WATER QUALITY AND PLANT GROWTH

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As Daubenmire (2) has observed water is the closest approximation of a universal solvent. It has the capability of dissolving soil minerals and is the medium through which both organic and inorganic solutes enter the plant and move from cell to cell. It is a reagent in photosynthesis and is essential for the maintenance of plant turgidity.

As well as being a necessary factor for plant growth water is also used in nursery operations to manipulate climatic factors through such practices as frost protection and for cooling in periods of extreme heat.

The quality of water is often beyond the control of the nurseryman; however in many situations the nurseryman is able to monitor and alter some aspects of water quality.

The contamination of water used for irrigation purposes can occur through physical, biological, or chemical means.

Physical contamination of a water supply with sand or larger soil particles or from organic debris can result in clogged sprinkler and mist lines and subsequently prevent uniform water distribution. It is thought by many that a better plant growth response is achieved through the use of warmed water than from the use of very cold water. The application of cold water (40° to 55°F.) to plants growing in air temperatures above 75°F. appears to provide some measure of physiological stress that is detrimental to growth. I think we get a better growth response in our nurseries when the water source has had exposure to air temperatures (i.e. lakes, reservoirs) than in those nurseries that irrigate directly from wells, although I have no data to substantiate this observation.

Biological contamination of irrigation water by pathogens and weed seeds can be a problem, particularly when water is drawn from sloughs and lakes. Mosses, algae, and liverworts are continuing problems at several of our nurseries, particularly on containerized stock. At Surrey the irrigation water is thought to be the vector for a blue-green algae that is a problem on container stock.

There are increasing reports of *chemical contamination* of irrigation water. The gradual entrance of salt water into fresh water aquifers has become a serious problem in many parts of the world. In British Columbia the problem is minimal except in several areas where water is drawn from rivers or streams adjacent to a tidal influence and in several areas on the coast where salt water has permeated ground water sources. In its broadest sense saline water is defined as water that contains more than 1,000 ppm of the salts of sodium, calcium, magnesium, potassium, and other rarer elements (5). All of these elements, with the exception of sodium, are essential for growth; however an excess of any of them can be detrimental to plant growth.

The origin of excess salts can be from fertilizers, soil, or water. Over-application of fertilizers, or use of inappropriate fertilizers, can be overcome and soils containing excess salts can be leached. It is much more difficult to remove salts from an irrigation water supply, although where high value crops such as ornamentals are produced the use of demineralizing, ion-exchange resins can overcome the problem. The use of domestic water softeners is not adviseable as they act by replacing the Ca, Mg and other cations with Na which is toxic to most plants; Na also breaks down soil structure. The measurement of salinity through conductivity readings has become a standard monitoring operation at many nurseries. The problems of salinity and the related testing techniques are well outlined in the Western Fertilizer Handbook (6) and in a University of California publication on producing container-grown plants (1).

The concentration of salts in irrigation water is rarely so high as to cause immediate injury to plants but continuous use of water with a moderate salt concentration can create problems. If a thorough leaching of the soil in the root zone does not take place, the concentration of salts in the soil solution may increase through the loss of soil water by plant uptake and evaporation, until the soil water reaches the limit of solubility of each salt (3).

The quality of irrigation water can also affect the soil reaction. Most species of conifer seedlings do best under acid soil conditions (pH 4.5-5.5). In mineral soils, acidity is commonly defined as a condition of low base saturation. The continued use of irrigation water high in mineral cations can increase the degree of base saturation and raise the soil pH, particularly in soils with a low buffer capacity. The development of plants, particularly conifers, is greatly influenced by soil reaction which affects soil flora and fauna populations and the availability of most nutrients. In bareroot conifer nurseries the use of acid organic amendments such as peat, the use of "acid type" fertilizers, and leaching may be necessary to maintain or reduce soil reaction. In the Pacific Northwest the high annual total precipitation provides a natural means of maintaining acid soil conditions.

Pesticides are often the cause of water contamination. If the number of fish killed each year in the streams and lakes of North America was the only criterion of water quality, pesticides would occupy first place among water pollutants (4). Similarly if losses and damage to nursery crops were tabulated I am of the opinion that pesticides would be very high on the list of causal agents. The application of fungicides, insecticides, and miticides through irrigation systems has gained more acceptance in recent years. Problems with the use of these chemicals in this manner on plant materials have not been widespread but there have been reports of phytotoxic affects that in all probability would have occurred had these materials been applied using conventional methods. When chemicals are applied through irrigation systems there is danger of contaminating the water supply in the event of a sudden drop in the main line pressure although this potential means of contamination can be prevented through the installation of a reduced pressure backflow preventer between the water source and the point of chemical injection.

The application of herbicides through irrigation systems has gained some acceptance in recent years, particularly in the central pivot system.

The contamination of irrigation water with fertilizers, fungicides, insecticides, or miticides, while not desirable will in most instances not result in plant damage provided the amount of contamination is minimal and short lived. Contamination of irrigation water with herbicides, on the other hand, can have disastrous effects on plant growth.

The following is a summary of an incident at the Surrey Nursery in 1974 that resulted in substantial crop losses. I hope that it will serve as a warning to all nurserymen of the hazards of using herbicide-contaminated water for irrigation purposes.

The Surrey Nursery is the largest of the eight principal nurseries operated by the British Columbia (Canada) Forest Service. There are a number of smaller establishments operated in conjunction with the major nurseries and several nurseries are currently in the developmental stage. The total annual production of the organization currently runs around 75 million seedlings, of which 80% are grown as bareroot and 20% as plugs in containerized styroblocks. The species grown at Surrey include Interior spruce (*Picea spp.*), Douglas fir (Pseudotsuga menziesii [*Mirb.*] *Franco*), and Western hemlock (*Tsuga heterophylla* [*Raf.*] *Sarg.*)

The irrigation water for the nursery is drawn from a 14-acre lake which is located on municipal property ½ mile south of the nursery. The lake is being developed by the municipality as a recreational area. As a result of a number of drownings in recent years in which the submerged aquatic weeds, mainly *Elodea canadensis* were implicated, the municipality, after an unsuccessful attempt to reduce the weed population by mechanical means, solicited and received the assistance of the provincial Department of Agriculture in an attempt to control the weeds with herbicides. In 1973 some preliminary aquatic weed control trials and conifer seedling phytotoxicity trials were conducted with Diquat (Reglone A). The phytotoxicity trials on the conifer species produced no damage but the rates of Diquat used did not provide adequate weed control in the lake. In 1974, at the urging of the municipality to resolve the problem as soon as possible and after consultation with aquatic weed specialists elsewhere in Canada, a proposal was made to treat the lake with Diquat (Reglone A) and Paraquat (Gramoxone S) to provide an effective concentration of ½ ppm of each material in the lake. The municipality's proposal was reviewed and approved by an interdepartmental committee that oversees the application of pesticides to public lands in this province.

The lake was treated on July 30th and, prior to the herbicide application, the nursery replenished its two reservoirs (capacity 2.8 million gallons) in anticipation of the 5-day waiting period between treatment and use of water. The lake water was not used for irrigation purposes until 7 days after treatment; however one of the reservoirs was partially recharged 3 days after the treatment and the contaminated water was allowed to stay in the reservoir for a further 4 days prior to use.

The Canadian distributor's specifications indicate that where Diquat or Paraquat are used for aquatic weed control it is safe to use the water for irrigation purposes 5 days after treatment. In subsequent discussions with the distributor's technical representatives it was indicated that these materials are normally deactivated to safe levels for irrigation within 48 hours and the additional 3 day delay is built in as a safety factor. The cationic behaviour of Diquat and Paraquat provides for their deactivation through contact with anionic materials such as clay, silt, and living or dead organic matter. In retrospect it may have been better to further delay the use of the lake water for irrigation but the seedlings were under drought stress conditions at the time and no alternate source of irrigation water was available.

A herbicide residue analysis of the lake indicated a total Diquat-Paraquat concentration of 3.3 ppm two hours after treatment, 2.4 ppm at six hours, 0.7 ppm at 24 hours, 0.3 ppm at 48 hours, and 0.33 ppm after one week, indicating that most of the deactivation occurrred during the first 48 hours and that there was no appreciable change in the level of herbicides present during the next five days.

Those familiar with Diquat or Paraquat are aware that when these materials are used for conventional weed control purposes at rates between 500 and 1200 ppm results are usually evident within 48 to 72 hours. With the sub-lethal levels of the herbicides present the damage to the conifer seedlings did not become evident until two weeks after the use of the contaminated water on some species and several months later on others. Two weeks after commencing to use the water foliar damage to container-grown hemlock and Sitka spruce became evident. The container grown white spruce did not appear to be affected and both the coastal and interior fir appeared to be only slightly damaged at that time. In the field-grown stock there was some tip damage to 2-0 Sitka spruce but a severe out-break of aphids that went unchecked for some time made it difficult to ascertain whether the contaminated water or the aphids were responsible for the damage.

Analysis in late August indicated the continued presence of trace amounts of both herbicides in the lake and reservoirs (0.06 ppm Diquat and 0.09 ppm Paraquat) and healthy bracken ferns *(Pteridium aquilinum pubescens)* used as indicator plants continued to show foliar damage after being irrigated well into September. We had been working on the assumption that the herbicides had been deactivated by this time and that the damage to the container-grown stock resulted from the initial irrigations following the treatment of the lake. By late August only the container-grown hemlock showed serious signs of damage. With the continuing damage to the bracken ferns and the evidence of trace amounts of both herbicides still remaining, clay was added to the reservoirs and charcoal filters were installed in the irrigation mainlines.

It was not until late September, eight weeks after the lake was treated, that the presence of serious injury to both the 1-0 bareroot and container-grown Douglas fir became evident. Examination of the fir seedlings revealed the presence of a constricted area on the lower stem. Foliar damage was confined to the hemlock and analysis of dead foliage indicated residues of Diquat and Paraquat.

Fortunately, damage to the 1-0 and 2-0 white spruce, which is the nursery's principal species, was negligible. There was no damage to the 1-0 Sitka spruce; however there was substantial culling in the 2-0 Sitka spruce at lifting time as a result of the herbicides and/or aphid damage to the terminals. There was some damage to the 2-0 Douglas fir but buds appeared intact and no losses were recorded.

The constriction on the 1-0 bareroot and container-grown Douglas fir had seriously damaged the cambium tissue and it was postulated that the cambium would either heal or eventually result in the death of the upper portion of the seedlings. During the winter of 1974/75 the latter occurred. By the spring of 1975 the fields of Douglas fir were orange with dying or dead foliage, a condition not uncommon in Douglas fir nurseries that have received winter desiccation injury or a late spring frost; however in this instance the damage extended much farther down the stem than normally occurs from desiccation or frost injury. With diligent use of irrigation and an enriched fertilizer programme the seedlings have been brought back to good health. Of the 10.3 million bareroot Douglas fir seedlings grown we anticipate shipping 70 to 75% of this number, which is approximately 10% less than in a "normal" year. The damage to the bareroot portion of the nursery was minimal although the delay in the availability of about 3.5 million Douglas fir seedlings which were to be shipped as 1-0 for mud-packing caused considerable inconvenience to consignees.

The inventory of planable bareroot species of all age classes at Surrey in August of 1974 was 56.2 million. The total figure will be down by 10% by the time all of the stock is shipped. Total bareroot shipments out of Surrey during the past planting season were 22.7 million, compared with 18.3 and 17.5 million in the previous two seasons and approximately 33 million will be available for the coming fall and spring planting season.

As a result of the more intensive water requirements, damage to the container-grown stock was very severe. A total of 4.9 million were culled. The only container-grown species suitable for shipping were lodgepole pine and interior spruce and 1.2 million of these two species were shipped. It is probable that a good percentage of the culled container stock could have been salvaged but the nursery had no facilities to carry the crop in containers for a second year and the costs associated with transplanting this stock in the field with no guarantee of success was not justifiable.

Container shipments from Surrey in the previous years were 7.9, 2.2, and 5.1 million respectively and a crop of 5.9 million is anticipated this year.

While we have attributed most of the damage to the 1974 crop to the contaminated irrigation water it is acknowledged that some portion of it may result from diseases, insects, over-winter injury, and poor cultural techniques which plague every nursery operation.

We have had some difficulty in convincing herbicide specialists that such trace amounts of herbicides could cause such extensive damage. The fact that the seedlings were under drought stress conditions at the time and the interactions with fertilizers, insect injury, insecticides, and other herbicides may have been contributing factors.

Contamination of irrigation water supplies by herbicides is something many of us would rather not think about and because of the sophisticated techniques necessary for pesticide analysis and the time involved it is not practical to carry out a continuous monitoring programme. The use of sensitive indicator plants and the experienced eye of the nurseryman to stock abnormalities are perhaps the most practical means of monitoring water quality.

I would hope that our misfortune would alert plant propagators to the necessity of maintaining and protecting the quality of their irrigation water supply.

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