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Nutritional Preferences Exhibited By Plants In Ad Libitum Feed Systems

L. A. ERREDE*

ABSTRACT—*Ad libitum* feeding plant systems fitted with two reservoirs were used to monitor daily aqueous uptake by plants from paired reservoirs. When the reservoirs contained aqueous solutions of the same chemical composition, a plant accepted nourishment from alternate sources without bias; but when the reservoirs contained different aqueous solutions, i.e. either tap water or standard nutrient solution, a sharp bias was exhibited, depending on the plant's need for mineral nutrient, which changed with time. Eventually a "stable-end-state" was attained, favoring water over the standard nutrient solution in the ratio of 3 to 1. When the plant was pruned severely, however, preference oscillated sharply from one source to the other for six months while new growth developed to reestablish the "stable-end-state". If a toxic pollutant was added to the favored reservoir, the plants preference switched sharply to the other source until the toxicant was eliminated from the polluted reservoir, thus ensuring the plants survival.

It was reported (Errede and Ronning 1980) that the permeability of certain microporous membranes, placed in intimate contact with a water reservoir on one side and the root network of a plant on the other, is controlled by that plant in accordance with its chronobiological needs for aqueous nourishment. Daily water uptake by the plant in such *ad libitum* feeding systems oscillates in a pattern that exhibits a weekly cycle, superimposed on a lunar cycle, which in turn is superimposed on a seasonal cycle. The seasonal cycle is characteristic of the plant species, but the weekly cycle and perhaps the lunar cycle appear to be universal for all plants in a given general area, i.e. the oscillations are well synchronized as if all the plants in isolated locations were responding to a common stimulis, probably the pattern of alternating light and darkness.

When such systems are fitted with two or more reservoirs, (insets of Figs. 1 through 5) it is possible to challenge that plant with a nutritional option by refilling the reservoirs daily with aqueous solutions of different chemical compositions. Typical results for such an experiment are shown in Fig. 1, which plots in the lower portion the daily uptake, V_i in cc/day, by a *ficus Japonica* plant from each of its two 285cc capacity reservoirs, No. 1 and No. 2, as a function of time, and in the upper portion the corresponding percent of the total uptake, $V_T = V_1 + V_2$, supplied by reservoir No. 2, i.e. $P_2 = 100\ V_2/(V_1 + V_2)$. The data recorded over the first three weeks shows the characteristic manner in which water permeability of the microporous membrane decreases as a function of continued water flow (Errede and Martinucci 1980). Plant control over water permeability is established when root contact is made with the membrane, usually within a few weeks. Thereafter, V_i oscillates as shown after day 25.

Fertilizer solution introduced after 80 days

In this experiment both reservoirs No. 1 and No. 2 were refilled daily for 80 days with tap water. During this period the rhythmic patterns for water uptake from the paired reservoirs were well synchronized and virtually superimposable, such that P_2 was essentially constant and equal to $P_0 = 100\ A_2/(A_1 + A_2)$, where $A_1 + A_2$ are the microporous areas of the respective reservoirs (in this case $A_1 = A_2 = 12\ cm^2$ and therefore $P_0 = 50$ percent). Beginning on day 80 (12 December, 1976), reservoir No. 1 was refilled daily with tap water and reservoir No. 2 was refilled daily with aqueous fertilizer solution containing one gram of mineral nutrient per gallon of water. The composition of this nutrient mixture was 27 percent NH_4 (+), 3 percent NO_3 (-), 10 percent P_2O_5 and 10 percent K_2O. This change caused the rhythmic patterns for V_1 and V_2 to deviate sharply from synchronized response such that P_2 oscillated as much as 30 percentage points above and below the no bias line at $P_0 = 50$ percent over the next 300 days. During the ensuing year the pattern for P_2 drifted downward to a "stable-end-state" that oscillated 8 percentage

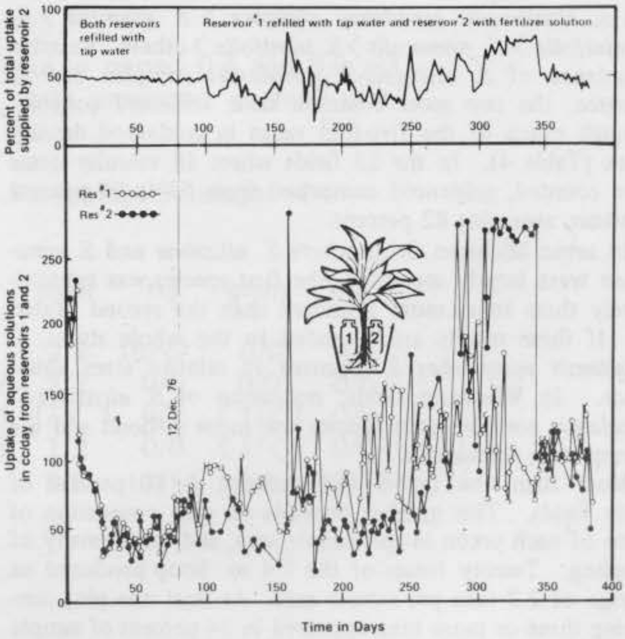

Figure 1 - Chronological pattern of aqueous uptake by a *ficus japonica* from two 285 cc reserv oirs (implanted in the soil as shown in the inset).

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points above and below a line given by $P_2 = 25$ percent, which corresponds to a "stable-end-state" bias of about 3-to-1 in favor of water over the arbitrary standard nutrient solution.

The characteristic drift from a no-bias initial state ($P_2 = P_0$) to the "stable-end-state" bias of ca. 3-to-1 in favor of water is shown more clearly in Fig. 2. This is a plot of the averaged percent perference for reservoir No. 2 i.e. P_2, exhibited by the set of 23 coleus systems whose daily uptakes of aqueous nourishment from reservoirs No. 2 and No. 2 were monitored independently by volunteers (Listed in the acknowledgment). The large amplitudes in the oscillating P_2 patterns for the individual systems (Fig. 1; top portion), were essentially eliminated in the averaged P_2 patterns (Fig. 2) showing clearly that the oscillating pattern for percent preference by one plant is not in synchrony with that of another plant of the same species. Essentially the same results were obtained when the data for $V_T = V_1 + V_2$ for sets of 12 Dieffenbachia, 9 ficus elastica and 7 Schefflera, which also were monitored independently by the volunteer group, were treated in like fashion. This means that P_2 for a given self feeding system changes independently in accordance with its individual needs despite that $V_T = V_1 + V_2$ of this system osillates rhythmically in synchronization with all other plant systems of the same species as shown for example in Fig. 3, which plots the average total daily uptake, V_T, for the same set of 23 coleus systems recorded in Fig. 2.

Reservoirs assignment reversed as check

To demonstrate that the observed "stable-end-state" at P_2 = Ca 25 percent is not attributable to the fact that the smaller reservoir (No. 2) was refilled daily with standard nutrient solution and the larger reservoir (No. 1) was refilled with water, the refill assignments for the paired reservoirs were reversed on day 530 for a sub-set of 4 of the set of 23 coleus systems. This reversal caused P_2 for each number of the test set to rise from 22 ± 2 percent on day 530 to 74 ± 3 percent on day 700 as indicated by the dashed line beginning at 16 April 1979 in Fig. 2; whereas P_2 for the remaining 19 systems in the control set increased only from 22 ± 2 percent to about 24 ± 2 percent during the same interval. Thus the 3-to-1 bias in favor of water is established by the plant regardless of the refill assignment.

This observed "stable-end-state" bias has no real theoretical significance except in a qualitative sense. It is a fortuitous result associated with the arbitrary choice of one gram of soluble mineral nutrient per gallon of water, which was chosen for convenience. It was shown, albeit with only one plant system, that this bias ratio was about 5 to 1 when the concentration of the nutrient solution was doubled.

It was observed that the initial response exhibited by a self-feeding plant challenged with a nutritional option depends on the history of the system. In those examples in which the system had been conditioned by refilling the paired reservoirs with water, the initial response to the option was to swing sharply in favor of reservoir No. 2, which was refilled daily with standard fertilizer solution; the percent of total aqueous uptake supplied by this reservoir increased from $P_2 = P_0$ to $P_2 > 60$ percent, depending on the time allowed for depletion of original soil nutrients before the system was supplied daily with standard nutrient solution. This initial response was followed by oscillations of greater than 15 percentage points above and below a line that descended gradually to a "stable-end-state" line given approximately by P_2 = ca. 25 percent.

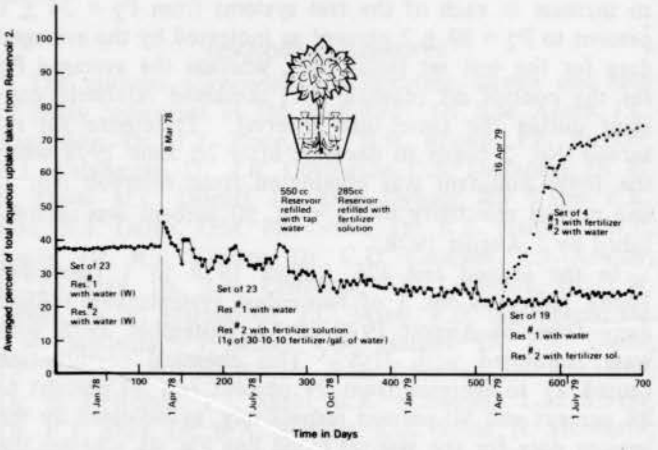

Figure 2 - Chronological average percent preference for reservoir No. 2 exhibited by a set of 23 c oleus in *ad libitum* feeding systems fitted with two reservoirs as shown in the inset.

In those examples in which the system had been conditioned by refilling the paired reservoirs with standard fertilizer solution, the initial response to the option was to swing sharply in favor of reservoir No. 1, which was refilled daily with water; the percent of total aqueous uptake supplied by reservoir No. 2, which contained nutrient solution; decreased from $P_2 = P_0$ to $P_2 < 15$ percent, depending on the time allowed for accumulation of excess nutrients before water was supplied daily. This initial response was followed by oscillations of less than 2 percentage points above and below a line that ascended gradually to the same "stable-end-state" line given by P_2 = ca. 25 percent, which was established in the above examples from the opposite direction.

Response to chemical and physical perturbations

After the "stable-end-state" is established, the percent preference for reservoir No. 2 oscillates within a narrow range, i.e. ca. 5 percentage points avove and below a line that corresponds approximately to a 3-to-1 bias in favor of the water reservoir. Oscillation within this relatively narrow range continues so long as the system remains undisturbed by chemical or physical perturbations. Whenever a toxic pollutant is added to one of the paired reservoirs, however, the percent preference for the other reservoir increases sharply. This cause and effect relationship is illustrated in Fig. 4 which plots the average percent preference, P_2, for the test set of n-systems relative to that of the control set (23-n systems) during the same time interval. In the first test (28 April 1978 to 1 August 1978) reservoir No. 1 of three coleus systems were refilled daily from 28 April 1978 to 26 June 1978, with 0.1 percent methylamine hydrochloride solution instead of water. This chemical perturbation caused the percent preference, P_2, for reservoir No. 2, which contained standard nutrient solution, to increase in each of the test systems from $P_2 = 34 \pm 1$ percent to $P_2 = 89 \pm 2$ percent as indicated by the averaged data for the test set (solid line), whereas the averaged P_2 for the control set (dashed line) remained relatively constant during the same time interval. Preference for reservoir No. 2 began to decrease after 26 June 1978 when the toxic pollutant was eliminated from reservoir No. 1, and normal selectivity of P_2 = ca. 30 percent was reestablished by 1 August 1978.

In the second test (26 August 1978 to 1 December 1978), reservoirs No. 1 of two coleus systems were refilled daily from 26 August 1978 to 14 September 1978 with water saturated with H_2S. This chemical perturbation caused P_2 to increase from 29 percent and 30 percent to 88 percent and 90 percent respectively, as indicated by the average data for the test set (solid line Fig. 4), whereas the averaged P_2 for the control set (dashed line Fig. 4) remained relatively constant. Preference for reservoir No. 2 began to decrease after 14 September 1978, when the toxic pollutant was eliminated from reservoir No. 2, and normal selectivity of P_2 = ca. 25 percent was reestablished by 1 December 1978.

In the third test (8 January 1979 to 30 March 1979), reservoirs No. 1 of three coleus systems were refilled daily from 8 January 1979 to 6 March 1979 with 0.1 percent aqueous acetic acid solution. This caused P_2 to increase from $P_2 = 25 \pm 1$ percent to $P_2 = 55 \pm 3$ percent as indicated by the average data for the test set (solid line Fig. 4), whereas the averaged P_2 for the control set (dashed line Fig. 4) remained relatively constant during the period. Again preference for reservoir No. 2 began to decrease on 6 March 1979, when the reservoir No. 1 was again refilled daily with water, and normal selectivity of P_2 = ca. 24 percent was reestablished by 30 March 1979.

Physical damage to the plant also causes marked perturbations in the preference pattern. If, for example, much foilage is removed by pruning, the system exhibits unusually large oscillations in P_2 above and below the no-bias line at P_0 until such time that the plant can recover from the physical damage by growing new foilage. Usually this recovery to the "stable-end-state" occurs within six months.

Potential applications in a wide range

The results described in this and earlier publications (Errede and Ronning 1980) show that these *ad libitum* feeding arrangements can be used as a means for studying plant-water relationships. Because of their ease of assembly and relative simplicity, they are particularly useful in experiments that involve multiple replications that must be tmonitored over long periods. This can be done periodically or even continuously if the systems are interfaced with a computer, eliminating the drudgery of processing enormous quantities of recorded data. Systems fitted with multiple reservoirs, for example, could be used in the study of ion preferences, i.e. $Na^{(+)}$ vs. $K^{(+)}$ or $SO_4^{(=)}$ vs. $HPO_4^{(=)}$, or in the study of tolerance and receptivity of physiologically active organic compounds, such as growth regulators or systemic insecticides.

The *ad libitum* feeding capability can of course be adapted to horticultural applications, especially when water availability is limited, as in the south western part of the United States, Israel, Egypt and Iran. It also has obvious utility in the care of houseplants to preclude over-or-under watering. Because of the plant's ability to control flow from alternate sources with different chemical compositions, systems with two reservoirs can also be used to preclude over or under fertilization. In this regard, the present

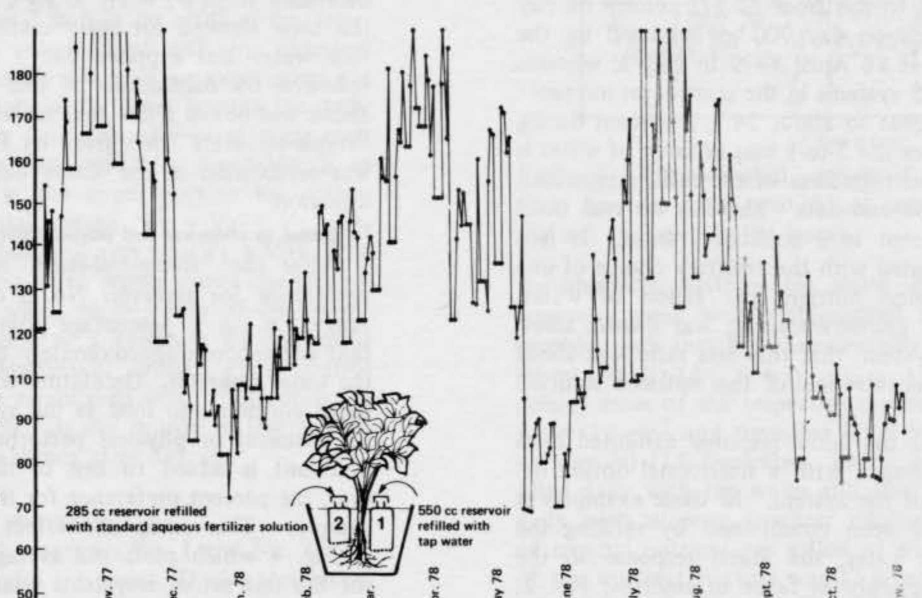

Figure 3 - Chronological pattern of averaged daily total aqueous uptake exhibited by a set of 23 coleus in *ad libitum* feeding systems assembled as shown in the inset.

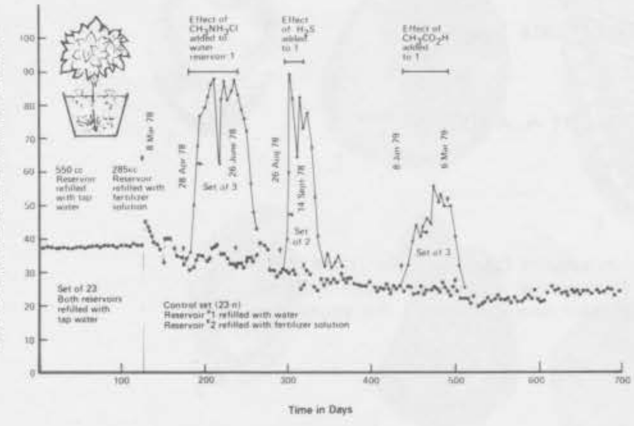

Figure 4 - Effect caused by addition of pollutants to reservoir No. 1 on the chronological average percent preferences for reserv oir No. 2 exhibited by a set of 23 coleus in *ad libitum* feeding systems (assembled as shown in the inset).

study found that a combination utilizing a small internal reservoir (as shown in the inset of Figs. 1 through 5) which is refilled with relatively concentrated fertilizer solution and a large external reservoir (Errede and Ronning, 1980) which is refilled as needed with tap water, is a particularly effective self regulating system. Detailed procedures for assembling these ad libitum feeding systems and for selecting appropriate bioresponsive microporous water varriers have been described previously by the authors.

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Area File of Associations at Hill Reference Library

A file of professional and business associations of the St. Paul-Minneapolis area has been made available at the James J. Hill Reference Library in St. Paul, and the library invites additional inputs of information.

The Hill Library, at Fourth and Market Streets in downtown St. Paul, is open to the general public for direct resource use and also maintains a telephoen reference service in the fields of business and economics that form its central focus.

The association file includes listings of local area groups and also local contacts for national associations. Listings of officers and membership directories of some are included.