Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

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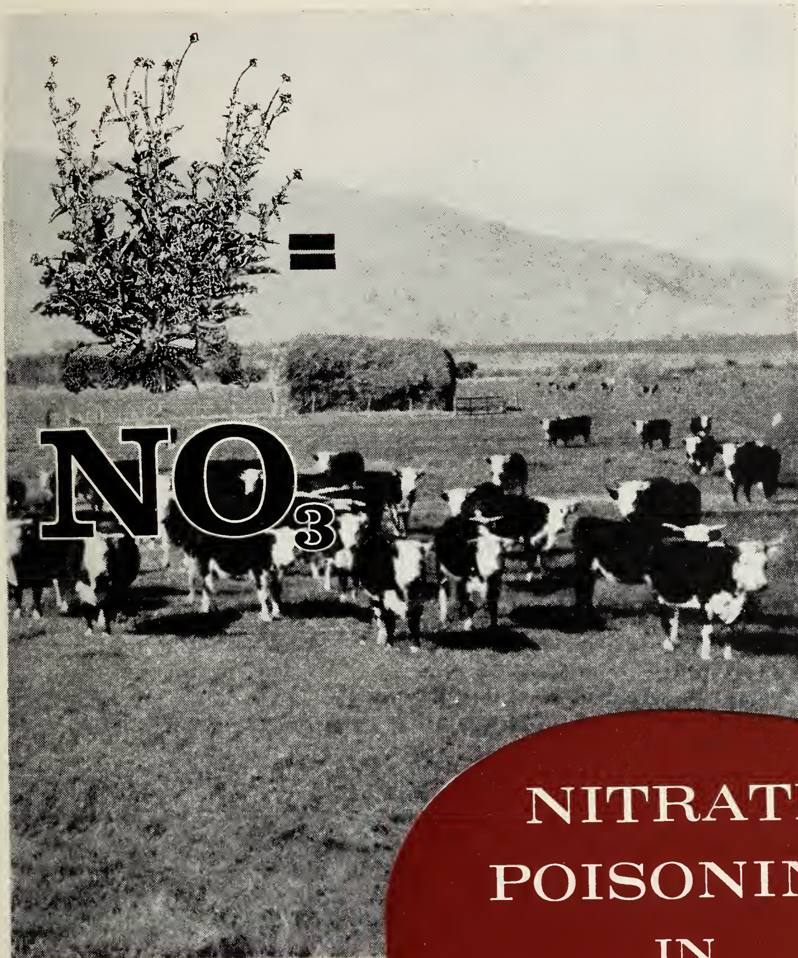

NITRATE POISONING IN LIVESTOCK

CALIFORNIA AGRICULTURAL
Experiment Station
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CIRCULAR 506

FIDDLENECK

MILK THISTLE

Nitrate accumulation in plants presents a potential danger to livestock which feed on them. Various factors can affect such accumulations, and different plants are known to be capable of accumulating nitrates in appreciable or even lethal amounts. This circular, which brings together much data which has been widely scattered, discusses these factors (pages 3, 4, and 5), lists plants known to accumulate nitrates (pages 5 through 9), and suggests approaches to the control of losses from nitrate poisoning (page 9).

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NITRATE POISONING IN LIVESTOCK

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What is nitrate poisoning?

Nitrates, absorbed from the soil by most plants, serve as a source of nitrogen which plants convert into proteins and other nitrogen-containing compounds. Normally functioning plants usually contain relatively small amounts of nitrate because the nitrate is converted into other nitrogenous compounds almost as soon as it is absorbed. Under certain conditions, however, some plants may accumulate fairly high concentrations of nitrate. While these concentrations are not toxic to the plant itself, animals feeding on such plants may sometimes suffer fatal poisoning.

Nitrate itself is not very toxic, but is readily converted into nitrite. Probably most of the conversion of nitrate to nitrite takes place in the animal digestive tract, although some field studies indicate that nitrite may already be present in the plants before they are eaten. Nitrite converts the hemoglobin in red blood cells to methemoglobin, which cannot transport needed oxygen from the lungs to the body tissues. Thus, animals affected with nitrate poisoning show general symptoms of oxygen deficiency.

Animals most often affected

Ruminants, particularly cattle, are the principal victims of nitrate poisoning because of the large amounts of plant material they eat and the action of microorganisms in the rumen. Sheep and swine are less susceptible, and sheep and horses have been known to suffer no ill-effects from oat hay that was poisonous to cattle. However, one case of poisoning in sheep in California has come to the authors' attention (see table 1) and other cases have been reported in Wyoming. In New Zealand, a case in which 200 pigs succumbed to nitrate poisoning after eating mangels (*Beta vulgaris* var. *rapa*) is on record.

There appear to be few recorded cases of horses dying from nitrate poisoning under pasture or range conditions. Despite this, it has been demonstrated experimentally that horses can be fatally poisoned by nitrate and that the mode of action of the poison is the same as in cattle.

Symptoms of poisoning

The symptoms most frequently observed in nitrate poisoning are depression, weakness (often appearing suddenly), rapid pulse, and respiration which is often very noisy and labored as though the animal were in great pain. Mucous membranes become dark in color. The recumbent animal may show convulsive movements of the legs. Death is due to asphyxia and in acute cases may occur within a few hours after the plant is eaten. The animal's blood is often dark and sometimes chocolate brown. The fourth stomach and the intestine are sometimes congested due to the direct irritating action of high levels of nitrate.

Cows not fatally poisoned may abort dead calves.

Table 1. Recent Cases of Nitrate Poisoning in California

Date of occurrence	Location	Animals lost	Plants involved	Nitrate analyses as KNO_3 on dry weight basis (maximum values)
August, 1952	Sacramento Co.	calves (number not recorded)	Rough pigweed (*Amaranthus retroflexus*)	4.30%
May, 1953	Yolo Co.	9 Shorthorn heifers	Milk thistle (*Silybum marianum*)	10.30%
March, 1954	Stanislaus Co.	1 Holstein calf	Miner's lettuce (*Montia perfoliata*)	1.97%
			Fiddleneck (*Amsinckia* sp.)	1.16%
			Popcorn flower (*Plagiobothrys* sp.)	0.87%
Spring, 1956	San Bernardino Co.	12 heifers	Sudan grass (*Sorghum sudanense*)	"exceptionally high levels of nitrate"
June, 1957	Yolo Co.	2 head of cattle	Sudan grass (*Sorghum sudanense*)	2.00%
November, 1957	Alameda Co.	21 head of cattle	Lamb's-quarters (*Chenopodium album*)	8.66%
February, 1959	Los Angeles Co.	40 sheep	Coast goldenbush (*Haplopappus venetus*)	3.40%
			Soap plant (*Chenopodium californicum*)	2.60%
			California chicory (*Rafinesquia californica*)	4.90%
September, 1960	Marin Co.	5 dairy cows lost	Pigweed* (*Amaranthus* sp.)	4.48%
		15 aborted	Alfalfa* (*Medicago sativa*)	1.22%

* These plants were in hay grown at Isleton, Sacramento County, cut in May, 1960

Factors affecting nitrate accumulation in plants

Much remains to be learned about the factors responsible for the accumulation of high levels of nitrate in plants. This capacity seems to vary widely among different species. Many familiar plants—crop plants as well as common weeds—are capable of accumulating appreciable amounts of nitrate; evidently many other plants cannot ordinarily do so. The stage of the plant's growth is an important factor. In a study involving 25 different weed species, one investigator found that the pre-blooming period was nearly always the time of highest accumulation and that by full maturity the nitrate concentration had dropped to very low levels. This pattern was shown both by species that accumulated considerable amounts and by those that had only very small amounts at most.

An ample supply of available nitrate in the soil is evidently of primary importance among factors in the plant's external environment which promote high nitrate accumulation. But other soil factors also have an important influence. An adequate moisture supply, for example, tends to promote soil nitrate formation and plant absorption of the nitrate. Despite this fact greenhouse experiments with oats suggest that in plants under drought conditions nitrate *accumulation* may be higher than in well-watered plants. Other studies indicate that although drought during flowering may result in increased accumulation, plants grown *continuously* under dry conditions contained low nitrate concentrations.

An acid, rather than an alkaline, soil solution tends to promote nitrate absorption from the soil. Sulfur deficiency, for example, has been shown to result in high nitrate accumulation. An excess of phosphate tends to retard nitrate absorption. When nitrogen fertilizers are used to increase forage production in range or pasture improvement programs, adequate amounts of phosphorus and/or sulfur should also be applied, if these elements are deficient, to enable the plants to utilize the nitrogen.

Relatively low temperatures (around 55°F.) also tend to promote nitrate accumulation. At such temperatures absorption of nitrate apparently is not decreased to the same extent as is its reduction and utilization; hence, the net effect is an accumulation of nitrate. The amount of shading a plant receives during its growth can be very important with some species. Experiments with oats indicate that reduction in light intensity results in a considerable increase in nitrate accumulation. Similarly, high nitrate accumulation has frequently been recorded under short day (as compared with long day) conditions; light apparently is an important or even essential factor in nitrate reduction and utilization. The reduction process is evidently an enzymatic reaction, and the activity of this particular enzyme has been shown to decrease in complete darkness, and eventually to stop altogether.

Since nitrate accumulation in dangerous amounts may be related to many conditions and situations, it is not possible to predict where or when poisoning may occur.

Plants involved in nitrate poisoning

Cases of fatal poisoning in cattle resulting from eating oat hay or straw have been known for many years in the western plains, both in the United States and in Canada. It was not until the late 1930's, however, that this type of poisoning was shown to be a result of nitrate accumulated in the plant tissues. More recently, certain other plants have been involved in this type of poisoning. One of the most spectacular series of losses recorded to date was presumably caused by a common California range weed, fiddleneck (*Amsinckia*). Reliable reports indicate that between 2,000 and 3,000 head of cattle were lost in the upper Salinas Valley as a result of eating this plant during the winter and spring of 1952, and field observations and laboratory tests by the California Department of Agriculture pointed to nitrate as the main killer. Other instances of nitrate poisoning in California which have come to our attention in recent years are summarized in table 1.

In addition to plants which have been involved in actual cases of nitrate poisoning, many others are known to be capable of accumulating appreciable—possibly toxic—amounts of nitrate. One recent survey in Australia revealed that out of a total of 589 plants tested, 55 different species gave strong positive tests for the presence of nitrate. The following list, compiled from several sources, includes plants that have been involved in cases of poisoning, and also many that have been shown to be capable of accumulating sizeable amounts of nitrate. Some of these reports are well confirmed and quantitative, others are based on presumptive clinical observation or equivocal chemical determination. The list is offered only to indicate the wide range of plant species which are capable of nitrate accumulation. All of the plants in the list occur in California, although relatively few of them have been involved in cases of livestock loss in this state.

Plants Which Have Been Involved in Nitrate Poisoning or are Capable of Accumulating Appreciable Amounts of Nitrate

PLANT	COMMON NAME	FAMILY
Amaranthus blitoides	Prostrate pigweed	Amaranthaceae
A. graecizans	Tumbling pigweed	Amaranthaceae
A. retroflexus	Rough pigweed	Amaranthaceae
Ammi majus	Bishop's weed	Umbelliferae
Amsinckia douglasiana	Douglas' fiddleneck	Boraginaceae
A. intermedia	Common fiddleneck	Boraginaceae
Apium graveolens	Celery	Umbelliferae
Avena sativa	Oats	Gramineae
Beta vulgaris	Sugar beet	Chenopodiaceae
B. vulgaris var. *rapa*	Mangel	Chenopodiaceae
Bidens frondosa	Beggar-ticks	Compositae
Brassica campestris	Turnip	Cruciferae
B. napobrassica	Rutabaga	Cruciferae
B. napus	Rape	Cruciferae
B. oleracea vars.	Brocolli, Kale, Kohlrabi	Cruciferae
B. rapa	Turnip	Cruciferae
Bromus catharticus	Rescue grass	Gramineae
Chenopodium album	Lamb's-quarters	Chenopodiaceae
C. ambrosioides	Mexican tea	Chenopodiaceae
C. californicum	Soap plant	Chenopodiaceae
C. murale	Nettle-leaf goosefoot	Chenopodiaceae
Cirsium arvense	Canada thistle	Compositae
Cleome serrulata	Rocky Mountain bee plant	Capparidaceae
Conium maculatum	Poison hemlock	Umbelliferae
Convolvulus arvensis	Wild morning-glory	Convolvulaceae
Cucumis sativa	Cucumber	Cucurbitaceae
Cucurbita maxima	Hubbard squash	Cucurbitaceae
Daucus carota	Carrot	Umbelliferae
Eleusine indica	Goose grass	Gramineae
Euphorbia maculata	Spotted spurge	Euphorbiaceae
Glycine max	Soybean	Leguminosae
Gnaphalium purpureum	Purple cudweed	Compositae
Haplopappus venetus	Coast goldenbush	Compositae
Helianthus annuus	Common sunflower	Compositae

PLANT	COMMON NAME	FAMILY
Helianthus tuberosus	Jerusalem artichoke	Compositae
Hordeum vulgare	Barley	Gramineae
Kochia americana	Fireball	Chenopodiaceae
Lactuca sativa	Lettuce	Compositae
L. scariola	Prickly lettuce	Compositae
Linum usitatissimum	Flax	Linaceae
Malva parviflora	Cheeseweed	Malvaceae
Melilotus officinalis	Yellow sweet clover	Leguminosae
Montia perfoliata	Miner's lettuce	Portulacaceae
Panicum capillare	Witch grass	Gramineae
Parkinsonia aculeata	Horse bean	Leguminosae
Pastinaca sativa	Parsnip	Umbelliferae
Plagiobothrys sp.	Popcorn flower	Boraginaceae
Rafinesquia californica	California chicory	Compositae
Raphanus sativus	Radish	Cruciferae
Salsola kali	Russian thistle	Chenopodiaceae
Secale cereale	Rye	Gramineae
Silybum marianum	Milk thistle	Compositae
Solanum carolinense	Carolina horse nettle	Solanaceae
S. nigrum	European black nightshade	Solanaceae
Sonchus asper	Prickly sow-thistle	Compositae
S. oleraceus	Common sow-thistle	Compositae
Sorghum halepense	Johnson grass	Gramineae
S. sudanense	Sudan grass	Gramineae
S. vulgare	Sorghum	Gramineae
Thelypodium lasiophyllum	California mustard	Cruciferae
Tribulus terrestris	Puncture vine	Zygophyllaceae
Triticum aestivum	Wheat	Gramineae
Verbesina encelioides	Crownbeard	Compositae
Zea mays	Corn	Gramineae

Potentially dangerous nitrate accumulations

In the past, plants containing more than 1.5% nitrate (expressed as potassium nitrate) on a dry weight basis have been considered potentially dangerous. Recently, however, subclinical poisoning (inconspicuous ill effects) has been attributed to nitrate levels below this percentage, and any amount over 0.5% in the *total* ration has been considered a possible source of trouble. Toxicologists often express the amount of nitrate present in plant tissue as if it were potassium nitrate (KNO_3). Agronomists and agricultural chemists usually express nitrates in terms of actual nitrogen derived from nitrates present in the tissue; this is referred to as nitrate nitrogen (NO_3-N). These different methods of expression have led to considerable confusion as there may appear to be contradiction in the amounts of nitrate reported, depending on the method of expression used. For example, plants are considered by some investigators as potentially toxic if they contain nitrate

amounting to more than 1.5% expressed as KNO_3 on a dry weight basis. This means 15,000 ppm KNO_3 or 2078 ppm actual N (nitrate-nitrogen).

Whether or not poisoning will result in the animal depends not only upon the amount of high nitrate material consumed, but also upon conditions in the animal's rumen which favor reduction of nitrate to nitrite.

Control of losses from nitrate poisoning

An early, accurate diagnosis is imperative. Methylene blue in sterile aqueous solution is used intravenously in treating affected animals. Preparations containing sodium nitrite should be avoided. Treatment *must* be prompt. Affected animals must not be forced to exercise and must not be excessively handled during treatment, as they may die from oxygen deficiency. A laxative should be given if it can be administered without undue stress.

Certain investigators have shown that there are marked differences in nitrate accumulation between different plant species even when grown under similar conditions. The small grains, such as wheat, oats, barley and rye, and some weeds, have been found to contain several times the nitrate content found in timothy, certain brome grasses, orchard grass, and Ladino clover. This may indicate why only a few cases of apparent nitrate poisoning have been observed on California irrigated pasture and native ranges which have been regularly treated with high rates of nitrogen fertilizer.

Livestock operators can reduce some of the danger of nitrate poisoning by exercising certain precautions. Forage containing a high percentage of plants known to be probable nitrate accumulators, or which has been treated with high amounts of nitrogen fertilizer, should not be harvested or grazed during, or immediately following, the climatic conditions mentioned previously in this leaflet. Hay having a relatively high nitrate content can be utilized if a supplement with high sugar content (such as molasses) is added to the ration. High nitrate forage can also be reduced to safe levels by mixing with liberal quantities of feed known to be safe.

Field sampling for nitrate accumulation

Occasional plants of a species may accumulate toxic amounts of nitrate while only a short distance away in the same field other plants of the same species may contain mere traces. Therefore, in sampling a field to check for nitrate accumulation two points should be observed:

1. Ten or more individual plants or samples should be collected from all over the field, particularly from areas of luxuriant growth.
2. The plants collected should be analyzed as separate samples, not as a single, composite sample.

By using this method, any dangerous accumulation in plants in one part of a field will not be masked in a composite sample, which could easily happen if the other collections were quite low in nitrate.

***Photo 1,* Fiddleneck (*Amsinckia*) a native orange-flowered spring annual, common on rangeland and as a roadside and grain field weed in California. Fiddleneck was presumably the cause of heavy cattle losses in the upper Salinas Valley during the late winter and spring of 1952.**

Photo 2, **Milk Thistle, Bull Thistle, or Variegated Thistle (*Silybum marianum*). This weed, naturalized from Europe, was the cause of nitrate poisoning in cattle near Davis in 1953. The name, Milk Thistle, refers to the conspicuous white mottling of the leaves.**

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. . . in photos

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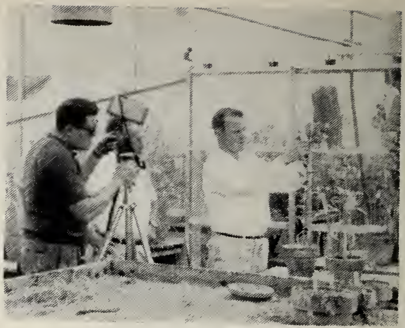

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