Contributions

Commentary

A History of the Ecological Sciences, Part 14: Plant Growth Studies in the 1600s

In Part 13 we saw that Francis Bacon grew a few plants in water and discovered that some grew faster in it than in soil, from which he concluded: "for nourishment the water is almost all in all, and that the earth doth but keep the plant upright, and save it from overheat and over-cold" (Bacon 1857–1874, Volume 2: 478–479; Egerton 2004). Later investigators read this in his *Sylva Sylvarum* (1627), which may have stimulated their own experiments, though his was not the only discussion of plant growth.

There is an ancient Christian work of uncertain authorship known as pseudo-Clement's *Recognitions*, translated from Greek into Latin by Rufinus of Aquileia soon after AD 400, that is a dialogue between a skeptical father and his Christian sons. Within this context, various questions about nature were discussed, such as "Does not the rebirth of seed from earth and water and its growth into plants for the use of man sufficiently demonstrate the workings of the providence of God?" (translated by Howe 1965: 409). One of the skeptic's son then answers his own question: "When they are sown, the earth, by the divine will, pours out upon these seeds the water it has received, as if it were milk from the breast." Any doubting Thomases can see this for themselves (Howe 1965:410):

> *...let us prove that nothing is supplied to seeds from the substance of the earth, but that they are entirely derived from the element of water and the spirit (spiritus) that is in it. Suppose, for example, that into some barrel of enormous size we put a hundred talents [about three tons] of earth. Now let different sorts of seeds of herbs or bushes be planted in it, and enough water supplied to keep them moist. For several years take good care of it; collect all the seed that develops, the wheat and the barley and other kinds separately, year by year, until the pile of each amounts to a hundred talents. Then uproot the plants and weigh them. When they have all been removed, the barrel will still present its hundred talents without loss. But where did all that bulk come from, that mass of different sorts of seeds and vegetation? Is it not obvious that it came from the water?*

This seems to have been only a hypothetical experiment, as there is no statement that it was actually performed.

In the late Middle Ages there was a perceptive churchman (a Cardinal) with a serious interest in science, Nicolaus Krebs of Cusa (1401–1464; Hofmann 1971), who in 1450 wrote *Idiotae, dialogus IIII* (*The Idiot in Four Books*) in the same spirit as pseudo-Clement's *Recognition*, which he likely had read (Howe 1965:411). In Book IV, "Of Statick Experiments," he argued that some things cannot be determined by reasoning and logic, but require experiment and measurement. The existence of God was now taken for granted, but a question that interested the Idiot and his Oratour was how to understand the elements. The Oratour asked: "There is a saying that no pure Element is to be given, how is this prov'd by the Balance?" (Nicolaus Cusanus 1650:188, quoted in Hoff 1964:107). The Idiot replied (Nicolaus Cusanus 1650:188–189, in Hoff 1964:108):

> *If a man should put an hundred weight of earth into a great earthen pot, and then should take some Herbs, and Seeds, and weigh them, and then plant or sow them in that pot, and then should let them grow there so long, untill hee had successively by little and little, gotten an hundred weight of them, hee would finde the earth but very little diminished, when he came to weigh it againe: by which he*

might gather, that all the aforesaid herbs, had their weight from the water. Therefore the waters being engrossed (or impregnated) in the earth, attracted a terrestreity, and by the operation of the Sunne, upon the Herb were condensed (or were condensed into an Herb). If those Herbs bee then burn't to ashes, mayest not thou guesse by the diversity of the weights of all; How much earth thou foundest more than the hundred weight, and then conclude that the water brought all that? For the elements are convertible one into another by parts…

There is no indication that Nicolaus Krebs of Cusa performed the experiment either, though he improved it by recommending that one weigh the seeds before planting and burn the vegetation at the end of the experiment to determine its dry weight.

The Idiot was widely read as late as the mid-1600s, when a physician-scientist, Johannes Baptista van Helmont (1579–1644), did perform the experiment. He was as devout a Catholic as Galileo was, and like Galileo, van Helmont was condemned for his writings. In his case, the condemnation was by his own university, in Louvain (1623 and 1633–1634), and by the Catholic Inquisition (1625) for a book he had written in 1621 on healing wounds with magnets (Pagel 1972:254, López Piñero 2000:290). He was placed under house arrest in 1634 (a year after Galileo) and remained under an ecclesiastical cloud until 1642.

Fig. 1. Portraits of J.B. van Helmont and F.M. van Helmont (Ihde 1964:28).

Although he coined the word "gas" and tried to distinguish different kinds, he also defended Nicolaus' idea (which actually goes back to Thales in antiquity) that water is a universal element and other substances are modifications of it. After his encounter with the Inquisition, he did not publish his other writings on science and medicine, and only after he died did his son Franciscus Mercurius van Helmont publish his *Ortus Medicinae* in 1648. The account of van Helmont's plant growth experiment attracted much interest because it was a real, not merely a hypothetical experiment (van Helmont 1662:109, in both Hoff 1964:110 and Krikorian and Steward 1968:286–287):

…all Vegetables do immediately, and materially proceed out of the Element of water onely. For I took an Earthen Vessel, in which I put 200 pounds of Earth that had been dried in a Furnace, which I moystened with Rainwater, and I implanted therein the Trunk or Stem of a Willow Tree, weighing five pounds; and at length, five years being finished, the Tree sprung from thence, did weigh 169 pounds, and about three ounces: But I moystened the Earthen Vessel with Rain-water, or distilled water (alwayes when there was need) and it was large, and implanted into the Earth, and least the dust that flew about should be co-mingled with the Earth, I covered the lip or mouth of the Vessel with an Iron-Plate covered with Tin, and easily passable with many holes. I computed not the weight of the leaves that fell off in the four Autumnes. At length, I again dried the Earth of the Vessell, and there were found the same two hundred pounds, wanting about two ounces. Therefore 165 pounds of Wood, Barks, and Roots, arose out of water onely.

It seems ironic that he who distinguished gases from air did not notice that his willow was in contact not just with dirt and water but also air, from which it might also have absorbed substance. His younger contemporary, René Descartes (1596–1650), published his *Discours de la méthode* (1637), on how to do science, in time for van Helmont to have pondered his four rules, the fourth of which was "to make enumerations so complete and reviews so general that I should be certain of having omitted nothing" (Descartes 1911: 92), but in this case, van Helmont failed to follow rule 4 (not that Descartes always followed his own rules either). If van Helmont had followed rule 4, he might have itemized air as a potentially relevant factor. Of course, he might have reasoned instead that since everything comes from water, and he was already allow-

ing for the plant to absorb water, that air need not be considered; but if this was his thought, most likely he would have said so.

Van Helmont's *Ortus medicinae* had already attracted interest in England before it was translated in 1662. Isaac Walton discussed the willow growth experiment in *The Compleat Angler* (1653; quoted from second edition (1655:31–32 in Webster 1966:99) and it seems likely that Thomas Browne read the works of both Van Helmont and Walton. Webster (1966:102) claimed that "The first exhaustive study of the efficacy of water as a plant nutriment was made by Sir Thomas Browne (1605–1682)." However, neither the passage he quotes from *Garden of Cyrus* (1658; 1964, Volume 1:217) nor Browne's botanical notes that remained unpublished until 1929 contain any quantitative data, unless one considers this note quantitative (Browne 1964, Volume 3:393):

> *How much humor is exhausted by a single plant & what perspiration necessarie, is evidenced in a plant that groweth in a glasse wherein a single plant of balme or mint will in a sumer exhaust a gallon of water, whereas rue or a wooddie plant, that only lives without shooting roote, will not make more sensible exhaustion then what is conceved the sunne may make in a narrowe mouthed glasse.*

Webster's claim seems overly flattering to Browne.

In 1658 plant growth attracted the interest of two colleagues at Oxford University, Robert Boyle (1627–1691) and Robert Sharrock (1630–1684). Sharrock published *The Propagation and Improvement of Vegetables by the Concurrence of Art and Nature* in 1660, a year before Boyle published *Sceptical Chymist*. Sharrock wanted to verify Bacon's claims in *Sylva Sylvarum*, and he decided to test a wide range of species growing just in water (Arber 1960, Clowes 1975). He placed small shoots without roots in vials of water and found that at least 24 species sprouted roots and 17 did not; a few of the rooted species died shortly after sprouting roots. He weighed the surviving plants and published his data on their increase over a stated period of time. He also found that "in jointed stems the adventitious roots arose from the nodes, while in non-jointed shoots they appeared from beneath axillary buds" (Webster's words, 1966:104–105). Sharrock dedicated his book to Boyle, and since Boyle observed some of his experiments, he may have aroused Boyle's interest in plant growth.

Fig. 2. Robert Boyle (Ihde 1964:28).

Boyle indicated in *Sceptical Chymist* that he began his own experiments before he knew of van Helmont's work and that he might not have bothered if he had read his book beforehand (Nash 1957:331, Krikorian and Steward 1968:289). Boyle was an active experimenter (Hall 1970, Davis 2000, Hunter 2000), but in this case he entrusted the experiment to his gardener when he was not even at home. Webster's conclusion on Boyle is more equivocal than on Browne (1966: 107):

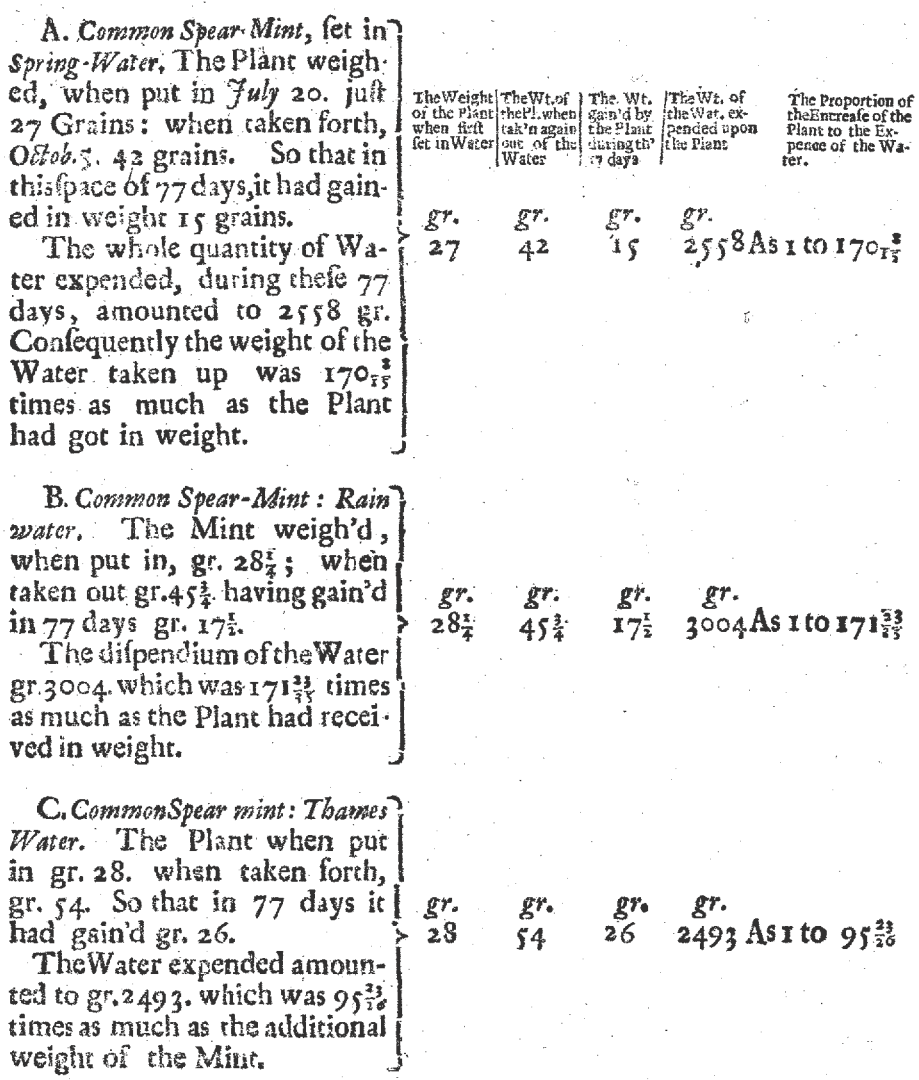
> *The willow tree and water culture experiments left Boyle with an abiding doubt about the elementary nature of water. Nevertheless, he was less confident in opposing Bacon's judgement that water was "all in all" for generation of organic bodies.*

Although Boyle was a highly respected experimental scientist, he did not have the last word on the subject in his own century. John Woodward (1665–1728) was a London physician, professor at Gresham College, and a member of the Royal Society of London (Eyles 1976, Levine 1977). He read what Bacon, Helmont, and Boyle wrote about water being the source of plant growth with skepticism and decided to conduct his own experiments. He was skeptical of both the experiments growing plants in dirt, adding water, and weighing the dirt and plant after a period of time and also growing plants in water only. In the

first place, he doubted one's ability "to *bake* the Earth with that *Accuracy*, as to reduce it *twice* to just the *same Dryness*," (Woodward 1699:194), but more fundamentally, he doubted that the water used in those previous experiments was pure. He had been to various parts of England and examined the waters and never found any that was pure. If one put the clearest water in a glass vial and stopped it up, and waited a few days, one sometimes found either a green color emerging or mineral particles settling to the bottom of the vial. He conducted about two dozen experiments in 1691–1692 in which he placed different kinds of plants in similar glass vials covered with parchment except for a hole for the stems of the plants, and placed in a row at a window where they received air, light, and sun.

As the water diminished in the vials, he replenished it, but weighed the amounts added. In the process, he discovered transpiration, though he did not name it. He offered eight interesting "reflections" upon his experiments (Woodward 1699:207–225):

> 1) *In Plants of the same kind, the less they are in bulk, the smaller the Quantity of the Fluid Mass in which they are set is drawn off...*
> 2) *The much greatest part of the Fluid Mass that is drawn off and convey'd into the Plants, does not settle or abide there: but passes through the Pores of them, and exhales up into the Atmosphere.* ***



A. *Common Spear-Mint*, ſet in *Spring-Water*. The Plant weighed, when put in *July* 20. juſt 27 Grains: when taken forth, *Octob.* 5. 42 grains. So that in this ſpace of 77 days, it had gained in weight 15 grains.
The whole quantity of Water expended, during theſe 77 days, amounted to 2558 gr. Conſequently the weight of the Water taken up was $170\frac{8}{15}$ times as much as the Plant had got in weight.

B. *Common Spear-Mint: Rain water.* The Mint weigh'd, when put in, gr. $28\frac{1}{4}$; when taken out gr. $45\frac{3}{4}$. having gain'd in 77 days gr. $17\frac{1}{2}$.
The diſpendium of the Water gr. 3004. which was $171\frac{33}{35}$ times as much as the Plant had received in weight.

C. *Common Spear mint: Thames Water.* The Plant when put in gr. 28. when taken forth, gr. 54. So that in 77 days it had gain'd gr. 26.
The Water expended amounted to gr. 2493. which was $95\frac{23}{26}$ times as much as the additional weight of the Mint.

The Weight of the Plant when firſt ſet in Water	The Wt. of the Pl. when tak'n again out of the Water	The Wt. gain'd by the Plant during th' 77 days	The Wt. of the Wat. expended upon the Plant	The Proportion of the Encreaſe of the Plant to the Expence of the Water.
gr.	*gr.*	*gr.*	*gr.*	
27	42	15	2558	As 1 to $170\frac{8}{15}$
$28\frac{1}{4}$	$45\frac{3}{4}$	$17\frac{1}{2}$	3004	As 1 to $171\frac{33}{35}$
28	54	26	2493	As 1 to $95\frac{23}{26}$

Fig. 3. A portion of Woodward's published data on his first three vials (Woodward 1699) is shown.

*3) A great part of the terrestrial Matter that is mixt with the Water, ascends up into the Plant as well as the water.****
*4) The Plant is more or less nourish'd and augmented in proportion as the Water in which it stands contains a greater or smaller quantity of proper terrestrial Matter in it.****
5) Vegetables are not form'd of Water: but of a certain peculiar Matter. It hath been shewd that there is a considerable Quantity of this Matter contain'd both in Rain, Spring, and River Water…
*6) Spring and Rain water contain pretty near an equal Charge of Vegetable Matter: River-water more than either of them.****
*7) Water serves only for a Vehicle to the terrestrial Matter which forms Vegetables: and does not it self make any addition unto them. Where the proper terrestrial Matter is wanting, the Plant is not augmented tho' never so much Water ascend into it.****
8) Water is not capable of performing this Office to Plants unless assisted by a due Quantity of Heat…

While discussing his second reflection, he commented that countries with trees and larger vegetables have great humidity and more frequent rains than other countries with more open space. In America, the early settlers were annoyed by the humidity, but after they cut down the forests, "the *Air* mended and *cleared* up apace: changing into a Temper much more *dry* and *serene* than before" (Woodward 1699:209). He also thought that plant odors are conveyed by the water evaporating from the plant. While discussing his fourth reflection, he commented (Woodward 1699: 215):

> It is not possible to imagine how one, uniform, homogeneous Matter, having its Principles or Original Parts all of the same Substance, Constitution, Magnitude, Figure, and Gravity, should ever constitute Bodies so egregiously unlike, in all those respects as Vegetables of different kinds…
>
> Furthermore, why do fields become infertile over time and need to be replenished with manure if the plants only grow from water? Why would cherries flourish best in Kent, apples in Herefordshire, saffron in Cambridgeshire, and teazles in Somersetshire if all they needed was water?

Woodward was a more sophisticated experimenter than his predecessors, but in disproving that the growth of plants comes only from water, he went too far by denying that water contributes to growth at all. Furthermore, although he said he placed his vials where the plants could get air and sun, he did not consider either as potential factors in growth.

Each of these authors built upon the work of his predecessors and improved somewhat the understanding of plant growth and how to study it. However, they still fell short of a basic understanding of plant growth. Before that could be achieved, chemists would have to identify the gases in the air. That would happen in the next century.

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