Problems with pyridine-based pesticides in organic fertilisers continue

Experiences from Sweden

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FOR
FRITIDSODLINGENS RIKSORGANISATION

Innehåll

Preface

In the spring of 2021, Fritidsodlingens Riksorganisation (Swedish Leisure Garden Association), FOR released the report *Pesticide residues in organic fertilisers and soil*. That report summarised the state of knowledge on pyridines in organic fertilisers and documented analysis carried out in 2020 (report only available in Swedish).

This report now picks up where the previous one left off and summarises the 2021 growing season. New samples have been analysed and more recreational growers have shared their experiences of plant damage caused primarily by *clopyralid*, but also *aminopyralid* and *picloram*. The literature review now focuses more on the environmental effects and goes into more detail on areas that were only briefly described in the previous report.

We would like to thank everyone who made themselves available to be interviewed – from the authorities and the fertiliser industry – and everyone who shared their knowledge about pyridines in legislation, fertilisers and potting soil. The exchange of knowledge with Horticultural Societies in Denmark (Haveselskabet) and Norway (Hageselskap), advisers at the Norwegian Centre for Organic Agriculture in Norway (NORSØK) and Organic Norway (Økologisk Norge) as well as Marit Almvik at the Norwegian Institute for Bioeconomic Research (NIBIO) have all contributed valuable information to this work. And without the voluntary efforts of recreational growers, the pyridines would have never been on the agenda. We extend therefore a special thanks to Lena Israelsson and Katja Jassey in Sweden, Janne Frydenlund in Norway and Jukka Lehto in Finland. And very special thank you to all the recreational growers that took the time to answer our survey and send in samples for analysis.

Ulf Nilsson

Summary

Clopyralid, and the closely related substances aminopyralid and picloram belong to a group of substances known as *pyridines*. These herbicides are used to kill herbaceous weeds in, for example, cereals, oil crops, grazing and forage crops and sugar beet fields. The weeds die because their hormone systems are disrupted when their auxin receptors are blocked. Auxin is a plant hormone that controls plant growth and the development of various plant organs such as leaves and flowers. When enough receptors are blocked, the plant dies. But even at low levels, serious disturbances may occur to sensitive plants causing for example, the malformation of shoots, leaves and fruits. Particularly sensitive are Compositae plants (Asteraceae family), pea plants (Fabeaceae family), potato plants (Solanaceae family) and sedge plants (Polygonaceae family) (Recycled Organics Unit, 2006). The pyridines are very difficult to degrade, meaning they stay in/on the crops when they are harvested and are not broken down within the growing season. They can be found in fodder and hay. And they can pass through an animal's body without being inactivated and thus be present in stable manure. And they are not broken down easily by the composting process.

READING GUIDE

In this report, the term **pyridines** is used throughout to refer to **clopyralid**, **aminopyralid** and **picloram** as a group. These three substances have several properties in common and cause the same type of plant damage.

When referring to just one of the substances specifically, we use the name of that substance. However, correct chemical nomenclature for this class of pyridines is **pyridine-carboxylic** acids.

Already in 2020, we were able to demonstrate that certain liquid organic fertilisers sold to recreational growers were contaminated by the pesticide clopyralid. What the products had in common was that they were based on vinasse, a residual product from sugar production. We thought then, that the solution to the problem would be for manufacturers to replace vinasse with other organic raw materials in their fertiliser products.

Unfortunately, this study shows that the problems with pyridines are even more widespread than we suspected in 2020. Pyridines can be found in almost all organic raw materials originating in agriculture, and used by recreational growers as fertilisers. The analyses have shown residues of clopyralid in cow, horse, sheep and chicken manure as well as in fertiliser products based on residues from sugar production and other vegetable raw materials. Aminopyralid was detected in corn starch and cow manure and picloram in horse manure. It can equally affect recreational growers who buy organic vegetable fertilisers at garden centres, as those who have access to stable manure, straw or silage from riding schools or local farms. However, we do not know how big the risk that individual growers will be affected is.

The only solution is to stop the use of pyridines. The government can give the Swedish Chemicals Agency the task of banning products containing pyridines in Sweden. But it is only at EU level that the active substances can be banned. Sweden's government must therefore take active measures for a ban at EU level.

Background – Summary 2020

In 2020, it was discovered that some liquid organic fertilisers sold to recreational growers were contaminated by the pesticide clopyralid (Nilsson, 2021). These products had in common that they were based on vinasse, a residual product from sugar production. The problem could thus be traced back to weed control, with *clopyralid*, in sugar beet fields in France, Germany and Poland. In addition, it was found that vinasse-based organic fertilisers intended for private consumers in Denmark, Norway and Finland, could contain residues of clopyralid.

In Sweden, the journalist Lena Israelsson has been a driving force for increasing knowledge of the problem among consumers, and for influencing authorities to act on the issue through her blog Odlamat.com and her Facebook page. The Swedish Leisure Garden Association, FOR, became involved in the spring of 2020 after contact with recreational growers and with Lena Israelsson. FOR obtained information from affected recreational growers via a web survey, collected and sent suspect products for analysis and was in contact with manufacturers, retailers, authorities and decisionmakers.

The attention led to several of the large Swedish retailers to stop selling fertilisers based on vinasse. Manufacturers withdrew products from the market and KRAV – a Swedish label for organic food – launched an investigation and made regulatory changes to reduce the risk of soil and fertiliser products being contaminated by pesticide residues (KRAV, 2021b).

The information that emerged also had an impact at an EU level. In the spring of 2021, the EU Commission introduced conditions for national permits for clopyralid products. According to the decision, countries must pay special attention to the risk posed by clopyralid, since it can spread into compost and stable manure and damage sensitive plants (2021/1191/EU). Sweden was the driving force in raising the issue in the EU, and the Swedish Chemicals Agency translated parts of our report as a basis for the discussions.

Unfortunately, the problems did not end there.

Introduction – about pyridines and their impact on plants and the environment

Clopyralid, and the closely related substances aminopyralid and picloram, are herbicides used to kill herbaceous weeds in, for example, cereals, oilseeds on grazing and forage crops and sugar beet fields. They are used throughout the EU. Pyridines are systemic, meaning they are absorbed by the targeted weed and transported around inside of it. The weeds die because the hormone system is disrupted when the auxin receptors are blocked. Auxin is a plant hormone that controls plant growth and the development of various plant organs such as leaves and flowers. When enough receptors are blocked, the plant dies. But even at low levels, serious disturbances can affect sensitive plants, for example causing malformation of shoots, leaves and fruits (Nilsson, 2021). The damage is concentrated in the growth zones such as top shoots and root tips. This means that older leaves and shoots, fully grown before the weed absorbed the pyridine, are not damaged. On the same tomato plant, the top shoots can therefore be grotesquely deformed, while other parts of the plant remain unaffected (figure 1). The damage is irreversible, which means that it will not disappear with time.

Figure 1. Tomato plant damaged by pyridines in one of Pungpinan's allotment gardens. Note the deformities in the leaves of the top shoots while older leaves remain unaffected. Photo: Linda Wahl.

PYRIDINES

Picloram was introduced to the global market as early as 1963, clopyralid in 1977 and aminopyralid in 2005. The first approval for use in the Swedish market came for clopyralid in 1991 (product named: Ariane) and for aminopyralid in 2016. Picloram was approved in Sweden in 1966, then banned in 1978 only to be approved again in 2011 – as a result of harmonising rules within the EU for plant protection products.

Particularly sensitive are Compositae plants (Asteraceae family), pea plants (Fabeaceae family), potato plants (Solanaceae family) and sedge plants (Polygonaceae family) (Recycled Organics Unit, 2006). In a Norwegian cultivation experiment, tomato and pea plants were fertilised with liquid organic fertiliser, containing 480 µg/L clopyralid according to analysis, in different concentrations. At a low dose (1 %), the tomato plants developed fewer buds and flowers and the few fruits that did form lacked normally developed seeds. Higher doses (2 and 4 %) severely damaged or killed the pea and tomato plants (McKinnon *et al.*, 2021).

In a Japanese study, damage to tomato plants was demonstrated at 5 µg/kg clopyralid in the growing soil, shown by severely shrivelled leaves and impaired growth, while lighter damage such as cupped leaves occurred at just 1 µg/kg clopyralid (Namiki *et al.*, 2019). Potatoes are also very sensitive to clopyralid. In addition to direct leaf damage, reduced shoot formation, malformed tubers and reduced yield, the substance can accumulate in the potato tubers and cause damage the following year if they are used as seed potatoes (Seefeldt *et al.*, 2014).

However, monocotyledon plants such as lilies, grasses and onions are not particularly sensitive. For example, a tomato plant is up to 10,000 times more sensitive to pyridines than corn plants. This means that growers can control weeds in grain fields without damaging the crop. Swedish farmers use clopyralid above all to control larger weeds from the Compositae family, *e.g.*, scentless

Figure 2. Deformed potato tubers from plant fertilised with horse manure contaminated with clopyralid and pickloram. Photo: Ulf Nilsson.

Figure 3. Pyridine damaged potato. Photo: Linda Wahl.

mayweed (*Tripleurospermum inodorum*), dandelion and thistle (Johnson, personal correspondence, 2021-12-01).

There are currently 11 registered products based on pyridines in Sweden. Six of these contain clopyralid, three contain aminopyralid, one contains picloram and one product contains both picloram and clopyralid (appendix 1). Combining several active substances against weeds is common since they differ in how effective they are in combating specific weed species. Thus, these products can make more of an impact in the field with each application. There are no products approved for private use in gardens in Sweden.

The amount of clopyralid sold in 2019 was almost 10 times greater than picloram and 100 times greater than the amount of aminopyralid (Swedish Chemicals Agency). For 2020, the companies have chosen not to publish the amount sold for aminopyralid and picloram (table 1). The twelve tons of clopyralid sold in Sweden in 2020 can be compared to the 170 tons of MCPA (2-methyl-4-chlorophenoxyacetic acid) sold during the same period. MCPA is also an auxin-mimicking herbicide but it has a significantly shorter persistence than pyridines (Swedish Chemicals Agency).

WHAT PERCENTAGE OF THE CULTIVATED LAND AREA IN SWEDEN IS TREATED WITH CLOPYRALID?

In Sweden, clopyralid is mostly used in fields growing cereals and rapeseed. The recommended dose per hectare differs from crop to crop – from 80 grams per hectare to 140 grams per hectare. The 12.3 tons of clopyralid sold in 2020, with an average dose of 120 grams per hectare, would be enough to treat 102,500 hectares of cropland.

Of the total 1,007,600 hectares of cereals and oilseed cultivation in Sweden in 2020, rapeseed and turnip rapeseed accounted for 99,300 hectares. The 12.3 tons of clopyralid would then be sufficient to treat 9% of the cereals and rapeseed cultivation area. Clopyralid can also be used on grazing and forage crops, but this is uncommon due to the high cost per hectare and because grazing and forage crops often contain plants from the pea family, especially various clovers, which are very sensitive to clopyralid (Johnson, personal correspondence, 2021-12-01). When including pasture and grazing plants, the total area reaches 1,138,800 hectares and in such a case, 12.3 tons of clopyralid is enough to treat 5% of the area. These calculations are based on several assumptions and should mostly be seen as rough estimates. For example, it's not likely that the total amount of clopyralid purchased would be used in the same year and farmers may use a lower dosage per hectare.

Table 1. Quantity sold (in tons) of aminopyralid, clopyralid and picloram for the period 2013–2020 in Sweden.

Active substance	2013	2014	2015	2016	2017	2018	2019	2020
Aminopyralid	Not approved	Not approved	Not approved	*	0,3	0,3	0,1	*
Clopyralid	17,1	8,6	*	*	9,6	*	10,1	12,3
Picloram	0,7	0,4	*	*	1	1,8	1,4	*

* The company considers itself unable to publish the information. Source: The Swedish Chemicals Agency (2021).

Persistent substances

Chemical substances that are resistant to degradation in the environment are classified as *persistent* substances. This means that they can remain in, for example, soil, sediment and water for several years. According to the Swedish Chemicals Agency, organic substances that are resistant to degradation also pose a possible risk to human health and the environment. This is because the long-term effects are difficult to predict in the standard tests used to determine chemical risks.

Pyridines are significantly more persistent than most other plant protection products that are approved in Sweden. For example, the half-life in soil can be over 500 days for aminopyralid and picloram and 250 days for clopyralid (WRAP, 2010; Lewis *et al.*, 2016; Dow Agrosciences, 1998). The decomposition of pyridines is largely driven by soil-dwelling microorganisms. The higher the microbiological activity, the faster the degradation. But soil temperature and humidity also affect the rate of decomposition (WRAP, 2010). The rate of decomposition increases as temperature increases. Decomposition is slowest in dry or oxygen-poor soils with low microbiological activity.

Table 2. Half-life in soil and light sensitivity of clopyralid, aminopyralid and picloram.

	Clopyralid	Aminopyralid	Picloram
Half-life in soil	8 to 250 days	31.5 to 533 days	167 to 513 days
Light sensitive (photolysis)	No	Yes (0.6 days half-life in sunlight in water solution, 72 days on soil surface)	Partly

Figure 4. Pyridine damaged tomato. Photo: Tina Henriksson.

Aminopyralid, unlike clopyralid, also breaks down in sunlight through a process known as photolysis (WRAP, 2010). Under typical composting conditions, the half-life of clopyralid was 30 days. However, the degradation rate increased with increasing temperatures and oxygen content (WRAP, 2010). For growers, this means that the decomposition of pyridines can be accelerated if the conditions for microorganisms in the soil and compost are optimised by maintaining the right balance of humidity and oxygen content. One way to achieve this is by turning the compost heap more frequently.

Impact on environment and health

A large number of studies have investigated the effect of pyridines on the environment and on health. The studies are not all in complete agreement, but what can generally be stated is that the risks to human health are considered low to moderate according to most studies (*e.g.* European Food Safety Authority, 2009; 2013; 2018). For example, clopyralid and aminopyralid are not considered to be acutely toxic to humans and clopyralid is not expected to bioaccumulate in the human body. However, there are some question marks regarding aminopyralid and bioaccumulation (Lewis *et al.*, 2016). Current knowledge of the effect on reproduction is not completely clear for clopyralid and picloram, while aminopyralid is not considered to have a negative impact (Lewis *et al.*, 2016). The substances pass largely unaffected through the bodies of mammals and are excreted in urine (Tu *et al.*, 2001). There is a risk of eye damage as well as skin and respiratory irritation when handling concentrated clopyralid in agriculture.

The ecological risks of pyridines are primarily linked to unintentional damage to plants through wind drift during field treatment and runoff via surface water reaching plants (Environmental Protection Agency, 2021). All of these substances are highly mobile and the risk of leakage to groundwater is considered high. Clopyralid and picloram are persistent in soil and water, while aminopyralid is considered persistent in soil but not in surface water.

Several of the commercial products containing pyridines as active substances approved for use in Sweden – such as including Ariane, Kinvara and Lancelot – are considered to be very toxic to aquatic organisms. Their toxicity is also based on other active substances included in the product and not just the pyridines. The acute toxicity of clopyralid for algae, aquatic plants (*Lemna* spp.) and crustaceans (*Daphnia* spp.) is, however, assessed as medium to medium-high (Franzén *et al.,* 2007). The risk associated with aminopyralid is assessed as medium to medium-high for aquatic plants and algae (DowAgrosciences, n.d.). Picloram's acute toxicity is assessed as medium to medium-high for fish and crustaceans (Lewis *et al.*, 2016). However, it should be noted that the aquatic plant *Lemna* spp. used as the test organism, belongs to the monocotyledonous plants which are generally insensitive to pyridines. This may therefore contribute to an underestimation of the negative effects of pyridines on aquatic plants.

CLOPYRALID IS FOUND IN GROUNDWATER – NATIONAL ENVIRONMENTAL MONITORING

Clopyralid has been analysed since 2002 and picloram since 2012 in the Sweden's national environmental monitoring of chemical pesticides in four regions; Skåne, Halland, Västergötland and Östergötland. Aminopyralid has not been included in environmental monitoring. Sampling takes place in surface water, groundwater and in some cases also precipitation and air. Clopyralid has been found in all areas in surface water, in varying amounts, however with a definitive centre of concentration in found in Östergötland. However, the levels found are considered low (Lindström, 2021). Findings of clopyralid in groundwater have been made in Östergötland and Skåne in recent years. Picloram has only been found in three samples at low concentration; in surface water in Skåne and Västergötland and in groundwater in Östergötland.

How can pyridines become a problem for recreational growers in Sweden?

The major risk associated with pyridines is the unintended damage they can cause to other more sensitive crops, grown after a less sensitive crop has been treated. Farmers are generally aware of these problems and they take certain considerations into account when planning crop rotation on their own lands. However, damage to garden plants outside one's own fields, for example, can be more difficult to prevent. The substances are very difficult to degrade, meaning they stay in/on the crops when they are harvested and are not broken down within the growing season. They can be found in fodder and hay. And they can pass through an animal's body without being inactivated and thus be present in stable manure. And they are not broken down completely by the composting process. Accidental plant damage caused by clopyralid and aminopyralid-contaminated compost soil has been reported several times from the USA, New Zealand, Ireland and Japan (WRAP, 2010; Heasman, 2019; Naimiki *et al.*, 2019; Danovich, 2020). In the spring of 2021, Hasselfors Garden – a company producing growing media and soils – reported that they detected clopyralid in large-scale produced compost soil that is included in some of their soil products (Hasselfors Garden, 2021a). The compost consisted of vegetable material from the food industry and agriculture and was approved for use in organic farming.

Clopyralid can neither be degraded by pasteurisation, baking, boiling or sterilisation (European Food Safety Authority, 2018) nor through other industrial processes, for example when organic raw materials are used to produce fertilisers. The content of pyridines in fertiliser products reaching consumers may still be high enough to cause harm. Finally, several of the most popular plants grown by recreational growers belong to the plant families

Figure 5. When cows are fed with contaminated feed, the pyridines pass through the animal's body undigested and ends up in the manure, which in turn can cause damage to fertilised plants. Photo: Ulf Nilsson.

Figure 6. Chicken manure was found to be contaminated with pyridine. Photo: Ulf Nilsson.

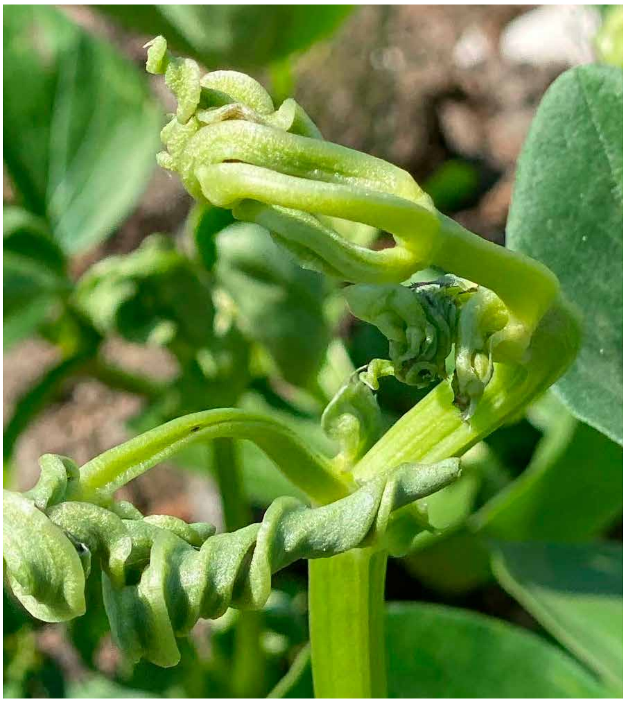

Figure 7. Pyridine damaged broad bean plant. Photo: Linda Wahl.

that are very sensitive to pyridines, even at extremely low concentrations (Nilsson, 2021). During the 2020 season, problems in recreational growing were primarily linked to vinasse, a residual product from sugar production, whose nutritional content makes it suitable for use as fertiliser (Nilsson, 2021).

Growers in several countries have been affected

Recreational and small-scale growers in several countries – including the USA, Great Britain, Ireland and Scandinavia – have had their plants damaged by pyridines (Nilsson, 2021 and references therein). In Denmark, the Danish Gardening Society (Dansk Haveselskabet) conducted an investigation of suspected contaminated organic fertilisers and found high levels of clopyralid in six products that also caused damage to fertilised plants (Haveselskabet, 2021). The Norwegian Centre for Organic Agriculture (NORSØK) conducted trials with tomato and pea plants, with fertiliser products where clopyralid was detected after several growers suffered plant damage in Norway (McCinnon *et al.*, 2021). Several cases of clopyralid poisoning through organic liquid fertilisers and chicken manure have also been discovered in Finland (Lehto, personal correspondence, 2022-01-24).

In 2020, an allotment garden society in Derbyshire, England suffered from malformed potatoes, beans, tomatoes and peas. They suspected that the cause was pesticide residues in horse manure. They contacted Corteva Agroscience, the company that developed and sells the majority of pyridine products on the global market, and tested samples the suspected manure. High levels of clopyralid were found (Minter, 2021). In the Netherlands, a non-profit growing organisation is preparing to investigate the presence of pyridines in organic fertilisers in the spring of 2022. They suspect that recreational growers have been affected.

Although the reports of plant damage have been numerous globally, they have largely focused on the individual organic raw materials as the source of pyridine poisoning, in for example compost soil. Connected cases of pyridine poisoning have only been documented in a few instances. The conclusion that poisoning was caused by pyridines has been based on visible plant symptoms and has usually not been followed up by laboratory analyses due to high costs. Lack of analyses and a collective documentation of pyridine damage caused by several organic raw materials may be a reason why the responsible authorities, agricultural organisations and producers of these products have not acted more forcefully to solve the problem.
In this investigation, our goal has therefore been to collect, analyse, test cultivate and document the damage caused by pyridines – through different raw materials from agriculture – that have affected recreational growers in Sweden.

Results section

Survey responses

A survey was available as a web link on FOR's website between May 27th and October 21st in 2021. Recreational growers affected by pyridine damage were called upon to report their experiences, via FOR's newsletter, FOR's member associations, social media channels and Lena Israelsson's blog odlamat.com. A total of 124 responses were received and 83 % of the respondents stated that they had never before noticed similar symptoms in their cultivated plants. Those who responded to the survey are primarily residents of Skåne, the west coast and around Greater Stockholm (figure 8).

A total of 77 respondents sent in pictures of plants they thought were damaged by pyridines. Of these images, 66 % were images of tomato plants. Our assessment is that the corresponding 71 % of the images show clear symptoms that are likely to have been caused by pyridine poisoning, 12 % were assessed as probably caused by pyridines (but could not be verified) and 17 % of the plant damage was considered not to be related to pyridines.

What has caused plant damage?

About a third of the respondents suspected that the damage was caused by locally-produced manure, straw or silage (figure 9). A total of 23 % (28 out of 124) of respondents stated that the injuries were probably caused by horse manure, which was therefore the type of local stable manure that the majority identified as a source of contamination, followed by sheep manure (4 out of 124) and chicken manure (3 out of 124). The growers who suspected that their crops were damaged by contaminated stable manure or straw from local riding stables and farms were mainly located in southern Sweden and around Stockholm (figure 10).

A total of 25 % of respondents stated that purchased consumer packaged soil in a bag was a possible source of contamination. And less than one fifth of respondents named purchased organic fertilisers in liquid or solid form as a possible source of contamination. Furthermore, eleven different brands of bagged soil and fertiliser are suspected of having caused plant damage.

Figure 8. Survey responses distributed geographically in the country. Google Maps.

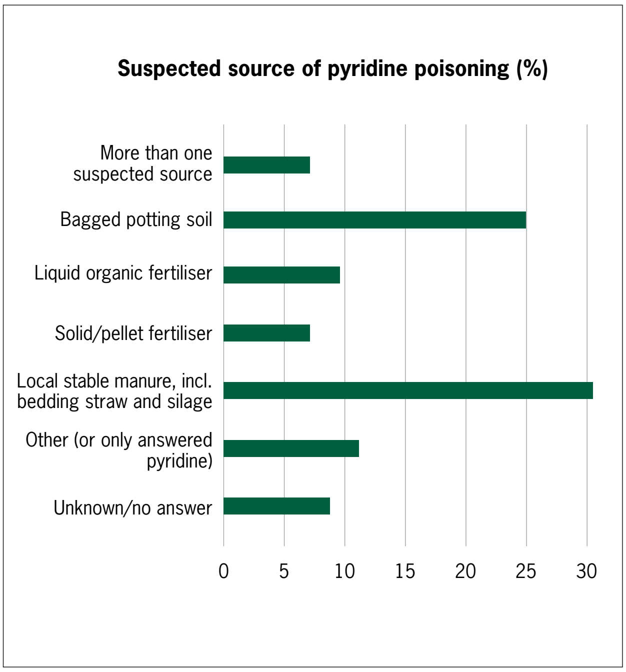

Figure 9. Suspected source of pyridine. Based on 124 respondents.

Figure 10. Places where locally-produced manure or straw as well as manure from growers own animals have been used and suspected of causing damage. Applies to a total of 38 answers. Google maps.

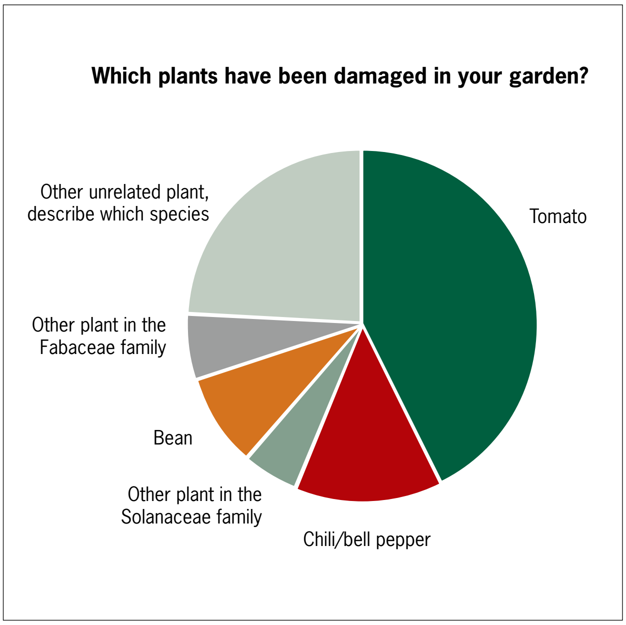

Figure 11. Plant species to which most respondents reported damage during 2021.

Figure 12. Broad beans damaged by pyridine contaminated sheep manure. Photo: Ulf Nilsson.

Which plants were damaged?

Tomatoes, peppers and chillies are the plants most often reported to have suffered damage during the 2021 growing season. These are followed by beans and peas (figure 11). Other plants affected include: cucumber, melon, pumpkin and squash from the cucumber family; eggplant, goldenberry and potato from the Solanaceae family, and artichokes and lettuce from the Asteraceae family. Damage has also been reported on summer flowers from the Asteraceae family, such as aster, dahlia, rosehip, sunflower, tagetes and zinnia. There are also plant species that have been reported where it is less likely that the damage was due to pyridine poisoning, for example strawberries, asparagus, yellow onions and cabbage plants, because these plants are not considered to be particularly sensitive to pyridines.

Consumer products

During the spring of 2021, FOR received several reports from recreational growers who had their plants damaged and where fertilisers and bagged soil were suspected to be the source of contamination. FOR therefore decided to send in more samples of organically-based garden products for analysis. A total of 31 products were purchased including bagged soils, liquid and solid (pelleted or granulated) organic fertilisers at building materials shops, grocery stores and garden centres during the last week of May 2021. One product, Green future organic tomato fertiliser, was submitted to FOR earlier in the spring by recreational growers who suspected that the product contained pyridines.

Laboratory analyses

Local manure, straw and silage. On June 22, FOR was contacted by the chairman of Pungpinan's allotment garden association who suspected that horse manure, which the association jointly procured for the allotment area, was contaminated with pyridines. A week later there was also information that two other allotment garden associations in Stockholm, Gubbängen and Årstafältet had also suffered damage from contaminated manure, in this case sheep manure that they bought from the same farm. FOR sent samples from horse and sheep manure for analysis during the summer. The horse manure was not well rotted and peat had been used as bedding in the stable.

FOR also collected samples of stable manure and straw from some recreational growers who responded to the survey and who suspected that these were the cause of plant damage. In total, four recreational growers sent in a total of six samples during September and October of 2021. In addition to these, a manure sample was also collected from horses that grazed in pasture during the summer and which came from the same horse farm where Pungpinan collected the manure that caused damage in the spring.

Plant samples. Analyses were also made of the leaves and fruit of tomato and potato plants that were fertilised with horse manure at Pungpinan's allotment gardens.

Laboratory analysis. The samples were sent to the Dutch laboratory Groen Agro Control. The samples were analysed for the content of four different herbicide products that are part of the pyridine carboxyl group; aminopyralid, clopyralid, fluroxypyr and picloram. Seven of the samples were also sent to NIBIO's laboratory in Norway to ensure the reliability of the test results through so-called double tests. NIBIO has a more refined testing method that can detect lower amounts of pyridines than Groen Agro Control tests. NIBIO's limit of determination (LOQ) for aminopyralid and clopyralid is 2 µg/kg in soil and 7 µg/kg in manure and fertiliser. For Groen Agro Control, the detection limit is generally around 10 µg/kg for analyses of liquid and solid fertilisers and below 5 µg/kg in soil and compost. However, the detection limit can be higher than 10 µg/kg in dry soil samples.

The analyses at Groen Agro Control were based on liquid chromatography coupled with double mass spectrometry (LC-MS/MS), while NIBIO uses high-resolution mass spectrometry (LC-HRMS). The methods are developed to detect and determine extremely small amounts of various substances with high certainty. Samples where substances have been positively identified are considered highly reliable.

Nine out of seventeen fertiliser products analysed contained residues of the herbicides clopyralid and/or aminopyralid. The concentration in the products varied between 12 and 800 µg/kg. Several brands have been contaminated, based on different kinds of raw materials. The highest levels of clopyralid were measured in two liquid fertiliser products Green Future Organic Tomato Fertiliser and Neudorff Effekt Kryddnäring, both of which contain sugar beet extract, as well as in Substral cow manure fertiliser. Aminopyralid was found in two products. Three fertiliser products based on chicken manure contained clopyralid, two of which are based on chicken manure from production in Sweden. No pesticide residues could be detected in the bagged soil samples that were examined.

Clopyralid and picloram were detected in the horse manure from Pungpinan's allotment gardens, and clopyralid was found in leaves and fruits of tomato plants fertilised with the same horse manure. However, the analysis could not detect pyridines in the potato plants from the same area, even though they were clearly malformed. The sheep manure that caused damage to two allotment gardens contained aminopyralid and clopyralid. In a sample of a mixture of chicken manure and straw, from recreational growers who keep their own chickens, there were traces of clopyralid. In other samples of horse manure, soil, straw and silage, the analysis results were negative.

An estimated 50 allotment gardeners suffered parts of their crops being destroyed by the contaminated horse manure at Pungpinan's allotment gardens and about 40 allotment gardeners suffered damaged caused by the sheep manure.

Double test. In six of the eight duplicate samples, both laboratories detected pyridines. However, the total measured amount of the substances differed significantly for some of the samples (Appendix 3).

In two cases, NIBIO detected the presence of pyridines but with the results showing concentrations below the limit of determination (LOQ) of 7 µg/kg, while Groen Agro Control's test results were negative. In this report, we have therefore chosen to treat these two samples as negative results.

Table 3. Results from laboratory analyses of the content of pyridine in various organic plant fertiliser products. ND = Not Detected.

Product	Type of fertiliser	Product content	Organic ceritified	Amino-pyralid	Clopyralid	Picloram	Fluroxypyr
Hasselfors Garden fertiliser for fruit and berries (Hasselfors Garden Gödsel för frukt och bär)	Pelleted fertiliser	Dried by-products from animal and plants (cacao, vinasse, sea weed, bone meal, molasses) (Torkade restprodukter från växt och djurriket (tång, kakao, vinass, melass, benmjöl, tångmjöl)	Yes	ND	ND	ND	ND
Neudorff Effekt garden fertiliser (Neudorff Effekt trädgårdsgödning)	Pelleted fertiliser	Animal and plant by-products from the food and feed industry (Animaliska biprodukter, vegetabiliska ämnen från livsmedel och foderindustrin)	Yes	ND	125 µg/kg	ND	ND
Solabiol tomato fertiliser (Solabiol tomatgödsel)	Pelleted fertiliser	Animal origin, compost of plant origin (Animaliskt ursprung, kompost av vegetabiliskt ursprung (presskaka, fruktmassa))	Yes	ND	ND	ND	ND
Stroller tomato fertiliser (Stroller tomatgödsel)	Pelleted fertiliser	Animal origin (feathers, bone, meat meal) and compost of plant origin (Animaliskt ursprung (fjäder, ben, köttmjöl) samt kompost av vegetabiliskt ursprung (presskaka, fruktmassa))	Yes	ND	26 µg/kg	ND	ND
Substral vegetable fertiliser (Substral grönsaksgödsel)	Pelleted fertiliser	Molasses, vinasse, malt sprouts (Vegetabiliska råvaror (melass, vinass, maltgroddar))	Yes	ND	ND	ND	ND
Emmaljunga chicken manure (Emmaljunga hönsgödsel)	Pelleted fertiliser	Chicken manure	No	ND	96,2 µg/kg	ND	ND
Hasselfors Garden chicken manure (Hasselfors Garden hönsgödsel)	Pelleted fertiliser	Chicken manure	No	ND	102 µg/kg	ND	ND
Rölunda chicken manure (Rölunda hönsgödsel)	Pelleted fertiliser	Chicken manure	No	ND	ND	ND	ND
Substral chicken manure (Substral hönsgödsel)	Pelleted fertiliser	Chicken manure	No	ND	12 µg/kg	ND	ND
Södra Årshults Torv chicken manure (Södra Årshults Torv hönsgödsel)	Pelleted fertiliser	Chicken manure	No	ND	ND	ND	ND
Engeltorp, cow manure 40% (Engeltorp, Kogödsel 40%)	Solid manure	Cow manure	No	ND	ND	ND	ND
Fagerhultstorv AB, cow manure (Fagerhultstorv AB, kogödsel 80%)	Solid manure	Cow manure	No	ND	ND	ND	ND
Plantagen cow manure (Plantagen kogödsel)	Naturgödsel	Peat, cow manure, chicken manure (Torv, kogödsel, hönsgödsel)	No	ND	ND	ND	ND
Substral cow manure (Substral kogödsel)	Naturgödsel	Dried cow manure (Torkad kogödsel)	Yes	172 µg/kg	447 µg/kg	ND	ND
Algomin*	Liquid organic fertiliser	Sea weed, maize starch (Alger, majsstärkelse)	Yes	155 µg/kg	ND	ND	ND
Green Future Organic Tomato Fertiliser*	Liquid organic fertiliser	Sea weed and plant extracts (Sjögräs och vegetabilisk råvara)	No	ND	800 µg/kg	ND	ND
Neudorff Effekt herb fertiliser* (Neudorff Effekt kryddnäring)	Liquid organic fertiliser	Sugar beet extract (Sockerbetsextrakt)	Yes	ND	667 µg/kg	ND	ND

* These products are diluted before use which reduces the amount of pyridine that reaches the plant/fertiliser occasion.

Table 4. Results from laboratory analyses of the content of pyridine in various bagged soil products. ND = Not Detected.

Product	Type of product	Ecolabel	Aminopyralid	Clopyralid	Picloram	Fluroxypyr
Blomsterlandet tomatjord PRO	Potting soil	KRAV	ND	ND	ND	ND
Emmaljunga exklusiv plantjord för ekologisk odling	Potting soil	KRAV	ND	ND	ND	ND
ICA Garden blomjord	Potting soil	KRAV	ND	ND	ND	ND
Simontorp blomjord	Potting soil	KRAV	ND	ND	ND	ND
Södra Årshults Torv grönsaksjord	Potting soil	KRAV	ND	ND	ND	ND
Änglamark blomjord	Potting soil	KRAV	ND	ND	ND	ND
Hasselfors Garden naturgödslad såjord	Seed starting mix	KRAV	ND	ND	ND	ND
Simontorp såjord med perlite	Seed starting mix	KRAV	ND	ND	ND	ND
Änglamark såjord	Seed starting mix	KRAV	ND	ND	ND	ND
Engeltorp planteringsjord	Potting soil	No	ND	ND	ND	ND
Gardol planteringsjord	Potting soil	No	ND	ND	ND	ND
Hasselfors Garden P-Jord	Potting soil	No	ND	ND	ND	ND
Plantagen premiumjord	Potting soil	No	ND	ND	ND	ND

Table 5. Results from laboratory analyses of the content of pyridine in animal manure, straw, silage and plants. ND = Not Detected.

Sample	Location	Aminopyralid	Clopyralid	Picloram	Comment
Horse manure	Pungpinan allotment gardens, Stockholm	ND	466 µg/kg	8,9 µg/kg	Not fully composted manure from local horse stable. Peat was used as bedding material in the stables. Therefore, it is likely that clopyralid and picloram came with the winter feed. The manure caused damage to more than 50 allotment plots.
Tomato leaves	Pungpinan allotment gardens, Stockholm	ND	102 µg/kg	ND	The tomato plant was fertilised with horse manure containing pyridine. The plant showed typical pyridine damage.
Tomato fruit	Pungpinan allotment gardens, Stockholm	ND	109 µg/kg	ND	The tomato plant was fertilised with horse manure containing pyridine. The plant showed typical pyridine damage.
Potato	Pungpinan allotment gardens, Stockholm	ND	ND	ND	The potato plant was fertilised with horse manure containing pyridine. The plant showed typical pyridine damage.
Sheep manure	Gubbängen and Årstafältets allotment gardens, Stockholm	17 µg/kg	9,4 µg/kg	ND	Sheep manure from small-scale farming. Winter feed purchased from conventional farmers north of Stockholm. The manure caused damage to more than 40 allotments.
Mixture of chicken manure and straw (Mix av hönsgödsel och halm	Skåne	ND	29,6 µg/kg	ND	Straw not treated with pyralid according to farmer. Chicken feed probable source of contamination.
Potting soil mixed with chicken manure and straw (Växthusjord med tillsatt hönsgödsel/strö och halm)	Skåne	ND	ND	ND	In bio-assay broad beans showed typical pyridine-damage when planted in this soil.
Horse manure	Skåne	ND	ND	ND	Horse manure where the feed has been treated with Ariane (a herbicide containing clopyralid). Fertilised tomato showed clear symptoms of pyridine damage.
Topsoil mixed with silage and horse manure (Matjord blandat med ensilage och hästgödsel)	Skåne	ND	ND	ND	Fertilised tomato showed clear symptoms of pyridine damage.
Horse manure	Dalarna	ND	ND	ND	Fertilised Jerusalem artichoke showed clear symptoms of pyridine damage.
Silage	Dalarna	ND	ND	ND	Fertilised Jerusalem artichoke showed clear symptoms of pyridine damage.
Horse manure (fresh)	Stockholm	ND	ND	ND	Fresh horse manure from horses that grazed only in pasture during summer.

Figure 13. Broad beans treated with organic fertilisation products contaminated with pyridines (first three pictures). Leaves in top shoots are cupped or rolled. Picture far right untreated control plant. Photo: Ulf Nilsson.

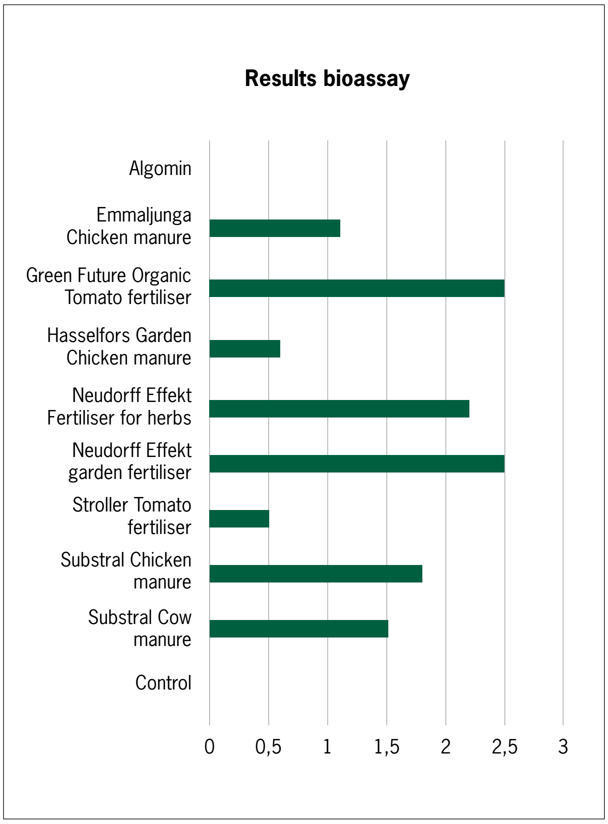

Figure 14. Results from broad bean bioassay test. The plants were fertilised according to the manufacturers' recommendations. Symptoms were assessed four weeks after treatment.

Assessment:
0 = No symptoms.
1 = Slight damage. Leaves from new growth are slightly cupped.
2 = Moderate damage. Leaves in top shoots are clearly cupped.
3 = Severe injury. Majority of leaves in top shoots are cupped or deformed and stems are twisted.

Bioassay testing

In a simple cultivation test, it was investigated whether the fertiliser products where the analyses showed the presence of pyridines (levels above the LOQ), would also cause damage to broad bean plants. A total of nine fertiliser products and an untreated control group were included in the test. The cultivation test was performed outdoors in natural light and temperature during the months of September and October in Sweden. Broad beans (*Vicia faba* cv. Valencia) were sown in pots of peat-based soil fertilised with the liquid fertiliser products. An inorganic fertiliser was used for the control group. Ten days after sprouting, the broad bean plants were fertilised with diluted nutrients according to the manufacturers' recommendations. The control plants were watered with only water. In total, each plant was fertilised with 2 dl of nutrient solution over a period of three days.

Pelleted and granulated fertiliser was mixed directly into growing soil, corresponding to 8 grams per litre of soil before sowing. The tested plants were placed on separate saucers to avoid contamination between treatments. Each treatment included six plants given liquid plant fertiliser products and eight plants given pelleted/granulated fertilisers and the control group. Plant damage to foliage was assessed visually after four weeks based on a modified experimental protocol from Washington State University (2002).

Liquid Algomin caused no plant damage in the cultivation test. Emmaljunga chicken fertiliser, Hasselfors chicken fertiliser and Stroller tomato fertiliser caused minor damage, for example, slightly upturned leaves in new shoots. The most severe damage was caused by Green Future Organic and two products from Neudorff.

Discussion

In 2020, we believed that the pyridine problem was linked to liquid fertiliser based on vinasse, a residual product from sugar production in Germany, Poland and France (Nilsson, 2021). The solution would then be for manufacturers to replace vinasse with other raw materials in their fertiliser products. Unfortunately, this study shows that pyridines can be detected in almost all raw materials originating from conventional agriculture, and used by recreational growers as fertiliser.

Pyridines in animal manure

Of particular concern is the presence of pyridines in manure collected from local horse stables and local farms, showing that animal feed is a suspected source of the spread of pyridines. Stable manure is an excellent basic fertiliser that adds both plant nutrients and organic matter to soils, and is an important resource for all kinds of cultivation. For recreational farmers, the easiest access is to horse manure, which can often be picked up near urban areas and which horse stable owners are happy to give away. Unfortunately, horse manure was the type of manure that most respondents (23 %) suspected had damaged their plants.

Furthermore, the laboratory analyses clearly detected clopyralid and picloram in the horse manure that was used in Pungpinan's allotment gardens, which caused damage to 50 allotments in the area. No pyridines were detected in the remaining five horse manure samples, in spite of images from growers showing probable pyridine damage to the fertilised plants. This may be because the level of pyridine content in the stable manure from early spring had time to break down to below the detection limit by the time samples were first analysed in the autumn. Thus, the amount was likely initially high enough to cause damage to sensitive plants. Horse manure as a suspected source of pyridine spread is nothing new in Sweden. In 2018, a grower in Gothenburg blogged that her tomato plants, which had been fertilised with horse manure from a local riding school, showed typical pyridine damage. By trial growing a new batch of plants in only sand and horse manure, she was able to isolate and identify the horse manure as the cause of the damage (Bergsten, 2018).

Pyridine spreads through animal feed?

Our study consistently shows that there is reason to suspect that animal feed can be a significant source of pyridine spread. This conclusion is also consistent with several other studies of animal feed based on hay and grass, grown on weed-treated fields (Ebato *et al.*, 2015; Derr *et al.*, 2016; Dow Agrosciences, *et al.*). When livestock are fed with contaminated feed, the pyridines pass through the animal's body undigested and ends up in the manure, which in turn can cause damage to fertilised plants (WRAP, 2010).

In the contaminated horse manure, which caused damage in the allotment gardens, picloram and clopyralid were detected. The only herbicide permitted in Sweden that contains both of these pyridines is Galera, which is permitted for use in rapeseed and turnip rapeseed cultivation. The horses were stabled on peat, so the pyridines must have therefore come from their feed, which likely contained the residual press cake of rapeseed or turnip rapeseed. The animal breeder who delivered pyridine-contaminated sheep manure to two allotment garden areas suspected that the pyridines entered the farm through the purchase of winter feed from conventional farming.

Even three of the five consumer-packaged fertiliser products based on chicken manure showed contamination with clopyralid. At least two of these were based on Swedish raw materials. There are only two possible routes of spread for pyridines in poultry production – either via the chicken feed or via the bedding material that is placed on the floor of the chicken coops. Since wood shavings and wood chips dominate as bedding material in Swedish poultry production (Gunnarsson, personal correspondence, 2021-12-01), the chicken feed is likely the primary source of pyridines. Chicken feed usually contains mainly mixtures of various cereals and grains, and it's thus likely that these cereals and grains have been treated with pyridines and this is the source of the contamination. However, there is currently a lack of scientific studies demonstrating the direct link between chicken feed based on pyridine-contaminated grain,

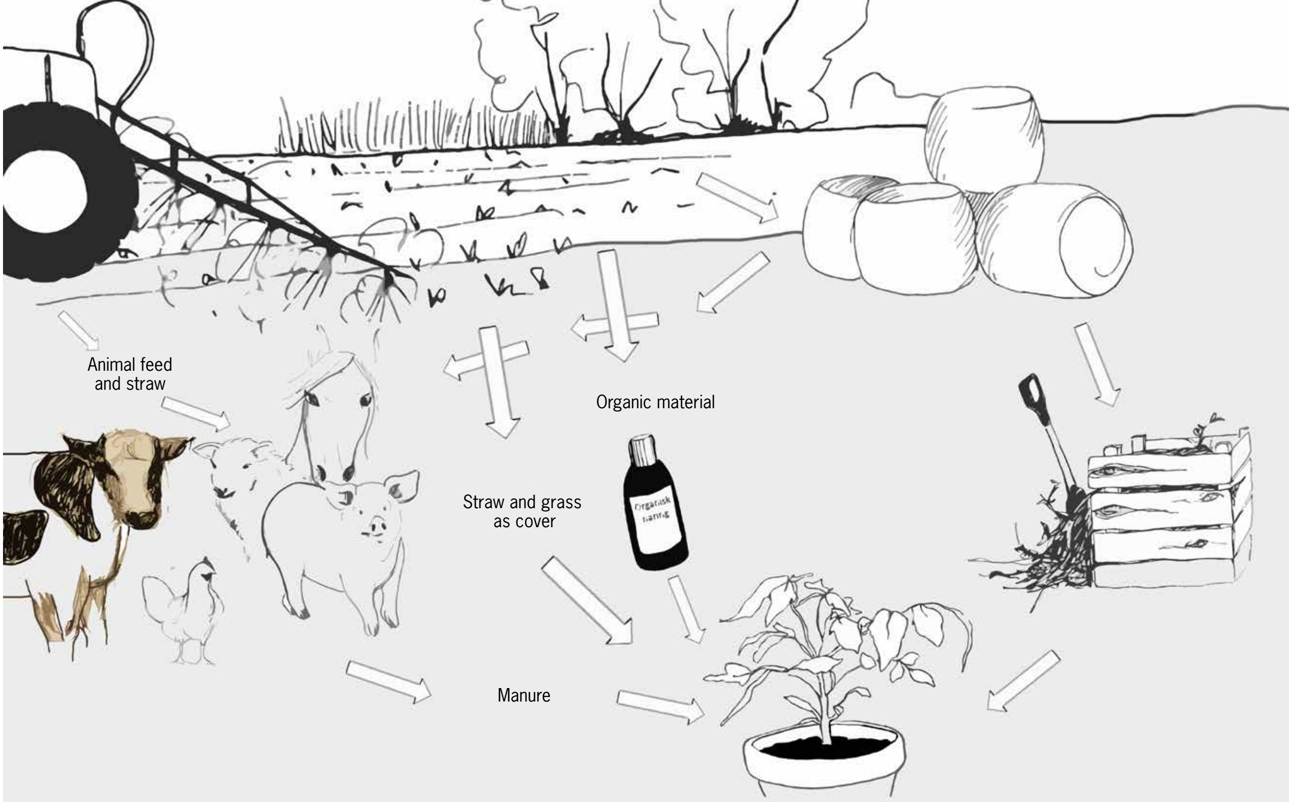

Figure 15. Examples of possible pathways that could bring picloram, amino- and clopyralid to your garden and plants. Illustration: Emma Franzén.

and the content of pyridines in the chicken manure and subsequent negative effect on sensitive plants. However, similar relationships have been shown between chicken feed and the herbicide glyphosate (Muola *et al.*, 2021). But, it is proven that pyridines are absorbed systemically by treated plants, *i.e.*, pyridines are transported around in the plant tissue and can be found in roots, leaves, stems and fruits as well as in the kernels of cereals and grains. In 2021, the EU raised the maximum amount (maximum residue levels) of clopyralid that wheat and oats for animal feed and human consumption are permitted to contain, from 2 mg/kg to 3 mg/kg (European Food Safety Authority, 2021). Consequently, there is a risk that animal feed may contain pyridines in a sufficiently large amount to ultimately damage sensitive plants (Bary *et al.*, 2016), which the results of our study also suggest.

This also means that Sweden's specific rules that currently regulate the use of herbicidal products containing aminopyralid are not sufficient to avoid plant damage outside the targeted fields. The current rules state that straw and manure originating from aminopyralid-treated fields may only leave the farms to be taken for incineration or industrial use (Kemikalieinspektionen, 2020). Similar rules are underway for clopyralid within the EU (EU Commission, 2021). This is desirable, but it will not solve the problem in the cases where the main agricultural products themselves, *i.e.*, the grain kernels or rapeseeds, contain pyridines that end up in animal feed and remain in the animal manure and manure-based fertilisers.

Clopyralid and aminopyralid were also detected in dried cow manure-based fertiliser imported from the Netherlands. For this product, it is not possible to determine whether the pyridines came from the feed or the bedding material.

Pyridines in consumer-packaged plant fertiliser products

FOR's analyses also show residues of clopyralid in consumer products based on sugar beet extract and in products containing a mixture of vegetable and animal raw materials. Aminopyralid was found in a product based on corn starch and in dried cow manure. Overall, almost half of the plant fertiliser products tested were contaminated (table 3).

The origins of these products are not easy to trace, but seem to mainly be based on raw materials sourced within Europe. The three products with the highest measured levels of pyridines – Green Future Organic Tomato Fertiliser, Neudorff Effekt Kryddnäring and Substral Cow Manure – are all imported, and the raw materials come from production outside of Sweden.

Pyridine contamination appears to affect all fertiliser producers who use organic matter and vegetable matter as raw materials in their production, not just those tested in this investigation. This assumption is also strengthened by the fact that several growers in the survey also indicate other products as a suspected source of pyridine damage.

In the cultivation tests where fertiliser products found to contain pyridines were used, the results all showed pyridine damage, with the exception of liquid Algomin – something that the company's own cultivation tests with the same batch also showed (Algomin, 2021).

This is presumably because the concentration of aminopyralid was too low to cause damage after dilution to the prescribed dose. For three of the products – Emmaljunga chicken manure, Hasselfors Garden chicken manure and Stroller tomato manure – the results only showed minor changes in leaf shape, something that most recreational growers would probably not notice.

But the question is: how would the plants have been affected if the test had included more fertilising occasions over a longer period? And what happens to the soil if small amounts of pyridines are added to it over several years? Does the pyridine have time to break down or will there be an accumulation in the soil that might eventually become high enough to cause damage to sensitive plants? There is a lack of knowledge about this, since almost all studies on pyridines have been based on agricultural conditions with high one-time doses of the herbicides and not repeated doses of small quantities as may be the case for recreational growers. What is known, however, is that decomposition takes longer in cold climates and this increases the risk of accumulation of pyridines in the soil. For example, a study from Alaska has shown that agricultural fields treated with clopyralid four years previously still contained enough of the herbicide to damage potatoes, and the long degradation time was thought to be partly due to the cold climate (Seefeldt *et al.*, 2014).

Pyridines in consumer-packaged, bagged potting soils?

Pyridines were not detected in any of the potting soils analysed in this study, despite the fact that over 25 % of those who responded to the survey suspected that purchased potting soil was the source of contamination. However, it is important to remember that the products and batches that were analysed in this study are not the same as those suspected of causing plant damage according to the survey responses.

Another reason that pyridines were not detected in potting soils could be that concentration levels may have been lower than the analysis company's detection limit (LOQ) of 10 µg/kg soil, although the amount may have been sufficient to damage the most sensitive plants.

Regardless of our analysis results, Hasselfors Garden, for example, informed customers that some of their premium potting soils have contained pyridines in the spring of 2021 (Hasselfors Garden, 2021b). And considering that many of the manufacturers in Sweden buy their raw materials from the same producer, it is very likely that the problem has affected other producers. For example, several soil producers in Sweden buy chicken manure from the same supplier, so if the manure is contaminated with pyridines, there is a high risk for pyridine contamination in potting soils because chicken manure is often the primary nitrogen source. The risk of contamination is probably the highest in richly fertilised premium products that contain higher doses of manure – usually chicken manure.

How is the industry taking action?

Despite FOR's analyses showing contamination by pyridines, several of the products continued to be sold to consumers by the large garden centre chains during the autumn of 2021, and without informing consumers about any of the risks associated with using the products. It's worth noting that the products from two producers – Neudorff and Green future – contained among the highest concentrations of clopyralid in both the 2020 and 2021 FOR surveys (Nilsson, 2021).

Furthermore, some of the contaminated products tested in 2021 were organically labelled by KRAV, just as in the survey from 2020 (Nilsson, 2021). This situation risks seriously damaging consumer confidence in this organic label.

At the same time, manufacturers of organic matter-based fertilisers and potting soils are in a tough situation since it is difficult to find of organic matter-based raw materials from agriculture that is guaranteed to be free of pyridines. The analysis methods are also not standardised, which means that different laboratories can get differing results in their measurements of pyridine concentration in submitted samples depending, for example, on the type of solvent used. The double testes that FOR analysed demonstrate this problem. In six out of eight samples, both laboratories detected pyridines but the concentration levels detected differed greatly in some cases. In two of the samples, the amount of pyridines measured was so low that it was below the detection limit of Groen Agro Control and was therefore negative. So, it is difficult as a manufacturer to know which laboratory can provide adequate analysis and thus almost impossible to achieve a common industry standard with limit values for the substances. It is clear that urgent help is needed from

Swedish expert authorities to produce limit values and reliable analysis methods that producers can use as a starting point.

At present, the industry's best course of action to reduce or eliminate the risk of pyridine contamination is probably to increase communication with the producers of organic compost, stable manure and other residual raw materials from agriculture to ensure that the source raw material has not been treated with pyridines. This is a huge and difficult task, considering how many different players may be involved in these processes. This may be easier for producers who purchase raw materials in Sweden rather than imported raw materials where herbicide use is likely more extensive than in Sweden while the raw material chain, from farmers to soil and plant nutrition producers, is also longer, which further complicates control.

Low awareness of the risks and lack of knowledge of the extent

General public awareness about the risks associated with pyridines and contamination of manure and compost is still low in Sweden (Vestin, personal correspondence, 2021). Only the most active growers are aware and knowledgeable about the problem. Thus, there is a great risk that many of the recreational growers who are affected do not understand that plant damage may be due to pyridines and not to a lack of cultivation knowledge or pests.

We must also be aware that we currently cannot know the extent of the risk of being affected as a recreational grower. One reason for this is that no systematic investigations into pyridine contamination risk have ever been made before – not in Sweden, nor anywhere else in the world. But it is cause for concern that nearly half of the fertiliser products that FOR analysed contained pyridines – although they were not expected or suspected to do so prior to the test – and that so many recreational growers have reported pyridine damage to FOR.

Pyridines are a threat to a sustainable bioeconomy

The EU's bioeconomy strategy, from 2018, is as an important part of the *Green Deal*, *i.e.*, the EU's major investment for reaching climate goals by 2030. The bioeconomy must be circular and sustainable as well as cost-effective and competitive (Fritsche *et al.*, 2020). A prerequisite for a functioning circular economy is that the cycles are not contaminated by harmful substances. The Government Office of Sweden (Regeringskansliet) emphasises in particular that everyone opting for recycled materials and products must be able to trust that these are safe for health and the environment (Regeringskansliet, 2020). The past two years' problems with pyridines in manure really bring this to a head. Pyridines are typical examples of problematic substances that need to be phased out in order for consumers to be able to trust circular products.

Who is responsible?

The issue of responsibility is complex and involves many different players. But two stand out: the European authorities who approved pyridines for use in agriculture and the manufacturers of the herbicide products, who have largely dodged any financial responsibility for the damage caused by the products in the gardens of recreational growers.

The negative effects of pyridines have long been well known. For example, picloram was banned in Sweden by the 1970s, since authorities deemed the substance's persistence to be problematic and made it difficult to predict possible negative long-term consequences (Bergkvist, personal correspondence, 2022-01-15). In 2011, as an effect of EU membership and the harmonising regulatory framework for herbicidal products within the Union, products with picloram were again allowed in Sweden. In 2015, Swedish Chemicals Agency also rejected an application for approval of a specific product (Lancelot) containing aminopyralid because it was deemed impossible to enforce conditions that would prevent the risks of damage to plants in later stages. However, following an appeal from the applicant companies, the Land and Environmental Court overturned the Swedish Chemicals Agency's rejection decision. Denmark had approved the product and the court determined that the risks with Lancelot were not specific to Swedish conditions and that the Swedish Chemicals Agency therefore had no basis for rejecting the application (Kemikalieinspektionen, 2016). A great responsibility therefore lies with the countries within the EU that approved pyridines in agriculture without having taken sufficient account of their negative effects. According to EU regulation 1107/2009, article 4, paragraph 3C: "A plant protection product must not have any unacceptable effects on plants or plant products". We believe that this report has clearly shown that herbicides based on picloram, aminopyralid and clopyralid do not fulfil this requirement. It is also worth noting that the documents from the European Food Safety Authority (EFSA), which is the basis for the substance's approval within the European Union, contains no problematisation at all of the risk that clopyralid may later cause damage to vegetation in gardens. On the other hand, they point out that the substance can cause damage in crop rotation in agriculture, but that more studies are needed (European Food Safety Authority, 2018; 2021). This is clearly a weakness in the process, and has failed to view the approval of the substance from a larger societal perspective.

Corteva Agroscience produces the majority of herbicides based on pyridines sold in the EU. It is a multinational company with an annual turnover of billions of dollars. The company has, of course, closely followed all cases of pyridine contamination that have been reported around the world over several decades, where pyridine-based herbicides have caused damage to recreational growers' plants several stages after they were used in the fields (Corteva agrosciences, n.d.). Reasonably, Corteva Agroscience should be held responsible for compensating affected recreational growers and producers of fertilisers and potting soils who suffered financially due to the negative effects of their products. Especially now, when much indicates that the spread of pyridines outside of the targeted fields also occurs with primary products, such as grain kernels and rapeseeds used for animal feed that end up in manure and damage recreational growers' plants. The problem can no longer be explained solely by farmers violating the conditions of product use.

Conclusion

Pyridines have now been found in almost all organic matter raw materials originating in agriculture and used by recreational growers as fertilisers. FOR's analyses have shown residues of clopyralid in cow, horse, sheep and chicken manure, aminopyralid in corn starch and cow manure, and picloram in horse manure. Pyridines affect both recreational growers who buy fertilisers at garden centres and those who use stable manure, straw or silage from riding schools or local farms. Even growers who use chicken manure from their own chickens fed with purchased feed are at risk of pyridine damage to their plants.

The extent suggests that this is a matter a flawed system – a system that allows pyridines to be used in agriculture despite the risks it entails for plants far from the fields – and not a lack of care on the part of individual farmers.

The only solution is to stop pyridines. The Swedish government can give the Swedish Chemicals Agency the task of banning products containing pyridines in Sweden. But it is only at EU level that the active substances – the poisons themselves – can be banned. Sweden's government must therefore take active measures for a ban at EU level.

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Appendix

Appendix 1. Herbicides, based on pyridines, approved for useage in Sweden

Source: Swedish Chemical Agency.

Herbicide	Producer	Active ingridient
Lancelot	Corteva Agriscience	Florasulam 15 weight-% Aminopyralid 30 weight-%
Tombo	Corteva Agriscience	Pyroxsulam 5 weight-% Florasulam 2,5 weight-% Aminopyralid potassium salt 5,92 weight-%
Mustang Forte	Corteva Agriscience	Florasulam 5 g/l 2,4-D (etylhexylester) 271,5 g/l Aminopyralid potassium salt 11,83 g/l
Galera	Corteva Agriscience	Picloram 67 g/l Clopyralid 267 g/l
Belkar	Corteva Agriscience	Halauxifen-metyl 10 g/l Picloram 48 g/l
Cliophar 600 SL	Arysta LifeScience	Clopyralid dimetylaminsalt 741 g/l
Matrigon 600 SL	Corteva Agriscience	Clopyralid dimetylaminsalt 741 g/l
Matrigon 72 SG	Corteva Agriscience	Clopyralid 72 weight-%
Korvetto	Corteva Agriscience	Halauxifen-metyl 5 g/l Clopyralid 120 g/l
Ariane S	Corteva Agriscience	MCPA (kaliumsalt) 238,1 g/l Clopyralid (monoetanolaminsalt) 26,4 g/l Fluroxipyr-1-metylheptylester 57,6 g/l
Kinvara	Barclay Chemicals (R&D)	MCPA (kaliumsalt) 277,4 g/l Fluroxipyr-1-metylheptylester 72 g/l Clopyralid (monoetanolaminsalt) 36,9 g/l

Appendix 2. Different plants tolerance for clopyralid. Based on NOEL (no-observal-effect-level)

Based on Recycled Organic Unit, 2006, The University of New South Wales.

Plant	Tolerance level clopyralid
Asters	Sensitive
Buckwheat	Sensitive
Bean	<1 ppb
Friut trees	Sensitive
Gras (forage)	600 ppm
Cucumber	Sensitive
Oat	3–12 ppm
Strawberry	1 ppm
Chick pea	Sensitive
Clover	1 ppb
Barley	1–9 ppm
Ornamentals	Sensitive
Turnip	1–4 ppm
Kålväxter	2 ppm
Flax	0,5–6 ppm
Lentils	<1 ppb
Lupins	Sensitive

Plant	Tolerance level clopyralid
Corn	1–10 ppm
Carrot	Sensitive
Mint, hay	3 ppm
Bell peppers	<10 ppb
Potatoes	10 ppb
Rapeseed	1–6 ppm
Lettuce	<1 ppb
Sugar beet	10 ppb
Sunflower	<1 ppb
Asparagus	1 ppm
Spinach	5 ppm
Stone fruit	0,5 ppm
Tobaco	10 ppb
Tomato	1 ppb
Wheat	1–12 ppm
Pea	<1 ppb

Note that two units are used in the table; ppm (parts per million, for example mg/kg in soil) and ppb (parts per billion, for example µg/kg in soil). When only sensitive is noted, it means that the plants have been found to be sensitive, but no quantities have been reported.

Marked fields indicate extra sensitive plants.

Appendix 3. Analyses of double samples

Eight samples were sent to two different laboratories; Groen Agro Control (Netherlands) and NIBIO (Norway). ND = Not Detected.

	Groen Agro Control			NIBIO			Comment
	Clopyralid	Aminopyralid	Picloram	Clopyralid	Aminopyralid	Picloram	
Neudorff Effekt garden fertiliser	125 µg/kg	ND	ND	147,9 µg/kg	ND	Not analysed	
Solabiol tomato fertiliser	ND	ND	ND	Detected but below 7 µg/kg (LOQ)	ND	Not analysed	
Substral Vegetable fertiliser	ND	ND	ND	Detected but below 7 µg/kg (LOQ)	ND	Not analysed	
Substral Chicken manure	12 µg/kg	ND	ND	68 µg/kg	ND	Not analysed	
Hasselfors Garden Chicken manure	102 µg/kg	ND	ND	18,4 µg/kg	ND	Not analysed	
Substral Cow manure	447 µg/kg	172 µg/kg	ND	49,8 µg/kg	ND	Not analysed	Groen Agro Control analyses sample in May and NIBIO in September
Pungpinan Horse manure	466 µg/kg	ND	8,9 µg/kg	356 µg/kg	ND	Not analysed	
Årstafältet Sheep manure	9,4 µg/kg	17 µg/kg	ND	ND	12,82 µg/kg	Not analysed	

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Problems with pyridine-based pesticides in organic fertilisers continue

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Cover photo: Pyridine damaged tomato plant. Photo. L. Lillebjörn.