Effect of Dissolved Oxygen Supply on Seedling Establishment of Water-Sown Rice

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WATER-SEEDING of lowland rice imposes unique environmental conditions for seedling establishment. Inundation conspicuously modifies the exchange of oxygen, carbon dioxide, and other gases among the air, water, and soil and alters the physico-chemical and biological relationships in the soil. Some workers have expressed the view that the dissolved oxygen concentration of the irrigation water at the time of seeding may influence seedling establishment of water-sown rice. As early as 1933, Jones (14) suggested that the poor stand establishment of late-sown rice could be due to a shortage of dissolved oxygen. Recent recommendations by Finnock and Miller (11) for establishing a crop of rice by seeding into water seem to be based upon the idea of conserving dissolved oxygen in the germination zone. It has been grower experience that for best seedling establishment the seedbed should be as dry as possible before flooding, and that the fields should be sown as soon as flooded. Also running water generally is considered to be more beneficial to the seedling establishment of lowland rice than is stagnant water. Some questions have arisen whether seedling mortality might have occurred because of the low dissolved oxygen status of the water used to irrigate the fields. These observations may, however, be a consequence of changed oxygen-carbon dioxide relationships or may result from removal of harmful metabolites.

Recent studies by Chapman and Peterson (8) indicate, however, that the dissolved oxygen concentration of the flood water is unlikely to limit the establishment of watersown rice even at water temperatures of 35° C. Their studies showed that when air-dried Stockton clay soil was flooded, the dissolved oxygen concentration of the water decreased only slightly during the first 24 hours. Within 3 days, however, a characteristic diurnal fluctuation in dissolved oxygen developed with maximums exceeding air-saturation. A net increase in dissolved oxygen accompanied the diurnal cycle. The presence of germinating rice seeds in numbers equivalent to field-seeding rates resulted in a substantial initial decrease in dissolved oxygen. There was also a greater diurnal range, and the net dissolved oxygen level ultimately exceeded that in the unplanted control cultures. The latter effect appeared to be related to the increased growth of filamentous green algae in the presence of the rice seedlings.

Dynamic changes in the concentrations of dissolved gases are characteristic of an aquatic environment and arise as a result of fluctuations in the photosynthetic and respiratory activities of the biota. Diurnal fluctuations in dissolved oxygen have been recorded frequently in lakes (19, 4, 7), in rivers (5, 13, 12, 10), in ponds, ditches and swamps (16, 3), and in rice fields (9). The occurrence of dissolved oxygen levels greater than air-saturation is due to the excess of oxygen produced by the photosynthetic activity of algae over the respiration requirements of the biota during the daylight hours (7, 23, 6, 19). Darby, (9), in his studies of California rice fields, found that in May the flood water at a depth of 1 foot was "supersaturated" with oxygen from about 7 a.m. to almost 10 p.m., and that at no time during the 24-hour period did the concentration of dissolved oxygen fall below 4 ppm. A peak level of 17 ppm was recorded.

The influence of organic matter incorporated in a flooded soil on the dissolved oxygen concentration of the water has been reported by Patrick and Sturgis (17). They show that fresh clover material added to the soil after a period of flooding brought about the consumption of dissolved oxygen at the rate of 25.0 ppm per hour as compared with 1.18 ppm per hour for flooded air-dried soil.

In view of the uncertainty concerning the supply of dissolved oxygen in the field and its relation to seedling establishment, studies were undertaken to provide information (1) on the effect of running water versus stagnant water on dissolved oxygen supply; (2) on the effect of the dissolved oxygen concentration of the soil solution at the time of seeding on root penetration; and (3) on the degree of reaeration of some well waters used to irrigate rice. The work was conducted in the greenhouse at Davis at the Rice Experiment Station, Biggs, Calif., during 1962.

MATERIALS AND METHODS

Seed and soil—The rice seed used in all pot culture experiments was Oryza sativa japonica, cultivar Caloro obtained from foundation stocks of the Rice Experiment Station. Pregerminated seed for water-sowing was prepared by soaking the seed in distilled water at temperatures around 30° C. until the plumule had just begun to emerge. The water was changed at least once during the soaking period. The soil used was Stockton clay, developed from fine textured basic igneous alluvium and underlain at a depth of 30 to 40 inches by a dark brown, calcareous clay subsoil.

Running water versus stagnant water studies—Open-air pot culture experiments were conducted at the Rice Experiment Station where a supply of well water with low oxygen concentration was conveniently available. The quality of the water otherwise was good. Fiber glass containers 38 cm. in diameter and 21.5 cm. deep were filled partially with 7.25 kg. of air-dried soil. Six containers were placed in each of 2 shallow, galvanized iron tanks 10 ft. X 7 inches. One of these tanks, used as a hot water bath, was insulated with sheets of fiber glass wool; an electrical heating coil was wrapped around each container to insure good temperature control. The other tank was used as a cold water bath; through it a rapid flow of cold (20° C.) well water was maintained. Each container was carefully filled to a depth of about 14 cm., with 16 liters of well water containing about 3 ppm dissolved oxygen. Stagnant water was maintained in three containers in each water bath, with daily additions being made to replace evaporation losses. In the other containers the water was kept flowing from the water source at such a rate that the total volume was entirely replaced after a certain interval. Replacement rates of 1/2, 8, and 24 hours were run in series. In order to avoid movement of the soil and dispersal of the clay in the running water treatments, the water stream was allowed to impinge on the bottom of a small porcelain crucible placed so that its upper edge was level with the surface of the soil in the container. An electrically heated hot water system connected to the same water supply was used to provide water for the high temperature treatment. It was found possible to maintain the temperature of the stagnant and running water treatments within 1 or 2° of each other. A continuous thermographic record was kept of the water temperature in one stagnant water container in each bath, and frequent checks were made daily with a thermometer. Daily temperatures ranged from 18 to 27° C. in the cold water treatments and from 35 to 58° C. in the hot water.