxalic acids and its oxalate salts are mainly found in docks and sorrels (Genus Rumex) which can be abundant in all types of pastures and meadows (Raamsdonk et al., 2015). Other species of Rumex are:
R. acetosa, R. obtusifolius, R. crispus, R. acetosella, R. conglomeratus, R. hydrolapathum, R. thyrsiflorus, R. palustris, R. crispus x obtusifolius. Goosefoot (Chenopodium album) also contains high levels of oxalic acids.
Oxalic acid can bind with dietary calcium (Ca) or magnesium (Mg) to form insoluble Ca or Mg oxalate. This may lead to low serum Ca or Mg levels, which may lead to milk fever symptoms. High levels may lead to renal failure due to precipitation of these salts in the kidneys (Rahman et al., 2013).

Piperidine alkaloids are mainly found in the horsetails (Equisetum). Examples are *E. palustre, E. arvense, E. fluviatile* and *E. x litorale*. Hemlock (Conium maculatum), is another source for piperidine alkaloids.
Piperidine alkaloids bind to central and peripheral cholinergic and nicotinic receptors. Initial stimulation is followed by sustained suppression. This can give neurotoxic damage in the central nervous system (da Silva et al., 2018).

Pyrrolizidine alkaloids (PA's) come mainly from common ragwort (*Senecio Jacobaea)*), which shows an increase in abundance in grass production fields. Endophytic fungi might contribute to the production of PA's in *Lolium remotum* grass species. Other sources of PA's are *Leucanthemum vulgare, Symphytum officinale, Jacobea aquatica, J. erucifolia, Senecio vulgaris, Tussilaria farfara and Anchusa arvensis.*
Pyrrolizidine alkaloids are highly toxic to most livestock. Liver tumours and pulmonary lesions have been observed since the 1960's. PA's may cause hepatotoxicity and carcinogenicity and lead to presence of PA's in human diet (Edgar et al., 2011).

Tropane alkaloids naturally occur in numerous plant families such as Erythroxylaceae (including coca) and Solanaceae (including mandrake, henbane, deadly nightshade, datura, potato, tomato), Proteaceae, Euphorbiaceae, Rhizophoraceae, Convolvulaceae and Cruciferae. The most common tropane alkaloids are atropine, hyoscyamine and scopolamine.
The pharmacological effects of atropine in mammals are mainly caused by L-hyoscyamine (EMEA, 1998). Tropane alkaloids have parasympatholytic action and show non-specific binding to muscarinic receptors. Clinical symptoms include pupil dilatation, dryness of the mouth mucosa, indigestions, respiratory depression, as well as central nervous system-mediated effects like restlessness and seizures. Moreover these alkaloids can be transferred to the milk (Lamp et al., 2021).

Phytoestrogens mainly include coumestans (including coumestrol), ligans, and isoflavones. Coumestans, are found in alfalfa (*Medicago sativa*) and clover (*Trifolium spp.).*
Phytoestrogens may lead to impaired ovarian function, reduced conception rates and increased embryonic loss. Males are relatively unaffected. The mammary glands in young females and castrate males can show hypertrophy of the duct epithelium, even with milk secretion (Adams, N.R., 1995).

Tropolone alkaloids Autumn crocus or meadow saffron (*Colchicum autumnale*), is a well-known alkaloid containing plants with several tropolone alkaloids, from which colchicine is the most abundant.
Colchicine, is a potent gastrointestinal toxin and causes lethal multi-organ failure (Cortinovis and Caloni, 2015).

Saponins are reported as toxins (van Raamsdonk et al., 2015), but toxicity is low. They are mainly found in chickweed (*Stellaria media*). Other sources are *S. uliginosa, S. graminea, S. palustris, Medicago lupulina, M. falcata, M. arabica* and *Anagallis arvensis.* Saponins are mentioned as compounds that can help reduce methane emission (Rochfort et al., 2008).

Essential oils were also mentioned as toxins by van Raamsdonk et al. (2015), but although in pure from there is toxicity when ingested (Lee et al., 2020), in the meadow or in roughage no toxicity is reported. Essential oils are investigated for their use as tick repellents (Salman et al., 2020) and their effects on gut health ad ruminal development in calves (Liu et al., 2020).

3.3 Toxic plants

A list of toxic plant, their constituents, biological effects and target tissues are given in Annex 1.

In this chapter some examples are given and where appropriate possible remedies mentioned (from Groot et al., 2018).

Acorns (*Quercus spp*.)
If a meadow is bordered by oak trees, the animals can eat a lot of acorns. Green acorns contain much more tannins than brown acorns, and can lead to acute death. This can be done, for example, after a violent storm as the immature acorns fall en masse from the trees. In less severe cases, acorn poisoning leads to depression, drowsiness, constipation, colic and greenish/mucous diarrhoea. In a later stage, death can still occur up to two weeks after poisoning due to reduced kidney function. Renal tubular necrosis was found in all fatal cases (Holliman, A. 1985).

Management

- Move animals to a different plot if there are many immature acorns (especially if there is a storm or strong wind is predicted).
- Calcium hydroxide 100-150 grams per animal per day.
- Bentonite clay through the feed.
- Polyethylene glycol PEG, called macrogol in pharmaceuticals.
- Activated charcoal.

Horsetail (*Equisetum arvense*)

Horsetail contains equisetin which has a thiaminase effect which decomposes vitamin B1. Most animals do not eat the plant or only eat it little, but animals that eat too much (because e.g. there is nothing else to eat) can show the following symptoms: spastic walking, blindness, head back. Lambs may develop diarrhoea and stunted growth. In lactating ewes, the milk yield decreases and the milk takes on a bluish hue and tastes bitter. In serious cases, paralysis may occur. Horsetail remains poisonous in hay or silage.

Marsh horsetail (*Equisetum palustre*)

Marsh horsestail is also an equisetum species which is even more poisonous (Cortinovis and Caloni, 2015). The plant contains several toxic compounds such as the enzyme thiaminase, the alkaloid nicotine and piperidine alkaloids like palustrin. Due to its high silicate content the plant is generally unpalatable and grazing cattle tend to avoid marsh horsetail when other palatable forage is available. Clinical signs include lack of appetite, emaciation, weakness, decrease in milk yield, diarrhea and bloody urine.

Management

- Move animals to another field.
- Provide a sufficiently varied diet.
- In case of symptoms, give thiamine or a multivitamin preparation.

Taxus (*Taxus baccata*)

Yew can be ingested by animals as pruning waste, but can also take place through grazing of areas with yew storage or near large trees with low hanging branches. Yew is very poisonous and animals may die after eating only 100-200 grams of greens. Animals are found or exhibited acutely dead cramps, shortness of breath, teeth grinding, blue mucous membranes and animals falling down (Cortinovis and Caloni, 2015).

Golden chain (*Laburnum anagyroides*)

Animals can also be exposed to this through pruning waste. Flowers and seeds contain nicotine and nicotine-like alkaloids, which are very poisonous and cause diarrhea, colic and later respiratory arrest (Schep et al., 2009).

Senecio species (*Jacobaea vulgaris or Senecio jacobaea*)

Rags are generally not eaten fresh, but remain poisonous in hay and silage. They contain pyrrolizidine alkaloids (PA's) that cause liver damage. Sheep are less sensitive than goats and other animals (Cortinovis and Caloni, 2015). Transfer of PA's to milk is possible, although in low quantities. But even low PA levels in milk may be of concern because of their hepatotoxic and genotoxic properties (Kalac and Kaltner, 2021).

Goosefoot, melde, (*Chenopodium album*)

This plant can occur on a large scale in newly sown grassland. Sheep love it and it goes well as long as it is eaten in the mix of other grasses and herbs. This plant contains high levels of oxalic acid. One case of toxicity in cattle was reported due to goosefoot hay (Ozman et al., 2003).

Saint John's Wort (*Hypericum perforatum*)

This plant can cause photosensitization (sunburn), which can cause swelling of the white colored parts of the skin. Fully pigmented cattle are about three and a half times better protected against *H. perforatum* toxicity than are unpigmented animals (Bourke and White, 2004).

Cowbane (*Cicuta virosa*)
This is the most toxic native wetland plant found in ditches and peat soils. this plant can end up on the pasture after e.g. dredging the ditches. A piece of the carrot can kill a cow. The plant contains the poisonous substance cicutoxin, a nerve poison which leads to cramps, inflammation of the mucous membrane and intestinal tract, vomiting and eventually respiratory arrest. Fortunately toxicity due to this plant is seldom reported.

Bracken (*Pteridium aquilinum* (Kuhn)
Just like horsetail, this fern contains anti-thiamine enzyme and causes long-term consumption issues. Cattle don't eat it unless there's really nothing else to eat. Bracken also causes cystitis, bloody urine, and in a later stage bladder carcinoma.

Garden plants (pruning waste)
Robinia, foxglove, lupins, acacia, azalea, oleander, boxwood, cherry laurel, rhododendron, ivy and autumn crocus are poisonous to ruminants. Pruning waste should never be fed to animals.

3.4 Discussion

In a meadow there is a possibility of occurrence of toxic plants which can be part of the normal flora. But naturally evolved feeding strategies of farmed animals show avoidance of many poisonous plants, which offers a principal safety level for the animals. Under natural grazing conditions animals avoid species of buttercups (Ranunculus), ragworts (Senecio and Jacobaea), and docks (Rumex) (Haeggström, 1990; Frohne and Pfänder, 2005; Cortinovis and Caloni, 2013). Breeding bulls have been reported to refuse to eat Marsh horsetail (*Equisetum palustre*) (Kamphues 1990). But in hay or silage these plants may be eaten. The metabolism of the animals may adapt on some groups of compounds which can be detoxified, decomposed or metabolised before actual absorption takes place (Fink-Gremmels, 2010). Some groups of compounds have only limited impact on the health of cattle, due to detoxification, such as protoanemonin which is detoxified during drying (EFSA, 2009).

Ruminants are more able to detoxify secondary metabolites than monogastric animals due to the variability of the ruminal flora. The ruminal flora shows a species-specific composition, unique for each individual animal. Dietary components can affect populations of microorganisms (Annison and Bryden, 1998), which show concentration-dependent, detoxification capacity based on the feeding history of the animals (Fink, 2010). A striking example of the adaptability of the ruminal flora is the degradation of mimosin, a metabolite of the tropical shrub leucanea (*Leucanea leucocephala*) (Hammond et al., 1995). In endemic areas the plant is well tolerated by ruminants, whereas intoxications are described in animals in non-endemic areas. It appears that some rumen bacteria convert the toxic compound mimosin into 3-hydroxy-4-(1H) pyridone, a strong goitrogen. Inoculation of affected animals in non-endemic areas with rumen fluid from endemic areas, tolerance to leucaena (and mimosin) could be achieved (Allison at al., 1990).

Another source of plant intoxication is formed by pruning waste form gardens or hedges (Ceci et al., 2020; Kennedy et al., 2020; Cortinovis and Caloni, 2015; Handeland et al., 2017). Many garden plants are toxic to animals as are shrubs and some trees. Examples are robinia, foxglove, lupins, acacia, azalea, oleander, boxwood, cherry laurel, rhododendron, ivy and autumn crocus. Pruning waste should never be fed to animals.

In the Netherlands there is a trend to increase the groundwater level for rewetting peat meadow areas. A high groundwater level not only puts a brake on subsidence but also on greenhouse gas emissions. Moreover it will increase biodiversity and bird life. But it has to be taken into account that several poisonous plants thrive on wet meadows, like Marsh horsetail (*Equisetum palustre*), Hemlock (*Conium maculatum*), Hemlock water dropwort (*Oenanthe crocata*), Cowbane (*Cicuta virosa*), meadow saffron (*Colchicum autumnale*) and comfrey (*Symphytum officinale*). Of these Marsh horsetail is the most common and especially when fertilization is reduced to remain the biodiversity in the pasture they may become invasive.

Climate effects such as prolonged dry periods may cause the grasses to falter, whereas herbs stay green. In the dry year 2019 productive herb-rich grassland yielded considerably more on sandy soil than perennial ryegrass (Koopman, W., 2020). Moreover, also the amount of unwanted weeds was reduced.

In conclusion toxic plants may occur in biodiverse herbal meadows and need monitoring. Cases of intoxication of cattle by meadow herbs are scarce, but rewetting peat meadows may pose a risk. Longer dry periods as we have seen the last years, may cause a lack of grasses, whereas herbs which generally have deeper root systems will be available. In case of toxic herbs like *Senecio Jacobea* remaining, this may cause intoxications. Garden pruning waste may also form a risk, since many garden plants are toxic.

4 Conclusions and recommendations

Conclusions

- Most poisonous plants are only eaten when there is nothing else to eat.
- In hay or silage poisonous plants may lose their smell and taste and may be eaten.
- If a plant is poisonous depends on the amount eaten, growth stage and the adaptation of the ruminal microflora.
- Especially in wet areas there is more risk of poisonous plants like Marsh horsetail (*Equisetum palustre*), Hemlock (*Conium maculatum*), Hemlock water dropwort (*Oenanthe crocata*), Cowbane (*Cicuta virosa*), meadow saffron (*Colchicum autumnale*) and comfrey (*Symphytum officinale*).
- Extended dry periods may lead to reduction of grasses and only herbs left to eat.

Recommendations

- In biodiverse pastures check the composition of the meadow regularly for poisonous plants, especially when pastures are rewetted.
- Careful inspection of hay and silage and removal of toxic plants from pastures.
- When poisonous plants are invasive, they should be controlled and the cattle prevented to graze affected areas or moved to another pasture.

References

Adams, N.R. 1995. Detection of the effects of phytoestrogens on sheep and cattle. Journal of animal science 73, 1509-1515.

Allison, M. J., Hammond, A. C., Jones, R. J. 1990. Detection of ruminal bacteria that degrade toxic dihydroxypyridine compounds produced from mimosine. Appl. Environ. Microbiol. 56, 590–594.

Anger, J.P., Anger, F., Chauvel, Y. 1976. Fatal intoxication by *Oenanthe safranee* (*Oenanthe crocata*) | [INTOXICATION MORTELLE PAR OENANTHE SAFRANEE (OENANTHE CROCATA)] European Journal of Toxicology and Environmental Hygiene 9(2), pp. 119-125.

Anadón, A.; Martínez-Larrañaga, M.R.; Castellano, V. Poisonous plants of Europe. In Veterinary Toxicology: Basic and Clinical Principles, 2nd ed.; Gupta, R.C., Ed.; Elsevier Inc.: San Diego, CA, USA, 2012; pp. 1080–1094.

Annison, E. F., Bryden, W. L., 1998. Perspectives on ruminant nutrition and metabolism. I Metabolism in the Rumen. Nutr. Res. Rev. 11, 173–198.

Bourke, C.A., White, J.G. 2004. Reassessment of the toxicity of *Hypericum perforatum* (St John's wort) for cattle. Australian Veterinary Journal 82, 707-710.

Brendieck-Worm, C. und Melzig, M.F. 2018. Phytotherapie in der Tiermedizin. Georg Thieme Verlag, Stuttgart.

Caroprese, M., Ciliberti, M.G. and Albenzio, M. 2020. In: Feed additives: Aromatic Plants and Herbs in Animal Nutrition and Health. Florou-Paneri, P., Christaki, E. and Giannenas, I (eds). Chapter 15 - Application of aromatic plants and their extracts in dairy animals. 261-277.

Ceci, L., Girolami, F., Capucchio, M.T., Colombino, E., Nebbia, C., Gosetti, F., Marengo, E., Iarussi, F., Carelli, G. 2020. Outbreak of oleander (nerium oleander) poisoning in dairy cattle: Clinical and food safety implications. Toxins 12, 471.

CliniPharm CliniTox: https://www.vetpharm.uzh.ch/perldocs/toxsyqry.htm.

Cortinovis, C., Caloni, F. 2015. Alkaloid-containing plants poisonous to cattle and horses in Europe. Toxins 7(12), pp. 5301-5307.

Cortinovis, C. and Caloni, F. 2013. Epidemiology of intoxication of domestic animals by plants in Europe. The Veterinary Journal, 197, 163–168.

da Silva, V.D.A., da Silva, A.M.M., Silva, J.H.C., Costa, S.L. 2018. Neurotoxicity of *Prosopis juliflora*: from Natural Poisoning to Mechanism of Action of Its Piperidine Alkaloids. Neurotoxicity Research 34, 878-888.

Dauncy, E.A. and Larsson, S. 2018. Dodelijke planten; een fascinerende reis langs de giftigste planten er wereld. KNVV, Zeist.

Driehuis, F., Wilkinson, J.M., Jiang, Y., Ogunade, I., Adesogan, A.T. 2018. Silage review: Animal and human health risks from silage. Journal of Dairy Science 101; 5, 4093-4110.

Dukes Phytochemical and Ethnobotanical databases: https://phytochem.nal.usda.gov/phytochem/search/list.

Edgar, J.A., Colegate, S.M., Boppre, M., Molyneux, R.J., 2011. Pyrrolizidine alkaloids in food: a spectrum of potential health consequences. Food Addit. Contam. A 28, 308–324. https://doi.org/10.1080/19440049.2010.547520.

EMEA Committee for veterinary medical products 1998, Summary report atropine.

European Food Safety Authority (EFSA) (2009a). Compendium of botanicals that have been reported to contain toxic, addictive, psychotropic or other substances of concern on request of EFSA. EFSA Journal, 7, 281. http://dx.doi.org/10.2903/j.efsa.2009.281.

Fink-Gremmels, J. 2010. Defense mechanisms against toxic phytochemicals in the diet of domestic animals. Molecular Nutrition and Food Research 54, 249-258.

Frohne, D. and Pfänder, H. J. 2005. Poisonous plants. In A handbook for doctors, pharmacists, toxicologists, biologists and veterinarians. London: Manson Publ. Ltd.

Giftige planten (gddiergezondheid.nl).

Gotfredsen, Erik, 2020. Liber Herbarum II Herbs Database http://www.liberherbarum.net/Index.htm.

Groot, Maria, van Asseldonk, Tedje en Judith van Andel. 2018. Stalboekje schapen, 2018: handboek voor natuurlijke diergezondheidszorg met kruiden en andere natuurproducten. RIKILT-uitgave 2018.705.

Haeggström, C. A. 1990. The influence of sheep and cattle grazing on wooded meadows in Åland, SW Finland. Acta Botanica Fennica, 141, 1–28.
Hammond, A. C. 1995. Leucaena toxicosis and its control in ruminants. J. Anim. Sci. 73, 1478–1492.
Handeland, K., Vikøren, T., Josefsen, T.D., Madslien, K., Valdecanas, B., Valdecanas, B., Uhlig, S. 2017. Yew (Taxus) intoxication in free-ranging cervids. PloS ONE 12, e0188961.
Holliman, A. 1985. Acorn poisoning in ruminants. Veterinary Record 116(20), pp. 546.
Kalač, P., Kaltner, F. 2021. Pyrrolizidine alkaloids of European Senecio/Jacobaea species in forage and their carry-over to milk: A review. Animal Feed Science and Technology 280, 115062.
Kamphues, J.J.J. 1990. Refusal of breeding bulls to eat hay contaminated with horsetail (*Equisetum palustre*). Tierärztliche Praxis 18: 4, 349-351.
Kennedy, A., Brennan, A., Mannion, C., Sheehan, M. 2021. Suspected cyanide toxicity in cattle associated with ingestion of laurel - a case report. Irish Veterinary Journal 74, 6.
Koopman, W. 2020. Droogte speelt kruidenrijk grasland in de kaart. Veeteeltvlees AUGUSTUS, 26-28.
Lamp, J., K. Knappstein, H.-G. Walte, T.Kraus, P. Steinberg, C. Schwake-Anduschusa 2021. Transfer of tropane alkaloids (atropine and scopolamine) into the milk of subclinically exposed dairy cows. Food Control 126, 108056.
Lee, K.A.Y.R., Harnett, J.E., Cairns, R. 2020. Essential oil exposures in Australia: analysis of cases reported to the NSW Poisons Information Centre. Medical Journal of Australia 212, 132-133.
Lingenfelter, D., Hall, M., Curran, W.S. 2022. Poisonous Weeds and Cherry Leaves in Pastures. https://extension.psu.edu/poisonous-weeds-and-cherry-leaves-in-pastures.
Liu, T., Chen, H., Bai, Y., Wu, J., Cheng, S., He, B., Casper, D.P. 2020. Calf starter containing a blend of essential oils and prebiotics affects the growth performance of Holstein calves. Journal of Dairy Science 103, 2315-2323.
Molyneux, R.J., Panter, K.E. 2009. Chapter 3 Alkaloids Toxic to Livestock, Alkaloids: Chemistry and Biology 67, 143-216.
Ozmen, O., Mor, F., Unsal, A. 2003. Nitrate poisoning in cattle fed *Chenopodium album* hay. Veterinary and Human Toxicology 45, 83-84.
Panter, K.E. and Keeler R.F. 1993. Quinolizidine and Piperidine alkaloid Teratogens from Poisonous plants and their Mechanism of action In animals. Veterinary Clinics Of North America: Food Animal Practice Volume 9, 33-40.
Pirhofer-Walzl, K., Søegaard, K., Høgh-Jensen, H., Eriksen J., Sanderson M.A., Rasmussen, J., Rasmussen, J. 2011. Forage herbs improve mineral composition of grassland herbage. Grass and Forage Science 66(3), 415-423.
Raamsdonk, L.W.D. van, W.A. Ozinga, L.A.P. Hoogenboom, P.P.J. Mulder, J.G.J. Mol, M.J. Groot, H.J. van der Fels-Klerx, M. de Nijs 2015. Exposure assessment of cattle via roughages to plants producing compounds of concern. Plant toxins Cattle Vegetation analysis. https://www.sciencedirect.com/science/article/pii/S0308814615002216?casa_token=cKqNNH9x1JYAAAAA:zudJviDlhyrqqzc-YIZa_AjP8syQhEr8507R2lvskFI_JksphtJg3una9XINTeOcZWL-tFfQ.
Rahman, M. M., R. B. Abdullah and W. E. Wan Khadijah 2013. A review of oxalate poisoning in domestic animals: tolerance and performance aspects. Journal of Animal Physiology and Animal Nutrition 97, 605–614.
Rochfort, S., Parker, A.J., Dunshea, F.R. 2008. Plant bioactives for ruminant health and productivity. Phytochemistry 69, 299-322.
Salman, M., Abbas, R.Z., Israr, M., Abbas, A., Mehmood, K., Khan, M., Sindhu, Z., Hussain, R., Saleemi, M.K., Shah, S. 2020. Repellent and acaricidal activity of essential oils and their components against Rhipicephalus ticks in cattle. Veterinary Parasitology 283, 109178.
Schep, L.J., Slaughter, R.J., Beasley, D.M.G. 2009. Nicotinic plant poisoning. Clinical Toxicology 47(8), 771-781.
Schrader, A., Schulz, O., Völker, H., Puls, H. 2001. Actual plant intoxications in ruminants of north-eastern Germany | [Aktuelle vergiftungen durch pflanzen bei wiederkäuern in nord- und ostdeutschland mitteilung aus der praxis für die praxis]. Berliner und Munchener Tierarztliche Wochenschrift 114(5-6), pp. 218-221.
Wynn, S.G. and Fougere, B.J. 2007. Veterinary Herbal medicine. Mosby Elsevier, St. Louis Missouri.

Annex 1 Poisonous plants in or around meadows and their possible effects

Name	Plant part	Constituents	Biological action	Effects	Sources /literature
Bracken (*Pteridium aquilinum* (Kuhn)	Young leaves and rhizome	thiaminase, cyanogenic glycosides, pterosine, ptaquiloside	Anti-vitamin B, carcinogenic	depression, fever, skin and mucous bleeding and bloody diarrhea	Giftige planten (gddiergezondheid.nl)
Bitter dock (*Rumex obtusifolius*)	Whole plant	Nepodin, vitamin C, neral, tannic acid, potassium oxalate	laxative, skin diseases	diarrhea	Liber herbarum II
Cherry laurel* (*Prunus laurocerasus*)	**leaves**	**cyanogen glycoside**	**hydrocyanic acid is formed from the glycoside by an enzyme present in the plant**	**Dizziness, headache, vomiting, accelerated breathing, unconsciousness, coma and finally death**	**Giftige planten (gddiergezondheid.nl) Kennedy et al., 2020**
Chokecherry (*Prunus virginiana* L.)	**Young leaves**	**cyanogen glycoside**	**hydrocyanic acid is formed from the glycoside by an enzyme present in the plant**	**Low dose: irritating upper respiratory tract and mucous membranes. Moderate: Cramps and unconsciousness occur with death within half an hour**	**Giftige planten (gddiergezondheid.nl)**
Comfrey (*Symphytum officinale*)	herb	pyrrolizidine alkaloids, nitrite	Stacks in the liver	Liver damage	Giftige planten (gddiergezondheid.nl) Molyneux, R.J., Panter, K.E. 2009
Cowbane (*Cicuta virosa*)	Whole plant	Polyynes (cicutoxin and oenanthetoxine)	Neurological effects	Muscle spasms, vomiting, seizures	Giftige planten (gddiergezondheid.nl) Dauncy and Larsson, 2018
Creeping thistle (*Cirsium Arvense* (vulgare)	herb	Acaciin, rutin, Protocatechu-aldehyd, betasitosterol, Tanning agents, Pectolinarin	Anti-menstrual, reduced appetite, diarrhea, choleretic	Anorexia, emetic, diuretic,	Liber herbarum II, used in TCM
European yellow-rattle (*Rhinanthus alectorolophus*)	herb	aucubin	Gastrointestinal effects	Colic, diarrhea, possibly nervous problems and kidney damage	https://www.vetpharm.uzh.ch/giftdb/pflanzen/0145_tox.htm
Foxglove** (*Digitalis purpurea*)	Whole plant	digitoxin, gitoxin and gilatine	Gastrointestinal effects	Gastrointestinal problems, such as salivation, vomiting, colic and diarrhea	Giftige planten (gddiergezondheid.nl)
Giant hogweed (*Heracleum mantegazzianum)*	Whole plant	furanocoumarins, (5-methoxypsoralin and imperatorin)	photosensibilisation	Itching, dermatitis and blistering on skin surfaces exposed to sunlight.	Giftige planten (gddiergezondheid.nl)

Name	Plant part	Constituents	Biological action	Effects	Sources /literature
Gold chain (Laburnum anagyroides)	**Whole plant**	**Quinolizidine alkaloids, including cytisine, N-methyl-cytisine ammodendrine, and anagyrine**	**Neurotoxicity, teratogenic**	**Irritability, stiff gait, stumbling, muscle tremors, frequent urination, salivation, diarrhea, vomiting and colic. Followed by weakness, collapse, and eventually death from respiratory arrest**	**Giftige planten (gddiergezondheid.nl)** Molyneux, R.J., Panter, K.E. 2009
Goosefoot, melde (*Chenopodium album*)	Whole plant	Oxalic acid	Binds calcium	drop in blood calcium levels. This can cause milk fever symptoms, resulting in death	Giftige planten (gddiergezondheid.nl)
Hemlock water dropwort (*Oenanthe crocata, Oenanthe safranee*)	Whole plant, root	oenanthotoxin	Neurological effects	increased salivation, dilated pupils, respiratory distress, and convulsions	Liber herbarum II, used in TCM
Hogweed or cow parsnip (*Heracleum sphondylium*)	Whole plant	furanocoumarins, (5-methoxypsoralin and imperatorin)	photosensibilisation	Itching, dermatitis and blistering on skin surfaces exposed to sunlight.	Giftige planten (gddiergezondheid.nl)
Ivy (*Hedera helix*)	**Leaves (in high amounts)**	**saponins and polyacetylenes**	**gastrointestinal effects Polyacetylenes are allergenic and possibly neurotoxic**	**gastrointestinal effects such as colic, vomiting and diarrhoea. In rare cases, muscle cramps and paralysis.**	**Giftige planten (gddiergezondheid.nl)**
Japanese Pieris (*Pieris japonica*)	**leaves**	**andromedotoxin**	**Affects muscles, both smooth and skeletal muscle**	**Overstimulation and finally paralysis. Vomiting tendencies. Salivation, intestinal cramps, foaming around the muzzle. Blue mucous membranes**	**Giftige planten (gddiergezondheid.nl)**
Jimson Weed (*Datura Stramonium*)	Whole plant	hyoscyamine, scopolamine and atropine	Neurological effects	tachycardia, pupil dilation, dry mouth, incoordination, disorientation, convulsions, delirium and coma	Cortinovis and Caloni, 2015 Molyneux, R.J., Panter, K.E. 2009
Lupins (*Lupinus spp.*)	Whole plant	d-lupanine and piperidine alkaloids	Liver damage, some species teratogenic	lethargy, emaciation, yellow mucous membranes, sometimes photosensibilisation	Giftige planten (gddiergezondheid.nl) Panter and Keeler, 1993
Marsh horsetail (*equisetum palustre (L.*)	Whole plant	Palustrin, N5-Formyl-palustrin (Palustridin), N5-Acetylpalustrin, N5-Formyl-palustridine	Depression, kidney problems	reduced milk production, diarrhea, weight loss, weakness, trouble standing up, blood in urine	CliniTox Giftpflanze: Equisetum sp. - Veterinärtoxikologie (uzh.ch) Cortinovis and Caloni, 2015.
Meadow buttercup (*Ranunculus acris)*	herb	poisonous glycosides, anemonol, saponins, Flavoxanthin, protoanemonin, anemonin, flemiphilippinin c	Gastrointestinal and skin effects	itching, blisters and nausea	Liber herbarum II

Name	Plant part	Constituents	Biological action	Effects	Sources /literature
Meadow Saffron or Autumn crocus (*Colchicum autumnale (L.*)	herb	Colchicin, Colchicosid, Demecolcin	Neurological, liver and kidney effects, gastrointestinal toxin and causes intractable multi-organ failure	Weakness, paralysis, colic, nausea, vomiting, diarrhea, liver failure, renal failure, bone marrow depression	Dauncy and Larsson, 2018 CliniTox Giftpflanze: Colchicum autumnale - Veterinärtoxikologie (uzh.ch)
Nightshade (Solanum spp.)	Seeds, fruits	Gluco-alkaloid Solanin, Solasodin, Solamargin, Solanigrin	Gastro-intestinal, kidney damage, mucous membranes affected	Excessive salivation, severe gastrointestinal disturbances, anorexia, haemorrhagic diarrhea, trembling, nasal discharge. Can cause sudden death.	https://www.vetpharm.uzh.ch/giftdb/pflanzen/0102_bot.htm
Oak (*Quercus robur*)	Seeds (green acorns), young twigs and leaves	Gallotannins, gallic acid, pyrogallol	binds protein and iron, gastrointestinal effects, kidney damage	gastroenteritis, constipation and diarrhea, kidney damage	Giftige planten (gddiergezondheid.nl) Holliman, 1985
Oleander (*Nerium oleande*r)	**leaves**	**Cardiac glycosides: oleandrin, nerin, digitoxigenin, and olinerin**	**Cardiac toxin**	**Severe depression, anorexia, ruminal atony, diarrhea, serous nasal discharge, tachycardia, and irregular heartbeat, death**	**Ceci at al., 2020**
Poison hemlock (*Conium maculatum)*	Whole plant, root	Piperidine-alkaloids, coniine and γ-coniceine	Neurological effects	irritability, stiff gait, stumbling, muscle tremors, frequent urination, salivation, diarrhea, vomiting, and colic	Giftige planten (gddiergezondheid.nl) Molyneux, R.J., Panter, K.E. 2009
Ragwort (*Senecio Jacobaea (L.)*	herb	Pyrrolizidin-alkaloids: Jacobin, Jaconin, Jacodin, Senecionin, Retrorsin, Seneci-phyllin, Senkirkin	Liver damage	Liver damage, apathy, weight loss, diarrhea, anorexia, photosensitivity, rumen paralysis, ascites	CliniTox Giftpflanze: Senecio sp. - Veterinärtoxikologie (uzh.ch) Kalac and Kaltner, 2021). Molyneux, R.J., Panter, K.E. 2009
Saint John's Wort (*Hypericum perforatum*)	herb	Hypericin, hyperforin	Photo-sensibilisation	Sunburn, skin damage	Giftige planten (gddiergezondheid.nl) Bourke and White, 2004
Sheep's sorrel (*Rumex acetosella*)	Leaf, root	Catechin-tannin, Adenosin, anthraquinon, Auxin, calcium oxalate, Chrysophanic acid, tannins, hyperoside, coumarin, rutin, tartaric acid, oxalic acid	diuretic, astringent	diarrhea	Liber herbarum II
Rhododendron spp.	**leaves**	**andromedotoxin**	**Affects muscles, both smooth and skeletal muscle**	**Salivation, muscle tremors, Colic, overstimulation finally paralysis. Death due to respiratory arrest**	**Giftige planten (gddiergezondheid.nl)**
Yew (*Taxus baccata*)	**shrub**	**Ginkgetin, taxol, taxine and taxicatin**	**Effects on Circulation, Respiration and Heart**	**Acute heart failure**	**Giftige planten (gddiergezondheid.nl) Molyneux, R.J., Panter, K.E. 2009**

* **Garden plants are in fat green.**

** Wild plants that are also garden plants.

Wageningen Food Safety Research
P.O. Box 230
6700 AE Wageningen
The Netherlands
T +31 (0)317 48 02 56
wur.eu/food-safety-research

WFSR Report 2022.020

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,200 employees (6,400 fte) and 13,200 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

To explore the potential of nature to improve the quality of life

Wageningen Food Safety Research
P.O. Box 230
6700 AE Wageningen
The Netherlands
T +31 (0) 317 48 02 56
wur.eu/food-safety-research

WFSR report 2022.020

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,200 employees (6,400 fte) and 13,200 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.