FACTORS INFLUENCING CYANIDE INJURY TO GREENHOUSE PLANTS.

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Hydrocyanic acid gas is used by florists and vegetable gardeners for the control of certain insect pests in the greenhouse. It is the cheapest known fumigant used and is the only one that is entirely effective for the control of white flies.

The gas is generated by placing sodium cyanide or potassium cyanide in a mixture of hot sulphuric acid and water. A great number of formulas are given for this mixture of cyanide, acid and water. A proportion of one ounce of sodium cyanide to two ounces of sulphuric acid and three ounces of water is commonly used. The main essential is to be sure that sufficient acid is present to react with all the cyanide added.

Recommendations relative to the amount of sodium cyanide which should be used vary from one ounce to one-tenth ounce per 1000 cubic feet of greenhouse space. Some of this great difference in dosage recommendation is no doubt due to the difference in the structure of various houses. Greenhouses recently constructed naturally confine the gas better than most old structures where the avenues for the escape of gas are numerous.

It is recognized, however, that something besides structure has a great influence upon the ability of plants to withstand differences in fumigation dosages. Various authorities recommend that the plant foliage be dry at the time of fumigation, others recommend reducing the temperature and still others recommend fumigating on dark nights upon the assumption that the stomata might open in the light of the moon and thus afford a better chance for the entrance of cyanide with its resultant injury. In tests conducted in the Purdue Agricultural Experiment Station greenhouses no noticeable effect was produced from the light of the moon and no injury resulted from moisture applied either as a spray on the leaves or condensed in the form of dew. Temperatures, of course, had considerable effect but not nearly as much as is commonly attributed to this factor. A relative humidity variation of from 55 to 95 per cent apparently had no effect upon plant injury or upon the effectiveness of the dosage. Clayton[1] found, "The resistance of the tomato to cyanide is increased by the presence of water on the leaf surface." This finding, relative to moisture on the foliage is contrary to most of the statements commonly made in relation to this subject.

In the Purdue tests it was found that hardened plants were able to stand a much greater dosage than tender plants. Figure 1 shows the effect of 1/5 ounce of sodium cyanide per 1000 cubic feet of greenhouse

[1] Clayton, E. E. Hydrogen cyanide fumigation. Bot. Gaz. 67:483-500, 1919.

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space on hardened as compared with tender lettuce and tomato plants. This difference was found to be very pronounced. In later fumigations it was found that tomato plants in a very tender condition could not stand a dosage of 1/7 ounce per 1000 cubic feet of greenhouse space. This difference in ability to withstand cyanide injury explains in part why larger dosages of cyanide can be given to potted plants as compared to plants growing in bunches and why bench-grown plants will stand more than ground-bed-grown plants. Regardless of the correlation between carbohydrate, sugar, pentosan and colloid content of hardened and non-hardened plants, it is generally conceded that the harden-

Fig. 1. Effect of hydrocyanic acid gas, from sodium cyanide used at the rate of 1/5 ounce per 1,000 cubic feet of greenhouse space, on hardened and tender tomato and lettuce plants. Hardened plants at the center and tender plants at the sides.

ing process is favored by a lowering of the temperature and by withholding the moisture either by actual drought or physiological drought. Plants grown in pots and to a lesser extent in benches, regardless of the care of the grower, are bound to suffer from lack of water and hence they are constantly in a more or less hardened condition. On the other hand, plants grown in ground beds seldom suffer from lack of moisture and since most greenhouse soils contain an abundance of plant food materials, especially nitrogen, these plants make an extremely soft growth, very susceptible to injury of any kind. The problem of preventing soft growth in ground beds thus becomes of great importance to both florists and vegetable forcers.

It must also be recognized that other factors may produce vegetative growth or a tender plant. Lack of sunlight from shading or from shortened days creates tender plants, likely due to the fact that the nitrogen cannot be synthesized into protein colloids and other essential constituents of the hardened plant. Clayton[1] found plants grown in the shade to be more susceptible to cyanide injury. He also states that "the radish endures without injury, three times the strength of fumigation which a tomato endures, yet microchemical examination reveals but little difference in the cuticular development."

During the tests conducted in the Purdue greenhouses it was found that radishes, lettuce and tomatoes, *grown under the same conditions*, had approximately the same degree of resistance to fumigation dosages. Hardened plants of all three vegetables withstood much greater dosages than unhardened plants. While species with cutinized or suberized epidermal membranes are doubtless more resistant to cyanide dosages, yet the chief factor of practical importance is the hardening of such plants as do not have such resistant membranes.

The ability of plants to withstand freezing temperatures has been attributed to various factors, such as increased sugar content, increased pentosan content and hydrophilous colloids, and to reduced water content and increased water holding capacity. Doubtless these same ingredients[2] serve in somewhat the same capacity in preventing cyanide injury. Clayton[1] found that plants infiltrated with glucose were resistant to cyanide injury. This was true of both hardy and tender plants. He attributed this protective action to be due to: 1. Supplying an excess of molecules to unite with the cyanide entering. 2. Glucose may take the place of the missing oxygen since oxygen transfer in the tissues of the higher animals is retarded by hydrocyanic acid gas.[3] While the above factors may play a part in the resistance to fumigation, it also seems logical to assume that the same factors which are operating to protect plants from freezing injuries are also acting to prevent cyanide injury. For instance all plants resistant to freezing (hardy), contain a higher percentage of glucose than non-hardened plants[2]. In the case of plants hardened against low temperatures, this increase of sugar content "would increase the osmotic concentration of the cell sap, depress the freezing point and perhaps serve to hold a somewhat larger amount of water in the unfrozen state"[2]. Infiltrated glucose, through its affinity for water, very likely reduces the free water content of the plant to such a degree as to prevent cyanide injury. This decrease in available water content and increase in osmotic concentration of the cell sap may cause the contraction of the stomata and thus lessen the chances of cyanide entrance[4]. The removal of surplus water may also reduce the amount of solvent through which the cyanide becomes active.

[2] Rosa, J. T. Investigations on the hardening process in vegetable plants. Mo. Res. Bul. 48, 1921. (141 references on the subject of hardening in plants included.)

[3] Geppert, J. Ueber das wesen der blausaurevergiftung. Zeit. Klin. Med. 1 Bd. 1 J. Heft. 3, P. 208-292, 1888.

[4] Palladin's Plant Physiology, p. 36. P. Blackiston, Son & Company, 1914.

The range of effectiveness of the gas against such insects as aphids, thrips and white flies, is quite large. In some tests conducted in a very tight house 1/20 of an ounce per 1000 cubic feet of greenhouse space was effective in killing aphids and white flies. The proper dosage for any particular greenhouse must be determined experimentally for that house and will be dependent largely upon the type of house, kind of plants, and the condition of the plants. A fairly safe rule is to start with 1/10 ounce dosages and increase these until the desired results are obtained. Fumigation should be given at the temperature and humidity ordinarily prevailing in the house on a perfectly still night (no wind), when the temperature changes are likely to be small, as the house is not usually entered until morning. Cyanide is a deadly poison and should be used with care. Use crockery dishes in generating the gas.