Cyanamide

Monograph

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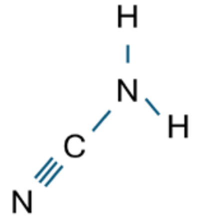
Summary

This monograph deals with cyanamide (hydrogen cyanamide) used as a plant growth regulator to promote bud break in various fruits including apples, grapes, kiwifruit, stone fruits, and blueberries[1]. Cyanamide has a considerable list of hazard classifications, including causing serious eye damage, damaging fertility and the unborn child, suspected to cause cancer and harmful to aquatic life with long lasting effects. There are numerous documented cases of acute poisoning and damage to health as a result of cyanamide exposure. Cyanamide use in agriculture is currently banned in 37 countries. In a number of other countries its use is subject to a set of use restrictions. Cyanamide is manufactured by companies in Germany, China, Japan and other countries. One of the best-known pesticide products containing cyanamide is Dormex® produced by AlzChem Group AG. Alternatives to cyanamide are being investigated.

Chemical Profile

CAS number (for hydrogen cyanamide): 420-04-2

Common name: Cyanamide.
Also known as: hydrogen cyanamide, amidocyanogen; carbanonitrile; aminoformonitrile; cyanogenamide; carbodiimide
Molecular formula and structure: CH_2N_2



Substance origin: Synthetic
Chemical group: Nitrile PGR (Plant Growth Regulator)
Molecular Weight: 42.040 g/mol

Physical state: Cyanamide appears as colourless deliquescent crystals, soluble in water (approx. 77 g / 100 mL at 15 °C), vapor pressure 0.5 Pa at 20 °C[2].

Mode of action: Contact. Inhibits photosynthesis.

Uses in Plant Protection

Cyanamide (hydrogen cyanamide) is used as a plant growth regulator to promote bud break in fruit including apples, cherries, grapes (table grapes, wine grapes), kiwifruit, stone fruit, peaches, nectarines and blueberries.[3]

Bud-break is a pivotal phase in vineyards and orchards, influencing fruit set, harvest timing, and crop quality. Achieving reliable yields necessitates that vines and trees accumulate sufficient chill units (CU) during winter. Grape cultivars (*Vitis vinifera* L.) generally require a minimum of 200–600 chilling hours (temperatures between 0–10 °C) to achieve satisfactory and uniform bud-break. Experimental studies have shown that approximately 200 hours between 0 and 10 °C or 400 hours at around 3 °C are sufficient for high bud-break percentages in many commercial varieties under controlled conditions.[4] In regions where natural chilling is regarded as insufficient, conventional growers often use chemical agents to overcome dormancy. One such agent is hydrogen cyanamide. It is applied to dormant buds to simulate the biochemical signals associated with natural dormancy release.

Biochemical Mode of Action

Biochemically, hydrogen cyanamide's mode of action involves the inhibition of catalase, an enzyme responsible for decomposing hydrogen peroxide (H_2O_2). This inhibition leads to an accumulation of H_2O_2, a reactive oxygen species that acts as a signalling molecule, triggering oxidative stress responses within the plant. These responses include the activation of genes associated with dormancy release and the promotion of metabolic pathways that facilitate bud-break.[5] Additionally, hydrogen cyanamide may influence hormonal balances, particularly by modulating levels of abscisic acid and gibberellins, which are crucial for dormancy maintenance and bud development.[6]

Manufacturers, Products and Trade

Manufacturers & suppliers[7]

Alzchem Group AG, Germany (until September 2011 Alzchem Trostberg GmbH) is a chemical company based in Trostberg, Bavaria, Germany, with four production sites in Germany (Trostberg, Schalchen, Hart, Waldkraiburg), one plant in Sweden (Sundsvall) and three sales companies in the USA, China and United Kingdom.[8] The Alzchem Group is a 100% subsidiary of Evonik Industries AG, Chemicals Business Area (formerly Degussa).[9] In 2009, the private equity investor BluO became a new shareholder.[10] Since 2017, the company has been listed on the Frankfurt Stock Exchange.[11]

During its shareholder meeting in 2025, Alzchem was confronted with the testimony of a former woman farm worker from South Africa who experienced pesticide poisoning from using the Dormex formulation of hydrogen cyanamide.[12] Claiming that the Executive Board failed to "adequately fulfil its human rights and environmental due diligence obligations", the Association of Ethical Shareholders Germany submitted a countermotion, asking the shareholders to formally deny approval of the members of the Executive Board.[13]

Ningxia Darong Chemicals & Metallurgy Co., Ltd., China. Founded: 1984.[14] According to its website information, it is the second biggest manufacturer of cyanamide products in the world.[15]

Zhejiang Longyou East Anasac Crop Science Co., Ltd. China. Formerly known as Zhejiang Longyou East Pesticide Co., Ltd., it is a Sino-foreign joint venture.[16] According to the company's website, it is one of the leading manufacturers and exporters of hydrogen cyanamide in China.[17]

Tide Group, China. Tide has three manufacturing plants (two on the Chinese mainland and one in Brazil) and eight overseas companies. Tide has been ranked among the top 20 Chinese pesticide export enterprises[18]. Hydrogen cyanamide is amongst its products.[19]

Kanto Chemical Co. Inc., Japan.[20] Founded in 1944 and headquartered in Tokyo, Japan it is a reagent manufacturer of a variety of chemical and industrial products including cyanamide. It has overseas affiliates in a number of countries, including China, France, USA, Taiwan, and Malaysia.[21]

Sumitomo Chemical Co., Ltd. Japan[22]**.** Founded in 1913, it is a major Japanese chemical company and member of the Sumitomo group. AgroSolutions Divisions is Sumitomo Chemical's crop protection unit. While no Cyanamide Products can be found on its website, **Sumitomo Chemical Australia**[23] indicates to source from the parent company, Sumitomo Chemical Company Japan and its USA based subsidiary and provide with Cyan a cyanamide containing product[24].

7 Worlds Ag, Australia[25] former Grochem Australia, is a supplier of different pesticides, including cyanamide containing plant growth regulator Cyan[26].

Otto Chemie Pvt. Ltd (Distributor), Mumbai, Maharashtra, India. Founded in Mumbai, India in 2006, Otto Chemie Pvt. Ltd. is an ISO 9001:2015- and GMP-certified chemical manufacturing company and distributor. Otto Chemie serves customers in many industries including agriculture.[27], [28]

BASF provides Dormex in their portfolios e.g. in Mexico and Brazil under the BASF brand.[29]

Sunshine Fine Chemsol Pvt. Ltd., Idia. Agrochemical manufacturer.[30]

Philagro South Africa[31]**,** established in 1998 when **Sumitomo Chemical Company**, Japan, expressed the wish to open an office in South Africa to support their product range. Philagro is also developing and distributing products from AlzChem in Germany, Aquamarine in the UK. Dormex® is in their portfolio.

Pesticide products containing cyanamide as active ingredient

- Dormex[32]
- HCN[33],[34]
- Dorsol[35]
- Wakeup®[36]
- Hi-Cane[37]
- BudPro®[38]
- Cyan[39]
- Rapibrot®[40]
- Fitobrot®[41]
- Duomax HC520[42]

Global production & trade

FAO is not providing global sales or use data for cyanamide in plant protection. Publicly accessible trade data is mainly provided by industry or journals specialised in agriculture/agricultural chemicals and investments in these areas.

China, Japan and Germany are indicated as the major producers in the world, sharing about 80% of the global total production[43]. While the global hydrogen cyanamide revenue is indicated with US$ 265 million in 2022, open accessible figures for the global production volume are stated inconsistently in different resources and therefore not provided in this monograph. The global volume of formulations used as plant growth regulators for 2022 is given as roughly 7,000 to 8,000 tons, used as a dormancy breaking agent and defoliant in high value crops like grape, kiwifruit, blueberry and apple.[44]

Apart from Cynamide use in plant protection, the substance is used for different other purposes like production of pharmaceuticals and for other compounds. According to incomplete statistics, the worldwide trade of cyanamide increased over recent years, from a worldwide import of 3,131.5 tons in 2019 up to 11,595.8 tons in 2021 and an even stronger growth in 2022. According to AgroPages, the main exporting countries are Germany, China and Japan with Germany being the main supplier country in 2022, providing 53% of global supply of cyanamide (Alzchem being the major supplier).[45]

According to AgroPages and Tides, the main markets for cyanamide are Chile, Peru, the United States and Brazil. Among these markets, Chile and Peru are the largest, where the annual importation of 50%-cyanamide solutions totals 2,000–3,000 tons. This is mainly imported from Germany's Alzchem and China's Longyou East Anasac Crop Science, Tide Group, Flagchem[46], and Generic Chemical[47]. The same source indicates that Chile's imports from Germany are 1.5 times more than from China, while Peru's imports from China are 2.7 times more than from Germany. Moreover, the Brazilian market, totalling, 600 to 700 tons, is mainly supplied by the German company Alzchem to BASF Brazil.[48] Those figures are in line with amounts indicated in the EU export notifications.

While the active substance was banned for use in the EU in 2008, cyanamide production in the EU and exports from the EU territory to third countries persist. According to the European Chemicals Agency (ECHA), all cyanamide exports from the European Union for pesticide use for the last 15 years were by Germany.[49] Investigations into the official export notifications showed that, in 2024, Alzchem issued export notifications for 6,700 tonnes of agricultural cyanamide products, of which almost two-third was destined for low- and middle-income countries including Peru, India, and South Africa.[50, 51]

Regulatory Status

- Cyanamide (NH_2CN) was first synthesized from ammonia and cyanogen chloride in 1851.[52]
- Hydrogen cyanamide was first registered by EPA in the US for use in 1984.[53]
- In 1993 US EPA granted a conditional registration for cyanamide containing Dormex for restricted use on desert grown grapes.[54]
- In the EU a pesticide product containing hydrogen cyanamide was first introduced in Italy in 2000.[55]

Bans, restrictions and other regulatory actions

Bans: Cyanamide / cyanamide hydroxide is banned in 37 countries (as of December 2024): Bahrain, EU (27 Member States), Kuwait, Oman, Qatar, Republic of Iraq, Saudi Arabia, Switzerland, Turkey, United Arab Emirates, United Kingdom.[56]

- In the EU (at that time including the UK) cyanamide lost its approval in 2008, with the consequence that the use of cyanamide containing products in the EU member states was banned since. However, making use of legal exceptions, emergency authorisations for cyanamide-containing products have repeatedly been granted in Greece (for the growing periods from 2021 - 2026) citing rising temperatures and insufficient winter chilling hours due to climate change as a reason. The authorities argued that no effective chemical, non-chemical or cultural alternatives to cyanamide were available to compensate for the poor and uneven budbreak and flowering.[57]

Restrictions:

- In New Zealand cyanamide use is subject to strict application provisions, e.g. limiting the annual use (for more see page 8)
- In California the use of Dormex in plant protection is subject to a broad range of use restrictions including specific requirements for protective clothing, limited annual use and use only by approved applicators (for more see page 9).

International regulatory action: none. Cyanamide is not regulated under the Rotterdam or Stockholm Conventions.

Toxicological Profile and Health Impacts

Contact with hydrogen cyanamide can cause severe eye damage, skin irritations and skin allergies. Systemic exposure to cyanamide can cause vomiting, shortness of breath, drop in blood pressure and tachycardia. It has been identified as an endocrine disrupting compound.[58] The substance has been classified as carcinogenic (category 2) and reprotoxic (category 2) by ECHA[59] as well as the Environmental Protection Agency of New Zealand.[60]

On 18 September 2008, the marketing authorisation of cyanamide was withdrawn in the European Union with the following statement: "During the examination of this active substance by the Committee, it was concluded, taking into account comments received from Member States, that there are clear indications that it may be expected that it has harmful effects on human health and in particular on operators, because the exposure is greater than 100% of the AOEL".[61]

Two years later, the European Food Safety Authority (EFSA 2010)[62] pointed out in its conclusion that operators were exposed more than 60-fold above the Acceptable Operator Exposure Level (AOEL) even when personal protective equipment is used.[63] According to EFSA's estimates, for bystanders, adult and child residents, the acceptable exposure level was exceeded 14 times, 3 times and 6 times, respectively.

GHS classification and labelling

Cyanamide has a considerable list of hazard classifications. In agreement with the Global Harmonized System, ECHA lists the following:[64]

Hazard Class	Hazard Statement	Explanation
Acute Toxicity	H301	Toxic if swallowed
Acute Toxicity	H311	Toxic in contact with skin
Skin Corrosion	H314	Causes severe skin burns and eye damage
Skin Sensitization	H317	May cause an allergic skin reaction
Eye Damage	H318	Causes serious eye
Carcinogenicity	H351	Suspected of causing cancer
Reproductive Toxicity	H361fd	Suspected of damaging fertility or the unborn child
STOT RE	H373 (thyroid)	May cause damage to organs through prolonged or repeated exposure
Aquatic Chronic	H412	Harmful to aquatic life with long lasting effects

See Annex I for a more detailed list of cyanamide classification according to UN GHS criteria (EU list).

Acute toxicity

In rats, cyanamide is described as having an acute oral toxicity between 142 and 223 mg/kg and an acute dermal toxicity of 848 mg/kg.[65] While it is classified according to GHS EU as toxic if swallowed and toxic in contact with skin, it does not fall into the category of (acute) highly hazardous toxicity according to WHO (2019).[66] Nonetheless, a considerable number of reports on human intoxications exist (see chapter "Impacts on Human Health").

Subchronic and long-term toxicity studies

Cyanamide is an inhibitor of several enzymes, in particular catalase and dehydrogenase, resulting in an accumulation of hydrogen peroxide in tissues.[67]

According to studies summarised in the EFSA conclusion (2010),[68] the No-Observed-Adverse-Effect-Level (NOAEL)[69] was below 0.6 mg/kg in a 90-day (subchronic) dog study and at 1 mg/kg in a chronic rat study. In dogs, the testes were identified as the target organ. The rat studies revealed the thyroid as the target organ. The effects on the thyroid explain the H373 classification.[70] These effects described in the regulatory studies the industry is required to provide were corroborated in the scientific literature. Davidson et al. (1979)[71] and Ramhøj et al. (2021)[72] demonstrated that cyanamide is a potent inhibitor of thyroid peroxidase, an essential enzyme for the biosynthesis of thyroxin (T4), one of the two main thyroid hormones, with potential consequences for brain development (see paragraph on developmental toxicity, below).

Carcinogenicity

Cyanamide is classified as a category 2 carcinogen.[73] According to the limited information provided,[74] ovary (granulosa cell) tumours in a mouse carcinogenicity study (at 39 mg/kg) and "equivocal evidence for phaechromocytomas in female rats, and hemangiosarcomas in male mice" were the reasons for this classification. The U.S. EPA (2015) describes cyanamide as a possible human carcinogen.[75]

Reproductive and developmental toxicity

Based on toxicological data from laboratory animal studies, cyanamide is a suspected human reproductive and developmental toxicant[76] classified as H361fd according to GHS (see above). The findings were summarised in more detail in regulatory documents.[77] Cyanamide impaired fertility in male rats and spermatogenesis in dogs. At higher doses the fertility of female rats was also impaired.

Reduced or absent spermatogenesis was seen in dogs at 0.6 mg/kg (no NOAEL reached). The NOAEL of the most sensitive of three 2-generation rat studies reported was below 1.25 mg/kg (no NOAEL reached). At this dose, decreased pup weight was observed. In another rat study, histopathological changes of the testes in the offspring generation were seen at 1.66 mg/kg (no NOAEL reached). It should be noted that NOAEL can be estimated when it is not reached in the study to derive health-based guidance values. In that case, either a specific mathematical method called benchmark dose (BMD) is applied, if sufficient data are available, or an additional uncertainty factor (UF - the default value is 10) is used to extrapolate from the LOAEL (Lowest Observed Adverse Effect Level) to the NOAEL.[78] In the case of cyanamide, this results in very low acceptable doses for occupational exposure.

In a rat teratology study[79] foetal body weight was reduced at 15 mg/kg and visceral and skeletal abnormalities were observed at the high dose (45 mg/kg). In a rabbit study, eye abnormalities were detected at 6 mg/kg. According to Baconi et al. (2024),[80] the reproductive toxicity seen in rats and rabbits could be the consequence of the tissue-specific inhibition of the enzyme aldehyde dehydrogenase.

Endocrine disruption

Because of its inhibition of thyroid peroxidase, cyanamide meets the specific criteria for endocrine disruption as set out in Regulation (EU) 2017/2100. Cyanamide is a potent inhibitor of thyroid peroxidase (Davidson et al. 1979)[81] and thereby exhibits thyroid-disruptive effects.[82] ECHA's Biocidal Products Committee pointed out that cyanamide was shown to fulfil the criteria for endocrine disruption in the so-called "T modality", i.e. affecting the thyroid, whereas uncertainties exist with regard to the "EAS modalities" (concerning estrogenic, androgenic or steroidogenic effects).[83] ECHA concluded that cyanamide has endocrine disrupting properties with respect to humans as well as with respect to non-target organisms and must not be approved, because it fulfils the criteria for non-approval of Regulation (EU) 528/2012, Article 5 (1d).[84]

Acute and local health effects

There are numerous documented cases of acute poisoning and damage to health as a result of cyanamide exposure across different parts of the world. Skin damage after exposure to hydrogen cyanamide was the most frequently observed effect. Abbas et al.[85] analysed 43 cases of acute Dormex intoxications admitted to two different hospitals in upper Egypt between January and March 2009. Of these, 68% were due to occupational exposure, and 30% due to unintentional ingestion (one case was related to a suicide attempt). The authors did not describe to what extent the 13 cases of high severity (five of them fatal) belonged to oral ingestion. Dermatological signs and symptoms were observed in 29 patients and ocular signs and symptoms in 17. In a retrospective study from an Egyptian poison control centre (period from 2015-2019),[86] 25 of 34 accidental cases were by ingestion and nine by dermal contact or inhalation. Throat irritation was the most frequent symptom reported by all patients, regardless of the route of exposure.

Prolonged dermal exposure (for several hours) through clothes can lead to systemic intoxication as demonstrated by a case report[87] where the person who used Dormex neither took a shower nor changed clothes and slept for two hours. Subsequently he was brought to a hospital's emergency unit in a stuporous state. It took eight days until he could be discharged, but the corrosive skin effects necessitated two more months of medical treatment.

In two case reports from France,[88] the well-known incompatibility of hydrogen cyanamide with alcohol (due to the inhibition of aldehyde dehydrogenase which is key for the metabolism of alcohol) led to hospitalisation of the affected persons. Not knowing the potentiating effect of this combined exposure may result in severe intoxications (see below for the "acetaldehyde syndrome"), even after dermal exposure to cyanamide combined with, e.g., three glasses of wine as described in this publication.

A retrospective analysis of the 68 cases notified to the National New Zealand Poison Centre between 1990 and 2006 (none of them suicide attempts) revealed a surprisingly high share of exposure by inhalation (56%), often (37%) by residents due to spray drift from neighbouring orchards, although it should be noted that – without specification of the subgroup affected – nine of the 68 exposures to hydrogen cyanamide were without symptoms of intoxication.[89] According to the authors, the symptoms described in this report – respiratory irritation, contact dermatitis, erythema, headache, nausea, vomiting and/or diarrhoea – were consistent with the symptoms known for cyanamide intoxications.

Unprotected handling of cyanamide products like Dormex – as it often is the case in in low income and/or low literacy contexts, particularly in Global South contexts– may lead to very severe cutaneous reactions as described in several of the publications reviewed here.[90] There, the four patients sprayed Dormex using a knapsack sprayer without personal protective equipment, but wahsed hands and feet with soap and water after work. Nevertheless, they showed symptoms after five to seven days.. Notably, it took five to seven days from handling Dormex until the appearance of symptoms.

Two reports of hydrogen cyanamide “illnesses” exist for Italy for the period prior to the 2008 EU ban. The first one describes 22 cases of occupational exposure and one case of unintentional ingestion in 2001.[91] Twelve of the cases needed hospitalisation after initial treatment in an emergency department. Because of the frequency of acute intoxications by Dormex, the Italian Ministry of Health suspended its use temporarily from 23 February 2002 to 20 June 2003. The suspension time was used to strengthen protective measures. Nevertheless, 28 cases of intoxications were recorded from 2002 to 2004, 14 of them after the sales resumed, i.e. after strengthening protective measures. [92] Interestingly, the circumstances of exposure were described where available in this publication: “Among the 25 cases involving exposure during application, 20 (80%) occurred in persons who were exposed while using a backpack sprayer, two (8%) while sitting in an open tractor cab, and one (4%) while crossing a treated field.” In two cases of the occupational exposures no further information was available. More than a decade after cyanamide’s ban in 2008, scientists from Italy’s National Toxicology Information Centre performed a retrospective analysis of further cases of intoxications, covering the period from January 2007 to December 2021.[93] A total of 30 cases was identified, 24 of them after market withdrawal of cyanamide, indicating illegal trade and use. The predominant area was Sicily, the island in the very South of Italy with 28 of the 30 cases.

As for the adverse effects, cyanamide causes severe acute skin damages, including sensitisation, i.e. allergic contact dermatitis.[94] Effects can also occur after oral ingestion.[95]

Cyanamide is a cytotoxic agent. The principal toxicological mechanism of cyanamide is inhibition of aldehyde dehydrogenase. Cyanamide can produce “acetaldehyde syndrome” when there is concurrent exposure to alcohol, resulting in symptoms that include vomiting, parasympathetic hyperactivity, difficulty in breathing, and confusion.[96]

In some countries, calcium cyanamide is used as a pharmaceutical product to discourage the consumption of alcohol, by potentiating the accumulation of acetaldehyde in the body. Sweet (2005)[97] summarised the acute effects of calcium cyanamide which are comparable to hydrogen cyanamide because of the same mechanism (accumulation of acetaldehyde). These were facial flushing, headache, nausea, vomiting, difficulty in breathing, sweating, chest pain, hypotension, weakness, blurred vision, and confusion. In the extreme, cardiovascular collapse and coma would be the result, with an estimated fatal dose in humans ranging from 40 to 50 g cyanamide.

Repeated inhalation of cyanamide may lead to pneumonitis and pulmonary edema.[98] In addition, liver toxicity has been described for cyanamide.[99]

Chronic health effects, protection and monitoring

As described above, endocrine disruption of the thyroidal function is the major concern of occupational, bystander and resident exposure to cyanamide. This is in line with the observation that thyroid effects, but also effects on male fertility, were seen at very low doses in experimental studies.

Related to this, it should be noted that ECHA’s Biocidal Products Committee (2021) pointed out that only very specific protective equipment is suitable for preventing exposure under certain conditions of use. Specifically, ECHA described “Pro-Chem® I”C” Typ3 coverall and Camatril® 732 gloves “as suitable protective clothing”, emphasizing that “some other coveralls were tested which did not result in the same level of protection”. In addition to the described coverall and gloves, ECHA recommends chemically protective boots, respiratory protective equipment against gaseous cyanamide, including full face mask or half face mask with safety goggles.

It should be noted that this equipment is recommended for application using a watering can onto slatted floors of pig stables,[100] whereas exposure scenarios during spraying with intensive aerosol generation can be considered a more difficult situation.

For monitoring exposure to cyanamide, measuring urinary concentrations of cyanamide’s main metabolite, acetylcyanamide, could be taken into consideration which can be quantified at concentrations as low as 10 µg/L.[101]

Ecotoxicology

Environmental fate and behaviour[102]

Soil: In soil, cyanamide is converted to nitrogenous compounds which are rapidly taken up by plants. In aqueous soil conditions, cyanamide is expected to decompose by hydrolysis to urea and by dimerization to dicyanamide. As a result of these two processes, the aquatic as well as the terrestrial bioaccumulation potential can be classified as low for cyanamide.

Under aerobic conditions in the dark, cyanamide showed low persistence, with rapid mineralisation to carbon dioxide representing the major degradation pathway (up to 95% of applied radioactivity after 14 days). Only a small fraction was bound as non-extractable residues. No relevant metabolites were identified under these conditions. However, soil photolysis experiments indicated the formation of transformation products exceeding 10% of the applied radioactivity, highlighting the importance of light-driven degradation processes. The substance exhibits very high mobility in soil, which increases the risk of leaching into groundwater.

Aquatic systems: Cyanamide is highly soluble in water. In natural water–sediment systems under aerobic conditions, cyanamide was characterised by relatively low persistence (DT50 values between 2.5 and 4.8 days). Urea was identified as the major metabolite, while sediment binding was limited (≤ 4.7%). Mineralisation to carbon dioxide was again a significant sink (84–86%). Exposure assessments using the FOCUS tiered modelling approach confirmed that mitigation measures such as buffer zones and consideration of volatilisation losses are necessary to reduce surface water contamination.

Groundwater: FOCUS groundwater modelling scenarios consistently indicated over a wide range of geoclimatic conditions a high potential for cyanamide leaching above the parametric drinking water threshold of 0.1 µg/L, and in many cases above the 0.75 µg/L trigger. This outcome was consistent across diverse geoclimatic conditions, and, given the toxicological properties of cyanamide, was identified as a critical area of concern.

Air and volatilisation: Cyanamide has a significant potential for volatilisation. Model calculations estimated an atmospheric half-life of more than two days, suggesting possible transport in the atmosphere. While long-range transport potential is considered low, short-range atmospheric transport and subsequent deposition into adjacent terrestrial and aquatic environments were confirmed by field studies and represent a relevant exposure pathway. If applied directly to plants or soil, drift for both people and environment is a major concern.[103]

Although cyanamide breaks down relatively quickly in soil and water, forming mostly carbon dioxide, its high mobility, potential to contaminate groundwater, tendency to volatilize, and short-range atmospheric deposition create significant environmental risks. This highlights the need for careful risk assessment and appropriate mitigation when using cyanamide, as described below for New Zealand.

New Zealand's EPA recently completed a reassessment of hydrogen cyanamide based on existing fate data and recommended that additional control measures are necessary to mitigate risks to the environment and human health.[104]

Use restrictions for hydrogen cyanamide in New Zealand

- Only one application per year is allowed
- Buffer zones of up to 50m must be put in place to protect bystanders
- Buffer zones of up to 25m must be put in place to protect the aquatic environment and non-target plants downwind
- Application is limited to ground-based methods. Only nozzles and appropriate mixtures of hydrogen cyanamide, water, and/or adjuvants that produce a coarse or larger droplet size can be used
- Specify minimum and maximum wind speed for application of 0.8 m/s and 5.6 m/s (3 km/h and 20 km/h) respectively
- Spraying is restricted to a specific time according to the growing season (1 July–10 September, i.e. during winter)
- Professional users are now required to have specific qualifications

Also, similar use restrictions are in place in California, where cyanamide-containing Dormex is approved in a broad range of fruits including blueberries, blackberries, cherries, kiwis, almonds, grapes and walnuts.

Use restrictions for Dormex in California[105]

- Due to corrosive effects to eyes and skin, the use is limited to certified applicators or persons under their direct supervision
- All handlers, mixers and loaders are required to wear specific PPE, including chemical-resistant aprons and gloves and protective eyewear
- General use restrictions prohibit aerial application or application via any type of irrigation system
- The product must be mixed, loaded, and transferred only in a closed system
- No application is allowed within 300 yards (274,32 meters) of any surface water that may be used as a source of drinking water
- During the application, no person shall be within 125 feet (38 meter) of the area to be treated unless involved in application or mix/load operations
- The use is restricted to one application per year and a general maximum of 4 gallons (17.6 lbs.) of hydrogen cyanamide per acre per year (37,4 litre/ hectare).

No such application specifications are in place in South Africa.

Environmental effects

Cyanamide is moderately toxic to mammals. It is an irritant and has a high potential for bio-concentration. It is moderately toxic to birds, fish, aquatic invertebrates, aquatic fauna, honeybees and earthworms.[106]

In agreement with the Global Harmonized System, cyanamide is classified as harmful to aquatic organisms with long lasting effects (see Table 1).[107] It is strongly advised that this substance does not enter the environment.[108] The New Zealand EPA identified risks to the aquatic environment from exposure to hydrogen cyanamide, in its risk assessment, with risk quotient levels for a number of species found to be above the level of concern. It recommends only buffer zones of up to 20m would mitigate exposure to the substance through spray drift and runoff and 45 m downwind buffer zones to protect aquatic life from adverse effects of spray drift when hydrogen cyanamide is applied to apple orchards.

The New Zealand EPA identified non-negligible risks to soil organisms – specifically reproductive effects on Collembola (springtails) – from the use of hydrogen cyanamide on kiwifruit and apples, even after accounting for prescribed and additional recommended control measures. Thus, they classified hydrogen cyanamide as hazardous to soil organisms.[109]

A critical area of concern is indicated in relation to the risk assessment for birds: both acute and chronic risks to birds from the use of hydrogen cyanamide on all fruit crop types is non-negligible. No modified or additional controls that are considered workable were identified in this assessment to mitigate the acute or chronic (reproductive) risks to birds to a negligible level.[110]

The New Zealand EPA's reassessment of cyanamide resulted in the following: Due to its potential impact on non target arthropods label statement should indicate "WARNING the substance may not be compatible with Integrated Pest Management (IPM) and can have effect on the 'off-field' population depending on crops (eg fruit trees)". In its decision, the EPA weighed environmental and health risks against economic benefits. While risks – particularly regarding human toxicity and environmental impacts – were acknowledged, the benefits were considered sufficient to continue approval under tighter rules.

It is important to note that New Zealand's pesticide legislation is not designed primarily to protect people or the environment. Instead, as explicitly stated by the authorities, it aims to balance risks and benefits. This means that if the economic gains from using a pesticide are believed to outweigh the risks to human health and the environment, the substance can be registered. A major gap in this process is the lack of transparent, quantitative modelling: there is no clear, mathematical way to see how risks and benefits are calculated or compared[111]

Alternatives

Bud-break is a decisive phase in vineyards and orchards, shaping fruit set, harvest timing, and overall crop quality. Reliable yields require adequate winter chill accumulation, with a general benchmark of at least 80% bud-break for economic viability. The winter chill requirements differ between grape varieties. To ensure high and uniform bud break, a requirement of approximately 200 hours between 0 and 10 °C or 400 hours at 3 °C is typically specified for wine grapes (for other fruits it might be different).[112]

With vines increasingly grown outside their original climatic range in less or unfavourable regions, and winters becoming progressively milder, chilling requirements are often unmet, leading to delayed, uneven, or incomplete bud-break, which reduces yield and fruit quality. To compensate, many growers have come to rely on hydrogen cyanamide to induce uniform bud-break.

Finding alternatives requires a deeper understanding of the biochemical mechanisms driving bud-break, alongside the effects of application timing, grape variety, climate conditions, and product combinations. Only by integrating this knowledge can viticulture adapt to regions where grapes are not naturally suited and ensure long-term production sustainability.

Orchard/vineyard planning and management measures

Restricting grapevine production to suitable areas

The most sustainable option is to restrict grapevine production to areas with sufficient natural chilling. Expanding into unsuitable zones is not only economically risky but also locks farmers into long-term chemical dependency with serious environmental and health consequences.

South Africa illustrates this challenge across its five major grape production regions:[113]

- The Hex River Valley and Paarl area of the Berg River Valley accumulate enough chill units to secure high bud-break percentages.
- By contrast, the Lower Orange River Region, the Saron/Porterville area of the Berg River Valley, and Limpopo fall short. Here, growers face delayed and uneven bud-break unless they intervene with chemicals like hydrogen cyanamide or alternative products.

Proposals to expand production (in this case fruit tree production) into regions with mild climates such as KwaZulu-Natal are deeply concerning.[114] With its warm climate, the province lacks sufficient chilling for apples, cherries. Any production would depend on heavy chemical use – a short-term fix that creates long-term risks. This path should be avoided. Instead, focus must remain on naturally suitable zones or on crops and varieties adapted to warmer climates, especially as climate change progresses.

Looking ahead, climate change will exacerbate chilling deficits globally.[115] Even regions that currently meet requirements will see warmer winters, reduced chill accumulation, and more frequent bud-break problems. Vineyard and orchard planning must anticipate these shifts now.

A further option sometimes discussed is moving grape production to higher altitudes. For instance, one winery in Spain has shifted part of its vineyards to the foothills of the Pyrenees (approximately 900–1,200 m elevation) to offset warming in lower regions. While higher altitudes can provide cooler conditions and help preserve grape quality under rising temperatures, this strategy comes with serious trade-offs. Mountainous and highland areas are often ecologically pristine, supporting unique biodiversity and serving as vital watersheds for downstream ecosystems and communities. Expanding agriculture into these zones can lead to land-use change, habitat disruption, soil erosion and contamination of fragile water systems through fertilizer and pesticide runoff . These risks highlight that shifting production upward is not a sustainable or broadly applicable solution, but rather a measure of last resort that should be avoided in favour of climate adaptation within existing suitable areas.

Pruning and canopy management

In addition to selecting climatically suitable sites and cultivars, vineyard management practices play a critical role in reducing reliance on hydrogen cyanamide and other rest-breaking chemicals. Among these, pruning and canopy management represent effective, non-chemical strategies that can enhance bud-break uniformity and vine productivity.

Such practices are particularly valuable in marginal climates, where natural chilling is close to the minimum threshold. By optimizing pruning and canopy management and integrating these practices with appropriate cultivar selection and careful site choice, growers can enhance natural bud-break, improve yield consistency, and significantly reduce dependency on chemical rest-breaking agents.

Identify the right varieties

In addition to restricting production to climatically suitable areas, another key strategy is to choose cultivars adapted to local chilling conditions. Each variety of fruit trees and vines has its own chilling requirement: some need as few as 200–400 hours, while others require more than 1,000 hours. Planting high-chill cultivars in warm areas almost guarantees annual reliance on hydrogen cyanamide or other rest-breaking chemicals.

Careful selection of cultivars that match the regional chilling profile provides a long-term, ecological adaptation strategy. While for established vineyards, changing varieties is not a practical short-term option – since grape cultivars and wine profiles are closely tied to long-standing regional identities and market expectations – for new vineyard developments or replanting, careful selection of cultivars that align with local chilling conditions offers a long-term, ecological adaptation strategy.

In South Africa, for instance, the wine market is dominated by a few grape varieties. Over 77% of grape production comes from just ten cultivars, led by Chenin Blanc, Colombard, and Cabernet Sauvignon.[116] Globally, more than 40% of wine comes from only ten wine varieties, with Cabernet Sauvignon as a key example.[117] Cabernet Sauvignon requires more than twice the chilling hours of Chardonnay, illustrating the mismatch that can occur if varieties are not well adapted.[118]

Grapevines also differ in their response to the interaction of chilling and heat requirements: Chardonnay typically bursts relatively early, while Cabernet Sauvignon bursts late.[119] By aligning the variety's dormancy needs with the climatic realities of the production zone, growers can secure reliable yields without chemical intervention.

This principle applies to other crops as well: apples and cherries, which require high chilling, often struggle in warm subtropical zones, whereas low-chill peach or grape cultivars can thrive naturally.[120] Breeding and selecting new low-chill varieties offers additional opportunities to adapt, while revitalizing locally adapted fruit and wine cultures.

Rather than forcing unsuitable cultivars into unfavourable regions with chemical shortcuts, the future of sustainable production lies in matching the right plant to the right place. Wine production does not need to be dominated by a handful of common varieties. Through ongoing breeding, selection, and a focus on regional adaptation, viticulture can move toward re-indigenizing local wine cultures and reducing dependence on chemicals, while maintaining diversity, quality, and resilience.[121] However, this transformation is only possible with the support and openness of consumers. Their willingness to explore and enjoy new or lesser-known varieties is crucial in enabling growers to experiment with diverse cultivars and adapt their practices toward more sustainable, locally suited viticulture.

Reducing the use of hydrogen cyanamide

Another management strategy is to apply bud-breaking chemicals sparingly and only when necessary, rather than as a routine practice. Surfactants or adjuvants like mineral oil can improve the efficiency of hydrogen cyanamide, allowing lower doses or more targeted applications.

Even in regions with sufficient natural chilling, such as the Hex River Valley and Paarl area of the Berg River Valley, many growers continue to use hydrogen cyanamide. In these cases, the chemical is not strictly required to induce bud-break but is applied to achieve greater uniformity and predictability in bud development.[122]

Adopting a "use only if necessary" approach reduces chemical dependency, lowers environmental and health risks, and encourages growers to integrate other long-term strategies, such as cultivar selection and site adaptation, into vineyard management.

Alternative products

Various products are being investigated as safer and more sustainable options for stimulating bud development, especially in the unpredictable spring conditions caused by climate change.

Gibberellic Acid (GA_3): One example of plant growth regulators is the naturally occurring plant hormone gibberellic acid, that regulates dormancy release, cell elongation, and flowering processes.[123] A commercial formulation, Promalin® – containing gibberellic acid and 6-benzyladenine – is registered and marketed in South Africa by Philagro South Africa, a division of Valent BioSciences, the original developer and a global leader in PGR technologies.[124] In South Africa it is primarily applied in apple orchards to improve fruit set, size, and quality (often used in combination with hydrogen cyanamide), and it has been shown to enhance return bloom in subsequent seasons.[125] In viticulture, research from China indicates that gibberellin-based treatments can improve berry quality and cluster morphology in table grapes.[126] However, to date, no published studies have evaluated the use of Promalin® or similar gibberellic acid–based formulations on grapevines in South Africa, highlighting a gap in region-specific research.

Ethanol Sprays: Preliminary trials show that ethanol can advance bud break in grapevine buds, offering a potential alternative to cyanamide application.[127] While for these trials ethanol was sprayed on the plant, it should be mentioned that direct oral consumption must be considered dangerous: According to the World Health Organization (WHO) there is no safe threshold for ethanol consumption. The International Agency for Research on Cancer (IARC) classified ethanol as a human carcinogen[128] when consumed.

Mineral Oil: Oil was the first chemical used to break dormancy. Adding several chemical compounds later enhanced its effect. It works by smothering and suffocation of buds, which helps to break dormancy. Currently it is often used in combination with hydrogen cyanamide, as the combination can reduce the rate of hydrogen cyanamide needed.[129] At the same time caution is needed when handling, because mineral oil was classified as a category 1 carcinogen by the International Agency for Research on Cancer (IARC 2012).[130]

Nitric oxide, hydrogen peroxide and hypoxia: Treating dormant grapevine compound buds with nitric oxide (NO) or hydrogen peroxide (H_2O_2) creates low-oxygen (hypoxic) conditions that can partially break bud dormancy. This supports the proposed molecular models explaining how hydrogen cyanamide (HC) induces dormancy release.[131]

Garlic Extract: Garlic (Allium sativum) has been investigated as a non-toxic alternative to hydrogen cyanamide for breaking bud dormancy in grapevines. Studies have tested various self-made formulations, including garlic extract, oil, and paste. To our knowledge, no garlic-containing products are currently registered in South Africa for this purpose.

Comparative effectiveness: The bud-breaking effect of garlic is attributed primarily to its organosulfur compounds, such as allicin and diallyl disulfide, which can induce mild oxidative stress in buds – stimulating metabolic activity and dormancy release.

- In multi-year experiments, garlic extract treatments showed similar results to low concentrations of hydrogen cyanamide, with no statistically significant differences in bud-break percentage or uniformity.[132]

- On the Muscat of Alexandria grapevine, garlic paste was found to be more effective than calcium cyanamide but less effective than hydrogen cyanamide.[133]

- Garlic oil applications gave satisfactory results in the Pione hybrid and in 'Thompson Seedless', demonstrating its potential across different cultivars.[134]

Limitations: Concentration and application method are critical. For example, garlic paste at 3% concentration caused up to 70% bud damage, likely due to excessive oxidative stress.[135] Results can vary by cultivar and climate, meaning garlic cannot yet be seen as a universal substitute.

Plant Biostimulants (PBs): Understanding the molecular mechanisms of hydrogen cyanamide has assisted in developing less toxic commercial alternatives, such as plant biostimulants (PBs). Several PBs have shown a potential to enhance bud-break, compared to no treatment, in apple, grapevine, pear, sweet cherry, blackberry, peach, and kiwi. These products include amino acids, seaweed extracts, and nano-fertilizers. A small-scale field trial on table grapes in South Africa also found that hydrogen cyanamide 3% and biostimulants have similar effects on bud break. Nitric oxide (NO), hydrogen peroxide (H_2O_2), and hypoxia, in combination with PBs, may potentially replace hydrogen cyanamide; however, this needs to be confirmed in future experiments.[136]

Products in use

Unibrot[137]: Biostimulant composed of enzymatic amino acids of plant origin and nutrients such as easily assimilated calcium, whose synergistic action concentrates, standardizes and boosts the development of vegetative and reproductive buds in woody plants, leading to more uniform and concentrated fruit growth, and an increased yield. It also stimulates deciduous fruit trees, bringing them out of dormancy, and reduces apical dominance, providing a nutritional advantage to buds that would not have sprouted naturally.

BudUp[138] is a commercial dormancy-breaking product developed as a safer alternative to hydrogen-cyanamide formulations, but its active ingredients have not been transparently disclosed in publicly available documentation. Successful trails has been done in various countries (e.g. South Africa, Italy, New Zealand) on table grapes, kiwifruit, apples, cherries, berries and plums.[139]

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3 Cyanamide in the form of calcium cyanamide is also used in agriculture, e.g. in onions, leeks, shallots, garlic and chives as a slow-release source of nitrogen fertiliser and soil conditioner. The monograph at hand focuses on hydrogen cyanamide and its use to promote break alone.

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Annex I

Cyanamide - Classification of the substance or mixture According to UN GHS criteria (EU GHS / EU GLS)[138]

Acute Tox. 3 (oral)
Acute Tox. 4 (dermal)
Skin Corr./Irrit. 1B
Skin Sens. 1
Repr. 2 (fertility)
Repr. 2 (unborn child)
STOT RE 2
Aquatic Acute 3
Aquatic Chronic 3
Eye Dam./Irrit. 1Pictogram:

Signal Word: Danger

Hazard Statement:

H301 Toxic if swallowed.
H312 Harmful in contact with skin.
H314 Causes severe skin burns and eye damage.
H317 May cause an allergic skin reaction.
H361 Suspected of damaging fertility. Suspected of damaging the unborn child.
H373 May cause damage to organs through prolonged or repeated exposure.
H402 Harmful to aquatic life.
H412 Harmful to aquatic life with long lasting effects.

Precautionary Statement:

P101 If medical advice is needed, have product container or label at hand.
P102 Keep out of reach of children.
P103 Read label before use.

Precautionary Statements (Prevention):

P201 Obtain special instructions before use.
P202 Do not handle until all safety precautions have been read and understood.
P260 Do not breathe dust/gas/mist/vapours.
P264 Wash contaminated body parts thoroughly after handling.
P272 Contaminated work clothing should not be allowed out of the workplace.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P301 + P330 + P331 IF SWALLOWED: rinse mouth. Do NOT induce vomiting.
P303 + P361 + P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304 + P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P305 + P351 + P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.
P362 + P364 Take off contaminated clothing and wash it before reuse.

Precautionary Statements (Storage):

P405 Store locked up.

Precautionary Statements (Disposal):

P501 Dispose of contents/container to hazardous or special waste collection point.

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